



# SPENVIS Tutorial Radiation Package

presented by

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# Tutorial objectives

- Overview of the SPENVIS radiation package
- How to access and run the radiation models
- Which radiation output is used as input to radiation damage models
- Upgrades

# Overview radiation package

## Radiation sources

## Radiation effects

ORBIT

- Trapped particles
- Solar particles
- Galactic Cosmic Rays

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Long term:

- solar cell damage
- doses (TID, NIEL)

Short term:

- single event effects (SEU)

*To run the radiation models, you first need to run an orbit*

# main template radiation package (Earth)

<b><u>Coordinate generators</u></b>
<b>Radiation sources and effects</b>
<b>Radiation sources</b>
<b><u>Trapped proton and electron fluxes</u></b>
Trapped proton flux anisotropy
<b><u>Solar proton fluences</u></b>
<b>Solar cell radiation damage</b>
Damage equivalent fluences for solar cells (EQFLUX)
NIEL based damage equivalent fluences for solar cells (MC-SCREAM)
<b>Radiation doses</b>
Ionizing and non-ionizing dose models for simple geometries
<b>Single event effects</b>
<b><u>Ion energy and LET spectra</u></b> → includes cosmic rays/solar particle fluxes
Single event upset rates
<b><u>Spacecraft charging</u></b>
<b><u>Atmosphere and ionosphere</u></b>
<b><u>Magnetic field</u></b>
<b><u>Meteoroids and debris</u></b>
<b><u>Miscellaneous</u></b>
<b><u>Geant4 Tools</u></b>
<b><u>ECSS Space Environment Standard</u></b>

# Part I. Radiation models

I.1. Trapped particles

I.2. Solar particles

I.3. Galactic Cosmic Rays

# I.1. Trapped particles



## Overview models (Earth, Jupiter)

	Earth	Jupiter
protons	<ul style="list-style-type: none"><li>• AP-8</li><li>• CRRESPRO</li><li>• SAMPEX/PETPSB97</li></ul>	<ul style="list-style-type: none"><li>• D&amp;G 83</li><li>• Salambo</li></ul>
electrons	<ul style="list-style-type: none"><li>• AE-8</li><li>• AE-8min update ESA-SEE1</li><li>• CRRESELE</li><li>• IGE2006/POLE</li></ul>	<ul style="list-style-type: none"><li>• D&amp;G 83</li><li>• GIRE</li><li>• Salamambo</li></ul>

*only available for GEO orbits*

*only available for advanced users*

### Trapped radiation models

<b>Proton model:</b> AP-8	<b>Electron model :</b> AE-8
<b>Model version:</b> solar maximum	<b>Model version:</b> solar maximum do not include <b>local time variation</b>
	<b>Confidence level:</b> 50.000%
<b>Model developed by:</b> 	<b>Model developed by:</b> 
<input type="button" value="Reset"/> <input type="button" value="Run"/> <input type="button" value="Combined Run"/>	

- ▶ first model in list = default model by ECSS
- ▶ for the the advanced user and AE-8 electron model:
  - a local time dependence implemented by Vette can be applied
  - confidence levels can be specified

## Output

- omnidirectional {
- orbit averaged
  - along the orbit      fluxes/fluences
  - peak (only for earth)

*If fluences < 0 then spacecraft outside spatial coverage!*

### Output files generated by the trapped radiation models

File name	Description
spenvis_trp.html	Report file
spenvis_ppeakfl.html	Report file specific for proton peak fluxes      (only for earth)
spenvis_epeakfl.html	Report file specific for electron peak fluxes      (only for earth)
spenvis_tr1.txt	<u>Orbit averaged spectra</u> for <u>SHIELDOSE(-2), NIEL, EQFLUX, MULASSIS, LETORE</u> (only for earth)
spenvis_spp.txt	<u>Proton spectra for each orbital point</u>
spenvis_spe.txt	<u>Electron spectra for each orbital point</u>


# Trapped particles on a grid

▶ geographical coordinate grid  
(single point/profile/worldmap)

**Coordinate generators**

[Spacecraft trajectories](#)  
or  
[Geographical coordinate grids](#)  
or  
[Switch to another planet](#)

**Trapped particle species:** protons

**Model developed by**  


**Proton model:** AP-8

**Model version:** solar maximum

**Energy [MeV]:** 50.0

**Pitch angle [deg]:** 90.0


Reset Run

▶ magnetic coordinate grid  
**!! inside miscellaneous!!**

**Miscellaneous**

[Data base queries](#)  
[Satellite illumination](#)  
[Visualisation of magnetic drift shells](#)  
[Trapped particle models on magnetic coordinate grids](#)  
[Coordinate transformations](#)  
[RDC converter](#)

**Trapped particle species:** protons

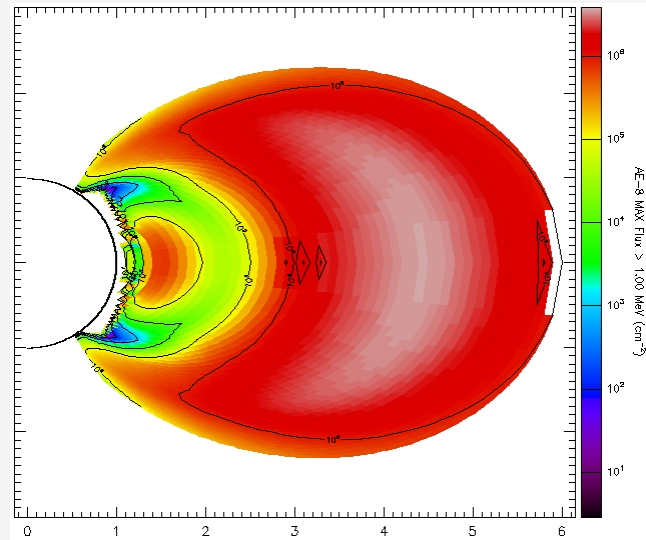
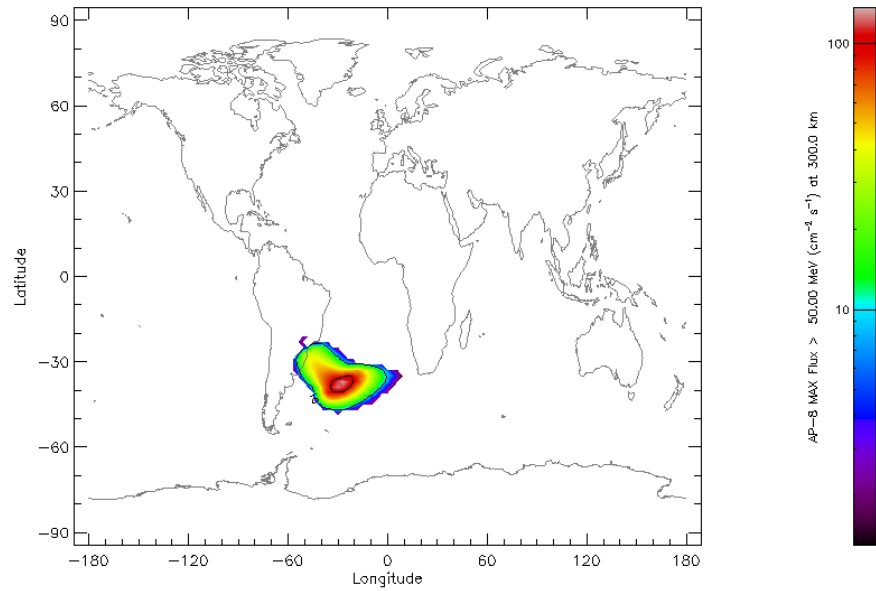
**Model developed by**  


**Proton model:** AP-8

**Model version:** solar maximum

Map type	Independent coordinate
<input checked="" type="radio"/> Flux spectrum	Energy
<input type="radio"/> Flux profile	<input type="radio"/> McIlwain's L <input checked="" type="radio"/> Other
<input type="radio"/> Flux map	Abscissa: McIlwain's L Ordinate: B/B0

Reset Next >>



# Application: **TRAPPED PROTON ANISOTROPY**

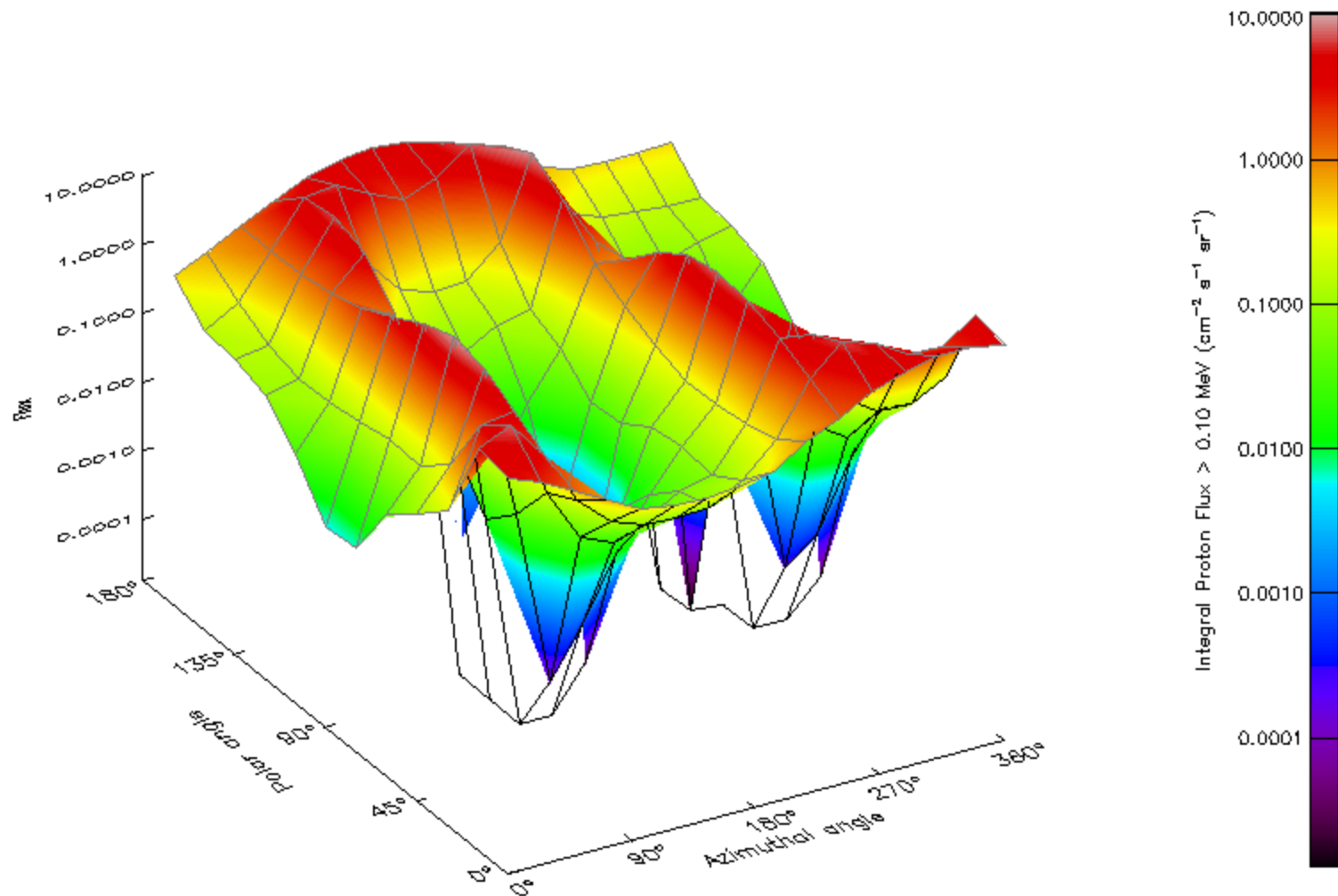
▶ transformation: *omni to uni* for  $\neq$  look directions

**ONLY AVAILABLE IF,**

**generated orbit (no upload trajectory!)**

**AP-8 proton model (min or max)**

The screenshot shows the SPENVIS Project: WORKSHOP interface. At the top, there is a dark blue header bar with the text "SPENVIS Project: WORKSHOP" and "Radiation sources and effects". Below this, it says "Trapped proton anisotropy: Model Parameters". There are buttons for "Output" and "Help" on the right side of the header. Below the header, there is a dropdown menu for "Trapped proton anisotropy model:" with the following options: "Badhwar & Konradi 1990 MAX", "Badhwar & Konradi 1990 MAX", and "Watts et al. 1989 VF1-MAX". Below the dropdown menu, there are buttons for "Reset", "Run", and "Combined Run". Below the buttons, it says "Model developed by" and shows the logo for BIRA-IASB. At the bottom of the interface, there is a dark blue footer bar with the text "© ESA" and several icons for navigation and settings.

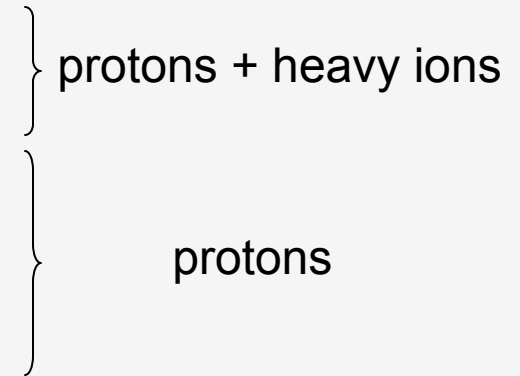


Trapped unidirectional integral proton flux at 0.1 MeV for a 10 days ISS orbit

# I.2. Solar particles

## *Overview models (Earth)*

- ESP-PSYCHIC (total fluence)
- ESP-PSYCHIC (worst case event)
- Rosenqvist et al. (2005, 2007)
- JPL91
- King





**Solar proton model:** ESP-PSYCHIC (total fluence) ▾

Prediction period: automatic ▾

Offset in solar cycle: automatic ▾

Confidence level [%]: 95.0

include heavy ion fluence for He ▾ to U ▾

**Geomagnetic shielding:** apply ▾ for quiet ▾ magnetosphere

quiet  
stormy

Reset Run Combined Run

Model developed by



► Geomagnetic shielding: cutoff (Störmer) + effect Earth shadow + effect geomagnetic storm

*prediction period = total mission length*

→ *SPENVIS calculates the portion of the prediction period in the solar maximum phases of the solar cycles covered by the mission, using the mission start date as a starting point*

**BUT**

the advanced user can override the prediction period and the offset in the solar cycle

<b>Solar proton model:</b> ESP-PSYCHIC (total fluence) ▼	
Prediction period:	override ▼
<b>Prediction period [years]:</b>	1.0
Offset in solar cycle:	override ▼
<b>Offset from solar maximum [years]:</b>	0 ▼
Confidence level [%]:	95.0
<input type="checkbox"/> include heavy ion fluence for	He ▼ to U ▼
<b>Geomagnetic shielding:</b> apply ▼ for quiet ▼ magnetosphere	

## Output

- ◀ omnidirectional fluences at skin spacecraft and at 1 AU
- ◀ attenuation factor (along the orbit and orbit averaged)
- ◀ exposure times

### Output files generated by the solar particle models

File name	Description
spenvis_sep.html	Report file
spenvis_sef.txt	<a href="#">Fluence spectra for SHIELDOSE(-2), NIEL, EQFLUX, MULASSIS</a>
spenvis_seo.txt	<a href="#">Attenuation factor</a>

# *interplanetary missions*

$r^{-2}$  for  $r < 1\text{AU}$  and  $1$  for  $r > 1\text{AU}$

Segment title:

Orbit type: near Earth interplanetary

Orbit start: calendar date

07  Jun  2010  00  : 00  : 00

Distance from Sun [AU]:

# *other planets*

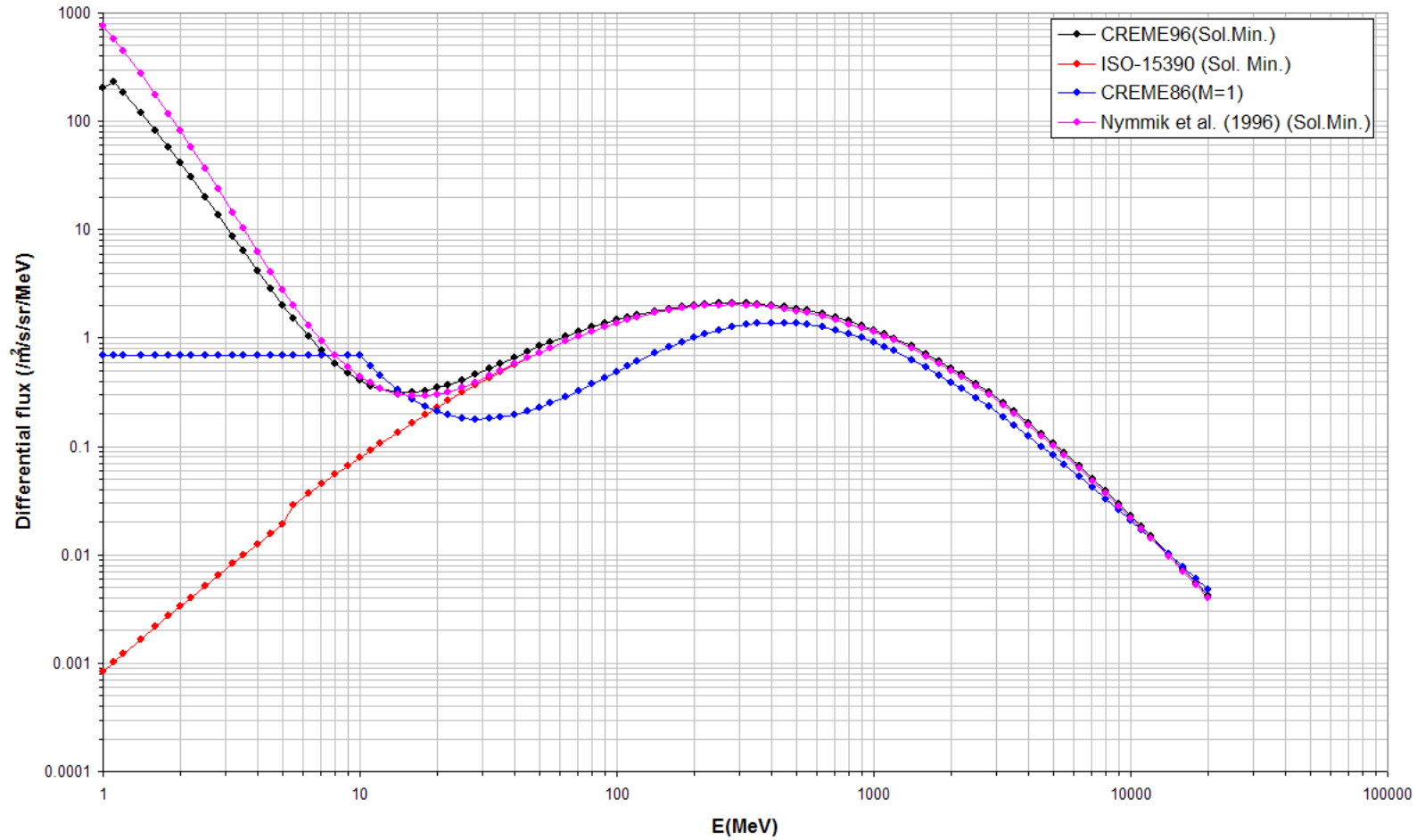
Mars: MarsRem (see talk D. Heynderickx)

# I.3. Galactic cosmic ray particles

## *Overview models (Earth)*

- ISO 15390
- Nymmik et al. (1996)
- CREME 86:
  - M=1-4 : only GCR particles
  - M=5-14 : GCR + solar particles

# The Hydrogen GCR flux near Earth predicted by the different GCR particle flux models at solar minimum



# Ion energy and LET spectra template

**SPENVIS Project: WORKSHOP**

**Radiation sources and effects**

Ion energy and LET spectra: Input parameters

UP

Output

Help

Target material: Si (CREME-86) or GaAs

Shielding thickness (Al equivalent): 0.2 cm

Ion range: H to U

Galactic cosmic rays model: ISO-15390 standard model

Model developed by



Solar activity data: Solar Minimum (May 1996)

Geomagnetic shielding: apply for quiet magnetosphere

Trapped protons: not available

Output resolution: mission segment averages

Reset

Run

Combined Run

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- ▶ By default tabulated solar cycle data (yearly sunspot numbers) from the year 1957 until 2007 are used. For future epochs the solar cycle is propagated by subtracting  $22 \cdot n$  years from the epoch.

As advanced user you can enter solar activity data for ISO and Nymmik et al. (1996) models

Solar activity data:	
<b>solar cycle number:</b> even	user defined
Solar Minimum (May 1996)	
mission epoch	
user defined	
<b>sunspot number statistics:</b>	
12-month average at minimum:	9.6
12-month average at maximum:	110.6
reversal moment (decimal year):	1968.87
12-month average at epoch:	110.0
12-month average at epoch - lag:	95.0

- ▶ If the trapped models are run, the trapped protons can be included if H is 1st element
- ▶ The advanced user has two options for the output spectra resolution:
  - segment averages
  - per orbital point

Transport of the flux through the spacecraft walls and the calculation of the LET spectra are done with the CREME model suite.

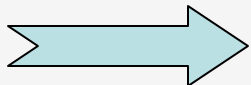
## Output

{ Orbit averaged  
Along the orbit } spacecraft shielded { ion  
proton } fluxes (1 -  $2 \cdot 10^4$  MeV/n)

{ Orbit averaged  
Along the orbit } spacecraft shielded LET fluxes ( $\sim 1 - 10^5$  MeV·cm<sup>2</sup>/g)

### Output files generated by the ion energy and LET spectra model

File name	Description
<code>spenvis_lop.html</code>	Report file
<code>spenvis_lof.txt</code>	<a href="#">Segment and mission averaged proton and ion spectra and LET spectra</a>
<code>spenvis_loo.txt</code>	<a href="#">Proton and LET spectra for each orbital point</a>



Used for SEU rate calculations

## ***interplanetary missions***

no scaling

## ***other planets***

Mars: MarsRem (see talk D. Heynderickx)

# **Part II. Radiation effects**

II.1. Solar cell radiation damage

II.2. Radiation doses

II.3. Single event effects

## II.1. Solar cell radiation damage

For the computation of solar cell degradation in a space radiation environment 2 methods are implemented in SPENVIS:

- 1) Equivalent fluence method (JPL) → EQFLUX
- 2) Displacement damage dose (NRL) → MC-SCREAM

# 1. Equivalent fluence method (EQFLUX)

## *Input*

- ▶ fluence spectrum: generated trapped protons & electrons - solar protons
- ▶ cell type: single junction (Si/GaAs), multiple junction, user defined (advanced user)
- ▶ *omnidirectional* RDC data (hardcoded or to upload by user in correct format!!)

## *Output*

1 MeV electron damage equivalent fluences for ≠ coverglass layers and for  $P_{\max}$ ,  $I_{\text{sc}}$ ,  $V_{\text{oc}}$

# SPENVIS Project: WORKSHOP

## Radiation sources and effects EQFLUX: Model parameters

Output

Help

(Computed fluences include solar protons and trapped particles)


**Cell type:** multiple junction

**Manufacturer:** Spectrolab 2J

Reset

**Model dev**

- Spectrolab 2J
- Spectrolab 2J EOL
- TECSTAR 3J
- Spectrolab 3J
- Spectrolab 3J EOL
- AZUR GAGET2
- AZUR 3G28
- EMCORE ATJ



available in next release?

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## From the help page <http://www.spennis.oma.be/help/models/eqflux.html>

[Advanced users](#) have the option to upload a file with RDC values. The input file should be in the same format as this [sample input file](#), i.e.

- the first block of the file should contain six header lines (free format, blank lines are allowed), giving the **cell name** and the values of the **proton-electron damage equivalence factors**
- 
- the rest of the file should exist of four blocks of RDCs, in the order: electrons, protons for  $P_{\max}$ , protons for  $V_{oc}$ , protons for  $I_{sc}$ ;
- each of these four blocks should contain five header lines (free format, blank lines are allowed);
- the blocks should be separated by a blank line;
- the data columns in the four input blocks should contain 'energy' in the first column, and the **RDCs for coverglass thickness (in mils) 0, 1, 3, 6, 12, 20, 30, 60**. The second column is not used, but should be present. The column format should be compatible with a Fortran READ(,\*) statement.
- the energies in the first column should correspond exactly to the energies used by EQFLUX.

Once a file has been uploaded, it can be re-used without uploading it again.

To generate an input file, the user can use the [RDC converter](#) tool that is available inside miscellaneous. The tool converts unidirectional RDCs into omnidirectional ones.

Accessible via:

[eqflux template](#)

or

[miscellaneous](#)

# eqflux template

**SPENVIS Project: WORKSHOP**  
Radiation sources and effects  
EQFLUX: Model parameters

Output

Help

(Computed fluences include solar protons and trapped particles)

To generate omnidirectional RDCs for covered cells,  
run [RDC converter](#) (inside Miscellaneous)

**Cell type:** user defined

**Uploaded RDC file**  
(Cell name: *workshop*)

Upload new RDC file

**Cell name:** workshop

Reset

Run

Model developed by

**JPL**

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# miscellaneous template

SPENVIS Project: WORKSHOP  
Model packages  
Planet: Earth

UP

Output  
Help

<a href="#">Coordinate generators</a>
<a href="#">Radiation sources and effects</a>
<a href="#">Spacecraft charging</a>
<a href="#">Atmosphere and ionosphere</a>
<a href="#">Magnetic field</a>
<a href="#">Meteoroids and debris</a>
<a href="#">Miscellaneous</a>
<a href="#">Data base queries</a>
<a href="#">Satellite illumination</a>
<a href="#">Visualisation of magnetic drift shells</a>
<a href="#">Trapped particle models on magnetic coordinate grids</a>
<a href="#">Coordinate transformations</a>
<a href="#">RDC converter</a>
<a href="#">Geant4 Tools</a>
<a href="#">ECSS Space Environment Standard</a>

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 environment.

Please do not use your browser's **Back** or **Forward** buttons (except for navigating in the help pages), as these actions do not save input parameters. Full navigation between model pages is available through the menu bar at the top of each page and the action buttons featured on each page.

For additional assistance (after consulting the help pages) and feedback, please contact the [SPENVIS team](#).

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# template RDC converter:

uni → omni for ≠ covergl. layers + output file in required eqflux format

SPENVIS Project: **WORKSHOP**  
Miscellaneous  
RDC converter

Cell name:

Cell material:  or silicon

Cell thickness [ $\mu\text{m}$ ]:


EFFs:  $P_{\text{max}}[\text{mW}]$ :   $V_{\text{oc}}[\text{mV}]$ :   $I_{\text{sc}}[\text{mA}]$ :

Uncovered, unidir. RDCs:

electron radiation		proton radiation			
E[MeV]	RDC	E[MeV]	RDC(Pmax)	RDC(Voc)	RDC(Isc)
100 x 2		100 x 4			

Reset Run

Tool developed by



EFFs = equivalent fluence factors  
RDCs = relative damage coefficients

## 2. Displacement damage method (MC-SCREAM)

### *Input*

- ▶ fluence spectrum: generated trapped protons & electrons - solar protons
- ▶ cell type: GaAs or manual input + coverglass layer thickness
- ▶ *NIEL parameters* (hardcoded or to define in template)

### *Output*

Proton and electron damage (for  $P_{\max}$ ,  $I_{sc}$ ,  $I_{p\max}$ ,  $V_{oc}$ ,  $V_{p\max}$ ) and degradation  $P(d)/P_0$

# MC-SCREAM template

SPENVIS Project: WORKSHOP  
Radiation sources and effects  
MC-SCREAM: Cell definition

Output  
Help

### Cell definition

Cell type: Manual input

Cover glass thickness [ $\mu\text{m}$ ]:

Number of cell layers excluding coverglass: 1

Layer number	Material	Thickness [ $\mu\text{m}$ ]	Visualisation colour
Layer 1	GaAs	10.0	white

### Radiation environment

#### Particle selection

Trapped protons
  Trapped electrons
  Solar protons

Energy biasing: no

Interpolation type: linear

Nr. of primary particles: 10,000

### NIEL parameters

	<input checked="" type="checkbox"/> $P_{\text{max}}$	<input checked="" type="checkbox"/> $V_{\text{oc}}$	<input checked="" type="checkbox"/> $I_{\text{sc}}$	<input checked="" type="checkbox"/> $V_{\text{pmax}}$	<input checked="" type="checkbox"/> $I_{\text{pmax}}$
<b>Proton parameters</b>					
$C$	0.2904	0.115	0.229	0.115	0.229
$D_x$ [ $10^9$ MeV/g]	1.10	1.15	2.52	1.15	2.52
<b>Electron parameters</b>					
$C$	0.363	0.0745	0.343	0.0745	0.343
$D_x$ [ $10^9$ MeV/g]	6.90	1.28	11.0	1.28	11.0
$n$	1.647	2.128	1.326	2.128	1.326

Reset Run

Tool developed by



## II.2. Radiation doses

Dose models:

- Ionizing energy loss (SHIELDOSE, SHIELDOSE-2)
- Non-ionizing energy loss (NIEL)

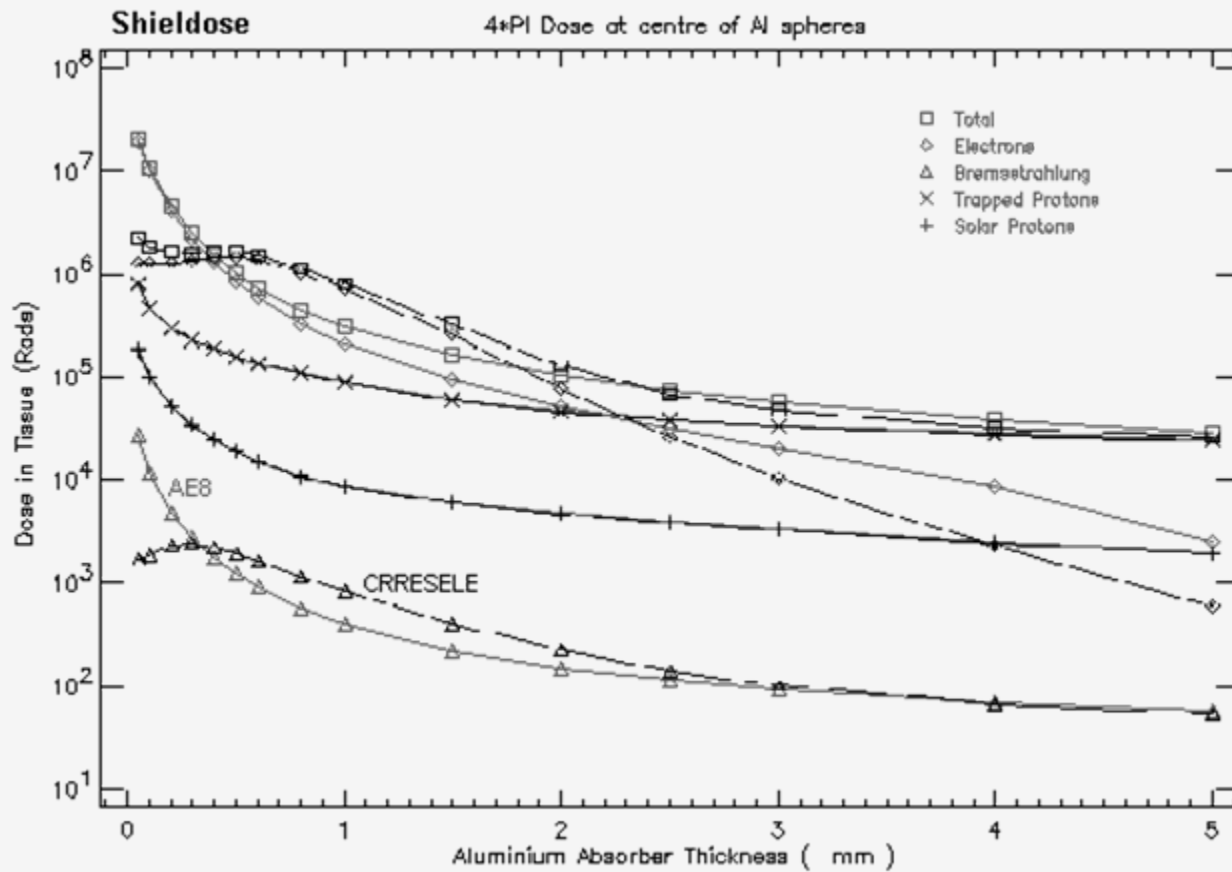
# Total ionizing dose

## *Input*

- ▶ fluence spectrum: generated trapped protons & electrons - solar protons
- ▶ shielding depths:
  - default values (0.05-20 mm)
  - table of values (user input, max. 50 values)
  - SSAT generated distribution (see talk N. Messios)
- ▶ ionise dose model: SHIELDOSE, SHIELDOSE-2
  - ▶ -shielding configuration: finite Al slab shields  
semi-infinite Al medium  
centre of Al sphere
  - target material: Si, Al, ...

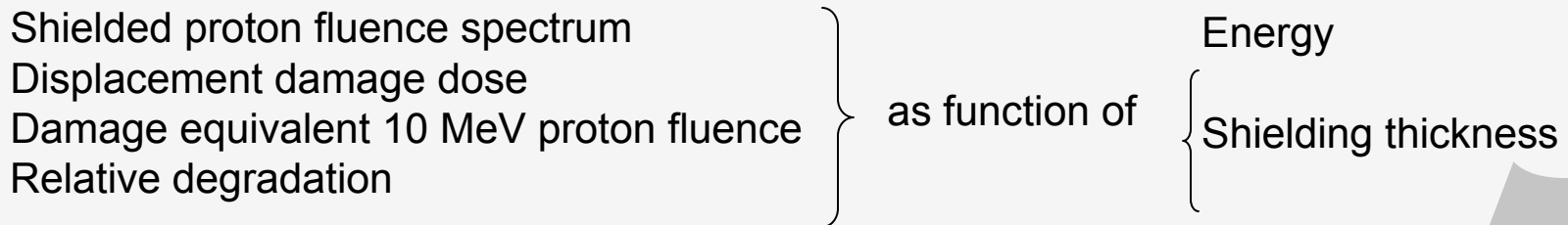
## *Output*

absorbed dose as a function of depth in aluminium shielding material of spacecraft



# Non ionizing energy loss

- ▶ fluence spectrum: generated trapped protons & electrons - solar protons
- ▶ shielding depths:
  - default values (0.05-20 mm)
  - table of values (user input, max. 50 values)
  - SSAT generated distribution (see talk N. Messios)
- ▶ non-ionise dose model:
  - damage factor
  - proton equivalent energy
  - proton NIEL curve: library, upload, table (user input )



## II.3. Single event effects

### *Input*

- ▶ Spacecraft shielded ion (GCR + solar + trapped protons) and LET spectra
- ▶ number of devices (max. 15)
- ▶ set-up devices: library, user defined
- ▶ LET treatment: constant or variable (advanced user)

### *Output*

segment averaged  
along the orbit } DI and PI SEU rate { /bit  
/bit/s for all devices  
/bit/day

# device set-up

1. device: user defined or select from list with predefined devices

## ***If user defined,***

2. device name (string)
3. shape SV:
  - rectangular: XxYxZ ( $\mu\text{m}$ )
  - arbitrary: top + tot area, volume, max. plength diff. plength distr.
4. cross-section methods for DI:
  - critical charge (pC)
  - Weibull fit
  - experimental data: (L,  $\sigma$ ) table
5. cross-section methods for PI:
  - Bendel param. or fit (E,  $\sigma$ ) table
  - Weibull param. or fit (E,  $\sigma$ ) table
  - PROFIT
6. LET treatment: constant (CREME) or variable (particle averaged LET (energy))

## ***If predefined device,***

Information (manuf. + reference) is given in report file

# **SPENVIS radiation package upgrades**

## **∈ next release**

- separation of GCR fluxes and solar particle fluxes → 2 extra modules
- force field approximation for propagating GCR flux through heliosphere
- magnetic shielding upgrade for Mercury and Jupiter
- slowing & stopping algorithm for SEUs

## Coordinate generators

### **Radiation sources and effects**

#### **Radiation sources**

##### Trapped proton and electron fluxes

Trapped proton flux anisotropy

##### Galactic cosmic ray fluxes

##### Long-term solar particle fluences

Short-term solar particle fluxes (only for SEU)

##### 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 and non-ionizing dose models for simple geometries

##### **Single event effects**

LET spectra and SEU rates

## Spacecraft charging

## Atmosphere and ionosphere

## Magnetic field

## Meteoroids and debris

## Miscellaneous

## Geant4 Tools

## ECSS Space Environment Standard



Output

Help

Solar particle flux model: CREME-96

ion range: H to Ni

Worst Week  Worst Day  Peak 5-minute-averaged fluxes

Magnetic shielding: *default* [edit](#)

Reset

Run

Combined Run

Model developed by



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### Short-term solar particle flux models:

- CREME 96: worst week / day / 5 min in 19-27 Oct. 1989 period
- CREME 86: M=5,6,7,8,9,10,11,12 – 1
- Xapsos et al. (2000): 19 / 22 / 24 Oct. 1989 event

Ion range: H to Ni

GCR model at 1 AU: ISO 15390

ISO-15390 standard model

solar activity data: Solar Minimum (May 1996)

Propagation from 1 AU: force field approximation

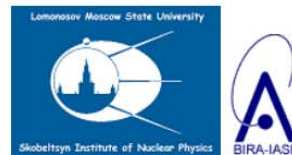
average radial solar wind velocity (km/s): no scaling  
force field approximation

radial diffusion coefficient: constant

$K_0(10^{22} \cdot \text{cm}^2/\text{s})$ : 4.38

Magnetic shielding: default [edit](#)

## Model developed by



Reset Run Combined Run

- extra GCR model: CREME 96 for solar minimum conditions
- extra option for propagating flux throughout heliosphere by force field approximation

# SPENVIS DEVELOPER Project: WORKSHOP

## Radiation sources and effects

Single event upsets: Input parameters

Output

Help

UP

### PARTICLE ENVIRONMENT

- solar event particles
- trapped protons
- GCR particles

**output resolution:** mission segment averages

**shielding thickness (Al equivalent):** 0.2 cm

**number of devices:** 1

Device 1: **defined**

93L422 (Si)

**edit**

Reset

Run

Combined Run

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Device material: Si (SRIM2008)

Device source: user defined

Device name: DEFAULT

- Device material: Si (SRIM2008)
- Device source: library
- 93L422 (BIPOLAR)(51x51x2)
  - 93L422AM (BIPOLAR)(38.7298x38.7298x2)
  - 2164 (MOS)(13x13x2)
  - D424100V (4M DRAM)(5.96x5.96x1)
  - HYB51410 (4M DRAM)(7.07x7.07x1)
  - MB814100 (4M DRAM)(8.73x8.73x1)
  - SMJ44100 (4M DRAM)(6.9x6.9x1)
  - TC514100 (4M DRAM)(7.08x7.08x1)
  - MT4C1004 (4M DRAM)(5.57x5.57x1)
  - KM41C4000 (4M DRAM)(5.57x5.57x1)
  - SAMSUNG 16M (3.3 V DRAM)(3.14x3.14x0.1)
  - HITACHI 16M (3.3 V DRAM)(1.5x1.5x0.64)
  - MICRON 16M (3.3 V DRAM)(1.38x1.38x0.81)
  - IBM E 16M (3.3 V DRAM)(0.51x0.51x0.22)
  - LUNA-C (IBM 16M DRAM)(0.94x0.94x1)
  - 01G9274 (IBM 4M DRAM)(1.52x1.52x1)

Shape Sensitive Volume: rectangular parallelepiped

Shape Sensitive Volume: arbitrary

top area [ $\mu\text{m}^2$ ]: 1.5e3

total area [ $\mu\text{m}^2$ ]: 3.3e3

volume [ $\mu\text{m}^3$ ]: 3.0e3

path length distribution

$\rho$ [ $\mu\text{m}$ ]	$D(\rho)$ [ $1/\mu\text{m}$ ]
<input type="text"/>	<input type="text"/>

38.7 x 38.7 x 2.0 [ $\mu\text{m}$ ]

1450 x 2.0 [ $\mu\text{m}$ ]

Proton induced upset

Cross-section method: ignore

$L_0$  [ $\text{MeV}\cdot\text{cm}^2/\text{mg}$ ]: 0.55

$W$  [ $\text{MeV}\cdot\text{cm}^2/\text{mg}$ ]: 5.49

$\sigma_{\text{lim}}$  [ $\text{cm}^2/\text{bit}$ ]: 1.5E-5

Algorithm: slowing and stopping ions

- slowing and stopping ions
- constant LET (CREME)
- variable LET

Proton induced upset rates

Cross-section method: experimental data

- Bendel function
- Weibull function
- PROFIT
- experimental data
- ignore

Energy [MeV]

Bendel fit  Weibull fit  Lin. interpol.

Direct ionisation upset rates

Cross-section method: critical charge

$Q_c$  [pC]: Weibull function

- Weibull function
- experimental data
- ignore

Algorithm: slowing and stopping ions



**End**