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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)

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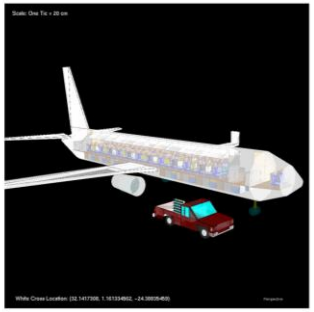
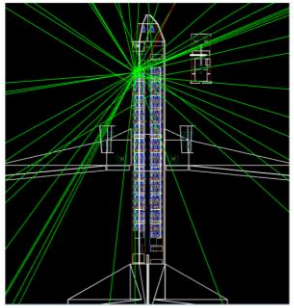
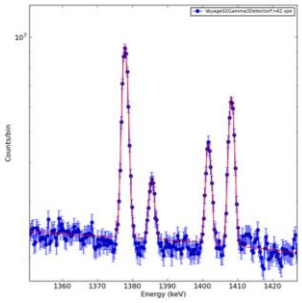
Introduction

DESIGN **SIMULATE** **ANALYZE**







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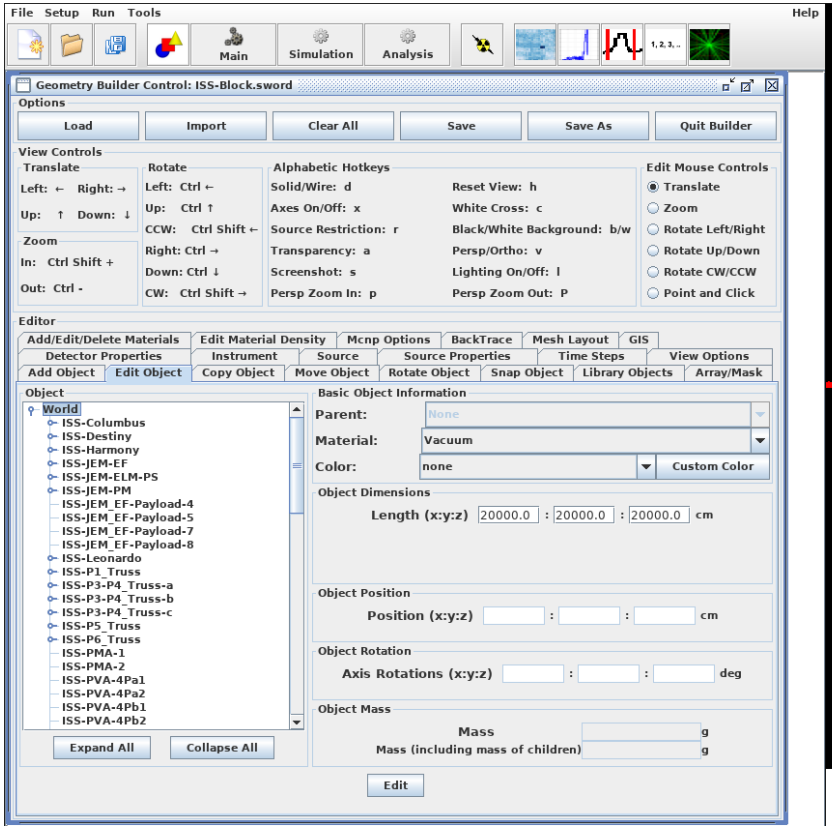
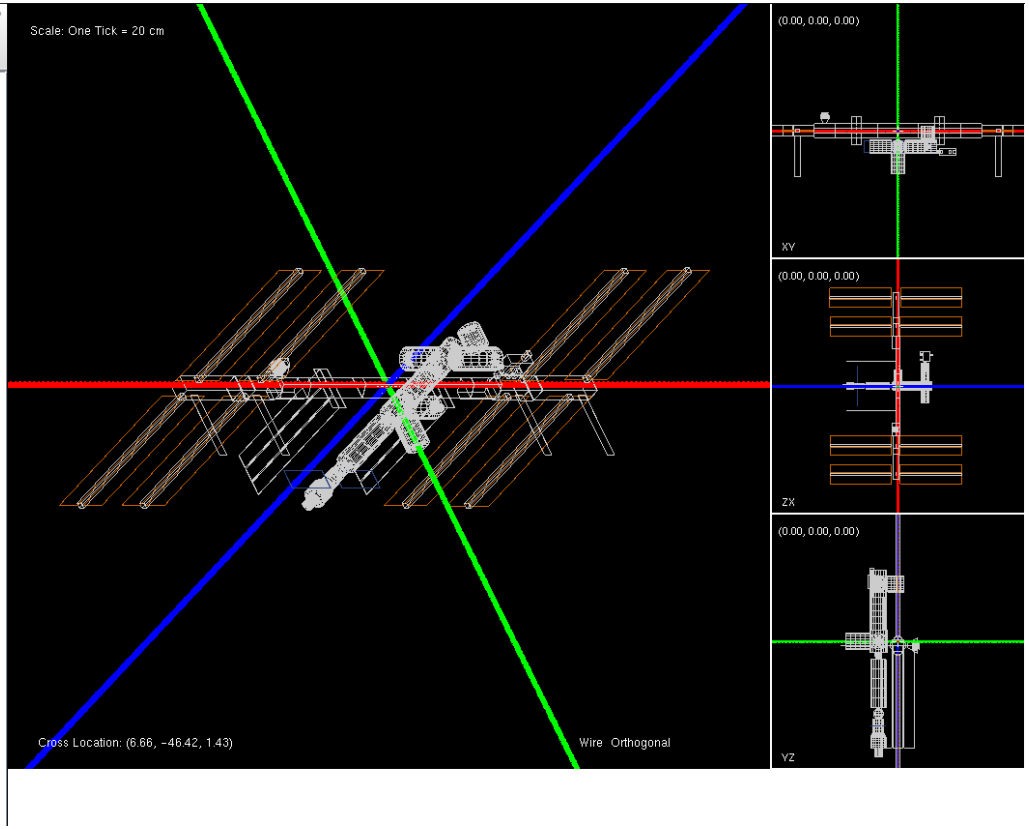
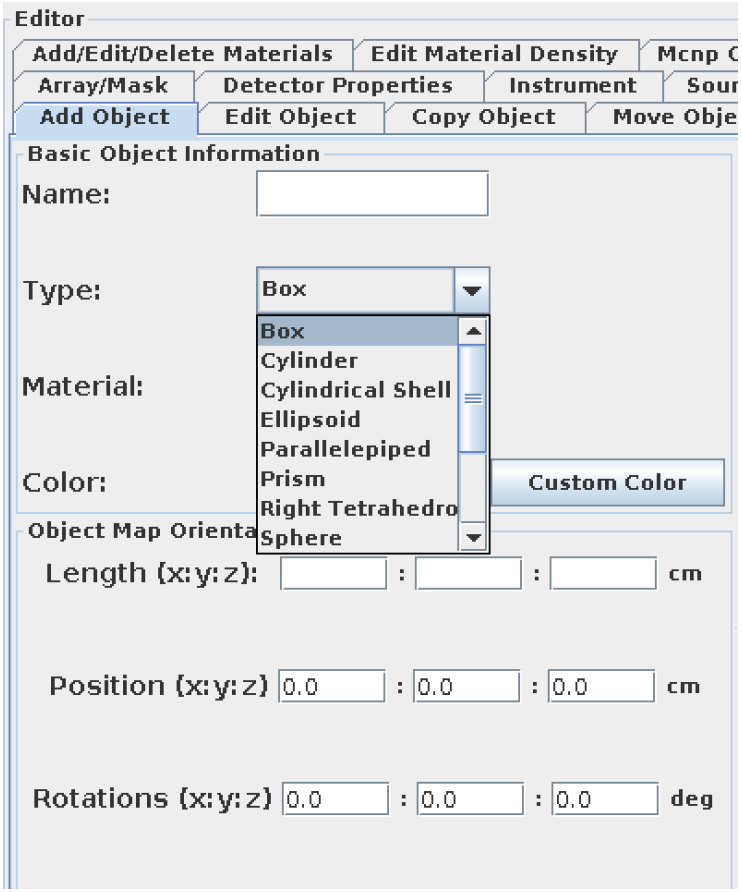
SWORD CAD System

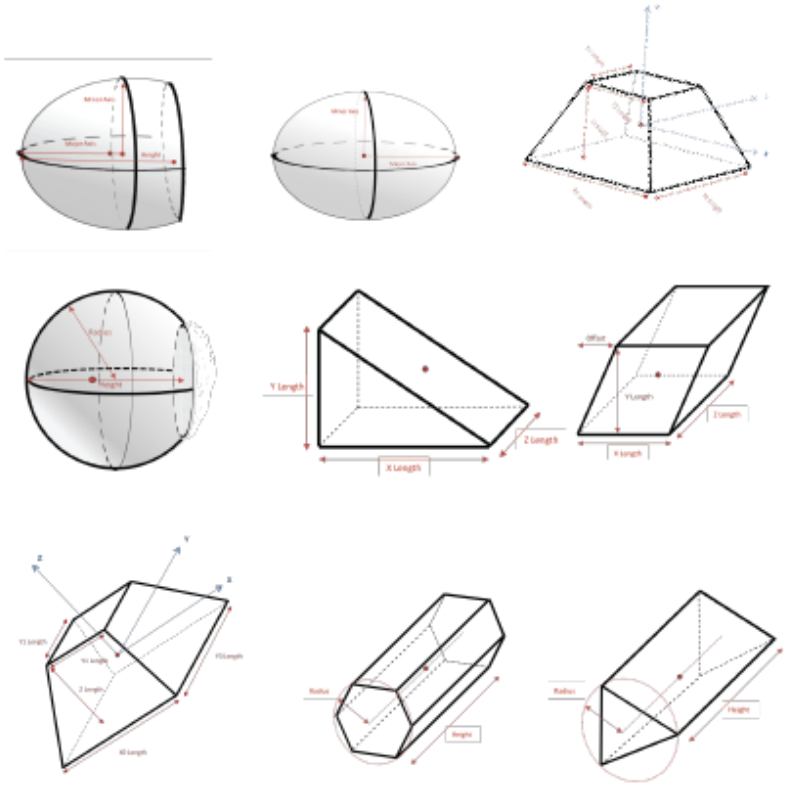




- Full view manipulation
- Object manipulation
- Object properties

SWORD CAD System





Construct objects from primitives

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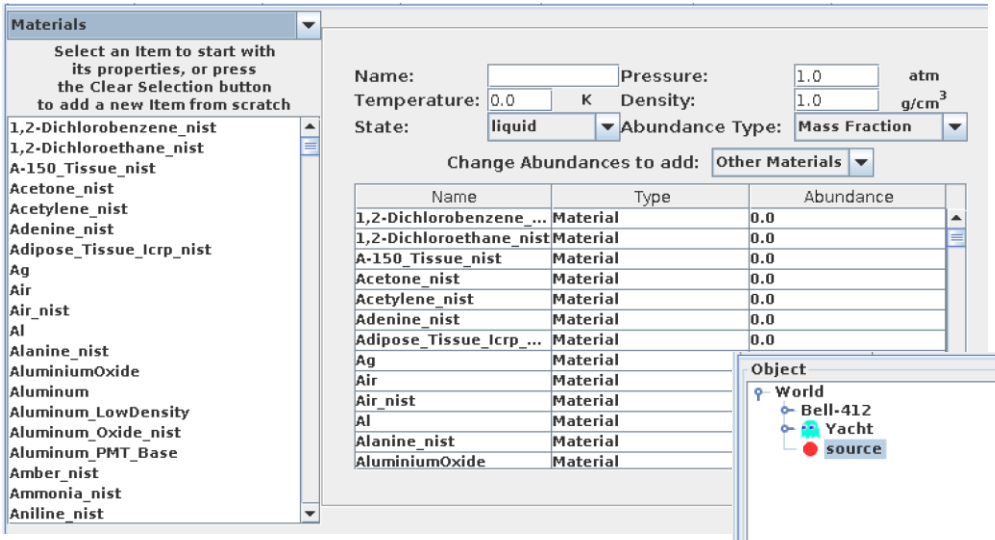
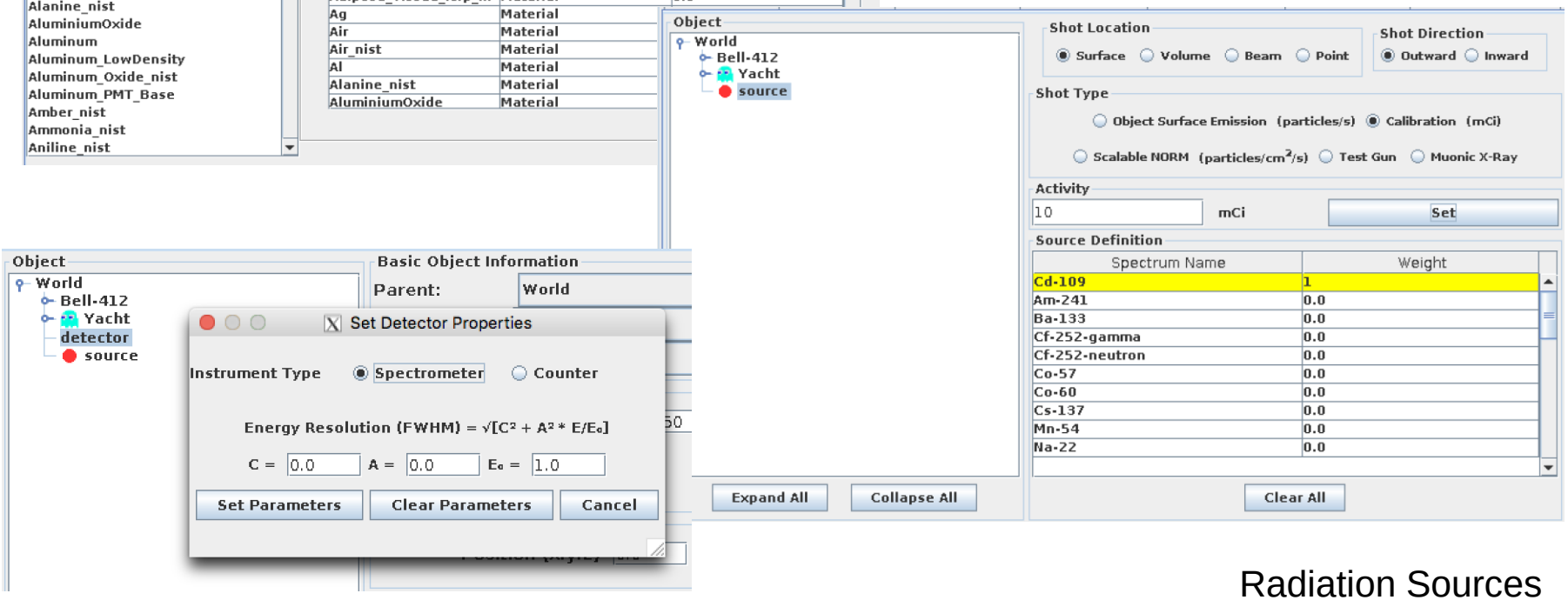
SWORD CAD System



Materials



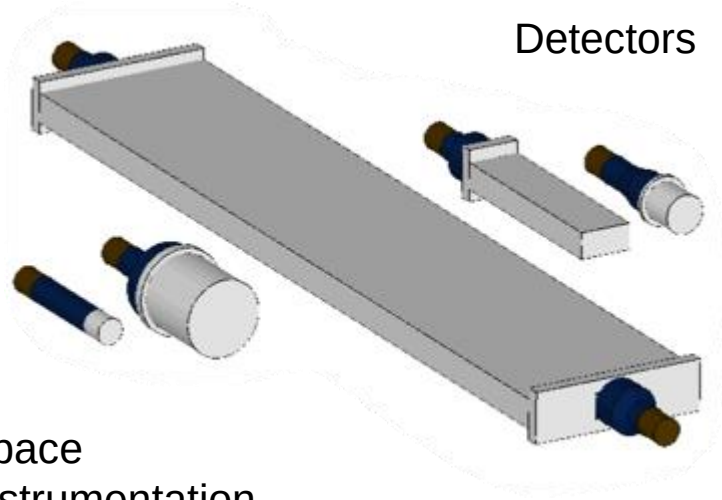
Radiation Sources

Detectors

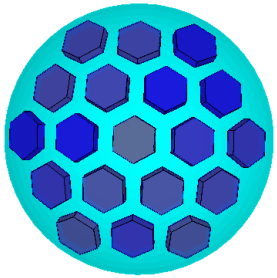
SWORD Standard Library

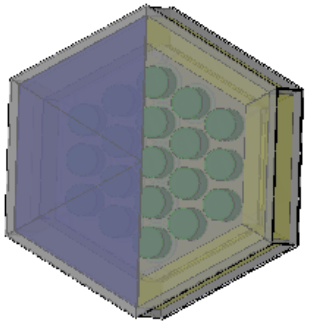
More space objects coming!

Detectors

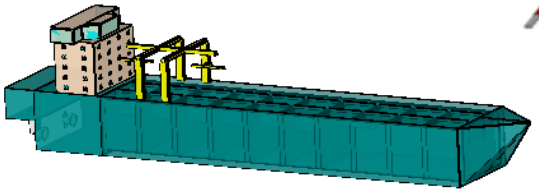


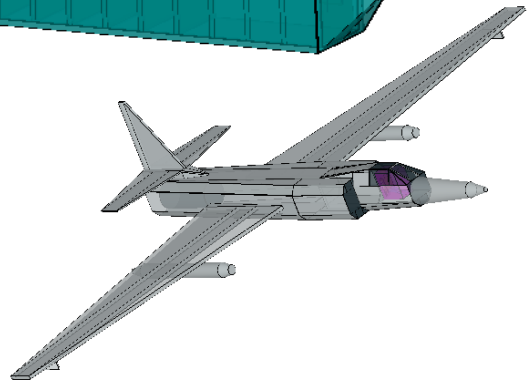
Space Instrumentation





Vehicles





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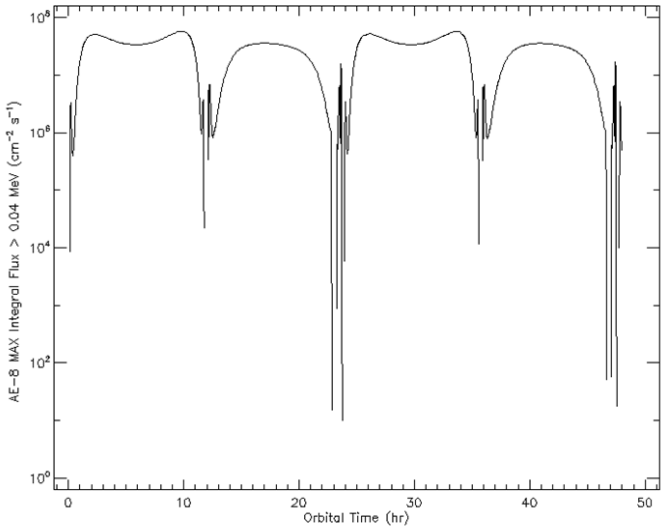
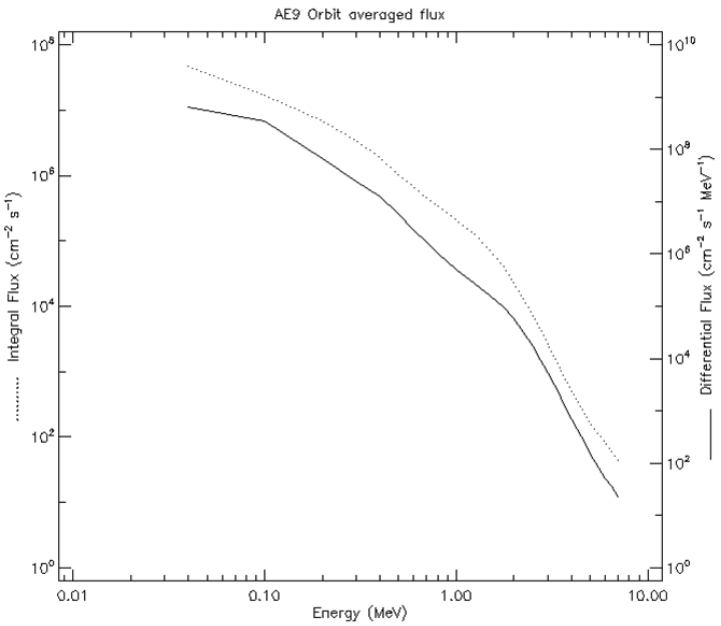
SWORD Emission Spectra

- 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





MARS and ISS

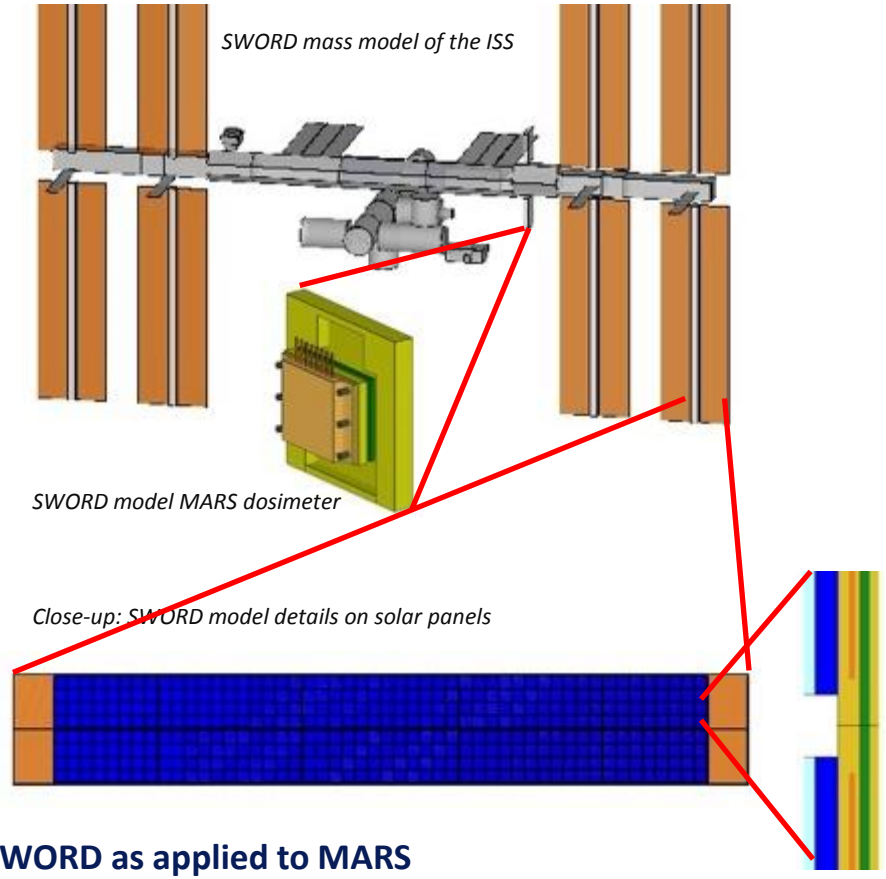
SWORD as applied to space situations

- 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



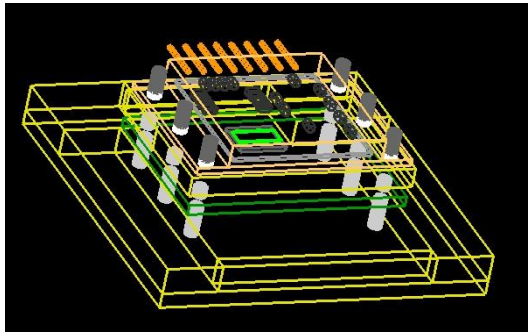
SWORD as applied to MARS

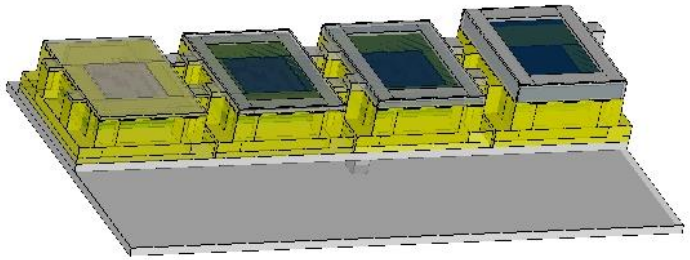
- Model dose to MARS dosimeters and include effects of material nearby and from entire International Space Station (ISS)
- Model dose to solar cells
- Establish correlation between dose to MARS and solar cells

MARS and ISS

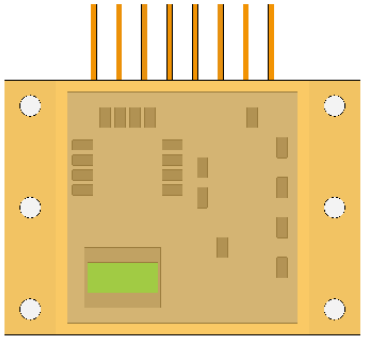
- SWORD models of MARS
  - Both host experiment and co-located units have been modeled
  - Constructed detailed model of Teledyne uDOS001 micro dosimeter
  - Initial study done with only aluminum shielding, Demron added later

Single MARS Module

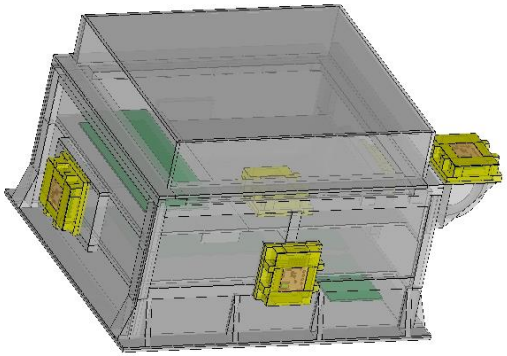




Co-located modules with various shield thickness

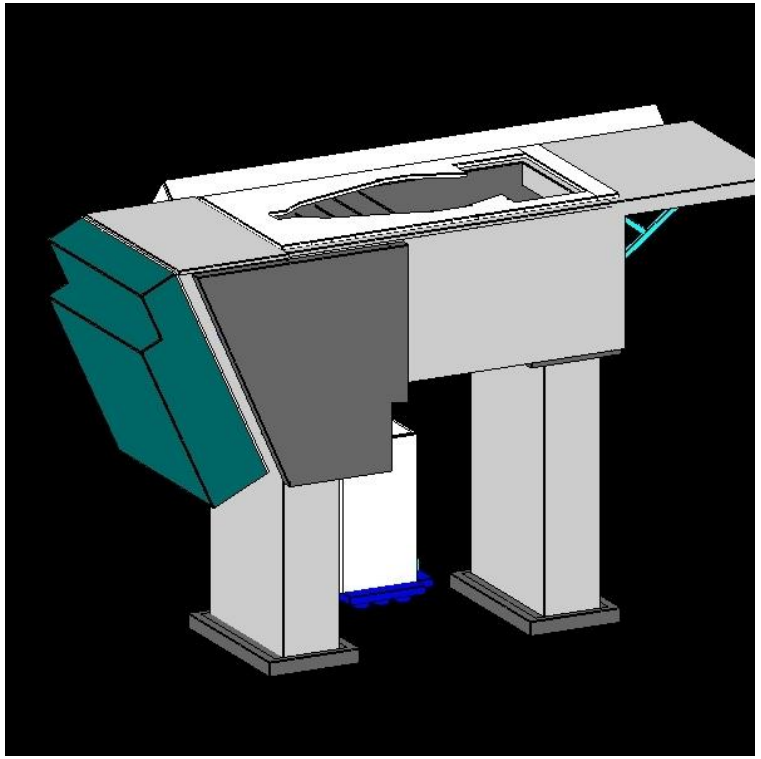


MARS modules outside and inside GLADIS



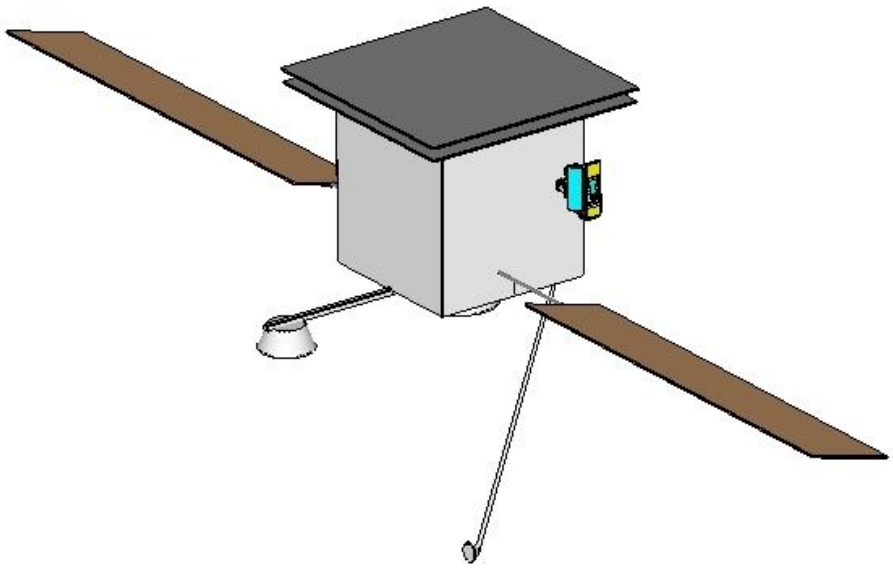
SoloHI Radiation Dose

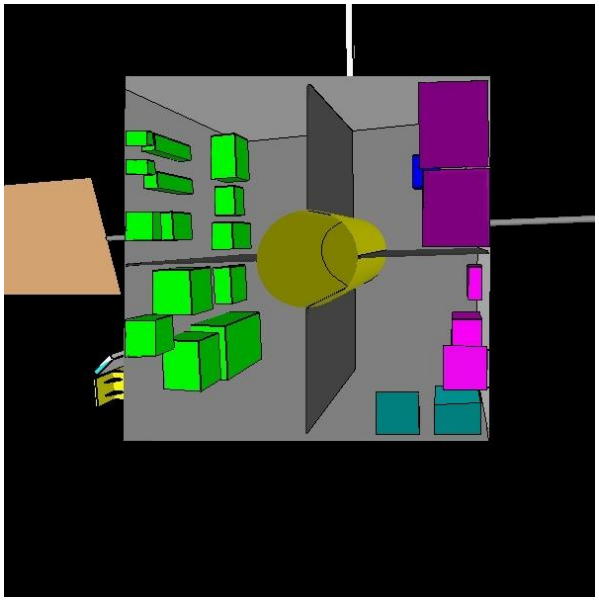
- SoloHI Radiation Dose Modeling Summary
  - Optical camera on board the ESA/NASA Solar Orbiter.
  - Model the radiation dose to specific electronics of the SoloHI Instrument on the Solar Orbiter from energetic particle radiation.
  - Model the dose using the actual geometry of the instrument and spacecraft 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

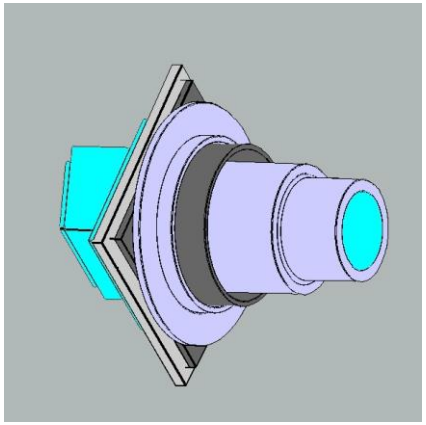
SoloHI Radiation Dose

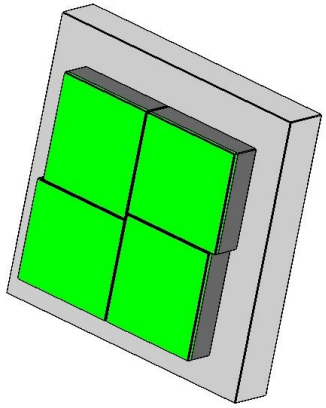


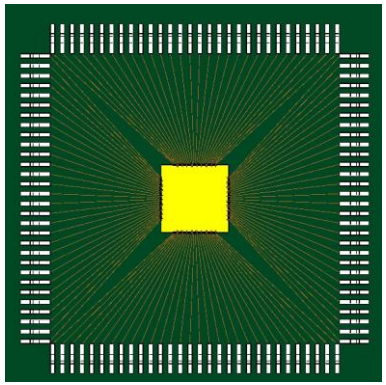


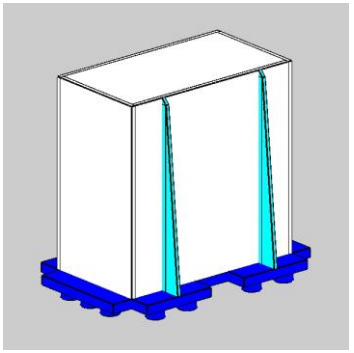
- Made a simplified spacecraft model.
- Mounted detailed SoloHI instrument model on spacecraft.
- Exposed entire geometry to radiation environment.
- Model based on document [EID-A_IR-21_SOL.S.ASTR.TN.00098_03].
- No details on materials or sub-system masses, so made model mass accurate (1047 kg) with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

SoloHI Radiation Dose









SoloHI Camera

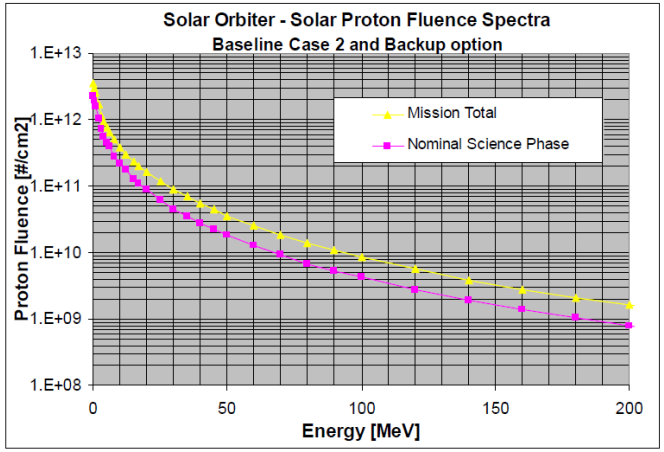
- Materials and dimensions are accurate.
- Some simplifications in geometry.
- Silicon is turned on as detector in terms of collecting energy for dose calculations.

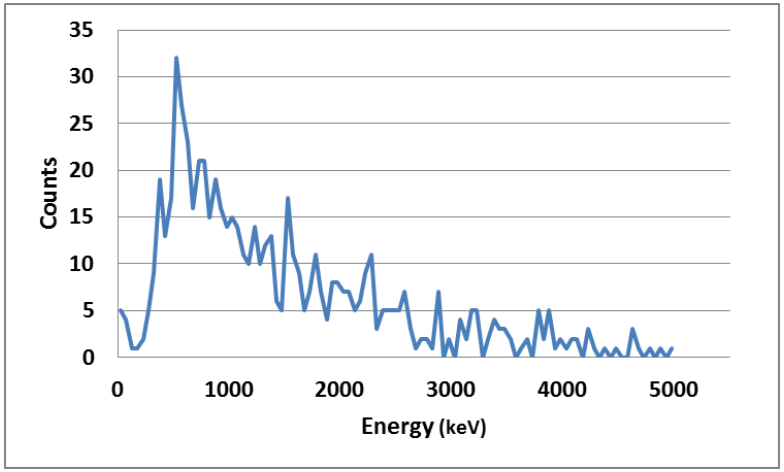
SoloHI FPGA

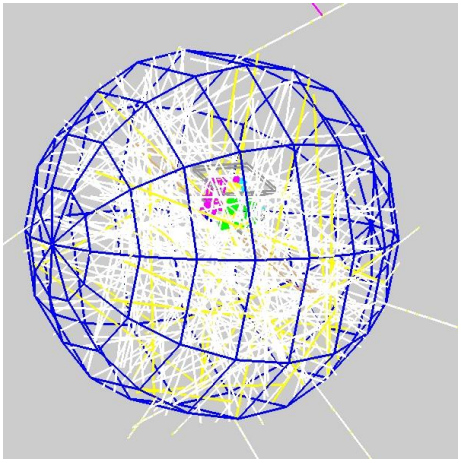
- No data on packaging of FPGA.
- Used standard quad flat pack package.
- FPGAs mounted on printed circuit boards as shown in documentation.
- Circuit boards are mounted in metal container as shown in documentation.

SoloHI Radiation Dose

Input Proton Spectrum







Geometry Of Particle Source

- Energy Deposition from Protons and secondaries in Focal Plane Detectors (2.4×10^{11} protons shot)
- Scale to mission total fluence yields 4500 Rad dose

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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

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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)