

Space Applications for SWORD

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Introduction: SoftWare for Optimization of Radiation Detectors (SWORD)



Objective

- Enable rapid radiation transport simulation of realistic scenarios
- Enable quick evaluation and optimization of radiation detector design, reducing development risk
- Enable studies of radiation-related scientific, engineering and national security topics

Approach

- Design, radiation transport simulation, analysis
- Use existing radiation transport codes (Geant4, MCNP, Omnibus/Denovo)
- SWORD includes:
 - A CAD system for scenario definition
 - A standard library of pre-defined objects of interest (e.g., vehicles, containers, detectors) and radiation emission spectra
 - Spectrum and imaging analysis tools
 - Geant4 (MCNP and Omnibus/Denovo must be obtained separately)

Sponsors

 SWORD is the primary tool for simulating radiological/ nuclear environments for CWMD, the ONR Maritime Weapons of Mass Destruction Detection Program (M-WMD-D), and the DTRA Operations Research, Modeling & Analysis Office (J91SM)

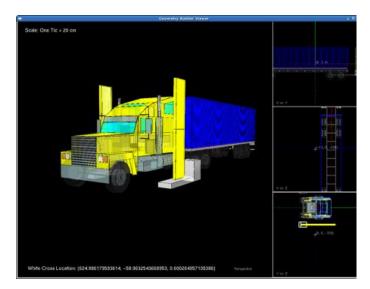


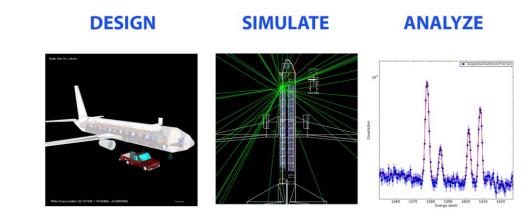
Introduction









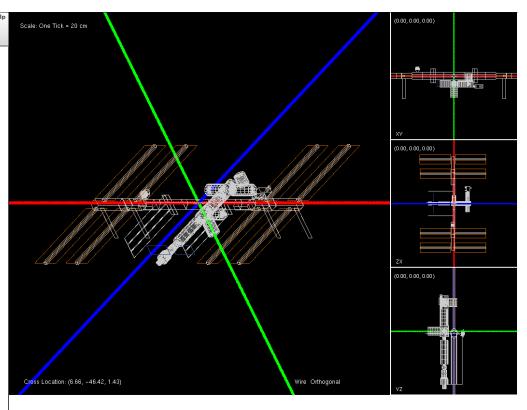




SWORD CAD System



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| | Right: Ctrl → | Trans | Transparency: a Persp/Ortho: v | | | Rotate Up/Down | | | | |
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| Detector Proper | | | Source | | rce Properties | Time Steps | View Options | | | |
| Add Object Edit | Object Copy Obj | ect M | ove Object | Rotat | e Object 🛛 Snap | Object Library C | bjects Array/Mask | | | |
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| ► ISS-Harmony | | | | | | | | | | |
| ► ISS-JEM-EF ➡ ISS-JEM-ELM-PS ➡ ISS-IEM-PM | | | Color: | | none | | ▼ Custom Color | | | |
| | | | Object Dimensions | | | | | | | |
| - ISS-JEM_EF-P - ISS-JEM_EF-P - ISS-JEM_EF-P - ISS-JEM_EF-P Φ ISS-Leonardo ↓ ISS-P1_Truss | ayload-5 ayload-7 ayload-8 | | Length (x:y:z) 20000.0 : 20000.0 : 20000.0 cm | | | | | | | |
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| ► ISS-P6_Truss | | | Object Rota | tion | | | | | | |
| ISS-PMA-1 ISS-PMA-2 | | | | | | | | | | |
| ISS-PVA-4Pa | | | Axis R | otatio | ons (x:y:z) | : | : deg | | | |
| ISS-PVA-4Pa ISS-PVA-4Pb | | | Object Mas | - | | | | | | |
| - ISS-PVA-4Pb | | - | ODJECT Mds | 3 | | | | | | |
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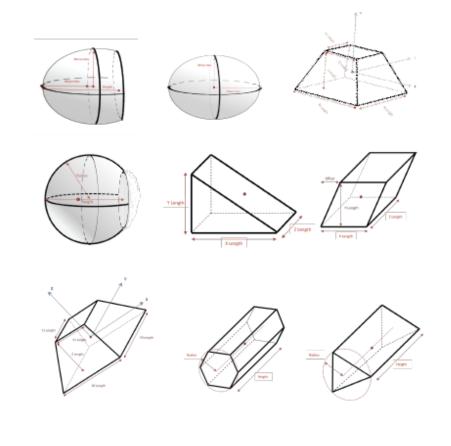
- Full view manipulation
- Object manipulation
- Object properties



SWORD CAD System



| Editor | | | | |
|----------------------|-----------------------------|----------------|--------------|--|
| Add/Edit/Delete Ma | aterials Edit Ma | terial Density | Mcnp C | |
| Array/Mask De | tector Properties | Instrument | Sour | |
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| | Box | _ | | |
| Belle State | Cylinder | | | |
| Material: | Cylindrical Shell | = | | |
| | Ellipsoid Parallelepiped | | | |
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| Object Map Orienta | aSphere | • | | |
| Length (x:y:z) | : : | : | cm | |
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| Position (x:y:z | z) 0.0 : 0.0 | : 0.0 | cm | |
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Construct objects from primitives



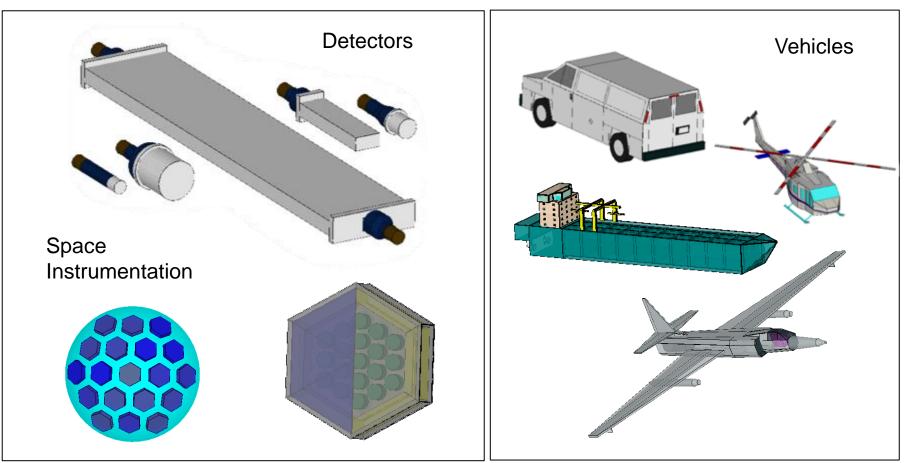
SWORD CAD System

| Materials | - | | | | | |
|--|-----------|--|--|---|--|---------------------------|
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| Al | | Adenine_nist | Material | 0.0 | | |
| Alanine_nist | | Adipose_Tissue_Icrp Ag | Material | 0.0 | | |
| AluminiumOxide | | Air | Material | Object | Shot Location | Shot Direction |
| Aluminum Aluminum_LowDensity | | Air_nist Al | Material Material | P World → Bell-412 → P Yacht | Surface Ovolume OBeam OP | oint 🖲 Outward 🔾 Inward |
| Aluminum_Oxide_nist Aluminum PMT_Base | | Alanine_nist | Material | - e source | Shot Type | |
| Amber_nist | | AluminiumOxide | Material | | Object Surface Emission (particle | |
| Ammonia_nist Aniline_nist | • | | | | ○ Scalable NORM (particles/cm ² /s) ○ |) Test Gun 🔾 Muonic X-Ray |
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| | | | | | 10 mCi | Set |
| | | | | | Source Definition | |
| bject | | Basic Object I | nformation | | Spectrum Name | Weight |
| - World | | Parent: | World | | Cd-109 1 | |
| ⊷ Bell-412 ∽ 😬 Yacht 🛛 🚺 🗖 | | | | | Am-241 0.0 Ba-133 0.0 | |
| - detector | | X Set Detector Prop | erties | | Cf-252-gamma 0.0 | |
| - source | | | | | Cf-252-gamma 0.0 | |
| | ment Typ | e 💿 Spectrometer | Counter | | Co-57 0.0 | |
| | | | - | - | Co-60 0.0 | |
| | | | | - 0 | Cs-137 0.0 | |
| | Energy R | tesolution (FWHM) = v | [C ² + A ² * E/E₀] | 50 | Mn-54 0.0 | |
| | C = 0.0 | A = 0.0 | $E_{a} = 1.0$ | | Na-22 0.0 | |
| Se | t Paramet | ters Clear Param | eters Cancel | Expand All Collag | Dise All Clear All | |
| _ | _ | | | | Radia | ation Sources |





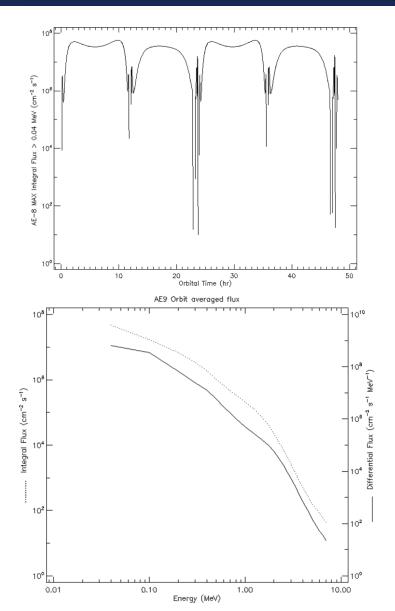
More space objects coming!





SWORD Emission Spectra

- Emission spectra distributed with SWORD
 - Relevant SNM spectra (gamma and neutron)
 - Various NORM, medical, industrial source spectra
 - Many scale by area
 - Source activity specified for industrial sources
 - Multiple sources allowed
- Relatively easy to add orbital environment spectra
 - Several common whole orbits included
 - AE9/AP9 after converting to SWORD input spectrum
- Future SWORD release will include AE9/AP9 integration
 - Input orbital data into SWORD GUI
 - Spectrum automatically generated





3



MARS and ISS



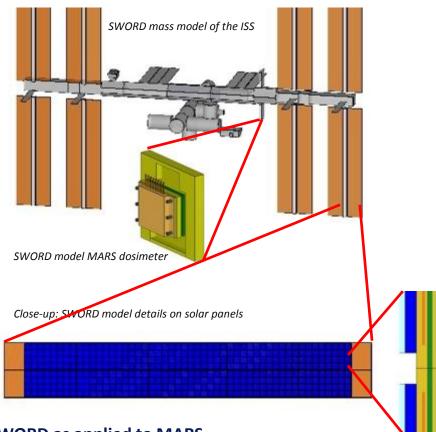
SWORD as applied to space situations

- Can make complex mass models of spacecraft for accurate radiation transport calculations
- Have made mass models with > 100,000 objects
- Can expose mass model to any high energy radiation:
 - Cosmic rays
 - Trapped particles
 - Solar X-rays and gamma ray flares
 - Albedo gamma rays and neutrons

MARS Micro-Dosimeters

NRL's MARS (Miniature Array of Radiation Sensors) is an array of persistent, ubiquitous sensors that monitor the total dose radiation on the host spacecraft for 3-D radiation modeling. The concept is to provide a radiation state-of-health measurement like that of a thermistor.

MARS was installed on the ISS in Aug 2013



SWORD as applied to MARS

- Model dose to MARS dosimeters and include effects of material nearby and from entire International Space Station (ISS)
- Model dose to solar cells
- Establish correlation between dose to MARS and solar cells

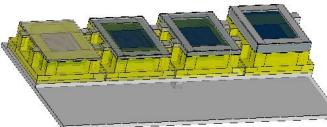


MARS and ISS

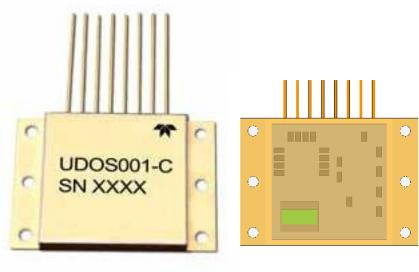


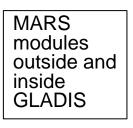
- SWORD models of MARS
 - Both host experiment and co-located units have been modeled
 - Constructed detailed model of Teledyne uDOS001 micro dosimeter
 - Initial study done with only aluminum shielding, Demron added later

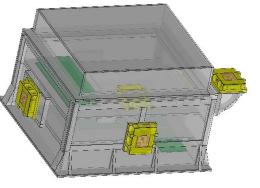
Single MARS Module



Co-located modules with various shield thickness





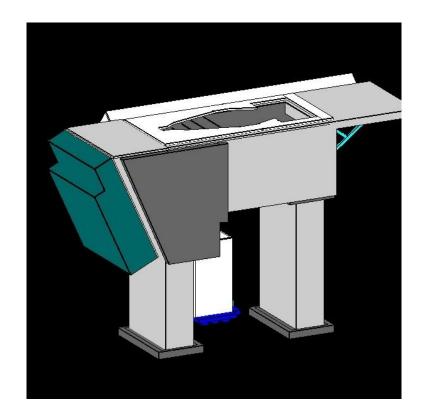


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SoloHI Radiation Dose



- SoloHI Radiation Dose Modeling Summary
 - Optical camera on board the ESA/NASA Solar Orbiter.
 - Model the radiation dose to specific electronics of the SoloHI Instrument on the Solar Orbiter from energetic particle radiation.
 - Model the dose using the actual geometry of the instrument and spacecraft as opposed to a generic thickness of material.
 - Of interest were the focal plane instrument silicon detectors and the FPGA on the readout electronics boards.

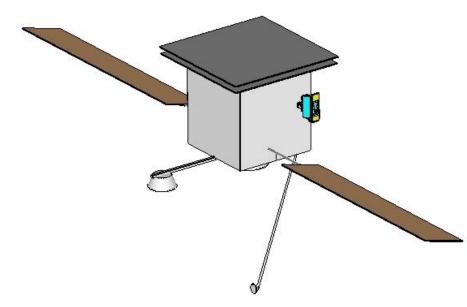


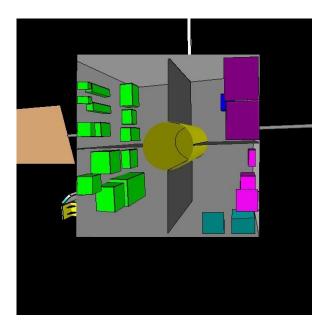
SoloHI Instrument

U.S.NAVAL RESEARCH LABORATORY

SoloHI Radiation Dose





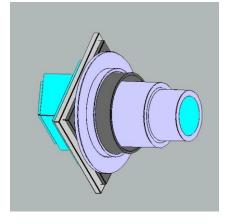


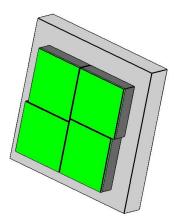
- Made a simplified spacecraft model.
- Mounted detailed SoloHI instrument model on spacecraft.
- Exposed entire geometry to radiation environment.
- Model based on document [EID-A_IR-21_SOL.S.ASTR.TN.00098_03].
- No details on materials or sub-system masses, so made model mass accurate (1047 kg) with Al and C as materials.



SoloHI Radiation Dose

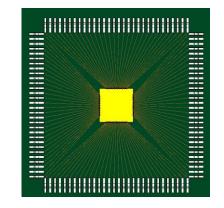


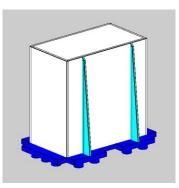




SoloHI Camera

- Materials and dimensions are accurate.
- Some simplifications in geometry.
- Silicon is turned on as detector in terms of collecting energy for dose calculations.





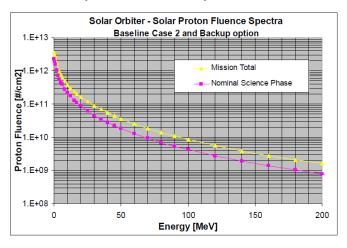
SoloHI FPGA

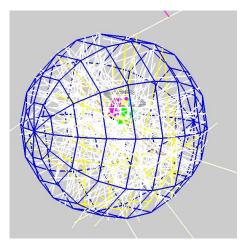
- No data on packaging of FPGA.
- Used standard quad flat pack package.
- FPGAs mounted on printed circuit boards as shown in documentation.
- Circuit boards are mounted in metal container as shown in documentation.



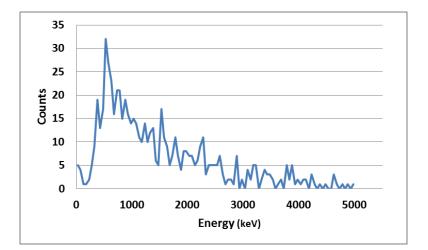
SoloHI Radiation Dose

Input Proton Spectrum





Geometry Of Particle Source



- Energy Deposition from Protons and secondaries in Focal Plane Detectors (2.4x10¹¹ protons shot)
- Scale to mission total fluence yields 4500 Rad dose



Introduction: SoftWare for Optimization of Radiation Detectors (SWORD)



SWORD improvements for space applications

- Chief of Naval Research has recently funded improvements for SWORD in space
- Improve on existing SPENVIS dosage calculations with more detailed geometries
 - Integrate SWORD directly with AE9/AP9
 - Add dosage and spacecraft activation calculations to analysis
- Add more spacecraft to SWORD standard library

Getting SWORD

- NRL releases SWORD to RSICC in the USA and OECD in Europe and has more than 230 current users worldwide
- Current version is 6.0, 7.0beta coming Q2 of CY2019



Conclusion



- SWORD is a general purpose tool for radiation transport modeling
 - CAD interface
 - Multiple transport code support
- SWORD outputs are useful for modeling component or biological dosages in space environments
- SWORD is well suited to optimizing shielding designs
- New SWORD versions released periodically

- Available from RSICC (http://rsicc.ornl.gov)
- For information, contact Wade Duvall (wade.duvall@nrl.navy.mil)