## Breakout Session Summary:

# *Correlative Environments*

**Chair: Paul O'Brien (The Aerospace Corporation)**

**Co-chair: Pat O'Neill (NASA/JSC)**

**SET-3 Requirements Workshop**
**March 29-30, 2007**

# *Background*

- Approach to the process
  - Brainstorming
  - Consolidation into topics
- General Issues discussed / Shortcomings identified
  - Benchmarking/establishing best practices for the use of wide variety of transport codes
  - Secondaries produced inside s/c
  - Under-utilization of ground-based test and on-orbit failure/anomaly data
  - Parts/materials databases lack information about on-orbit performance
  - Temporal variability of environment not usually accommodated
  - Relevant mass (i.e., shielding) often lost when manually simplifying from CAD output to transport code input

# *Prioritized Topics*

1. Characterization of radiation environments (primary and secondary) within a spacecraft
2. Mining Data from Existing on Orbit and Ground Based Measurements to Validate and Improve Radiation Environment and Transport Simulators
3. Use S/C anomalies, EDAC (error detection and correction) counts and similar effects to (1) study the transport of the space particle environment to the interior of the S/C and (2) add electronic parts to databases using in-flight data.
4. Improved tools to predict the access of solar and galactic cosmic radiations in the magnetosphere
5. Models of Transient Event Specification for Engineering Evaluation
6. Time Efficient-High Fidelity Radiation Transport Modeling from CAD

# *1. Characterization of radiation environments (primary and secondary) within a spacecraft*

- **Background: External radiation environment changes its characteristics (particle species and energy spectra) in the presence of a spacecraft structure/shielding material.**
- **Description of Needed Investigation: An investigation is needed to better understand and characterize the radiation environment within the spacecraft for different structural and shielding materials. The investigation should address the best practices of using different codes for space radiation environment application. The investigation also should include validation of transport codes using ground test and/or on-orbit data and should define each code's range of applicability.**
- **Justification: To mitigate the radiation effects on microelectronics and sensors, we tend to add shielding material. However, as future microelectronics and sensors become more sensitive to the space radiation effects, they might be susceptible to secondary particles generated within and transported through the shielding material.**

## *2. Mining Data from Existing on Orbit and Ground Based Measurements to Validate and Improve Radiation Environment and Transport Simulators*

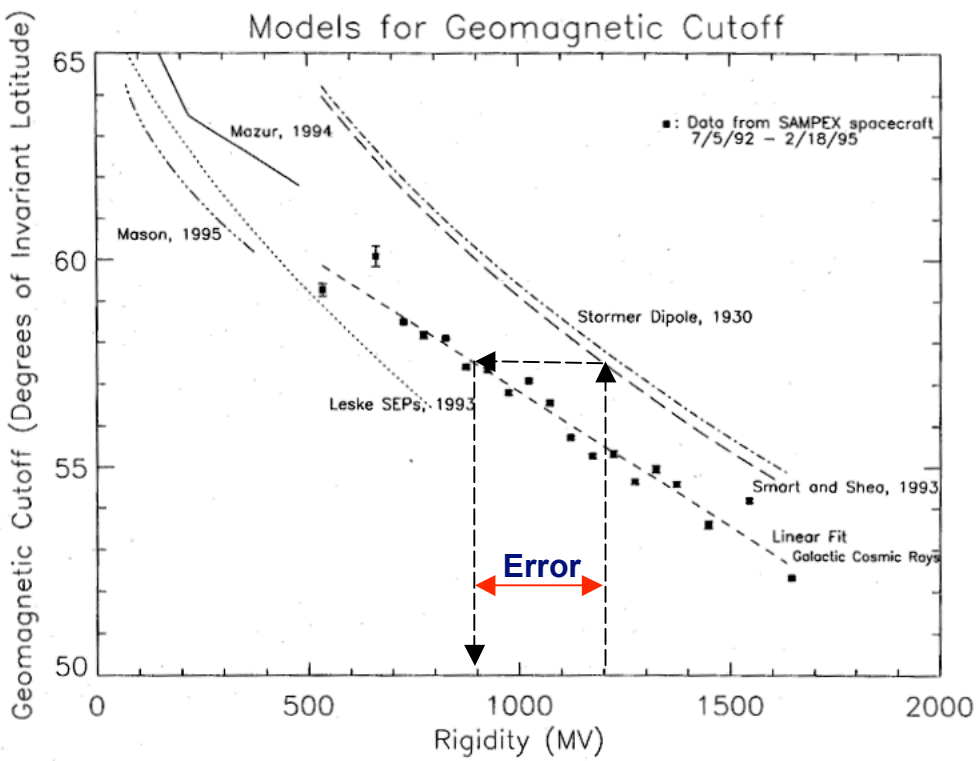
- **Background: Two possible sources of data which may exist but which are not presently being used are identified:**
  - **Data from detector experiments or other measurements which were performed for some primary purpose but which contains useful secondary results that may be extracted. As an example, energy deposition data for secondary spallation products may be extracted from multi-detector silicon proton telescope data.**
  - **Data from ground based scientific measurements which have not been analyzed or extracted in a useful form. As an example: double differential cross-section data from existing Silicon plus proton data.**
- **Needed Investigation: Identify potential sources of such data and perform the necessary extraction and analysis of relevant data.**
- **Justification: Validation and improvement of Monte Carlo nuclear interaction and transport models.**

## *3. Use S/C anomalies, EDAC (error detection and correction) counts and similar effects to (1) study the transport of the space particle environment to the interior of the S/C and (2) add electronic parts to databases using in-flight data.*

- **Background: Depending of the electronic part, anomalies and EDAC counts can be related to dose, flux or SEE environment. Bit errors on hardened parts can be used to determine the SEE environment inside the S/C. Upsets in softer parts in the inner belt are related to high energy proton flux. Anomalies due to discharges can be related to the internal high energy electron flux. Other anomalies can be traced to total dose effects. Electronic parts in proximity to the "tracer" parts can be evaluated for radiation properties.**
- **Description of Needed Investigation:**
  - **Identify SWx instrumented missions and use anomaly data to compare the internal radiation environment to the one predicted by transport codes.**
  - **Use uninstrumented missions to study the external environment and transport codes together.**
  - **Use electronic parts with known radiation properties as dosimeters, fluxmeters or SEE environment sensors**
  - **investigate other electronic parts.**
- **Justification: There is a number of SWx instrumented missions with the required anomaly and/or EDAC data where the external radiation environment is well characterized and are ideally suited for this task. On non instrumented missions, there are normally some well characterized parts or parts with flight history that can provide the needed information about the internal radiation environment.**

# *4. Improved tools to predict the access of solar and galactic cosmic radiations in the magnetosphere*

- **Better tools are required to calculate the access of solar and galactic cosmic ray heavy ions within earth's magnetosphere**
  - **Models are not well integrated into tools**
  - **Must allow for variable magnetic geometry (e.g. $D_{st}$)**
  - **Need validated tool for engineering assessments of single event effects**



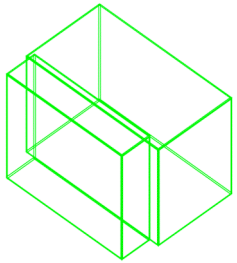
# *5. Models of Transient Event Specification for Engineering Evaluation*

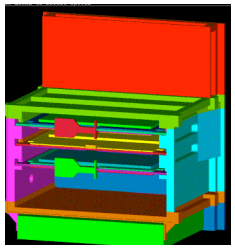
- **Background: Many environmental specifications used today in engineering applications are either static or use a simple max/min description. None capture the detailed time variation inherent in many transients, such as SEP events, passage through plasma density gradients or exposure to highly structured precipitation events (microbursts).**
- **Description of Needed Investigation: Data mining of existing environmental data to establish a statistical database of transient phenomena and assembly into useful statistical tools – distributions of parameter peaks, duration distribution, occurrence frequency, mean repeat frequency.**
- **Justification: With ever more computing power required in space and the continuing trend toward OTS parts, detailed knowledge of upset rates and rate repeatability is becoming an increasingly critical for assessment of past effects and for the successful design of future instrumentation (SEU mitigation strategies, differential spacecraft charging, discharge triggers).**

# 6. Time Efficient-High Fidelity Radiation Transport Modeling from CAD

- **Background**
  - **Accurate and highly resolved (component level) radiation transport of complex space structures is limited by the effort and program schedule required to translate CAD data into geometries required by the transport codes. To compensate, geometric simplifications are made which lead to artificially high radiation requirements (nominally 2-4x).**
- **Description of Needed Investigation:**
  - **Benchmarking different methodologies of translating CAD data into radiation transport model and evaluating fidelity and speed.**
  - **Validating high fidelity translations by comparing a radiation dataset (internal space structure) against a high fidelity prediction**
- **Justification:**
  - **Opportunity to lower radiation requirements by 2-4x which will enable more robust trades on rad-hard parts and added shielding weight.**
  - **Support science efforts to understand directionality of radiation effects on science payloads**

Traditional Result:
Model developed in SVC
Dose point at center of box





Advanced Result:
Model developed in TOPACT
Ability to calculate dose at critical components!

| **Technology Breakout Session (Check One):** | **Title of Issue Requiring Investigation:** Characterization of radiation environments (primary and secondary) within a spacecraft |
|---|---|
| _X_ **Environment Specification**<br>__ **Microelectronics** __ **Materials**<br>__ **Sensors & Detectors** __ **Charging/Discharging** | |

**Background:** External radiation environment changes its characteristics (particle species and energy spectra) in the presence of a spacecraft structure/shielding material.

**Description of Needed Investigation:** An investigation is needed to better understand and characterize the radiation environment within the spacecraft for different structural and shielding materials. The investigation should address the best practices of using different codes for space radiation environment application. The investigation also should include validation of transport codes using ground test and/or on-orbit data and should define each code's range of applicability.

**Justification:** To mitigate the radiation effects on microelectronics and sensors, we tend to add shielding material. However, as future microelectronics and sensors become more sensitive to the space radiation effects, they might be susceptible to secondary particles generated within and transported through the shielding material.

| **Benefiting Technology Areas:** Microelectronics, sensors, detectors. | **Benefiting Space Application Areas:** Any spacecraft system, especially "heavily-shielded" microelectronics and sensors. |
|---|---|
| **Investigation Resource Requirements:**<br><br>Data Access Requirements (data name, cost):<br><br>Investigation Cost to LWS SET:<br><br>Investigation Cost-Sharing Contribution:<br><br>Date for Final Deliverables: | **Submitter Information:**<br><br>Name: Insoo Jun |

**Technology Breakout Session (Check One):**

_x_ **Environment Specification**
__ **Microelectronics** __ **Materials**
__ **Sensors & Detectors** __ **Charging/Discharging**

**Title of Issue Requiring Investigation:**
Mining Data from Existing on Orbit and Ground Based Measurements to Validate and Improve Radiation Environment and Transport Simulators

**Background:** Two possible sources of data which may exist but which are not presently being used are identified:
1. Data from detector experiments or other measurements which were performed for some primary purpose but which contains useful secondary results that may be extracted. As an example, energy deposition data for secondary spallation products may be extracted from multi-detector silicon proton telescope data. 2. Data from ground based scientific measurements which have not been analyzed or extracted in a useful form. As an example: double differential cross-section data from existing Silicon plus proton data.

**Description of Needed Investigation:**

Identify potential sources of such data and perform the necessary extraction and analysis of relevant data.

**Justification:**
Validation and improvement of Monte Carlo nuclear interaction and transport models.

**Benefiting Technology Areas:**

Single Event Effects in micro/opto-electonics.

**Benefiting Space Application Areas:**

All spacecraft.

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

**Submitter Information:**

Name:Charles C. Foster

**Technology Breakout Session (Check One):**

__X **Environment Specification**
__ **Microelectronics** __ **Materials**
__ **Sensors & Detectors** __ **Charging/Discharging**

**Title of Issue Requiring Investigation:**
Use S/C anomalies, EDAC (error detection and correction) counts and similar effects to (1) study the transport of the space particle environment to the interior of the S/C and (2) add electronic parts to databases using in-flight data.

**Background:**
Depending of the electronic part, anomalies and EDAC counts can be related to dose, flux or SEE environment. Bit errors on hardened parts can be used to determine the SEE environment inside the S/C. Upsets in softer parts in the inner belt are related to high energy proton flux. Anomalies due to discharges can be related to the internal high energy electron flux. Other anomalies can be traced to total dose effects. Electronic parts in proximity to the "tracer" parts can be evaluated for radiation properties.

**Description of Needed Investigation:**
(1) Identify SWx instrumented missions and use anomaly data to compare the internal radiation environment to the one predicted by transport codes. (2) Use uninstrumented missions to study the external environment and transport codes together. Use electronic parts with known radiation properties as (3) dosimeters, fluxmeters or SEE environment sensors or (4) to investigate other electronic parts.

**Justification:**
There is a number of SWx instrumented missions with the required anomaly and/or EDAC data where the external radiation environment is well characterized and are ideally suited for this task. On non instrumented missions, there are normally some well characterized parts or parts with flight history that can provide the needed information about the internal radiation environment.

**Benefiting Technology Areas:**
EEE part evaluation, transport code validation

**Benefiting Space Application Areas:**
Internal dosimetry, flux measurements and SEE environments

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

**Submitter Information:**

Name: Bronek Dichter

**Technology Breakout Session (Check One):**

X **Environment Specification**
__ **Microelectronics** __ **Materials**
__ **Sensors & Detectors** __ **Charging/Discharging**

**Title of Issue Requiring Investigation:**

# Improved tools to predict the access of solar and galactic cosmic radiations in the magnetosphere

**Background:** While the theory for external particle access to the magnetosphere is well established, and extensive calculations have been performed to model the theory (e.g. Shea and Smart), the theory and models are not well described in engineering-level models or standardized techniques to specify radiation effects on satellite systems. Additionally, now-casting and post-flight assessment activities may require the capability to simulate a specific geomagnetic condition to estimate the actual environment at the spacecraft accurately, which today requires significant expertise in magnetospheric physics and modeling techniques to accomplish.

**Description of Needed Investigation:** The product of this investigation is a set of models that incorporate the transformation of the external solar and galactic cosmic ray fluxes to any location within the magnetosphere, applying the rigidity dependence, the charge states of the source particles, the directional dependence of the cutoff, and characteristics of the geometry of the magnetosphere (characterized by appropriate geomagnetic indices) to produce accurate predictions of the fluxes at the spacecraft.

**Justification:** Solar and galactic cosmic ray heavy ions cause SEE in satellite electronics. Improvements in the ability to calculate the access of solar and galactic cosmic rays within the magnetosphere will reduce the uncertainties in the resultant radiation effects calculations, which will enable more accurate predictions of on-orbit satellite performance and will remove uncertainties associated with the variability of geomagnetic conditions during disturbed conditions.

**Benefiting Technology Areas:**
Radiation models for solar and galactic cosmic ray fluxes.
On-orbit performance modeling and predictions
Effectiveness of radiation effects mitigation approaches

**Benefiting Space Application Areas:**
Performance modeling of satellite systems, with more benefit for lower-altitude orbits.

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost): TBD, but existing POES and other data sets will be valuabel for validation

**Submitter Information:**

Name: David Chenette

**Technology Breakout Session (Check One):**

_X_ **Environment Specification**
__ **Microelectronics** __ **Materials**
__ **Sensors & Detectors** __ **Charging/Discharging**

**Title of Issue Requiring Investigation:**

Models of Transient Event Specification for Engineering Evaluation

**Background:**
Many environmental specifications used today in engineering applications are either static or use a simple max/min description. None capture the detailed time variation inherent in many transients, such as SEP events, passage through plasma density gradients or exposure to highly structured precipitation events (microbursts).

**Description of Needed Investigation:**
Data mining of existing environmental data to establish a statistical database of transient phenomena and assembly into useful statistical tools – distributions of parameter peaks, duration distribution, occurrence frequency, mean repeat frequency.

**Justification:**
With ever more computing power required in space and the continuing trend toward OTS parts, detailed knowledge of upset rates and rate repeatability is becoming an increasingly critical for assessment of past effects and for the successful design of future instrumentation (SEU mitigation strategies, differential spacecraft charging, discharge triggers).

**Benefiting Technology Areas:**

Digital processor and memory design, solar panel design

**Benefiting Space Application Areas:**
All orbits exposed to transient events
SEP all orbits, density gradients ~MEO and beyond, structured precipitation LEO

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

**Submitter Information:**

Name: Reiner Friedel

**Technology Breakout Session (Check One):**

_x_ **Environment Specification**
__ **Microelectronics** __ **Materials**
__ **Sensors & Detectors** __ **Charging/Discharging**

**Title of Issue Requiring Investigation:**

# Time Efficient-High Fidelity Radiation Transport Modeling from CAD

**Background: Accurate and highly resolved (component level) radiation transport of complex space structures is limited by the effort and program schedule required to translate CAD data into geometries required by the transport codes. To compensate, geometric simplifications are made which lead to artificially high radiation requirements (nominally 2-4x).**

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**Justification:**

1) **Opportunity to lower radiation requirements by 2-4x which will enable more robust trades on rad-hard parts and added shielding weight.**
2) **Support science efforts to understand directionality of radiation effects on science payloads**

**Benefiting Technology Areas: microelectronics, sensors & detectors, radiation shielding, high performance materials, surface charging (internal)**

**Benefiting Space Application Areas: Near Earth and Inter-Planetary missions affected by radiation**

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

**Submitter Information:**

Name:James Chow

**Technology Breakout Session (Check One):**

__X Environment Specification
__ Microelectronics
__ Sensors & Detectors
__ Materials
__ Charging/Discharging

**Title of Issue Requiring Investigation:**

**Part Level Data from System Level Test**

**Background:**

**System and board level tests are routinely performed to qualify flight hardware using high energy protons (200 MeV). This data often contain Single Event Effect (SEE) failure rate info for specific identifiable chips.**

**Description of Needed Investigation:**

**This information will be added to existing parts SEE databases.**

**Justification:**

**This SEE data can be used by spacecraft designers if it is available in the standard data bases.**

**This allows comparison of "system test" results with "part level test" results.**

**Benefiting Technology Areas:**

**SEE in micro/opto-electronic components.**

**Benefiting Space Application Areas:**

**All manned , commercial, & scientific orbiting spacecraft**

**Investigation Resource Requirements:**

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

**Submitter Information:**

Name: Charles C. Foster