Space Environment and Effects Tool for STK (STK-SEET) Technical Primer

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Introduction

STK-SEET is a suite of commercial-grade space environment models adapted from the Air Force Research Laboratory's AF-GeoSpace software by AER for use with STK. It provides models for:

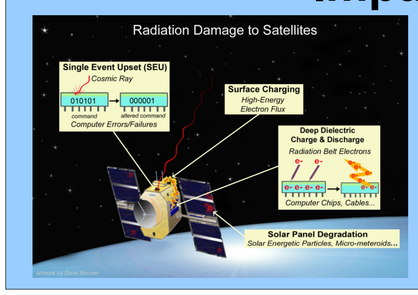
- radiation belts (AE8/AP8, CRRES Models, SHIELDOSE2)
- South Atlantic Anomaly fluxes and transit times
- magnetic fields (IGRF, Olson-Pfitzer)
- particle impacts (meteor and man-made)
- equilibrium vehicle temperature

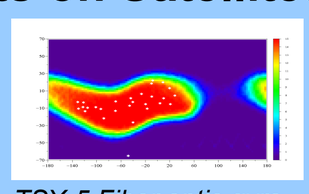
SEET is thoroughly integrated with AGI's Satellite Toolkit (STK) with access constraints, 3rd-party accessibility through STK-engine, and leveraging STK's professional orbit generation capability.

Relevance to DOD and Commercial Customers

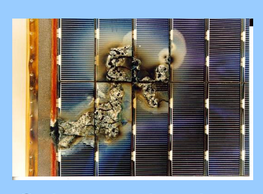
- satellite design and mission planning: radiation environment
  - ionizing dose exposure to satellites
  - single event effects/single event upsets (SEE/SEU)
- mission ops: South Atlantic Anomaly (SAA) maps
  - intense inner proton belt region with high SEU probabilities
  - determine when spacecraft will be inside the SAA

Impacts on Satellites





TSX-5 Fiber optic gyro anomalies in SAA.

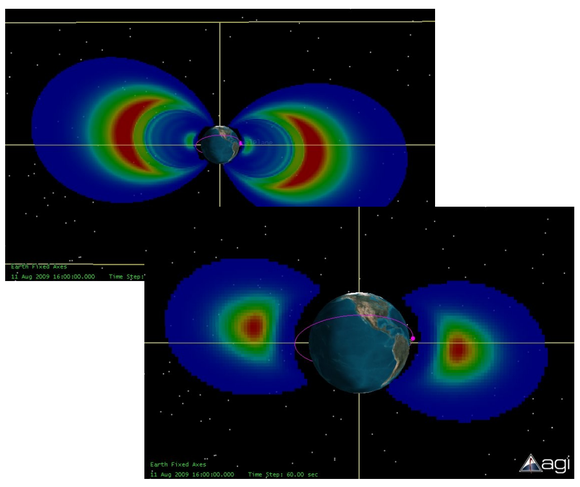


Solar panel arcing.

Radiation Environment

Overview

- integrated implementation of CRRESRAD, APEXRAD, CRRESELE/PRO, NASA AE8/AP8 and SHIELDDOSE2
- user-specified energy lists for flux/fluence output
- user-specified shielding depths, material types for dose rate/total dose output
- graphical representation of flux/dose distribution on satellite orbit



Typical Use-case

Objective: Perform a baseline trade study for component shielding for a 5-year Geosynchronous transfer orbit mission.

Background: With a geosynchronous transfer orbit, the satellite will visit all regions of the inner and outer radiation belts. Shielding is required to reduce total ionizing dose encountered to meet mission lifetime.

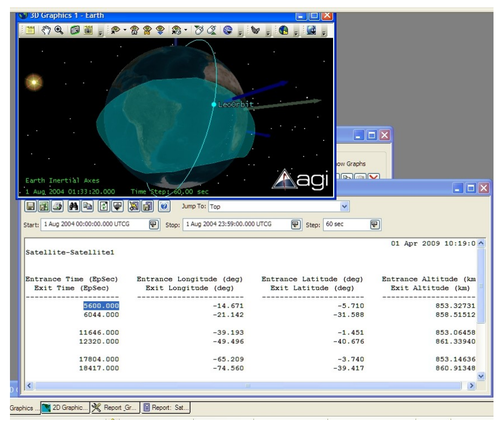
Need: determine total ionizing dose for representative shielding thicknesses over mission orbit and lifetime.

Strategy: use CRRESRAD/APEXRAD constituent models in the Radiation Environment feature to obtain total dose-depth curves for the planned mission.

SAA-Transit

Overview

- South Atlantic Anomaly: region of enhanced high-energy protons at LEO
- based on latest SAA studies/data by AFRL
- provides fluxes for user-selectable energy
- provides SAA entrance/exit times based on user-specified flux threshold



Typical Use-case

Objective: Plan a low-cost polar orbit LEO Earth observing mission.

Background: LEO orbits penetrate the SAA at least daily. Low-cost means less component shielding. SEUs in the SAA require turning off critical systems during transit.

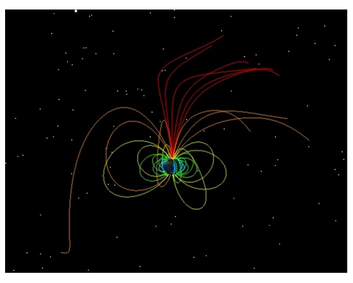
Need: determination of SAA transit times for trade studies of various possible orbits.

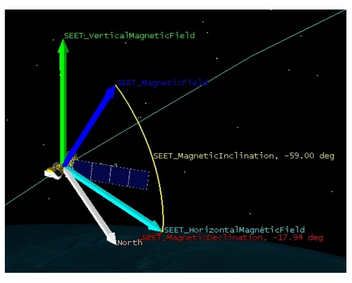
Strategy: use the SAA-transit feature of STK-SEET to obtain SAA entrance/exit times for various orbits (orbits can be designed with STK-Astrogator.)

Other Models

Magnetic Fields

- IGRF mainfield (or associated dipole or offset-dipole field models)
- Olson-Pfitzer external field (more to be added in future versions)
- vector components in any frame
- field-line tracing; conjugacy computations; footprints; McIlwain L computation





Particle Impacts

- based on AF-GeoSpace METEOR IMPACTS algorithm, plus man-made debris based on Kessler 1989
- accounts for standard meteor showers and storms
- small (< 10 mm), untracked particle distributions
- gives instantaneous or integrated probable particle fluxes
- user-specified material and pit-depth threshold

Vehicle Temperature

- simple equilibrium thermal model
- direct solar plus Earth albedo and IR
- spherical or oriented plate models available (user specified area)
- user specified spacecraft thermal properties (thermal absorption, emission and internal heat-sink dissipation)
- implemented from open literature

Future Updates

- Near-Earth Heavy Ion Environment Model: cosmic rays, SEPs, trapped ions, LET spectra, SEUs
- Ionosphere/plasmasphere densities
- Fast SHIELDOSE2 calculator
- Tsyganenko external magnetic field models