The CRÈME Tools on the Internet

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Acknowledgements:
- NASA MSFC: Advanced Avionics and Processor Systems (AAPS), formerly RHESE
- The Geant4 collaboration, especially Makoto Asai, Dennis Wright and Vladimir Ivantchenko
- DTRA Basic Research and Radiation Hardened Microelectronics Programs
- NASA GSFC: NASA Electronic Parts and Packaging (NEPP) Program
- LANL and TRIUMF, for collaborative work
What is the Crème site?

✦ Omnibus web site for modeling of energy deposition in materials due to heavy particle radiation

✦ Provides access to:
  ✴ Legacy Creme-86 and Creme-96 RPP models
  ✴ New, Geant4-based Crème-MC Monte-Carlo radiation transport in multilayer stacks
  ✴ Secure and simple management of files on site
  ✴ Plotting and download of data from all simulations
Site Feature Status

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<td>Updated GCR Model</td>
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- Naval Research Laboratory was shut down CREME96 on July 19, 2010
- Users should register with CRÈME: [https://creme.isde.vanderbilt.edu](https://creme.isde.vanderbilt.edu)
- Public release scheduled for November 2010
- Normal Registration does not provide access to MC tools... email a request to be a beta user
Why is Crème-MC important or useful?

✧ For simple geometries, provides highly detailed particle transport and energy deposition
✧ Allows Creme-96 GCR, trapped proton and geomagnetic transmission models to generate particle fluxes to transport with Geant4
✧ Has multiple-device coincidence capability built in
✧ Has weighted-sensitive-volumes built in to account for partial charge collection from regions distant from device center
✧ Includes CEM03 and LAQGSM nuclear models for high-fidelity breakup of heavy nuclei at cosmic-ray energies
Radiation Environments

✦ Legacy models
  ✴ CREME86 and CREME96
  ✴ Updated Galactic Cosmic Ray model (ISO 15390:2004)
  ✴ Lunar Neutron Albedo model (Adams, 2007)

✦ Probabilistic Solar Proton Models
  ✴ Worst-Case Peak Flux Spectra
    ✴ ESP model for protons (Xapsos et al., 1998)
    ✴ Extend to heavy ions
  ✴ Worst-Case Event Fluence Spectra
    ✴ ESP model for protons (Xapsos et al. 1999)
    ✴ Extend to heavy ions

✦ Worst-Case Cumulative Mission Spectra
  ✴ Psychic model extended to include heavy ions (Xapsos et al., 2007)
Crème-MC technology

✧ Web site is controlled via Plone to provide secure environment and file management
✧ Using much custom Python glue code, site produces a set of files which are digested by Vanderbilt MRED code
✧ MRED is a python-wrapped Geant4 application optimized for small (semiconductor-scale) geometries
Extended nuclear physics codes

✦ Heavy-ion driven nuclear fragmentation drives many important types of microelectronic events
✦ National labs, etc., have very detailed nuclear physics models, mostly written in FORTRAN, which can provide high fidelity reactions.
✦ Need to be able to use these codes in our framework
  ✔ These codes are not designed to be executed inside the framework of other codes. They are stand-alone.
  ✔ Common heritage of codes means many COMMON blocks and variables have same names
Tool for importing FORTRAN codes

✧ Automated Python script collects and rearranges code and renames structures to avoid conflicts
  ✪ All separate files collected into a single big file
  ✪ Main code body moved into FORTRAN ‘module’
  ✪ BLOCK DATA statements collected and moved to end, renamed with unique names e.g.
    BLOCK DATA constants -> BLOCK DATA constants_cem
  ✪ COMMON blocks renamed with unique names e.g.
    COMMON reaction -> COMMON reaction_cem

✧ c++ & python interface generated

✧ Automated procedure guarantees 2 things:
  ✪ low probability of bugs introduced via typos
  ✪ updates in master code easily reincorporated

✧ This is a unique tool -- no one else has this machinery
Sample rearranged code

```fortran
module cem03
private
contains
subroutine cem03event

common / adbf_cem / * amf, rom, ljsp, nhump
common / ajsbar_cem / * ainit, zinit, eb(30,70,100), egs(30,70,100)
...
end subroutine

end module cem03

block data bd1_cem

common / coefa_cem / * ankj(4,4,29)
common / coefbc_cem / * bnkj(4,4,8), clkj(3,8)
c j = 17; pi- + p --> pi0 n or pi+ + n --> pi0 + p Charge exchange
c scattering; Tlab <= 0.08 GeV:
data ((ankj(n,k,17),n=1,4),k=1,4) /
& 1.4988d-1 , 2.8753d0 , -5.3078d0 , 6.2233d0 ,
&-5.9558d0 , -1.6203d2 , 4.3079d2 , -6.2548d2 ,
& 1.2875d+2 , 3.1402d+3 , -7.9189d+3 , 1.0983d+4 ,
&-8.5161d+2 , -1.8780d+4 , 4.4607d+4 , -5.8790d+4 /
end block data
```

subroutines and functions collected inside ‘module’

BLOCK DATA not allowed in module, automatically moved to end
Conceptual framework of Crème-MC

Device Parameters

**Name:** dev1  **Ecrit:** 0.01
xmin  ymin  zmin  xmax  ymax  zmax  alpha  Use ellipsoid?
-20  -25  -2  -10  25  5  1  

**add volume**

Device Parameters

**Name:** dev2  **Ecrit:** 0.01
xmin  ymin  zmin  xmax  ymax  zmax  alpha  Use ellipsoid?
0  -20  2  10  20  5  1  

**add volume**

Kinetic Energy (MeV/nucleon)

Flux (m$^{-2}$s$^{-1}$sr$^{-1}$MeV/nucleon$^{-1}$)

Integral Cross Section of helium plug high stat
Capabilities

✧ Create stacks with arbitrary number of layers of materials commonly found in electronics
✧ Create either monochromatic beam or ‘space environment’ as radiation source
✧ Define multiple ‘devices’, each consisting of a set of RPPs or ellipsoids with specified collection weight
✧ Manage range cuts for either
  ✴ high detail of delta ray tracking (LET mode)
  ✴ lower detail, to allow very large numbers of incident ions (nuclear reaction mode)
✧ Produce histograms of energy deposition and of integral cross section
✧ Compute coincidence rates between devices
Weighted sensitive volumes relate spatial ionizing energy deposition with charge collected at a circuit node.

Volumes may be rectangular parallelepipeds or ellipsoids:
- Each have a location within the multilayer stack, size, and efficiency.
- Volumes may overlap or be disjoint.

\[ E_w = \sum_{k=1}^{N} a_k E_{\text{dep},k} \]
Multiple Device Models

- Represent class of failures requiring multiple circuit nodes to collect charge
- Multiple cell upsets, DICE latches, etc
- Sensitive volume models are specified for each device and given upset threshold
- Cross sections and SEU rates are provided based on frequency of events meeting coincidence requirement
Extended Services From ISDE

✧ Website is backed by the electronics expertise of ISDE
  ✧ Largest university-based microelectronics radiation group worldwide (?)
  ✧ Can provide expertise in setting up model systems, running simulations, and interpreting results
  ✧ Problems which are beyond capabilities of the web interface can be migrated to full MRED sims, with almost unlimited flexibility via Python interface.
  ✧ Maintain close working relation with G4 collaboration, especially SLAC group and EM physics.

✧ ISDE can coordinate full accelerator-based tests to validate calculations
The Institute for Space and Defense Electronics (ISDE) 
The Radiation Effects and Reliability (RER) Group 
Vanderbilt University, Nashville, TN

VANDERBILT ISDE & RER

ISDE & RER Capabilities

- Radiation Effects Research (RER) Group
  - Training ground for rad-effects engineers
  - Basic research and support of ISDE engineering tasks
  - Hundreds of technical publications
  - Open access
  - A few undergraduate students
  - 30 graduate students
  - 9 faculty with decades of radfx experience

World's largest university-based radiation effects program

ANALYSIS & SIMULATION

Supercomputer-Based Radiation-Effects Analysis

Do it once; do it right. Leverage supercomputer scaling.

DESIGN SUPPORT

- Rad-aware compact modeling: IC’s & discretes
- Process modeling with radiation effects
- Test chip design
- RHBD systems design & training
- Software tool development & automation

RADIATION TESTING

- Test and characterization capabilities
- Total Ionizing Dose
- Single Event Effects
- Displacement Damage
- Extensive set of characterization hardware

- ISDE has access to a suite of radiation sources and a fully equipped parts analysis laboratory

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Geant4 Space Users Workshop, 2010

19/Aug/2010

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