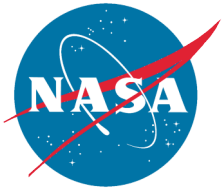


Breakout Session Summary:

Microelectronics

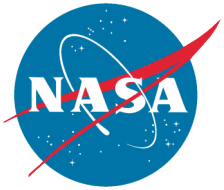
Chair: L.M. Cohn (DTRA)
Co-chair: Robert Reed (Vanderbilt University)

SET-3 Requirements Workshop
March 29-30, 2007

Background

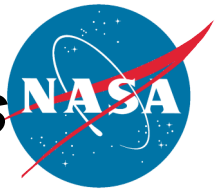
- **Problem statement: Concerning the use of advanced microelectronics technologies for space applications significant issues exist WRT our ability to:**
  - **Develop cost effective and efficient radiation effects mitigation methods.**
  - **Model and simulate radiation effects in these technologies**
  - **Predict the long tern response**
  - **Test and characterize the radiation response of complex integrated circuits**
- **Mission: Through "Data Mining" improve the capability to accommodate or mitigate the effects of solar variability on space craft and instrument design.**
- **Objective: Based on "Data Mining" identify approaches to support performance improvements for microelectronics used in space to include radiation effects:**
  - **Mitigation approaches**
  - **Modeling and simulation improvements**
  - **Test methods and protocols**
  - **Data set anomaly identification and resolution**

Technology Scaling



- **Pervasive issue that impacts all of the subsequent topical areas and includes, but is not limited to:**
  - **Reduced feature size and Increased integration density**
    - **Lower upset thresholds due to reduced operating voltages and nodal capacitance**
    - **Increased probability of multiple bit upsets due to increased packing density & charge sharing**
    - **New materials resulting in unknowns concerning radiation response (dose enhancement) and FIT projection (materials physics of failure)**
  - **Increased circuit complexity**
    - **Increased number of failure modes, e.g. SEFI**
    - **Increased difficulty in T&E of all operating modes, e.g. time for complete node coverage approaching infinity**
    - **Unobservable and uncontrollable states**
    - **Radiation sensitivity as a function of operation**
    - **Critical nodes covered by metal layers**
    - **Added probability of nuclear reactions with metal layers, e.g. low LET particles causing upset through secondary production**
  - **Increased circuit operating speed**
    - **Need for higher speed test equipment and/or approaches**
    - **Test facility arrangements**
    - **Device temperature control**
  - **Packaging complexity**
    - **Issues WRT test species package penetration, e.g. higher beam energy test facilities required**
    - **Shadowing of critical nodes**
  - **Modeling and simulation**
    - **3-D and mixed-mode models required**
    - **Over-layer and substrate interaction must be included**
    - **Simulation time**

Radiation Effects Modeling and Mechanisms



- **The "Data Mining" will support:**
  - **SEE/TID/DD Model Development, Verification, and Validation (Calibration to real data)**
    - **Model Deficiencies:**
      - **charge sharing, angular incidence, secondary reaction effects, design margin conservancy, operation speed, temperature effects**
      - **New models need to be development to improve predictability (e.g., event rate) of these effects**
    - **Mapping Data to Modeling Methodology (Transport codes, TCAD, Compact modeling, EDA)**
    - **Simulation Fidelity**
    - **Support model development for design**
    - **Integrated Modeling Approach (use data to support the development)**
      - **(radsafe validation)**

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics** **__ Materials** **__ Sensors & Detectors** **__** **Charging/Discharging**	**SEE Model Development, Verification, and Validation (Calibration to real data)**

Background:
Existing single event effects data show that existing models have deficiencies in several areas: Charge sharing, angular incidence, secondary reaction effects, design margin conservancy, voltage, operation speed, temperature effects, combined environment effects. Each impact that method that is used for single event effect rate predictions.

Description of Needed Investigation:
New models need to be development to improve predictability (e.g., event rate) of these effects. Also, there needs to be mapping existing data to modeling methodology (e.g.,Transport codes, TCAD, Compact modeling, EDA). The simulation fidelity must be quantified and improved. Integrated model approaches must be developed and validated (e.g., RADSAFE). Combined environment effects (e.g., TID and SEE) must be analyzed.

Justification:
More accurate models will improve space craft reliability, survivability and available predictions. They will also allow for reduced design margins, easing the desire to over-design space craft.

Benefiting Technology Areas:	**Benefiting Space Application Areas:**
Microelectronics	spacecraft electrical systems

Investigation Resource Requirements:	**Submitter Information:**
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics** **__ Materials** **__ Sensors & Detectors** **__** **Charging/Discharging**	**TID Model Development, Verification, and Validation (Calibration to real data)**

Background:
Existing TID data show that existing models have deficiencies in several areas: dose enhancement, design margin conservancy, voltage, operation speed, temperature effects, combined environment effects.

Description of Needed Investigation:
New models need to be development to improve predictability of these effects. Also, there needs to be mapping existing data to modeling methodology (e.g.,Transport codes, TCAD, Compact modeling, EDA). The simulation fidelity must be quantified and improved. Integrated model approaches must be developed and validated (e.g., RADSAFE). Combined environment effects (e.g., TID and SEE) must be analyzed.

Justification:
More accurate models will improve space craft reliability, survivability and available predictions. They will also allow for reduced design margins, easing the desire to over-design space craft.

Benefiting Technology Areas:	**Benefiting Space Application Areas:**
Microelectronics	spacecraft electrical systems

Investigation Resource Requirements:	**Submitter Information:**
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics** **__ Materials** **__ Sensors & Detectors** **__** **Charging/Discharging**	**Displacement Damage Model Development, Verification, and Validation (Calibration to real data)**

Background:
Existing data show that existing models have deficiencies in several areas: lifetime degradation, etc...

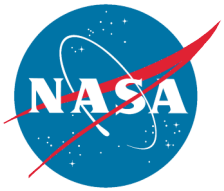
Description of Needed Investigation:
New models should be developed to improve predictability of these effects.

Justification:
More accurate models will improve space craft reliability, survivability and available predictions. They will also allow for reduced design margins, easing the desire to over-design space craft.

Benefiting Technology Areas:	**Benefiting Space Application Areas:**
Microelectronics	spacecraft electrical systems

Investigation Resource Requirements:	**Submitter Information:**
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Radiation Effects Mitigation Approaches



- **The "Data Mining" will support:**
  - **The validation, comparison and qualification of existing radiation mitigation approaches (RHBD methods to include TMR, EDAC, RH latch designs, etc and RHBD methods.) Identification of H/W and S/W improvements for future systems.**
  - **Identification of "Beacon" devices for real time environment awareness**
    - **Prognostics (early warning signs)**
    - **Agile satellite scheduling (re-configuration/operating mode changes)**

Technology Breakout Session (Check One):	Title of Issue Requiring Investigation:
__ Environment Specification _X_ Microelectronics __ Materials __ Sensors & Detectors __ Charging/Discharging	**Validation and qualification of existing radiation mitigation approaches**

Background:
New radiation mitigation approaches such as RHBD methods to include TMR, EDAC, RH latch designs, etc and RHBP have emerged over the past few years. There is a need to qualified and validated these approaches.

Description of Needed Investigation:
Other agencies have invested in development and ground based testing of RHBD techniques, existing data can be mined to improve the understanding (qualification and validate) of the these approaches. Identification of H/W and S/W improvements for future systems that must be performed in the space radiation environment.

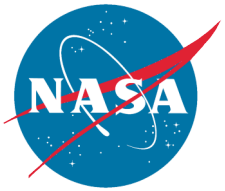
Justification:
Application of RHBD techniques will be required for future NASA missions. Funding to reduce and understand the data will help validate and qualify current approaches and provide direction for new approaches.

Benefiting Technology Areas:	Benefiting Space Application Areas:
Microelectronics hardening	Electrical systems

Investigation Resource Requirements:	Submitter Information:
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics __ Materials** **__ Sensors & Detectors __** **Charging/Discharging**	**Identification of "Beacon" devices for real time radiation environment monitoring.**
Background: Sensitivity of microelectronic devices and circuits to space radiation effects can be used to assess the variability of the radiation space environment.	
Description of Needed Investigation: Mine existing data on technologies to support development radiation beacons.	
Justification: Low cost, power, and weight early radiation detection systems are need to support real-time decision making so that avoidance measures can be implemented.	
Benefiting Technology Areas:	**Benefiting Space Application Areas:** Human exploration and spacecraft electrical systems
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: Phone: E-mail: Organization:

Test Methods Assessment



- **The "Data Mining" will support:**
  - **Anomalies identification for ground and space based data (mine to sanity check anomalies and perform studies to identify why the anomalies exist)**
  - **Method Development, Verification, and Validation**
    - **Method Deficiencies**
      - **(Cryo, charge sharing, angular incidence, secondary reaction effects, design margin conservancy, rate prediction at speed, temperature effects)**
    - **Testing fidelity, adequacy, and applicability**
      - **(dose rate, speed, bias, test conditions, species and energy, temperature, noise)**
    - **Integrated testing approach (use data to support the development)**
  - **Fault coverage, isolation, and grading**
    - **Alternative metric identification**
    - **Test vector descriptions**
      - **(fault isolation, analog testing considerations)**
    - **prognostic identification**

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics __ Materials** **__ Sensors & Detectors __** **Charging/Discharging**	**Test method enhancement, verification and validation** **-lack of test methods and incomplete test methods** **- existing test method fidelity**

Background: Existing test methods and protocols lack fidelity and are inadequate for the characterization of various failure modes since they fail to adequately address parameters that include dose-rate, operating speed, temperature effects and other salient parameters. Areas that are impacted include SEFI and high speed SET effects. Validated and verified radiation test methods and protocols fail to identify various failure modes and, in some cases, exist but fail to address critical issues that have been identified for ultra-deep submicron microelectronics technologies. Specific deficiencies in existing test methods include angular effects, secondary production effects, rate predictions at speed, etc

Description of Needed Investigation:

Through data mining investigate the magnitude of the problem and initiate corrective action to resolve these test method fidelity shortfalls and improve simulation accuracy.

Justification:

Spacecraft reliability is impacted due to these deficiencies.

Benefiting Technology Areas:	**Benefiting Space Application Areas:**
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: Phone: E-mail: Organization:

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics __ Materials** **__ Sensors & Detectors __** **Charging/Discharging**	**Radiation effects data anomalies identification**

Background:
Existing radiation effects ground and space based data show anomalies that need to be identified and studied to understand why the anomalies exist.

Description of Needed Investigation:
Radiation effects data anomalies identification to mine data to sanity check anomalies and perform studies to identify why the anomalies exist.

Justification:
Understanding of anomalies will lead to more reliable radiation effects models

Benefiting Technology Areas:	**Benefiting Space Application Areas:**
Microelectronics	Spacecraft electrical systems

Investigation Resource Requirements:	**Submitter Information:**
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Technology Breakout Session (Check One):	**Title of Issue Requiring Investigation:**
__ Environment Specification **_X_ Microelectronics __ Materials** **__ Sensors & Detectors __ Charging/Discharging**	**Validation of Radiation Testing Methods and Protocols**

Background:
Due to the significant differences between ground radiation testing and the natural radiation environment radiation test methods and guidelines concerning total ionizing dose (TID), to include ELDRS, single-event effects (SEE), and displacement damage require validation based on a comparison between ground test data and space data.

Description of Needed Investigation:
Accomplish validation of TID test method MUI-T-019 and ASTM 1892 for TID effects through analysis of existing space data.
Accomplish validation of SEE test methods ASTM1192 and JESD 57 through analysis of existing space data.
Accomplish validation of NASA test guidelines for SEE, TID and displacement damage through analysis of existing space data.

Justification:
Un-validated test methods and guidelines can impact the operation and survivability of space systems.

Benefiting Technology Areas:	**Benefiting Space Application Areas:**

Investigation Resource Requirements:	**Submitter Information:**
Data Access Requirements (data name, cost):	Name:
Investigation Cost to LWS SET:	Phone:
Investigation Cost-Sharing Contribution:	E-mail:
Date for Final Deliverables:	Organization:

Technology Breakout Session (Check One):

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

Title of Issue Requiring Investigation:

Fault coverage, isolation, and grading:
- **Alternate test metric identification for improved device monitoring and early failure warning.**
- **Improved fault coverage and grading.**

Background:

Present test methods rely on the monitoring of a limited standard set of circuit parameters to identify parametric/functional failure. While these standard have worked well in the past for VLSI technologies they do not always provide accurate indication of problems for advanced (ULSI) devices. In addition, for both advanced and contemporary digital programmable and analog devices this same situation exists.

Description of Needed Investigation:

Investigate existing space and ground test data to identify alternative device parameters that provide enhanced insight and early warning of circuit failures. Present methods to address system fault coverage and grading are inadequate and do not provide sufficient monitoring or support fault grading. Investigate existing space and ground test data to identify approaches that will improve/enhance system fault coverage and grading.

Justification:

The development of more accurate and sensitive alternative set of device parameters to support failure mode identification will lead to enhanced systems reliability and improved design practices.

Benefiting Technology Areas:

Benefiting Space Application Areas:

Investigation Resource Requirements:

Data Access Requirements (data name, cost):

Investigation Cost to LWS SET:

Investigation Cost-Sharing Contribution:

Date for Final Deliverables:

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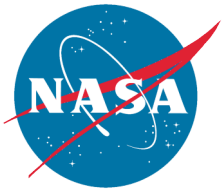
Organization:

Priorities



1. **Radiation Effects Modeling and Mechanisms**
   - SEE Model Development, Verification, and Validation (Calibration to real data)

2. **Radiation Effects Mitigation Approaches**
   - Validation and qualification of existing radiation mitigation approaches

3. **Test Methods Assessment**
   - Test method enhancement, verification and validation