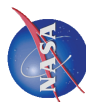


NASA - 2: MRED

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Sponsoring Agencies: NASA, DTRA, AFOSR
Geant4 Japan — 13/Feb/2008

VU-NASA Programs

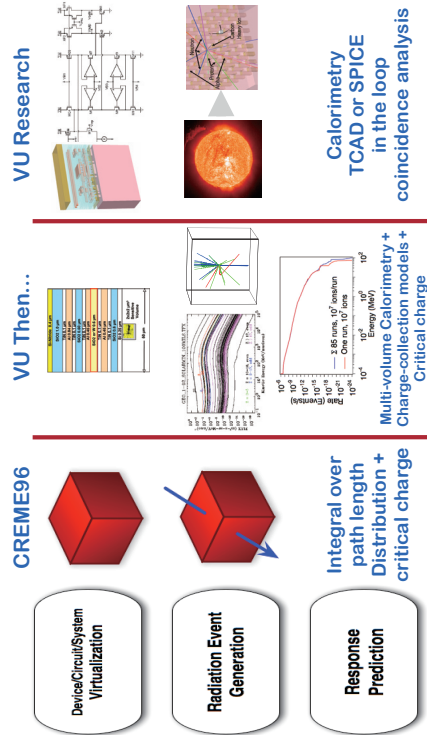
- With Goddard Space Flight Center
 - Undertake research leading to improved methods and models for SEU prediction in selected technologies.
- With Marshall Space Flight Center
 - Implement a CREME96 update with Monte Carlo capability using VU technology and leveraging NASA-sponsored research.

Goal

To develop a system for predicting radiation effects in arbitrary semiconductor devices and systems from first-principles.

- Founded on basic physics.
- Verified experimentally.
- Implemented on supercomputers.
- Useful now and improving continuously.

Progression of SEU Analysis



MRED Analysis Modalities

The flowchart illustrates the MRED analysis process. It begins with 'TCAD Geometry' and 'Virtual Irradiator' (containing a nested box with Python, SWIG, MRED, C++, and Geant4). These lead to 'Energy Deposition & Partitioning', which then feeds into 'Q(r,t)'. From 'Q(r,t)', the process branches into 'Poisson Solver' and 'Spice'. 'Poisson Solver' leads to 'Event Decision', which then leads to 'Nested Sensitive Volumes'. 'Spice' also leads to 'Nested Sensitive Volumes'. 'Nested Sensitive Volumes' leads to 'Approximate Response Models', which then leads to 'Radiation Environment Models'. 'Radiation Environment Models' feeds back into 'Virtual Irradiator'.

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Structure of MRED

The diagram shows a nested structure of MRED components. At the center is 'Geant4', surrounded by 'MRED C++', then 'SWIG', and finally 'Python' at the outermost layer.

- System language: Python.
- MRED: A Python module mredPy.
- Target machine: VU Linux cluster.
- Python: Writes scripts. Controls job execution. Merges results.
- SWIG writes: 170560 lines of c++. 7654 lines of Python.

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Calorimetry

The diagram shows a cross-section of a detector with layers: Si Nitride (0.4 μm), SiO2 (1 μm), Al (0.8 μm), TiN (0.8 μm), SiO2 (0.8 μm), Al (0.4 μm), SiO2 or V (0.6 μm), TiN (0.4 μm), Al (0.4 μm), SiO2 (0.6 μm), and Si (0.2 μm). A '2x2x2 μm Sensitive Volume' is indicated. A graph shows 'Relative Number of Events' vs 'Energy (MeV)' for 'Ne 523 MeV - W plug'. The graph shows a peak at low energy labeled 'LET' and a broader peak at higher energy labeled 'Nuclear Reaction Fragments'. The text 'In spite of advances, calorimetry remains the key thread linking radiation and response.' is present.

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Multiple Bit Upsets

The diagram shows a 'Cell Array' with 'Sensitive Nodes'. It illustrates the interaction of various particles: Neutron, Proton, Alpha, Carbon, Heavy Ion, and n+Si. The text 'MRED tracks energy deposited in all layers' and 'Energy at each sensitive node is calculated' is present. A graph shows 'Energy (MeV)' vs 'Relative Number of Events' for 'Ne 523 MeV - W plug'. The graph shows a peak at low energy labeled 'LET' and a broader peak at higher energy labeled 'Nuclear Reaction Fragments'. The text 'In spite of advances, calorimetry remains the key thread linking radiation and response.' is present.

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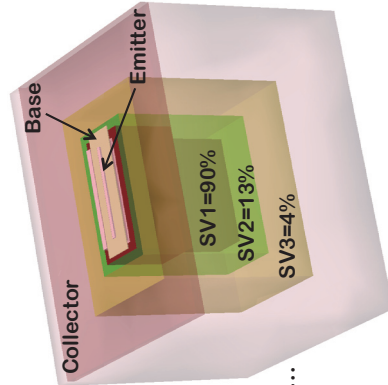
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Nested Sensitive Volumes

- Weighted sensitive volumes
- General charge collection model
- Calibrated with measured data

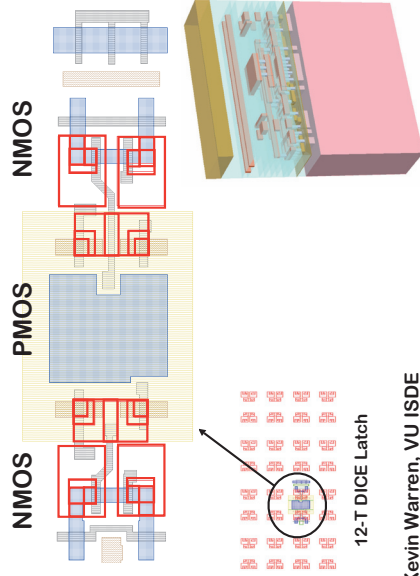


$$Q = \sum_{i=1}^N a_i E_i + \sum_{i,j=1}^N b_{ij} E_i E_j + \dots$$

E_i = Sensitive Volume Energies

Multiple Sensitive Volumes

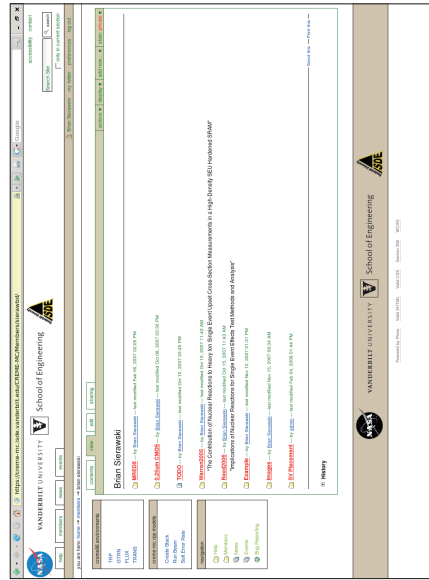
Nested SVs in Complex Systems



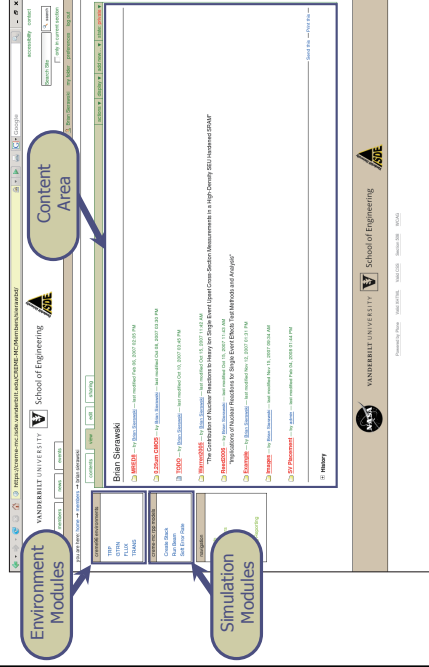
12-T DICE Latch

Kevin Warren, VU ISDE

CREME-MC Home Directory



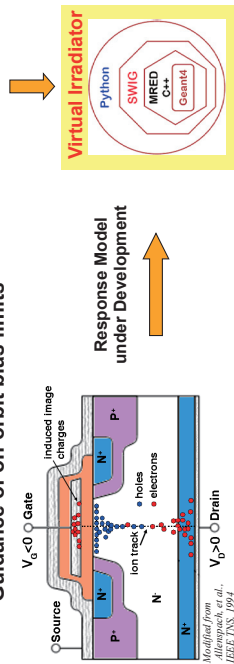
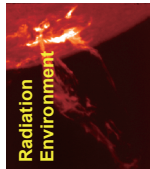
CREME-MC Tools



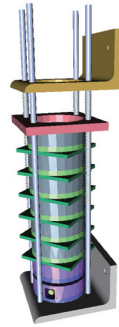
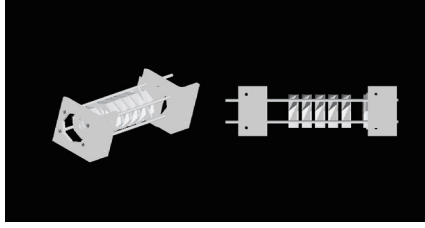
Use of MRED to Predict SEGR Sensitivity in Power MOSFETs - J.-M. Lauenstein, NASA GSFC

Single-event gate rupture modeling is needed for:

- Reduction of ground testing costs
- Determination of failure rate
- Analysis of high-energy response
- Guidance of on-orbit bias limits

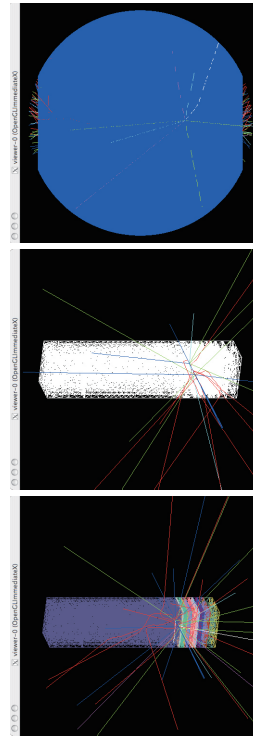


GDML Input



MSFC Spectrometer
(John Watts, MSFC)

TCAD ⇒ GDML ⇒ 100k Events



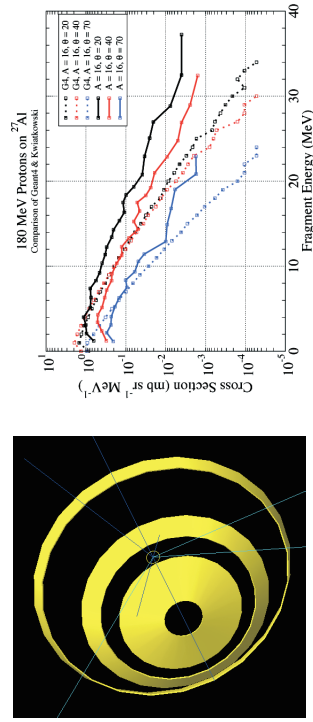
fet_msh.grd
1k Events

fet_msh.gdml
1k Events

fet_msh.gdml
100k Events
Random
No errors!

Validation: Nuclear Physics Literature

However, available data are sparse!



Summary

- MRED code development is converging.
- Improved physics and high-level integration are now priorities.
- Research to predict circuit and system behavior is on-going in multiple technologies.
- CREME-MC web site is on target for general beta testing in mid-2009.



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