

Using SPENVIS to evaluate the Space Environment

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ECSS-E-ST-10-04C

Trapped Rad. Belts Fluxes



Earth Orbit:

1. Long term average fluxes:
 - a. AE-8 and AP-8 models
 - b. IGE-2006 for GEO (+/- 500 km),
"upper" model for "conservative" analyses
 - c. ONERA MEOv2 for electrons in GPS orbits (20000km circular +/- 500 km altitude), "upper" model for conservative analyses
2. Worst Case for Internal Charging:
 - a. FLUMIC v3 model
 - b. NASA worst case model for GEO
 - c. Can also be used for short term analyses (1 day → 1 month)
of worst case cumulative radiation effects
3. Worst Case trapped proton fluxes:
 - a. No provision in the current standard

Solar Particles: ESP model, confidence level is a project decision.

- | | |
|----------------------------------|--|
| 1. Dose (TID/TNID) | ← total mission fluences |
| 2. Solar cell degradation: | ← total mission fluences |
| 3. Internal charging | ← peak daily fluences |
| 4. Single event effects: | |
| a. long term (destructive): | ← total mission fluence, probabilities |
| b. Short term (SEU, Transients): | ← peak fluxes, probabilities |
| 5. Instrument background/noise: | |
| a. Maximum noise levels: | ← peak fluxes, |
| b. Loss of "science" | ← duration of "events"
← frequency of "events". |
| 6. Material Degradation | ← total mission fluences
← low energies required (\sim keV). |

Confidence levels/Risk, uncertainty and errors → Margin policy

1. Introduction to SPENVIS – getting started
2. Generate a mission trajectory
3. Overview of available radiation environment models
4. The various simple effects tools
 - a. SHIELDOSE
 - b. EQFLUX/MC-SCREAM
 - c. Single Event Effects
5. The Geant4 tools (Mulassis, SSAT, GRAS, GEMAT)
6. Advice, Exporting results & other useful features.

Registration



<https://www.spenvis.oma.be/registration.php>

Temporary Accounts
available:

juice_1
juice_2

...

juice_70

Password for each is:

Lulea-2016

The screenshot shows a web browser window with the URL www.spenvis.oma.be/registration.php. The page features the SPENVIS logo, the ESA logo, and a navigation menu on the left. The main content area is titled "SPENVIS Registration" and contains a list of registration fields. The fields are: Username*, Email*, Title* (dropdown), First Name*, Last Name*, Phone Number, Fax Number, City*, Affiliation*, Affiliation Type* (dropdown), Affiliation URL*, Country* (dropdown), and Agreement* (checkbox). A "Next" button is located at the bottom right of the form.

SPENVIS
The Space Environment Information System

SPENVIS Registration

- The entries marked with * are mandatory.
- E-mail addresses should be linked to your affiliation, in particular hotmail, yahoo and similar accounts are not allowed.

Username*

Email*

Title* --Select One--

First Name*

Last Name*

Phone Number

Fax Number

City*

Affiliation*

Affiliation Type* --Select One--

Affiliation URL*

Country* --Select One--

Agreement* ☐ I have read and I fully accept the [Terms and Conditions](#).

Create a Project

Project management - Google Chrome

[https://www.spenviis.oma.be/htbin/spenviis.exe?%23resettoPrevious\(packages.html\)](https://www.spenviis.oma.be/htbin/spenviis.exe?%23resettoPrevious(packages.html))

UP

Project management

Create a new project

Output
Help


Please define a project. It will be used to gather both input and output of use. You could define more than one project.


Project settings	
Name	<input type="text" value="Project1"/>
Title	<input type="text" value="My First Project"/>
Abstract	<div>Textual information that describes the mission, assumptions, etc.</div>


Execute


© ESA


☆ ☆ ☆

















Link to project management

Link to User Profile

A Mission Trajectory is required



Three means of specifying the trajectory:

- **Orbit Generator**
 - Upload trajectory file (SPENVIS format - Advanced)
 - Upload CCSDS OEM trajectory file (JOREM extension)
- Orbit generator uses ephemeris and propagates the orbit
 - General
 - Semi-major axis/eccentricity
 - Apogee/perigee
 - Circular
 - Hyperbolic (for fly-by missions)
 - Geostationary
 - Helio-synchronous (SSO)
 - Near Earth Interplanetary

Model Home Page

Model packages - Google Chrome

<https://www.spenvis.oma.be/htbin/spenvis.exe>

▲ UP

SPENVIS Project: PROJECT1
Model packages
Planet: Earth

Output
Help

Coordinate generators
Radiation sources and effects
Spacecraft charging
Atmosphere and ionosphere
Magnetic field
Meteoroids and debris
Miscellaneous
Geant4 Tools
ECSS Space Environment Standard

[Coordinate generators](#)

[Spacecraft trajectories](#)
or
[Geographical coordinate grids](#)

The models implemented in SPENVIS are combined in the packages listed above. Clicking on a package name will expand the table with a list of models. Some model suites have to be executed in a prescribed order. Model links will not be available when pre-required runs have not been executed yet. Most models run on both a spacecraft trajectory and a geographical coordinate grid. Clicking on the coordinate generator links and returning to this page toggles between the two sets of coordinates. The model links will adapt to the choice of coordinates.

The model pages have deliberately been kept as concise as possible. A navigation bar is figured at the top of each SPENVIS page. The [Help](#) link in the bottom right hand corner of this bar points to context sensitive help pages, which in turn contain their own navigation system, including access to guidelines on model usage and background information on the space

Traditional GEO

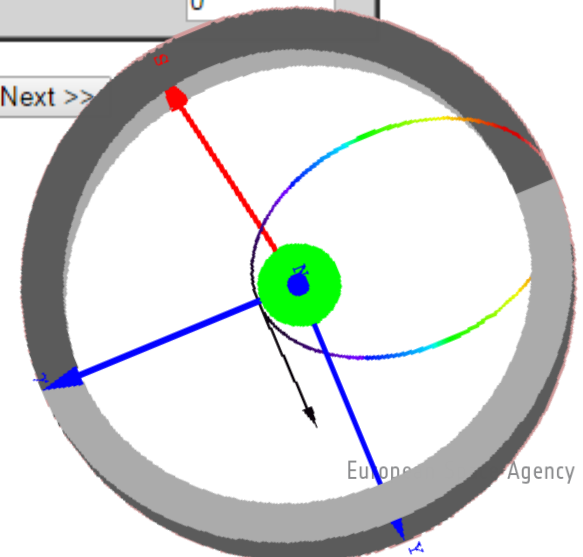
Trajectory generation:	use orbit generator ▼
Number of mission segments:	1 ▼
Mission end:	total mission duration ▼
Mission duration:	1.0 years ▼
Account for solar radiation pressure:	no ▼
Account for atmospheric drag:	no ▼

Segment title:	
GTO Phase	
Orbit type:	general ▼
Orbit start:	calendar date ▼
01 ▼ Jan ▼ 2020 ▼ 00 ▼ : 00 ▼ : 00 ▼	
Representative	number of orbits ▼ : 2
Altitude specification:	perigee and apogee altitudes ▼
Perigee altitude [km]:	300
Apogee altitude [km]:	36000
Inclination [deg]:	0.0
R. asc. of asc. node [deg w.r.t. gamma50] ▼ :	0
Argument of perigee [deg]:	0
True anomaly [deg]:	0



Segment title:	
Orbit type:	geostationary ▼
Orbit start:	calendar date ▼
02 ▼ Jan ▼ 2020 ▼ 00 ▼ : 00 ▼ : 00 ▼	
Representative	trajectory duration ▼ [days]: 1
Longitude [deg]:	0

<< Back Next >>

<< Back Next >>



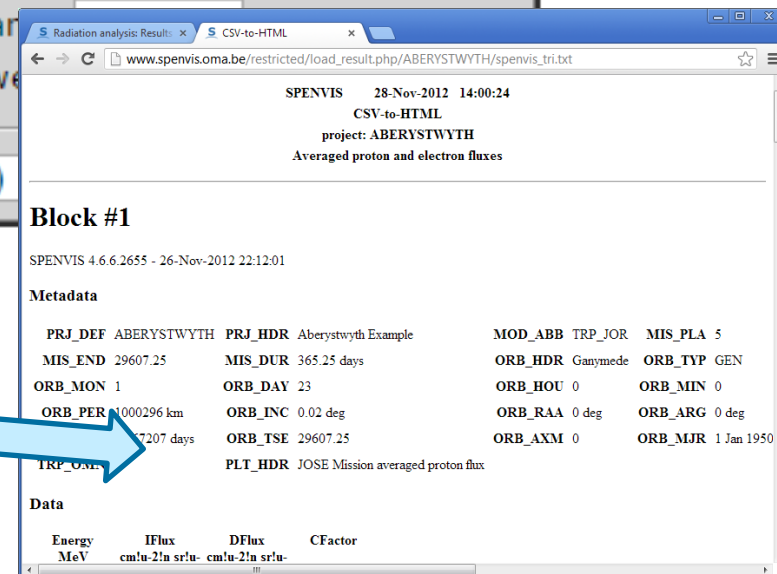
Output Pages

Tables	Plots
Report file Spacecraft coordinates  Attitude vectors 	3D-View of the orbit (png)

New plots	
<input type="checkbox"/> Orbit parameters as a function of time for mission segment 1 ▼	
<input checked="" type="checkbox"/> 3D view ▼	the altitude ▼ for whole mission ▼ with linear ▼
rainbow colour	scale in GEI ▼ coordinates
Viewing angles [deg]	
Tilt angle of rotation axis from screen north: 0	
Tilt angle of rotation axis from screen plane: 0	
Longitude pointing to view: 0	
Plot as	Portable Network Graphics (PNG)

Link that can be used by Excel
to download CSV formatted data
as HTML tables

CSV Format defined in help pages



SPENVIS 28-Nov-2012 14:00:24
CSV-to-HTML
project: ABERYSTWYTH
Averaged proton and electron fluxes

Block #1
SPENVIS 4.6.6.2655 - 26-Nov-2012 22:12:01

Metadata

PRJ_DEF	ABERYSTWYTH	PRJ_HDR	Aberystwyth Example	MOD_ABB	TRP_JOR	MIS_PLA	5
MIS_END	29607.25	MIS_DUR	365.25 days	ORB_HDR	Ganymede	ORB_TYP	GEN
ORB_MON	1	ORB_DAY	23	ORB_HOU	0	ORB_MIN	0
ORB_PER	1000296 km	ORB_INC	0.02 deg	ORB_RAA	0 deg	ORB_ARG	0 deg
ORB_TSE	29607.25	ORB_TSE	29607.25	ORB_AXM	0	ORB_MJR	1 Jan 1950
TRP_OMS		PLT_HDR	JOSE Mission averaged proton flux				

Data

Energy	IFlux	DFlux	CFactor
MeV	cm ² u ⁻² sr ⁻¹ u ⁻¹	cm ² u ⁻² sr ⁻¹ u ⁻¹	

Radiation sources include:

- Trapped radiation belts (AP8, AE8, IGE-2000, etc.)
- Solar protons (long, short term)
- Galactic cosmic rays

Models for all three sources in:
“Radiation Sources and Effects”



In most cases, the default parameters should follow ECSS-E-ST-10-04C

Coordinate generators
Radiation sources and effects
Radiation sources
<u>Trapped proton and electron fluxes</u>
Trapped proton flux anisotropy
<u>Short-term solar particle fluxes</u> (only for SEU)
<u>Long-term solar particle fluences</u>
<u>Galactic cosmic ray fluxes</u>
Shielded flux
Solar cell radiation damage
Damage equivalent fluences for solar cells (EQFLUX)
NIEL based damage equivalent fluences for solar cells (MC-SCREAM)
Long-term radiation doses
Ionizing dose for simple geometries
Non-ionizing energy loss for simple geometries
Effective dose and ambient dose equivalent
Single event effects
Short-term SEU rates and LET spectra
Long-term SEU rates and LET spectra
Spacecraft charging

Radiation Belt Models

>> Go to the [IRENE AE9/AP9 model](#) (for evaluation)

Trapped radiation models

Proton model: <input type="text" value="AP-8"/>	Electron model : <input type="text" value="AE-8"/>
Model version: <input type="text" value="solar minimum"/>	Model version: <input type="text" value="solar maximum"/>
Threshold flux for exposure(/cm2/s): <input type="text" value="1.00"/>	Threshold flux for exposure(/cm2/s): <input type="text" value="1.00"/>
Model developed by: 	Model developed by: 

Reset

Run

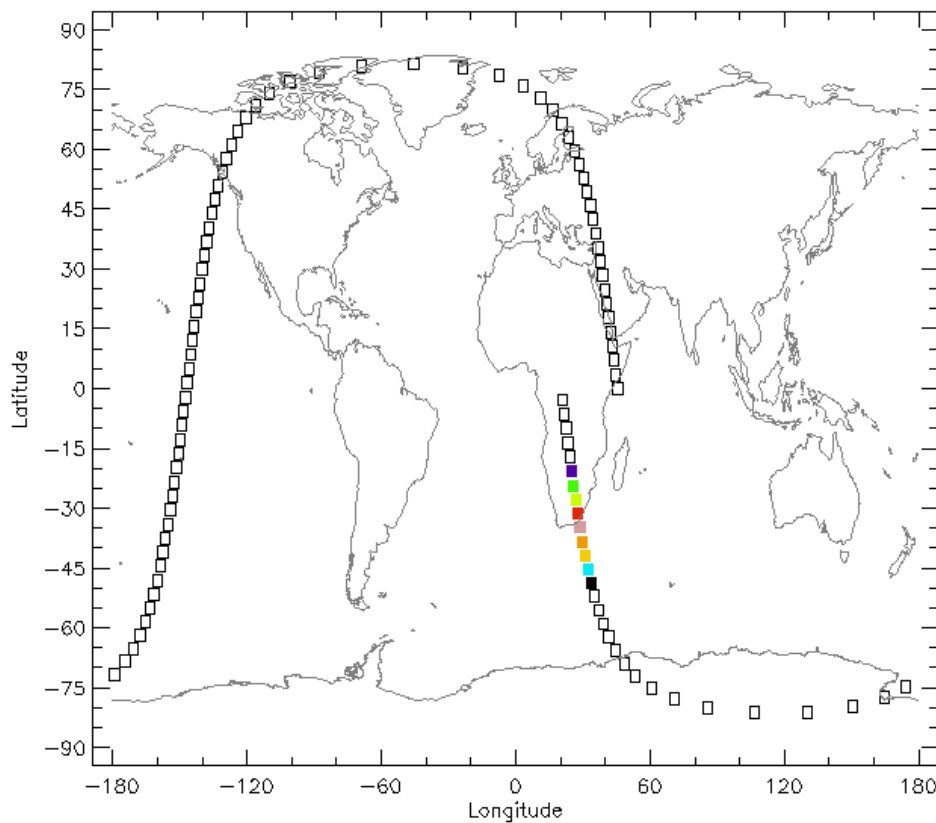
AP-8 and AE-8 come in two flavours: Solar minimum and Maximum
Slight anomaly: the IGE-2006 model is only available if a single mission segment is selected and "Geostationary orbit" type selected.

Plotting of fluxes around orbit as world map, 3D, or time series possible.

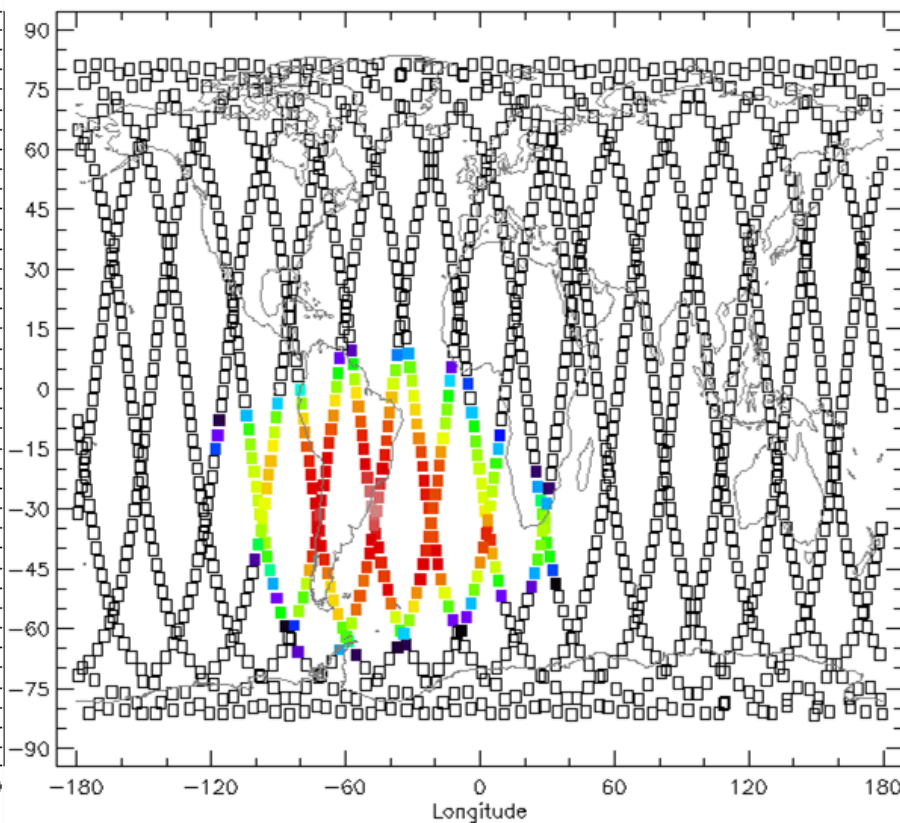
USE THIS TO CHECK YOU HAVE ADEQUATELY COVERED THE MISSION.

Number of representative orbits

Sun Synch. 800 km; 1 orbit



Sun Synch. 800 km; 1 day



Also run for Solar particles & GCR

Once the trapped proton spectra model is run, the option to run the anisotropy model is available (relevant for low Earth orbits).

Also run the short and long term solar particle flux models* and GCR model.

Then move on to the effects tools

Coordinate generators
Radiation sources and effects
Radiation sources
Trapped proton and electron fluxes
Trapped proton flux anisotropy
Short-term solar particle fluxes (only for SEU)
Long-term solar particle fluences
Galactic cosmic ray fluxes
Shielded flux
Solar cell radiation damage
Damage equivalent fluences for solar cells (EQFLUX)
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Long-term radiation doses
Ionizing dose for simple geometries
Non-ionizing energy loss for simple geometries
Effective dose and ambient dose equivalent

*For the Solar particle models, select a confidence level reasonable for the mission.

1. SHIELDOSE-2 Dose as function of shielding thickness (p+, e-)
2. Non-Ionising dose NID as function of shielding thickness (p+, e-)
(Opto-electronic degradation)
3. EQFLUX/MC-SCREAM Solar cell degradation models (p+, e-)
4. CREME models SEU rate predictions (GCR, p+)
5. Geant4
 - a. Mulassis Simple geometries (slab, sphere)
 - b. GRAS Complex 3D geometries (GDML)
 - c. SSAT Ray tracing/Sector Shielding (GDML)
 - d. GEMAT SEU effects in componentsGenerating GDML files

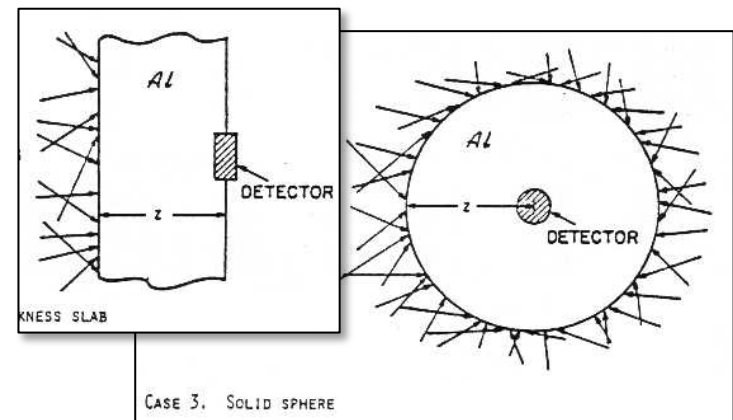
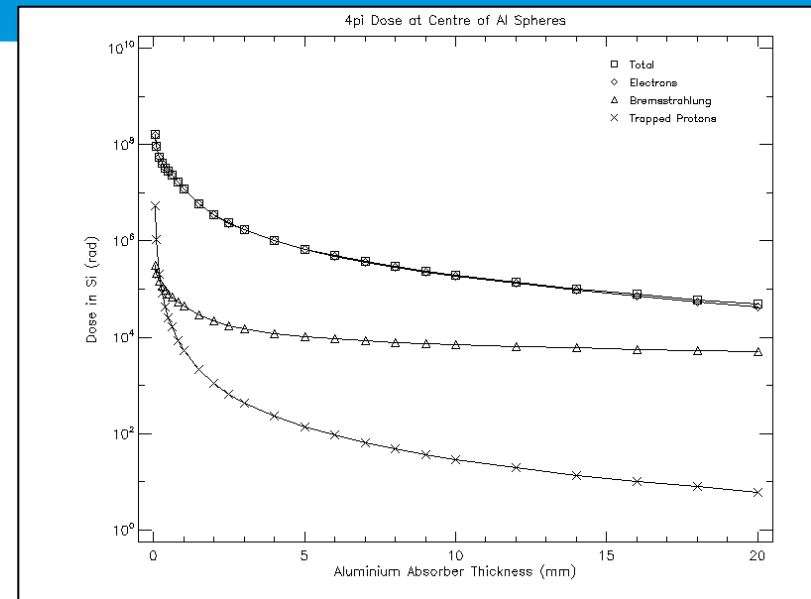
- Components are rated to a dose limit, beyond which they may fail or fade. This is typically in the range of <100 krad(Si). COTS components are closer to 1-15 krad(Si).
- The ionising dose limit is commonly established by testing using a Cobalt-60 source – Gamma ray dose (very penetrating). The non-ionising dose limit is determined with proton beam tests.
- The radiation dose from the space environment is mixed (protons, electrons, cosmic rays), each with varying levels of shielding effectiveness. This rich environment is simplified into a single metric, e.g. TID, TNID, etc.
- Non-Ionising dose mostly affects Opto-Electronics and Bipolar devices.
- It is often necessary to establish how much dose will be received by a component in the environment given the shielding available:
 - Simple shielding geometries (**solid sphere**, slab, spherical shell, etc).
 - Realistic shielding geometry:
 - Sector shielding analysis
 - Full physics simulations (Geant4, Fluka, etc.)

Simple Dose Effects Tools

SHIELDOSE(2,2-Q) provides dose-depth curves for simple geometries. Similarly, the NIEL model provides non-ionising doses .

This is the simplest, and most conservative approach to RHA of a component.

Generally, the **solid sphere geometry** is used and can serve as an input to the sector shielding approach (SSAT, FASTRAD, DOSRAD, etc.)



Simple Effects tools – SHIELDOSE-2



Coordinate generators
Radiation sources and effects
Radiation sources Trapped proton and electron fluxes Trapped proton flux anisotropy Short-term solar particle fluxes (only for SEU) Long-term solar particle fluences Galactic cosmic ray fluxes Shielded flux
Solar cell radiation damage Damage equivalent fluences for solar cells (EQFLUX) NIEL based damage equivalent fluences for solar cells (MC)
Long-term radiation doses Ionizing dose for simple geometries Non-ionizing energy loss for simple geometries
Single event effects Short-term SEU rates and LET spectra Long-term SEUs and LET spectra
Spacecraft charging

Ionizing dose models: Parameters

Shielding depths: default values ▼

Dose model: SHIELDOSE-2 ▼

Shielding configuration: centre of Al spheres ▼

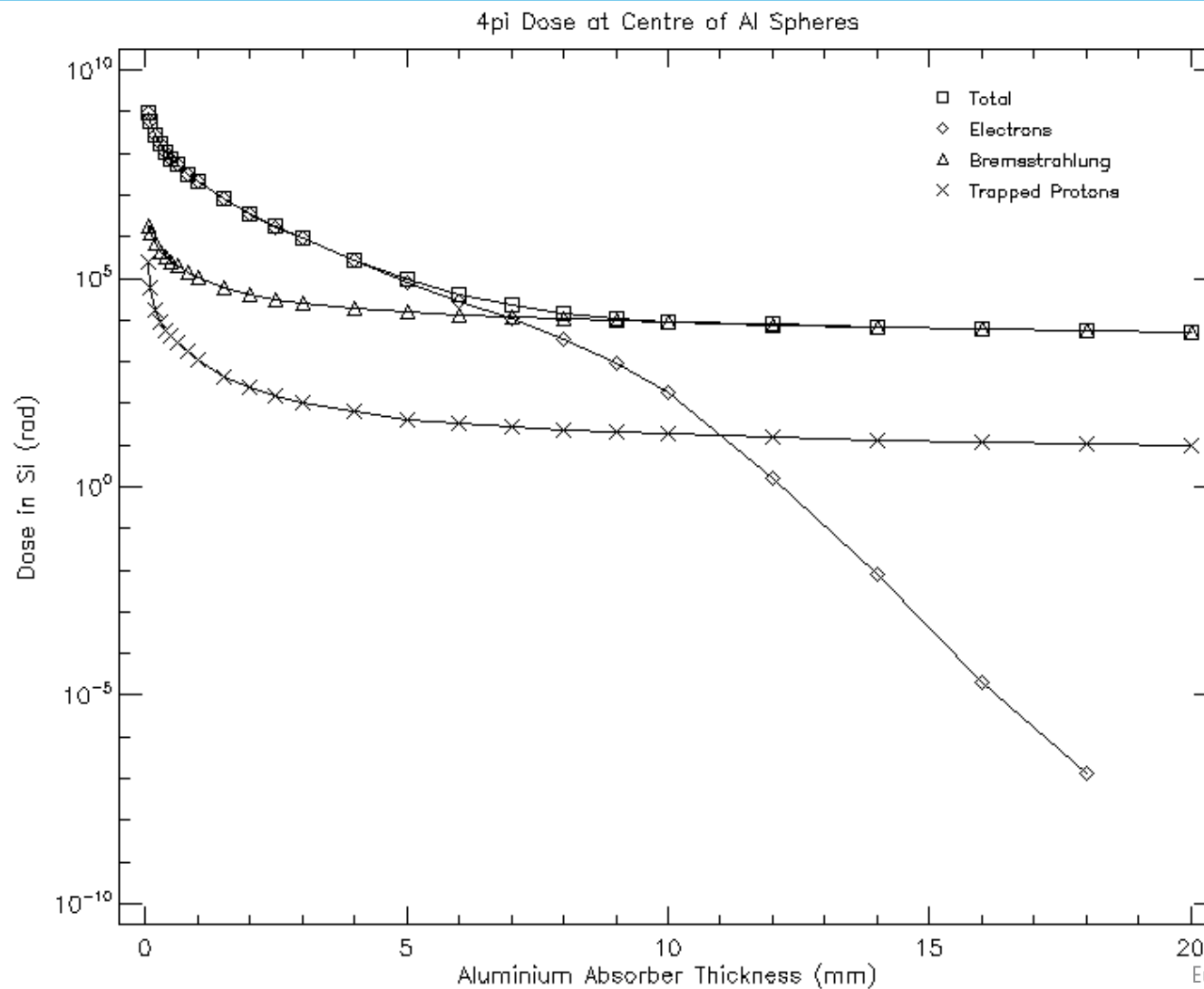
Target material: Silicon ▼

Non-ionizing energy loss: Parameters

Shielding depths: default values ▼

Damage factor [$g(\text{Si}) \text{ MeV}^{-1}$]: 1.0E-11

Dose-Depth Curve



Two Methods:

- Older JPL “EQFLUX” method
- (MC) SCREAM method

Older method relies on extensive test data related to equivalent 1 MeV electron fluxes and conversion of proton and electron spectra to an equivalent 1 MeV electron fluence

MC-SCREAM method converts the environmental spectra to Non-Ionising Dose and combines with solar cell test data based on NID to determine degradation.

The MC-SCREAM method is preferred.

Solar Cell Degradation

In the lab, assume the use of Azur 3G28 solar cells.

In the report file, the damage for the cells will be provided, as will the relative degradation of the cells during the mission:

Cell definition		Radiation environment	
Cell type: Azur 3G28		Particle selection	
Cover glass thickness [µm]: 150.0		<input type="checkbox"/> Trapped protons <input type="checkbox"/> Trapped electrons <input type="checkbox"/> Solar protons	
Reset		Create Macro only	
		Create Macro & Run	

Param set	Total Damage	Total Error	Proton Damage	Proton Error	Electron Damage	Electron Error	Degradation (P(d)/P0)
I _{pmax}	8.96e+08	5.46e+07	8.76e+08	5.46e+07	1.98e+07	2.12e+06	0.98956
I _{sc}	8.97e+08	5.46e+07	8.76e+08	5.46e+07	2.11e+07	2.25e+06	0.9913
P _{max}	8.90e+08	5.46e+07	8.76e+08	5.46e+07	1.44e+07	1.53e+06	0.95511
V _{oc}	8.90e+08	5.46e+07	8.76e+08	5.46e+07	1.37e+07	1.46e+06	0.96547
V _{pmax}	8.85e+08	5.46e+07	8.76e+08	5.46e+07	8.72e+06	9.31e+05	0.95453

Upset Calculation - Theory

SEE are caused by **GCRs** and **protons**

SEE can be:

destructive, e.g. Latch-up, or

temporary, e.g. Single event upset/bit flip

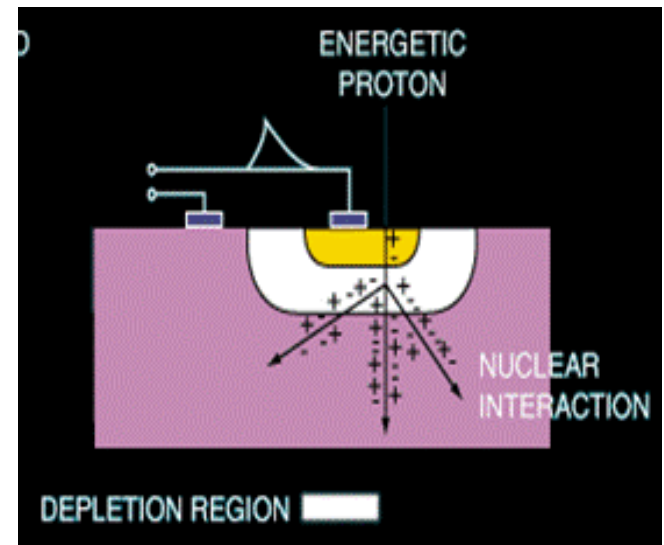
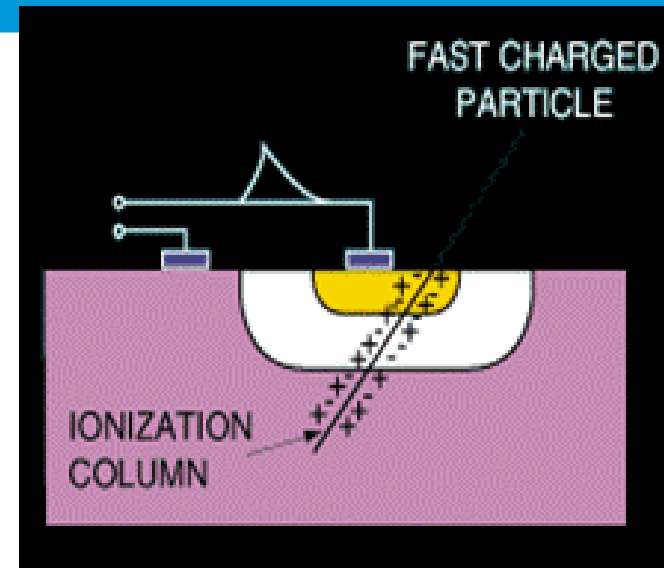
Mechanism is species dependent:

- **Ions:** cause upsets via ionization; this depends on the length of the ionization column in the sensitive volume of the component.
- **Protons:** cause upsets via a nuclear interaction leading to an ionization column ($LET_{th} < 15 \text{ MeV cm}^2/\text{mg}$).

Evaluating SEE requires knowledge of component

→ Test data

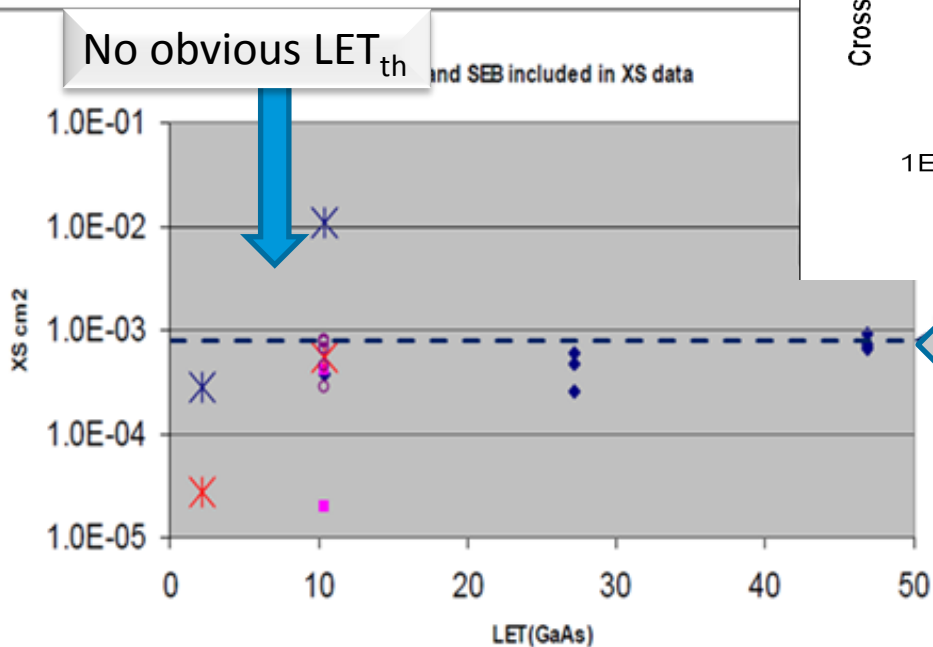
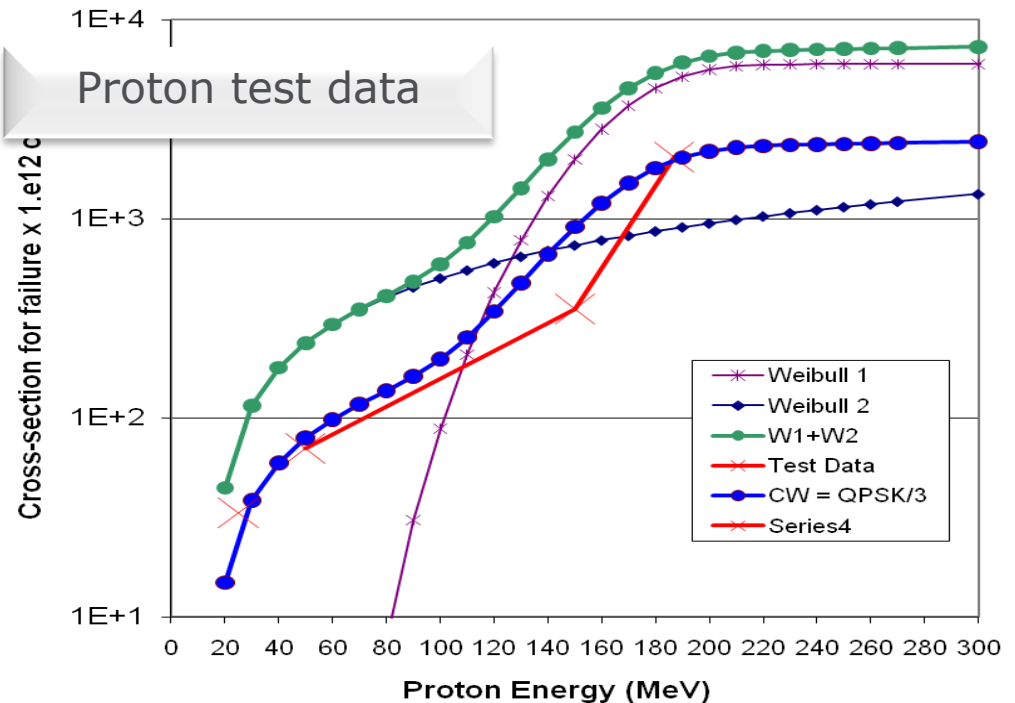
(some component data included in SPENVIS)



Device Test Data

Aim is to have a cross section curve as a function of incident particle LET or proton energy.

The data is typically fit to a Weibull or Bendel function

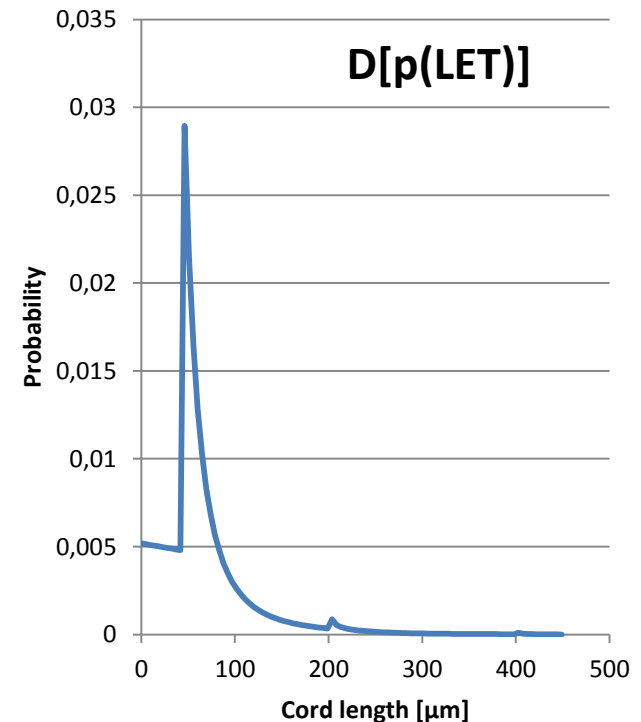


Test saturation cross section matches the visual inspection

Heavy Ion test data

CREME Rectangular parallelepiped (RPP):

- **Device Dimensions** ($l \times w \times h$) → RPP path length distribution. These dimensions are derived from actual device dimension measurements OR guessed from the cross section test data and device thickness.
- **$D[p(LET)]$** is the diff. path length distribution with $p(L) = (X/e)Q_c/L$ – the length over which a ion of LET L will produce a charge Q_c .
- **Critical Charge** (Q_c) – proportional to LET_{th} .
- **Cross section** (σ): is from the device test data.
- **$F(LET)$** is the integral LET spectrum



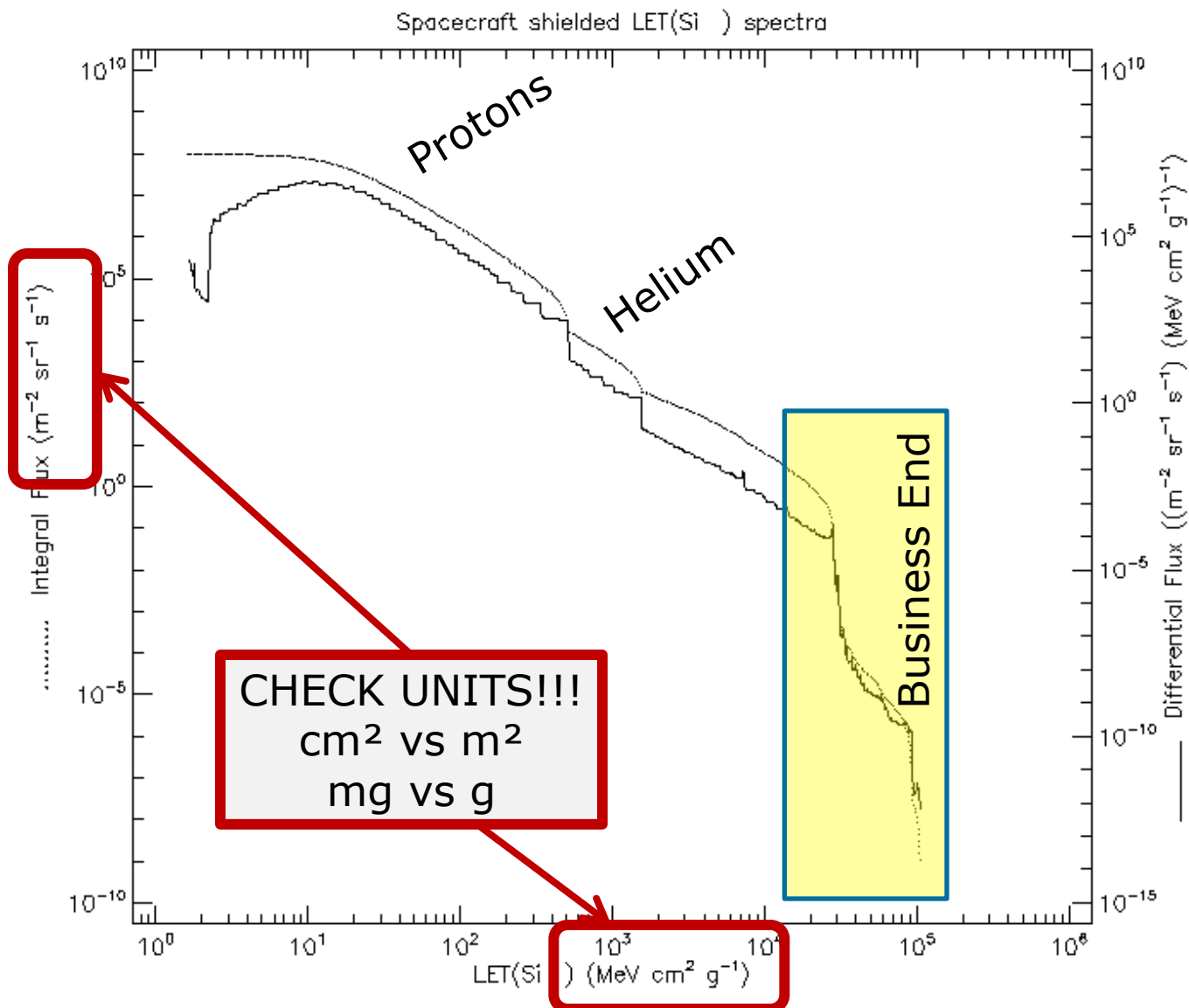
$$SEUrate(\# / bit - s) = 22.5 \pi \sigma Q_{crit} \int_{22.5 Q_{cri} / p_{max}}^{LET_{max}} \frac{D[p(LET)] F(LET)}{LET^2} dLET$$

Protons: CREME 86/96 method:

- Cross-section data (Bendel, Weibull, Profit)
 - Profit is a tool for estimating the cross section from heavy ion test data.
- In principle, there are no angular effects to consider.
- Components with an $LET_{th} < 15 \text{ MeV cm}^2/\text{mg}$ are considered susceptible. (Look up Si in Si Stopping power maximum value).

$$SEERate = \int f(E)\sigma(E)dE$$

LET Spectrum



SEE in SPENVIS

Shielding thickness (Al equivalent):	0.2	cm																																				
Device material:	Si (SRIM2008) ▼																																					
Device source:	user defined ▼																																					
Device name:	DEFAULT																																					
Shape Sensitive Volume: rectangular parallelepiped ▼																																						
Dimensions: <input checked="" type="radio"/> 38.7 x 38.7 x 2.0 [μm] <input type="radio"/> 1450 x 2.0 [μm]																																						
<table border="1"> <thead> <tr> <th colspan="2">Direct ionisation upset rates</th> <th colspan="2">Proton induced upset rates</th> </tr> </thead> <tbody> <tr> <td>Cross-section method:</td> <td>Weibull function ▼</td> <td>Cross-section method:</td> <td>Bendel function ▼</td> </tr> <tr> <td>S:</td> <td>0.66</td> <td>A [MeV]:</td> <td>4.88</td> </tr> <tr> <td>L_0</td> <td>0.55</td> <td>B [MeV]:</td> <td>7.09</td> </tr> <tr> <td>[MeV·cm²/mg]:</td> <td></td> <td></td> <td></td> </tr> <tr> <td>W</td> <td>5.49</td> <td></td> <td></td> </tr> <tr> <td>[MeV·cm²/mg]:</td> <td></td> <td></td> <td></td> </tr> <tr> <td>σ_{lim} [cm²/bit]:</td> <td>1.5E-5</td> <td></td> <td></td> </tr> <tr> <td>Algorithm:</td> <td>constant LET (CREME) ▼</td> <td></td> <td></td> </tr> </tbody> </table>			Direct ionisation upset rates		Proton induced upset rates		Cross-section method:	Weibull function ▼	Cross-section method:	Bendel function ▼	S:	0.66	A [MeV]:	4.88	L_0	0.55	B [MeV]:	7.09	[MeV·cm ² /mg]:				W	5.49			[MeV·cm ² /mg]:				σ_{lim} [cm ² /bit]:	1.5E-5			Algorithm:	constant LET (CREME) ▼		
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Algorithm:	constant LET (CREME) ▼																																					

Can also input test data instead of Weibull and Bendel parameters

Device source:	library ▼
<input type="radio"/>	93L422 (BIPOLAR)(51x51x2)
<input type="radio"/>	93L422AM (BIPOLAR)(38.7298x38.7298x2)
<input type="radio"/>	2164 (MOS)(13x13x2)
<input type="radio"/>	D424100V (4M DRAM)(5.96x5.96x1)
<input type="radio"/>	HYB51410 (4M DRAM)(7.07x7.07x1)
<input type="radio"/>	MB814100 (4M DRAM)(8.73x8.73x1)
<input type="radio"/>	SMJ44100 (4M DRAM)(6.9x6.9x1)
<input type="radio"/>	TC514100 (4M DRAM)(7.08x7.08x1)
<input type="radio"/>	MT4C1004 (4M DRAM)(5.57x5.57x1)
<input type="radio"/>	KM41C4000 (4M DRAM)(5.57x5.57x1)
<input type="radio"/>	SAMSUNG 16M (3.3 V DRAM)(3.14x3.14x0.1)
<input type="radio"/>	HITACHI 16M (3.3 V DRAM)(1.5x1.5x0.64)
<input type="radio"/>	MICRON 16M (3.3 V DRAM)(1.38x1.38x0.81)
<input type="radio"/>	IBM E 16M (3.3 V DRAM)(0.51x0.51x0.22)
<input type="radio"/>	LUNA-C (IBM 16M DRAM)(0.94x0.94x1)
<input type="radio"/>	01G9274 (IBM 4M DRAM)(1.52x1.52x1)
<input type="radio"/>	IBM 16M (4M DRAM)(0.88x0.88x1)

Geant4 tools have similar inputs

- Source particle definitions
 - Physics lists
 - Material lists
 - Geometry (GRAS, SSAT)
-
- Mulassis & GEMAT have their own geometry definitions.

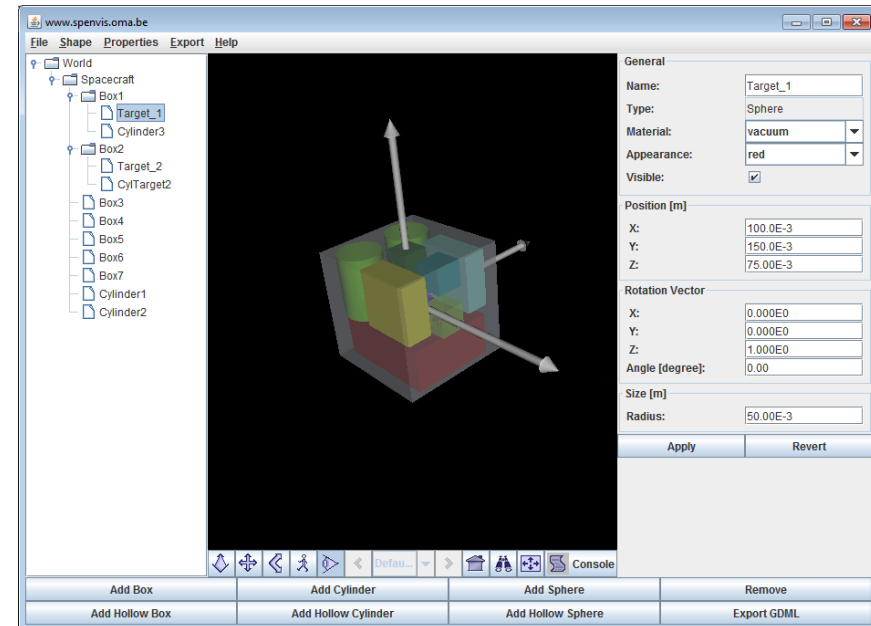
Geant4 input files (macros & GDML) available for download to permit local runs.

<u>Coordinate generators</u>
<u>Radiation sources and effects</u>
<u>Spacecraft charging</u>
<u>Atmosphere and ionosphere</u>
<u>Magnetic field</u>
<u>Meteoroids and debris</u>
<u>Miscellaneous</u>
<u>Geant4 Tools</u>
General models
<u>Multi-Layered Shielding Simulation (MULASSIS)</u>
<u>Geant4 Radiation Analysis for Space (GRAS)</u>
<u>Geant4-based Microdosimetry Analysis Tool (GEMAT)</u>
<u>Sector Shielding Analysis Tool (SSAT)</u>
Planet specific models
<u>Magnetocosmics</u>
<u>Planetocosmics</u>
Common settings
<u>Definition of source particles</u>
<u>User defined materials</u>
<u>Geometry definition tool</u>
<u>ECSS Space Environment Standard</u>

Geometry Definition (GDML)

Two tools available to generate simple GDML geometries:

- HTML based Geometry Definition tool
 - Series of HTML pages to specify a geometry with up to 10 elements using CSG (sphere, box, cylinder)
 - Visualisation available at each step using VRML (need plug in, such as Cortona (<http://www.cortona3d.com/>))
- Java Geometry Generation Tool
 - Downloaded Java application
 - Interactive visualisation
- Upload GDML file from CAD tool, e.g. FASTRAD.



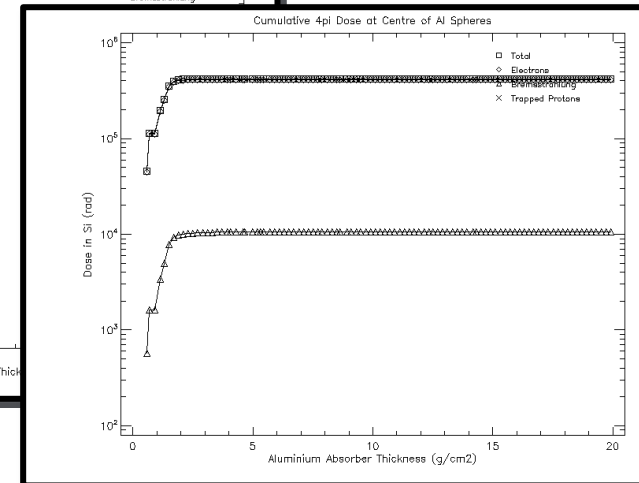
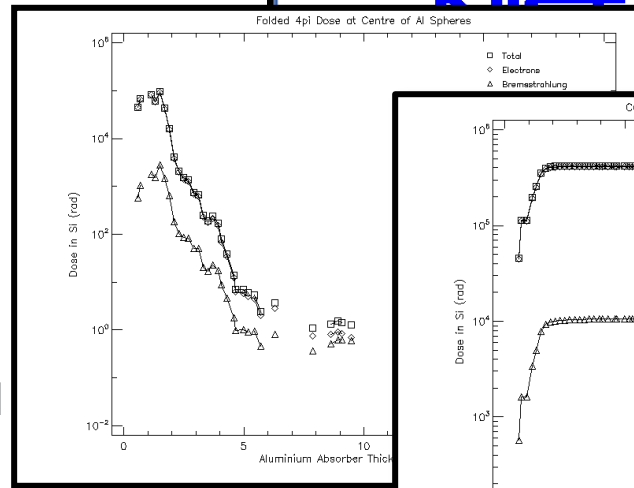
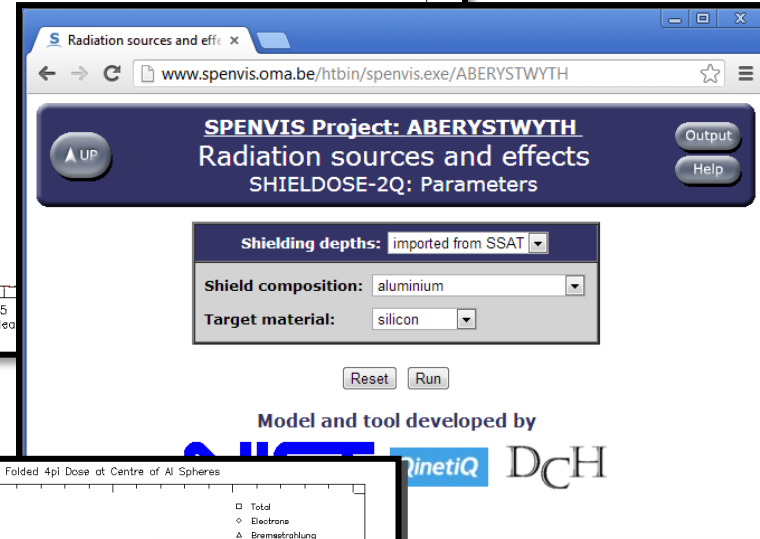
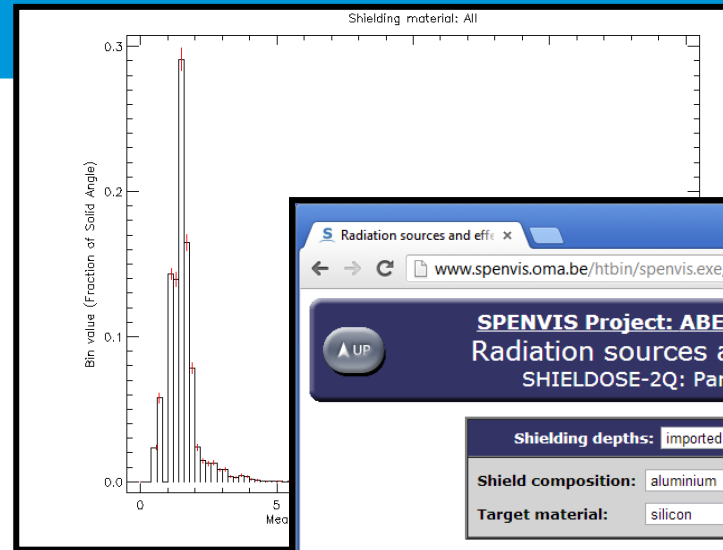
Sector Shielding Doses (SSAT)

Run SSAT to derive shielding distribution curve

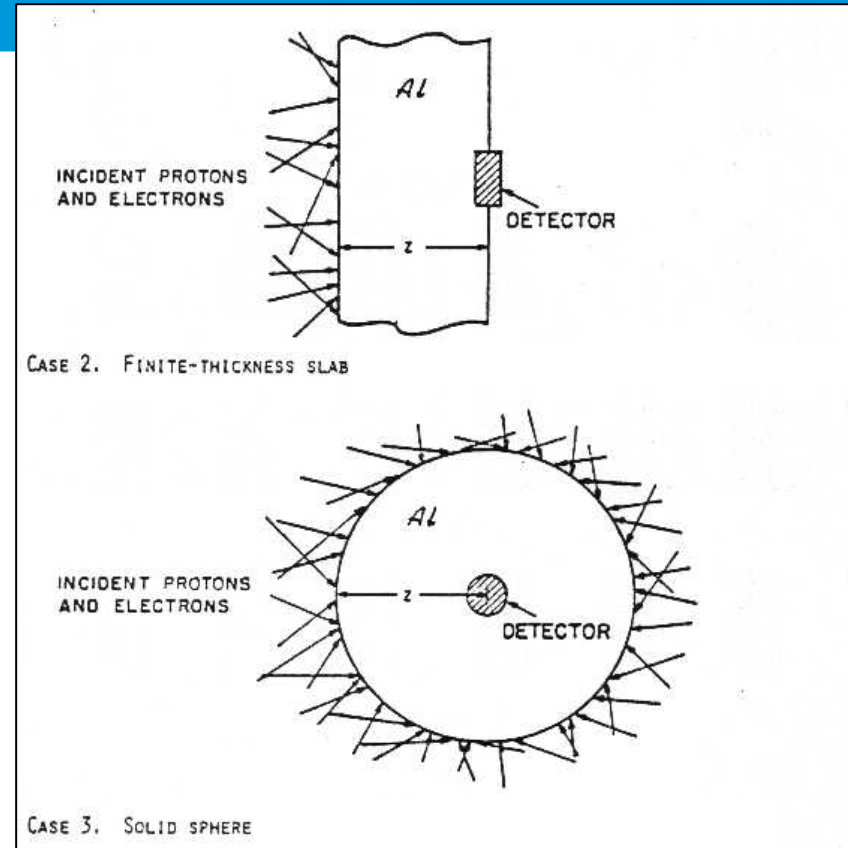
Use SHIELDOSE-2 or SHIELDOSE-2Q and import shielding depths from SSAT.

Running SD2(Q) will fold Shielding distribution curve with the Dose-depth curve to provide Dose contribution for each shielding thickness for the geometry. The cumulative curve gives the dose in the target.

Look in SSAT GDML file analysis to find location of target (not obvious)



1. Simple geometries, like Shieldose:
 - a. Slab
 - b. Spherical shells (solid sphere)
2. Can be used to investigate graded, or exotic shields and targets.
3. Outputs include:
 - a. Shielded flux spectra
 - b. Total Ionising dose
 - c. Non-Ionising dose
 - d. Pulse height spectrum
 - e. Dose Equivalent (Human effects)

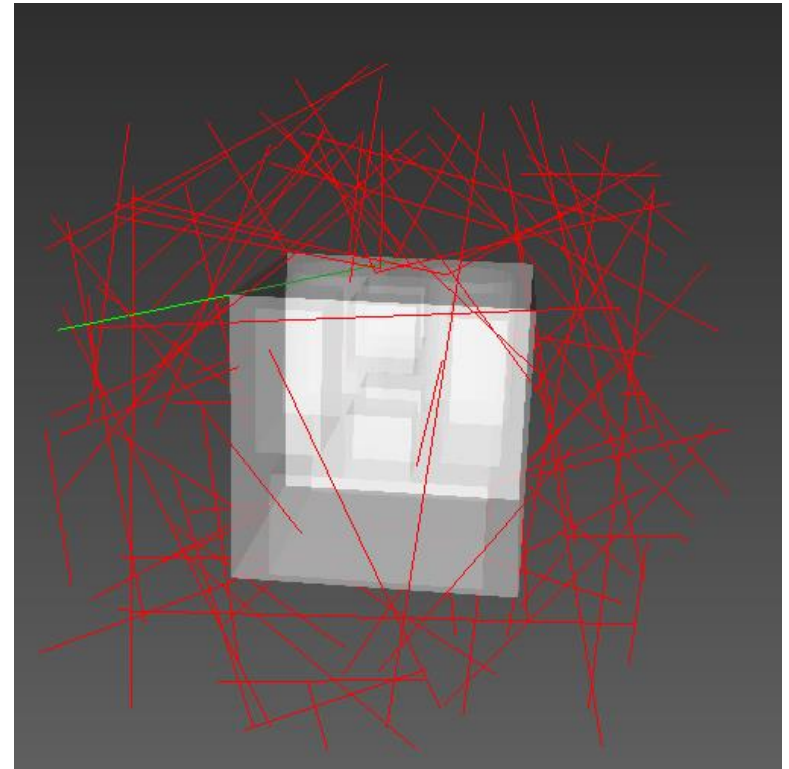


Recommend using slab geometries, as statistics are better. Although for solid sphere equivalent, a good approximation ($\sim 10\%$) is to use a spherical shell with a vacuum "core" that's $1/10^{\text{th}}$ the thickness of shield.

Complex 3D analysis module
Geometry defined by GDML file
Targets selected from GDML file

Can use the SPENVIS system to
set up a **basic** run, download the
input files and run more detailed
analysis locally.

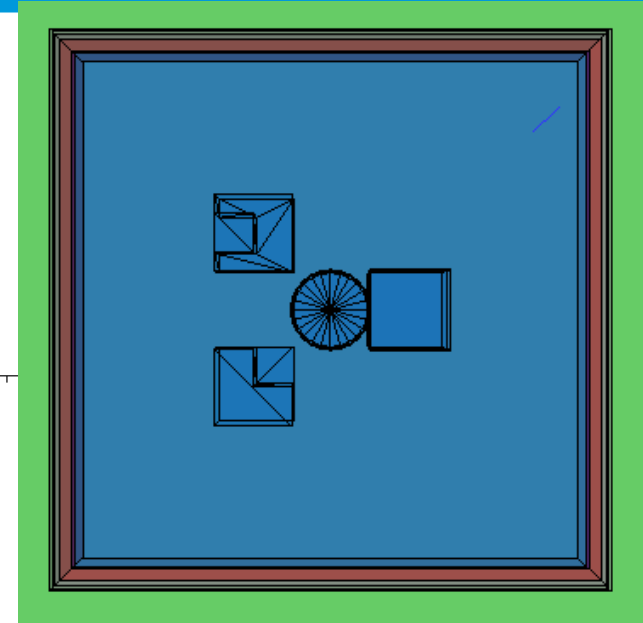
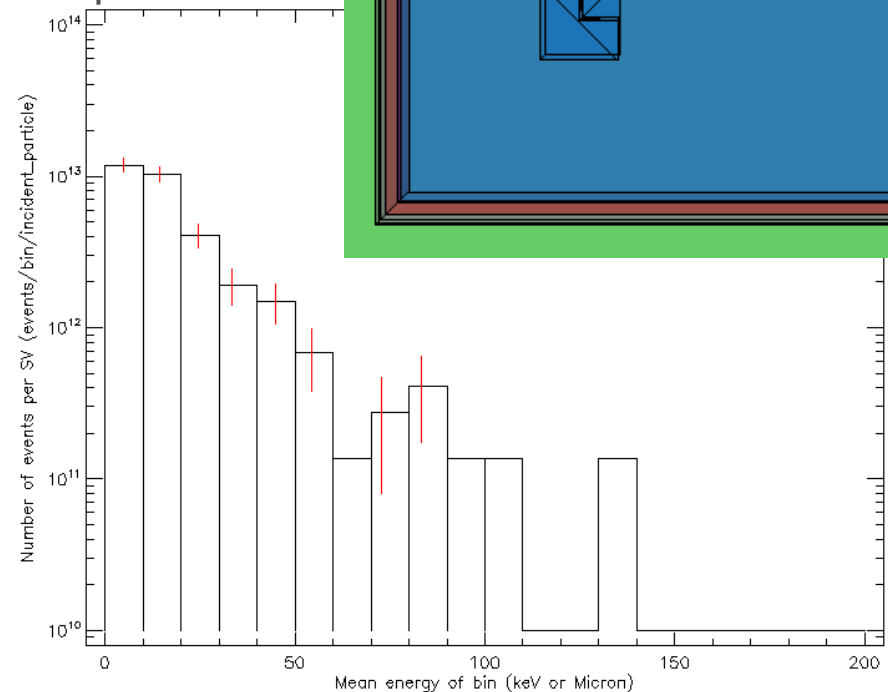
SPENVIS limits model runs to 600s,
Which can often be insufficient for a complex geometry to be analysed
with adequate statistics.



1. Used to study the effects of radiation on micro-electronics (Single Event Effects).
2. A geometry is defined for a component in terms of layers. Using common shapes cylinder, box, "L" and "U" shapes

3. Analysis of
 - a. incident flux
 - b. Pulse height

4. Allows analysis of more complex geometries than provided by CREME.



1. The SPENVIS system, being an on-line system, limits model runs to only 600 CPU seconds. Some models can take a significant time to run – sample an orbit of interest or use a single relevant orbit.
2. Resources:
 - a. SPENVIS BACKGROUND & HELP pages are extensive!
 - b. Normally only 2 projects are provided to users, this can be increased by request to the SPENVIS team
 - c. Similarly, CPU limits and disk usage can be extended beyond the default on request.
 - d. Forums are available for assistance.
 - e. **It is possible to ZIP and download the entire project**
3. ECSS Standards:
 - a. ECSS-E-ST-10-04C: Environment specification
 - b. ECSS-E-ST-10-12C: for determining radiation effects
 - c. ECSS-Q-ST-60-15C: Radiation Hardness Assurance standard
4. **For RHA – a margin of a factor of 2 should suffice in most cases**

- The trapped radiation belt models are stated to be accurate to within a factor of 2-3, but this will vary considerably over the magnetosphere.
 - In Geostationary orbit, AE-8 is known to be overestimating the fluxes.
 - At GNSS/Galileo orbits, AE-8 is underestimating the fluxes...usually.
 - The trapped proton model appears to be underestimating above, say 1000 km altitude.
 - The dynamic range of the environment can be several orders of magnitude → regression to the mean is important, long missions → lower margins (maybe).
- The solar proton models, while they have a statistical confidence level, suffer due to underlying data calibration uncertainties.
- It is necessary to balance the margin policy with the risk that can be assumed for the mission – over engineering is expensive, but getting it wrong is even more expensive.

Caveat Emptor!

CREME Stopping Powers in Silicon

