Modelling radiation effects in the Jupiter environment

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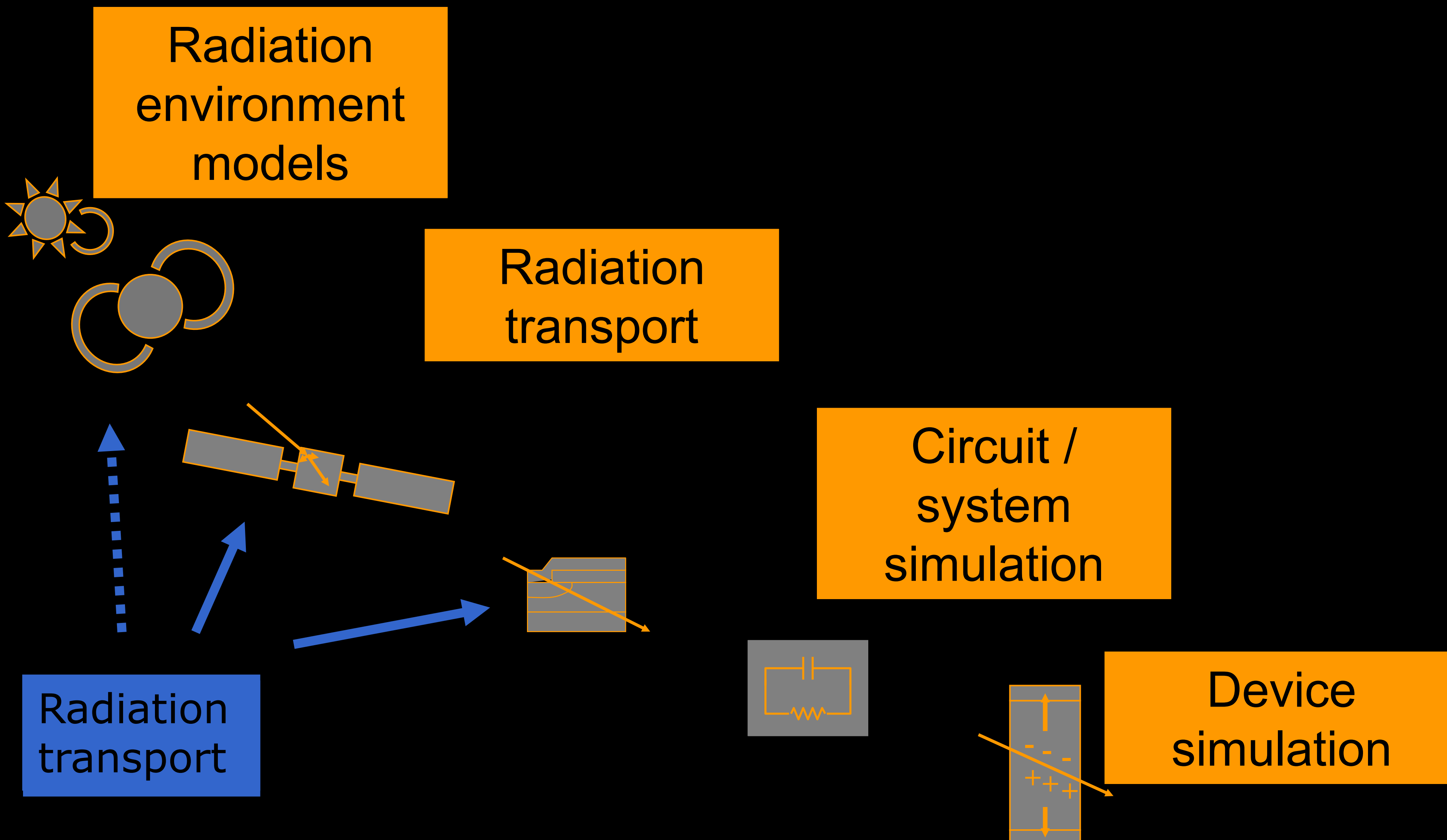
JUICE Radiation Modelling Workshop
28 November 2012

* *on loan employment from RHEA Tech ltd*

Outline

- Radiation effects modelling and tools, Ray-tracing v. Monte Carlo
- Some MC based tools and study examples
- Uncertainties, margins and risk
- GRAS / Geant4 tool
  - Features,
  - Lab tutorial
- REST-SIM radiation tool
  - Features
  - Demo
  - Lab tutorial
- Many thanks to the Aberystwyth team for the WS organisation and for the support in S/W installation

Particle radiation transport in space radiation effect analyses

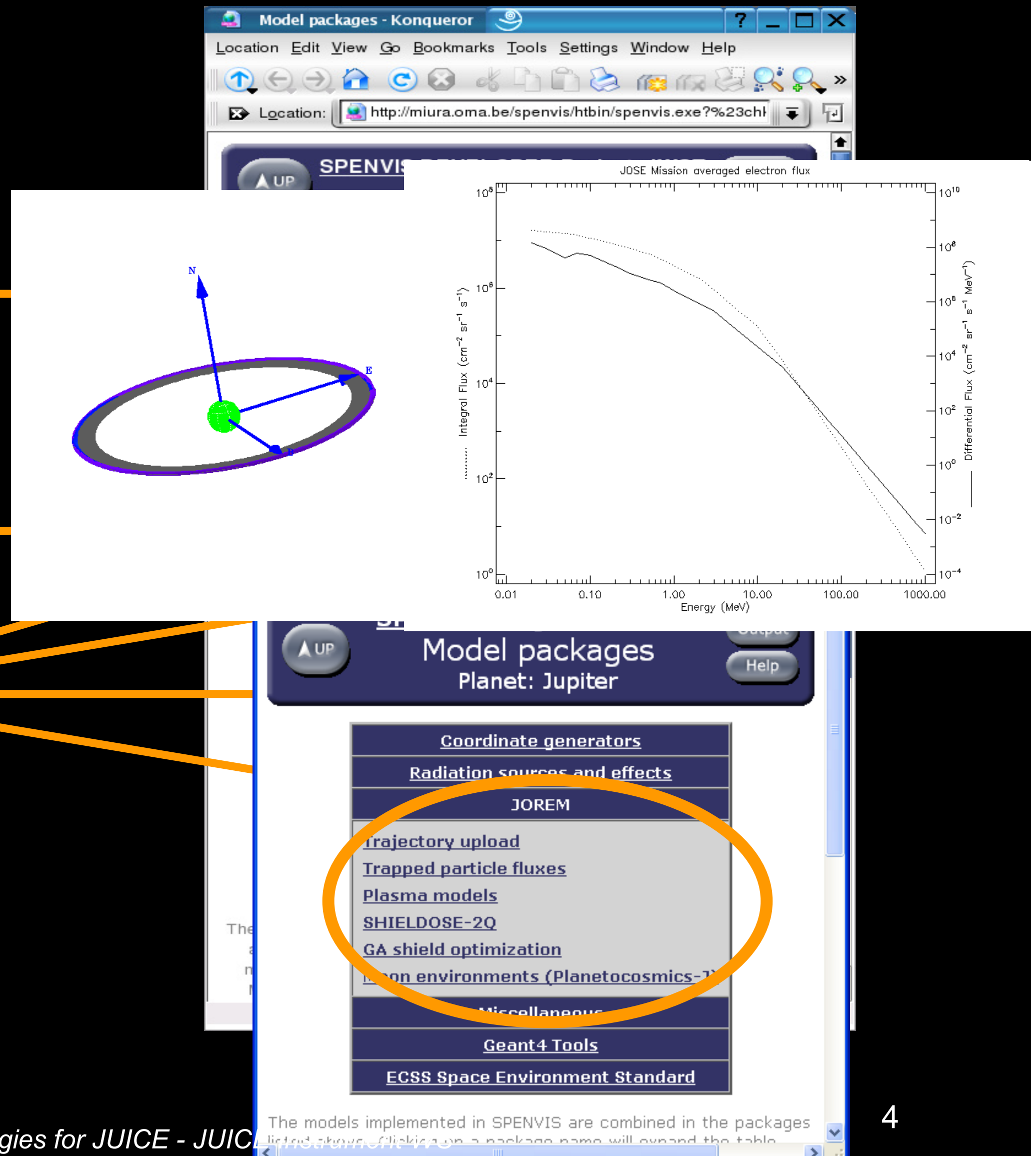


Engineering tools

Environments - Geometry - Visualisation – Analysis

SPENVIS

- Models and tools for the space environments effects analysis
- Web Interface
  - Mission model
    - Orbit, attitude
  - Space environment models
  - Radiation transport
    - Simulation engine
  - Effects Analysis
    - Damage mechanisms
    - Charging
    - SEE
    - Effects to humans



- Recent additions of Jupiter-related models and tools under “JOREM”: JOSE environment, shielding assessment

ECSS-E-ST-10-12C

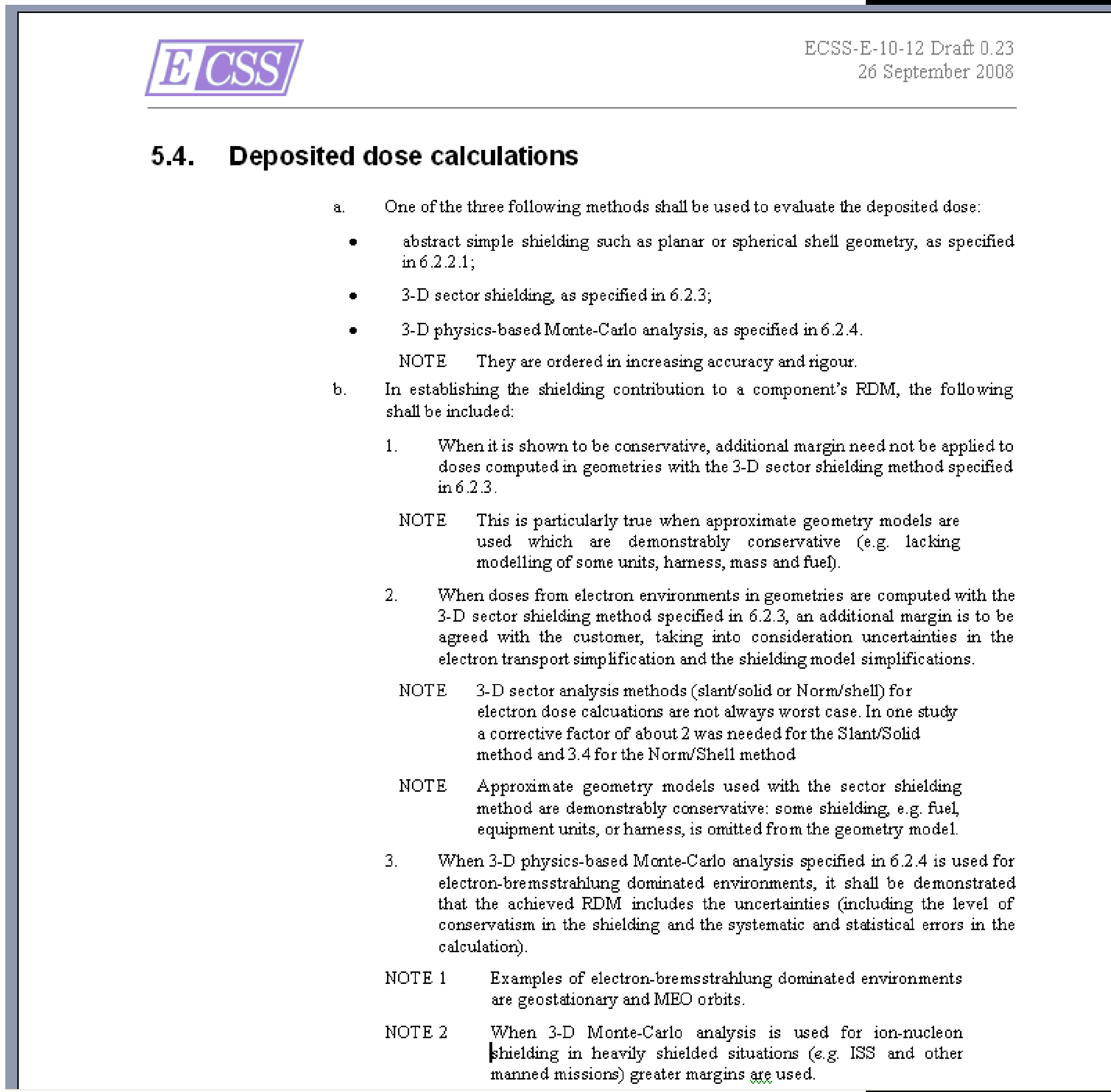
- Method for the calculation of radiation received and its effects, and a policy for design margins

- Increasing accuracy

  Solid Sphere

  →Ray tracing

  → 3D Monte Carlo



5.4. Deposited dose calculations

a. One of the three following methods shall be used to evaluate the deposited dose:

- abstract simple shielding such as planar or spherical shell geometry, as specified in 6.2.2.1;
- 3-D sector shielding, as specified in 6.2.3;
- 3-D physics-based Monte-Carlo analysis, as specified in 6.2.4.

NOTE They are ordered in increasing accuracy and rigour.

b. In establishing the shielding contribution to a component's RDM, the following shall be included:

1. When it is shown to be conservative, additional margin need not be applied to doses computed in geometries with the 3-D sector shielding method specified in 6.2.3.

   NOTE This is particularly true when approximate geometry models are used which are demonstrably conservative (e.g. lacking modelling of some units, harness, mass and fuel).

2. When doses from electron environments in geometries are computed with the 3-D sector shielding method specified in 6.2.3, an additional margin is to be agreed with the customer, taking into consideration uncertainties in the electron transport simplification and the shielding model simplifications.

   NOTE 3-D sector analysis methods (slant/solid or Norm/shell) for electron dose calcuations are not always worst case. In one study a corrective factor of about 2 was needed for the Slant/Solid method and 3.4 for the Norm/Shell method

   NOTE Approximate geometry models used with the sector shielding method are demonstrably conservative: some shielding, e.g. fuel, equipment units, or harness, is omitted from the geometry model.

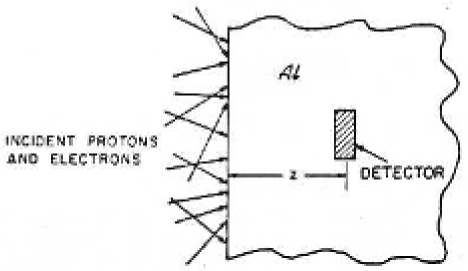
3. When 3-D physics-based Monte-Carlo analysis specified in 6.2.4 is used for electron-bremsstrahlung dominated environments, it shall be demonstrated that the achieved RDM includes the uncertainties (including the level of conservatism in the shielding and the systematic and statistical errors in the calculation).

NOTE 1 Examples of electron-bremsstrahlung dominated environments are geostationary and MEO orbits.

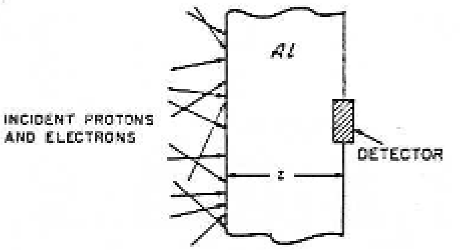
NOTE 2 When 3-D Monte-Carlo analysis is used for ion-nucleon shielding in heavily shielded situations (e.g. ISS and other manned missions) greater margins are used.

Dose-depth curve

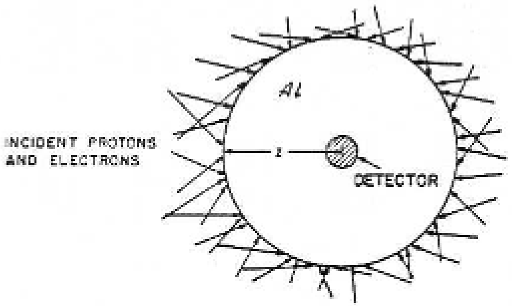
- SHIELDOSE-2



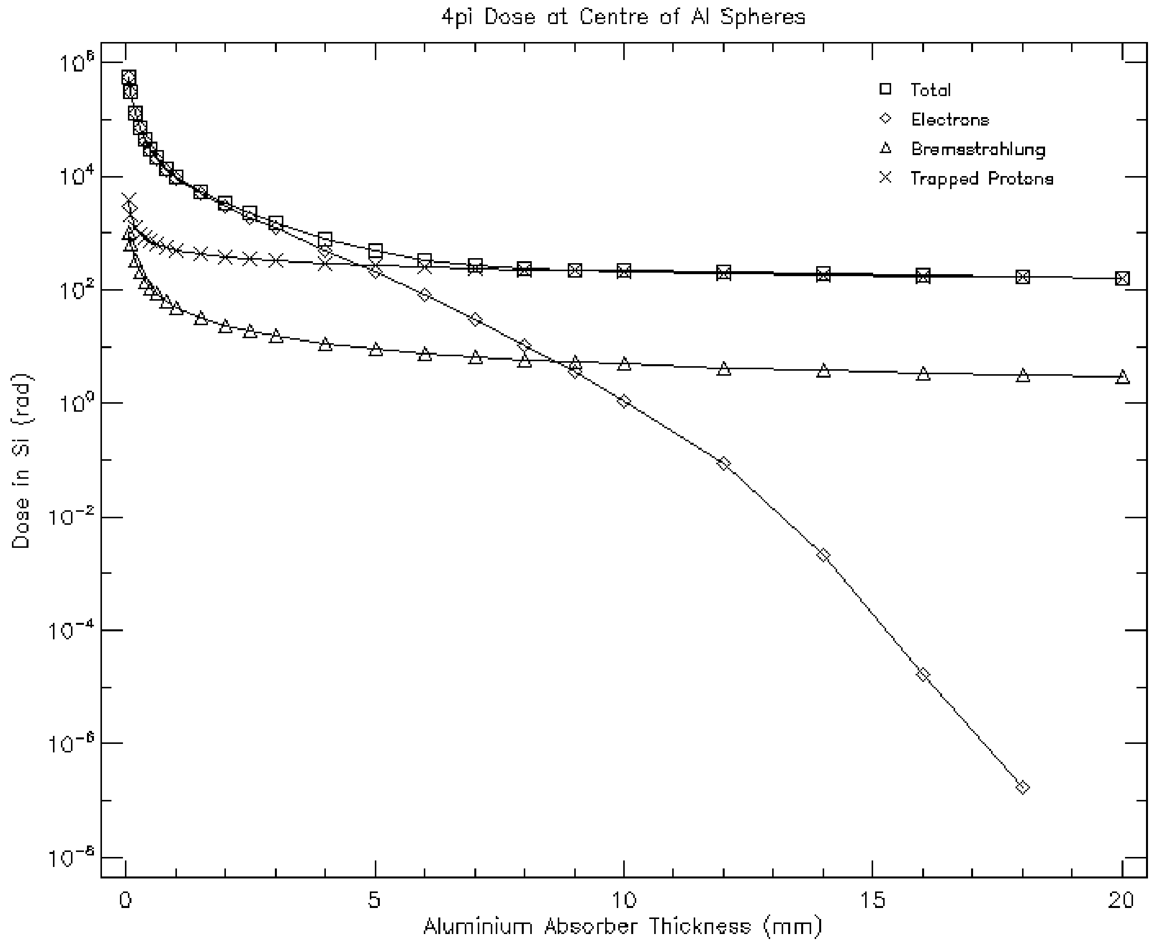
CASE 1. SEMI-INFINITE MEDIUM



CASE 2. FINITE-THICKNESS SLAB

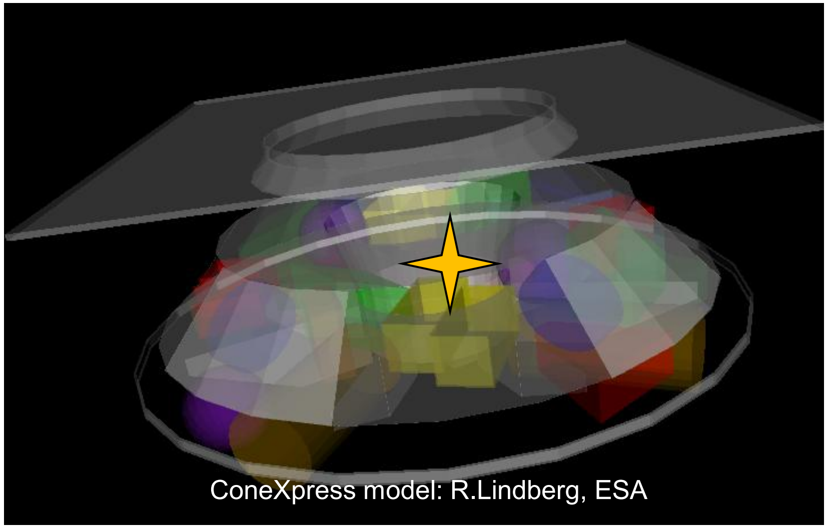


CASE 3. SOLID SPHERE



Ray tracing

- More realistic shielding distribution
- Works ~OK for protons, addressing geometry detail



ConeXpress model: R.Lindberg, ESA

Sector Shielding Analysis Tool SSAT

- Ray tracing: from a user-defined point within a Geant4 geometry
- Geant4 ray transport
- NORM, SLANT and MIXED tracing

SHIELDING

- shielding levels

  fraction of solid angle for which the shielding is within a defined interval

  global and from single materials

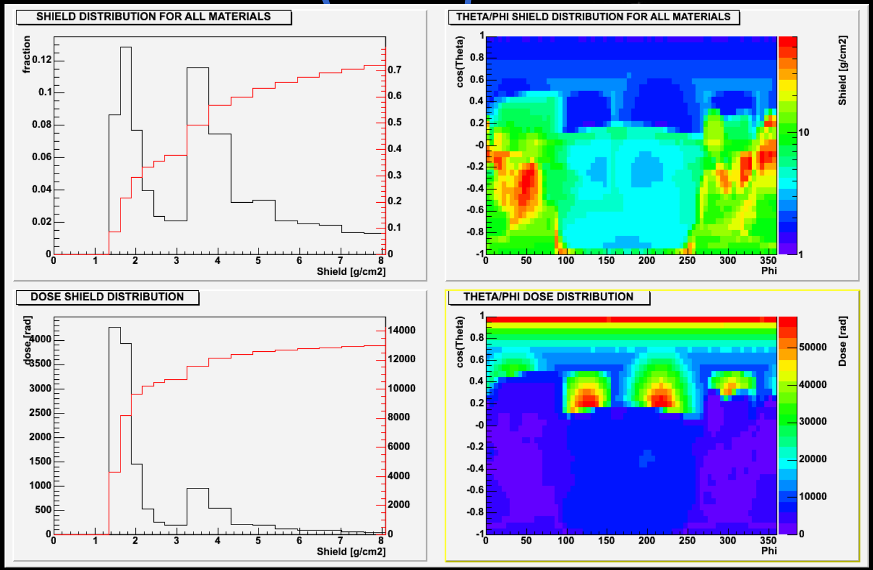
- shielding distribution

  the mean shielding level as a function of look direction

- It utilizes geantinos

DOSE

- Estimate of the dose at a point
  - Based on external Dose-Depth curve e.g. SHIELDOSE-2
  - Ray-by-ray dose calculation
  - All materials scaled to Aluminium
- Results:
  - Total dose
  - Dose-Depth profile
  - Dose directionality



Ray tracing accuracy
Earth orbit electrons

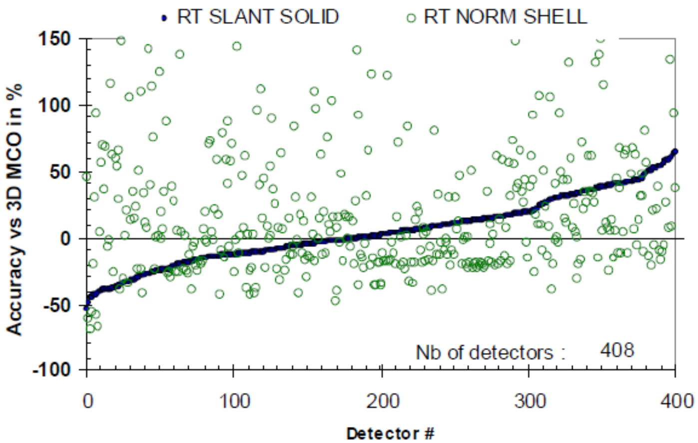
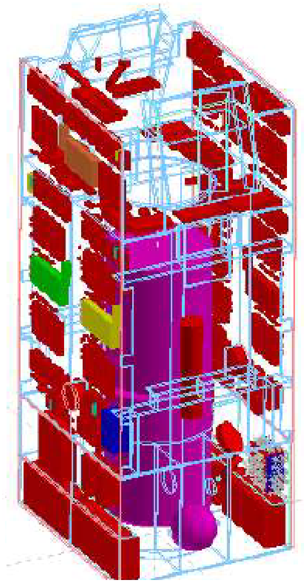


Figure 10 : Ray Tracing Methods Accuracies vs Monte Carlo



P. Calvel et al., IEEE Trans Nucl Sci, Vol. 55, No. 6, Dec 2008

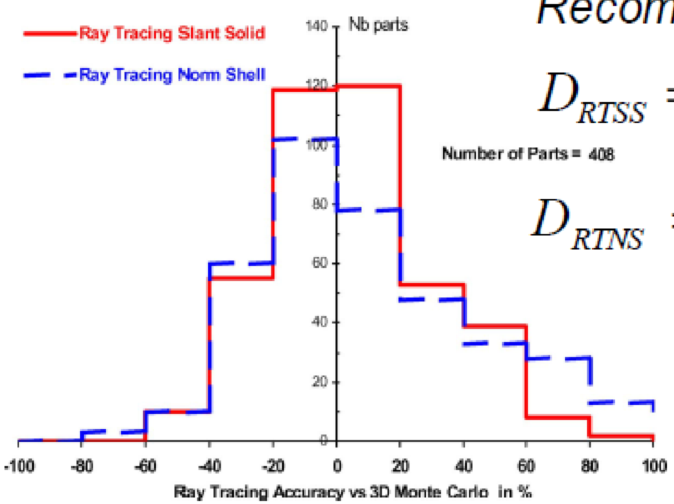


Fig. 11. Ray tracing methods accuracies versus 3D Monte Carlo NOVICE.

Recommended Hardness Assurance Issues

$$D_{RTSS} = (D_{electron} * 2.0) + D_{proton} + D_{bremsstrahlung}$$

$$D_{RTNS} = (D_{electron} * 3.4) + D_{proton} + D_{bremsstrahlung}$$

ESA ELSHIELD project

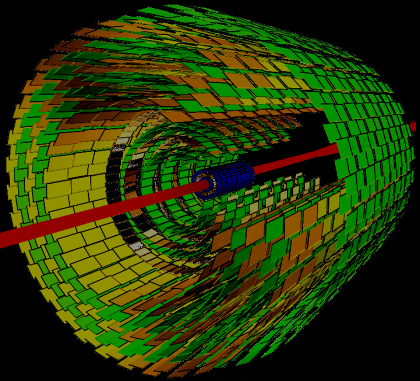
TAS-E with ONERA, ARTENUM, TRAD, INTA, G4AI DHC

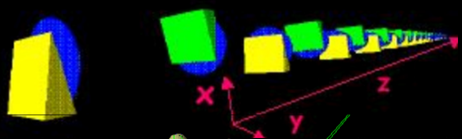
3D Monte Carlo is required

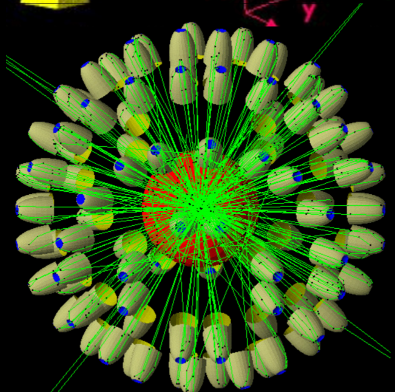
- "Once in a lifetime" opportunity to visit the Jupiter system
  - Underestimated radiation effects to electronics
    - → potential failure of S/C or P/L
  - Underestimated background / contamination
    - → lower scientific return
  - 5 ton spacecraft, 100 kg useful payload: over-dimensioned shielding
    - → lower scientific return

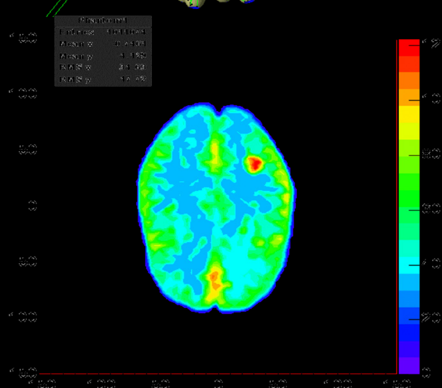
- High level of detail needed
  - Radiation impact on instrument performance (sensor, electronics)
  - Radiation effects on platform electronics
  - Several presentations at this WS already stressed the importance of MC analysis, at P/L and system level

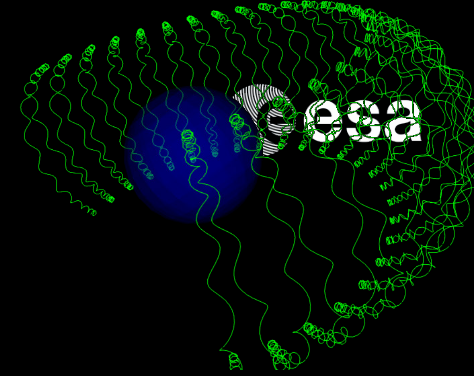
Geant4



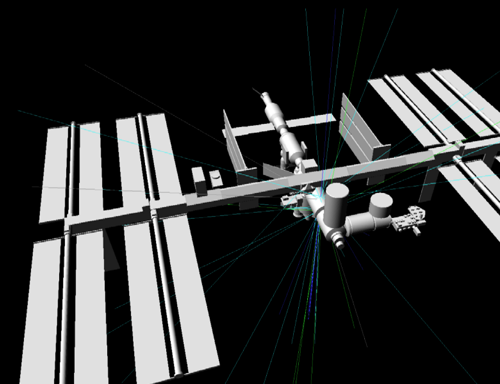


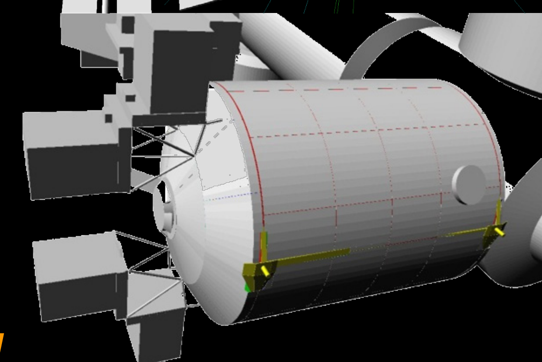






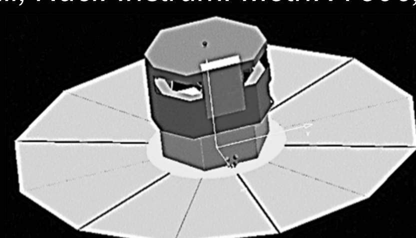
- Monte Carlo particle transport toolkit
- World-wide used toolkit for HEP detector simulation
  - ~40 organizations, institutes and projects
  - Mostly related to high energy physics (HEP)
  - ~15 years of collaborative developments
- UR from heavy ion, CP-violation, cosmic ray, astro- and astroparticle physics, space science and engineering,
  medical applications
- Strategic capabilities for the space engineering community
  - Advanced physics
  - Extendibility (OO design)
  - Interfaces (Geometry/CAD, visualization, post-processing, analysis)
  - Open source approach
  - Long term support

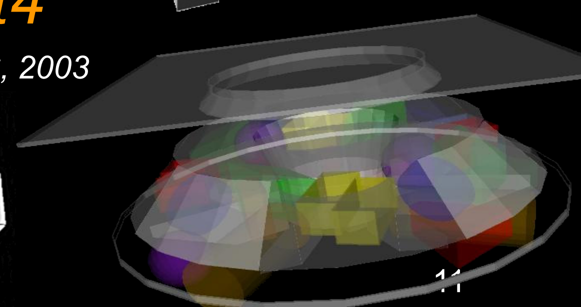




http://cern.ch/geant4

Agostinelli, Nucl. Instrum. Meth. A 506, 2003

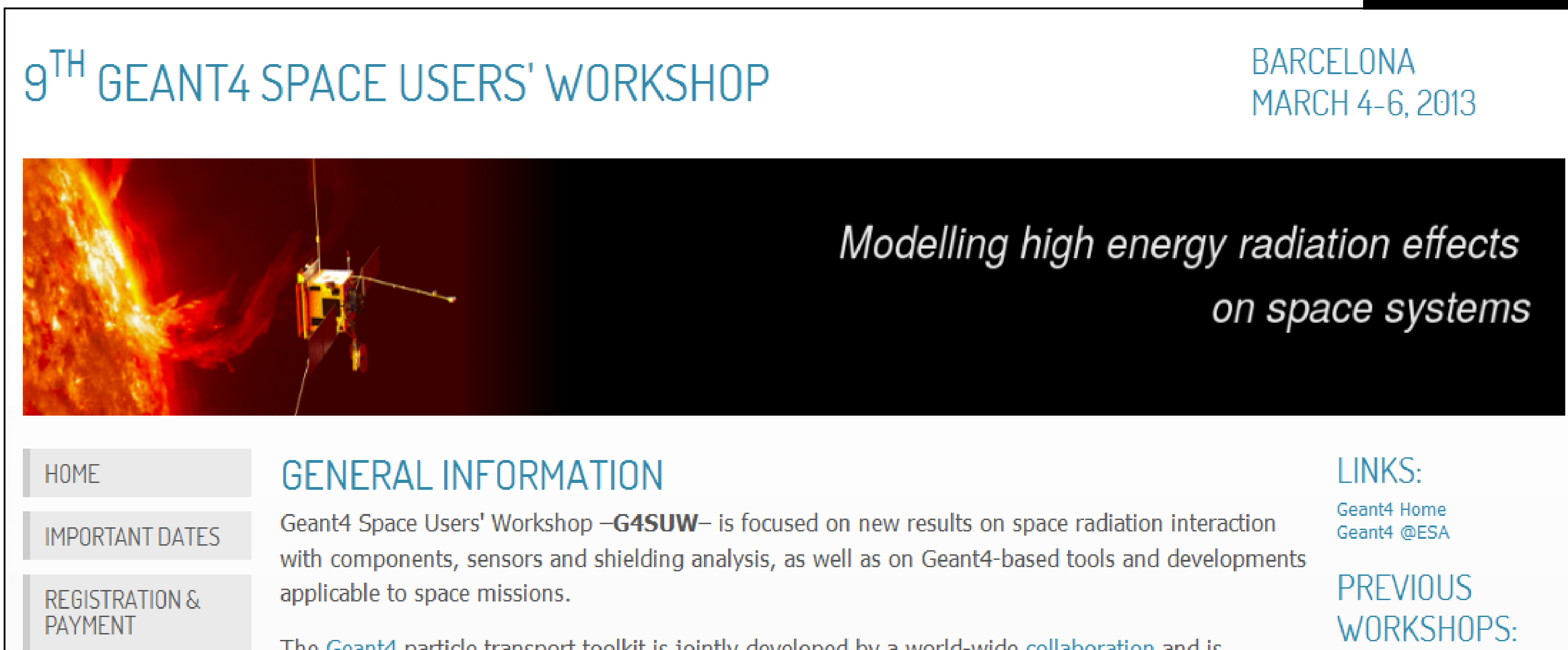




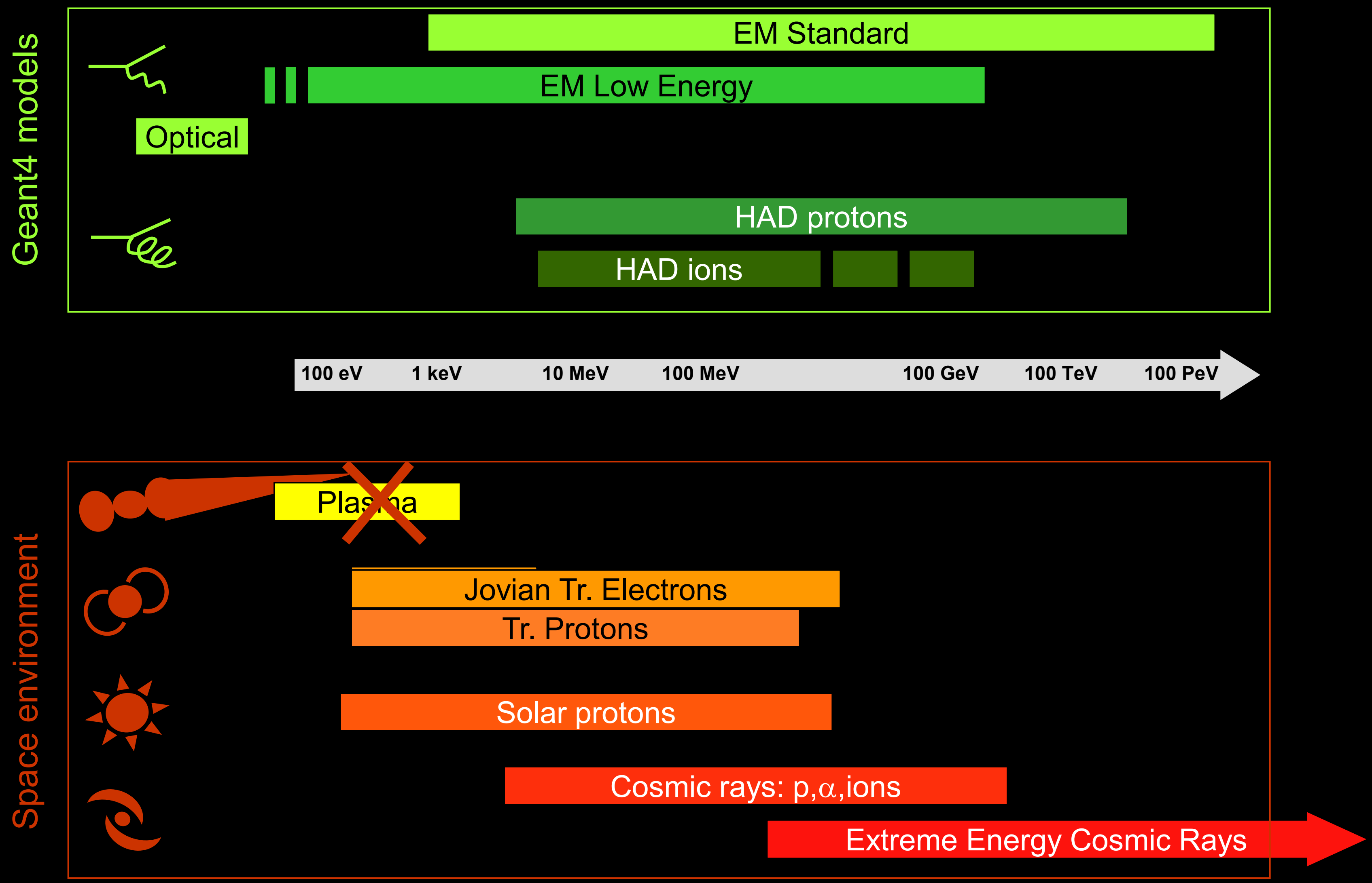
Geant4 space users' community

- Active community with varied expertise
  - Instrument developers, space Industry

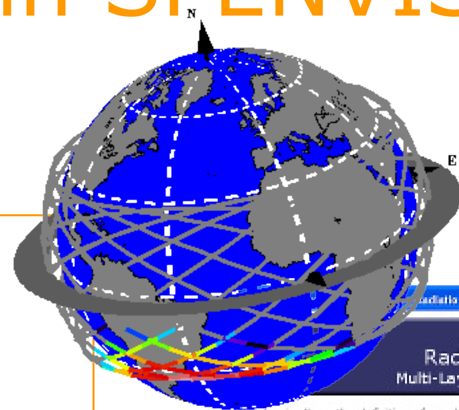
- Collaboration actively involved in support to space users
  - Dedicated "Space applications" HyperNews thread
  - Geant4 Space User Workshops (next one in Barcelona, March 2013) and linked Technical Forum
  - Please come and bring your experience, questions, requirements



Space environment and physics models



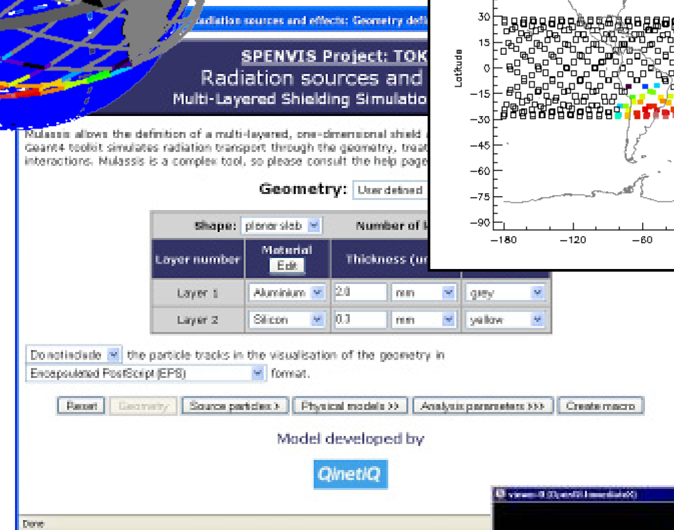
MULASSIS in SPENVIS

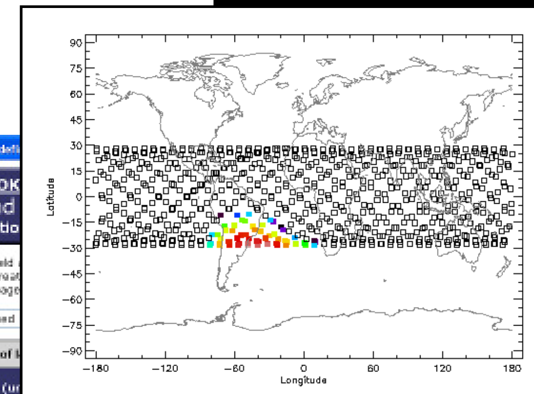


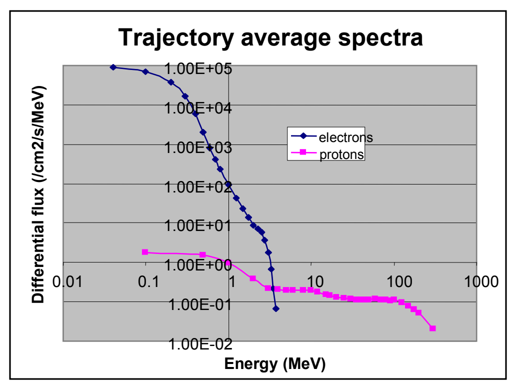
1. Orbit input parameters
2. Radiation environment models
3. MULASSIS interface

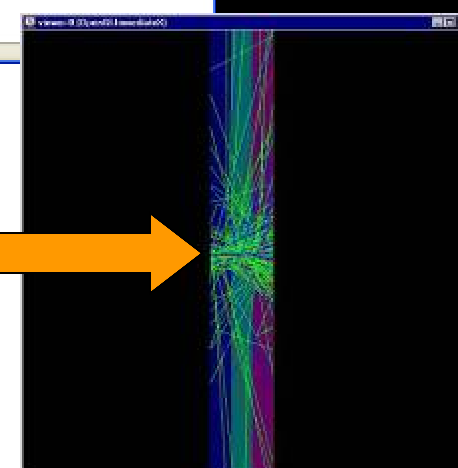
- Layered 1.5-D geometry (slab / sphere)
- Materials by chemical formula
- Primary particle spectrum and fluences
  - From SPENVIS
  - User defined
- Physics list choice
- Analysis options
  - Dose
  - Pulse Height Spectrum
  - Ion. Dose
  - NIEL
  - Dose Equivalent
- Generate the MULASSIS macro
  - Download for standalone version
    http://spitfire.estec.esa.int/trac/Mulassis/
- Run in SPENVIS

NEW

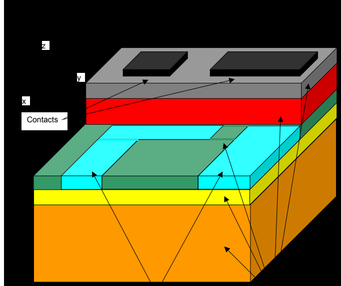






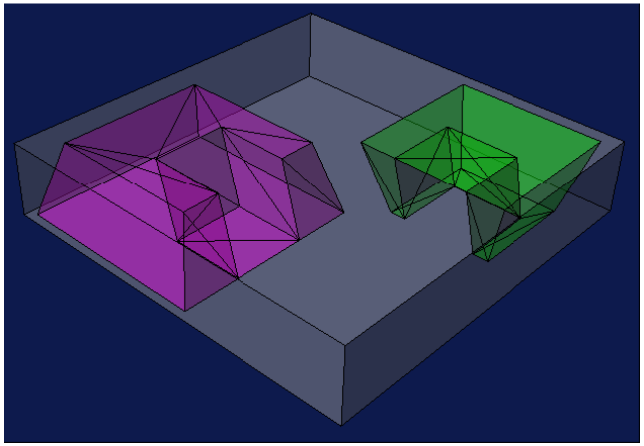


Single Event Effects: GEMAT



Geant4-based Microdosimetry Tool

- Microdosimetry in geometries representing features of a semiconductor device (transistor/junction geometries)



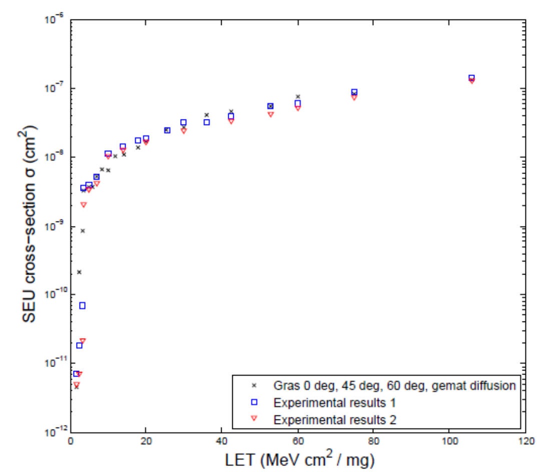


Figure 16: SEU cross-section with GEMAT diffusion

- Analysis includes
  - Single Event Effects (SEE)

    User-input collection "efficiencies" for different regions

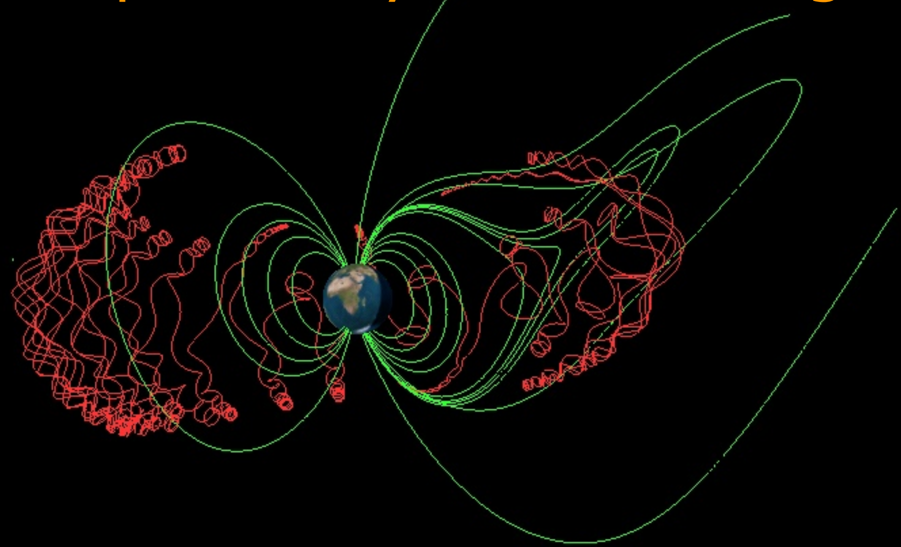
    Charge Collection Analysis (CCA, GRAS analysis module) includes diffusion equation for charge transport outside drift volumes
  - Simultaneous energy deposition in several sensitive regions (MBU)

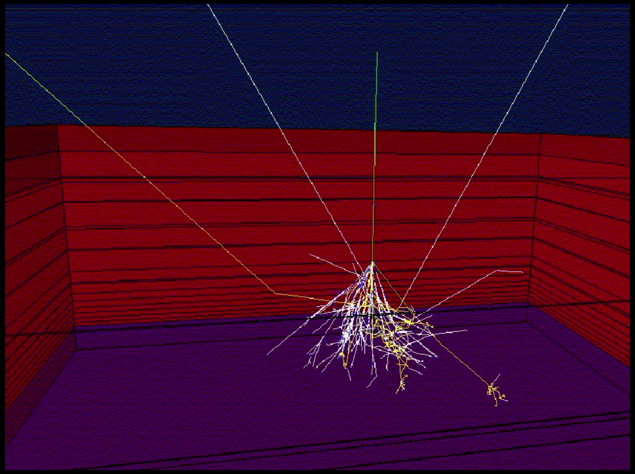
- Has been integrated into SPENVIS

NEW Standalone version at http://spitfire.estec.esa.int/trac/GEMAT/

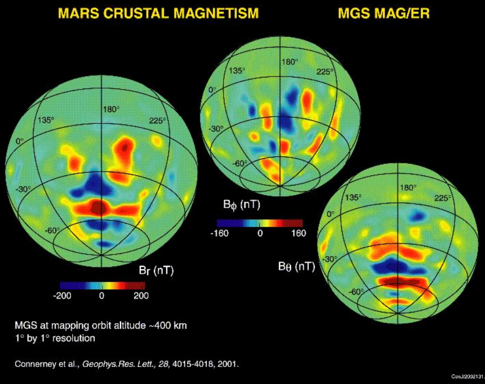
PlanetoCosmics

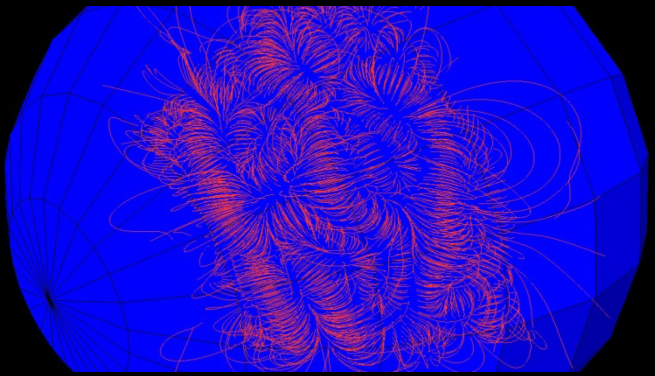
Geant4 simulation of Cosmic Rays in planetary Atmo- / Magneto- spheres





- Originally for Earth environment
- Extended to
  - Mars (local magnetic fields)
  - Mercury
- Under development
  - Jupiter
  - Saturn
  - Jovian moons





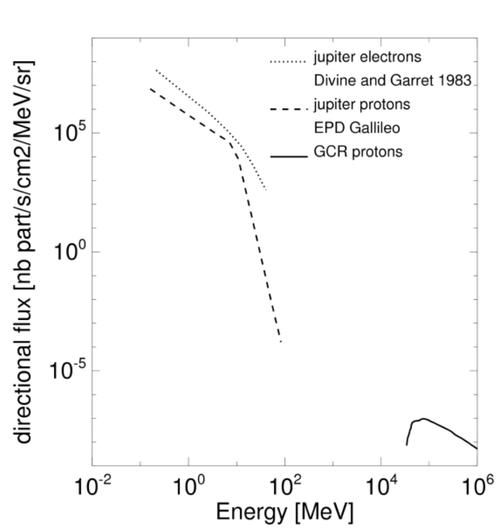
Geant4 implementation L. Desorgher, Space IT

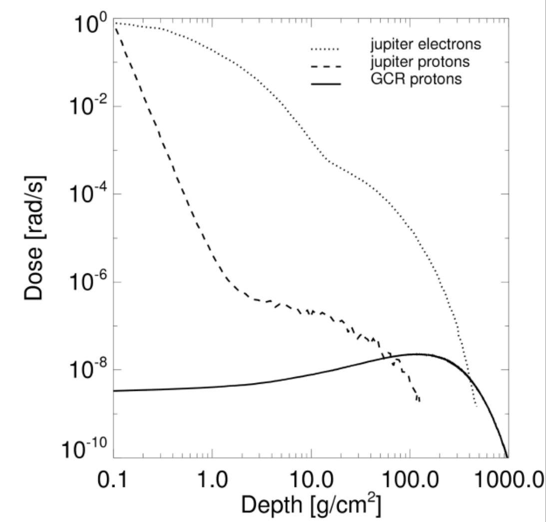
http://cosray.unibe.ch/~laurent/planetocosmics/

Planetocosmics at Jupiter

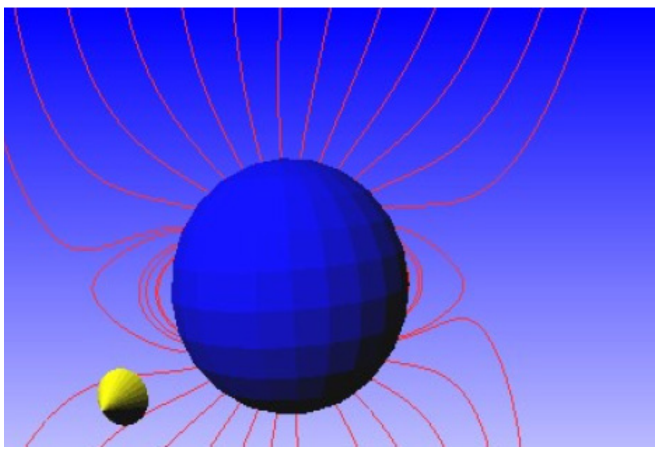
Early work by
L.Desorgher (SpaceIT), 2008

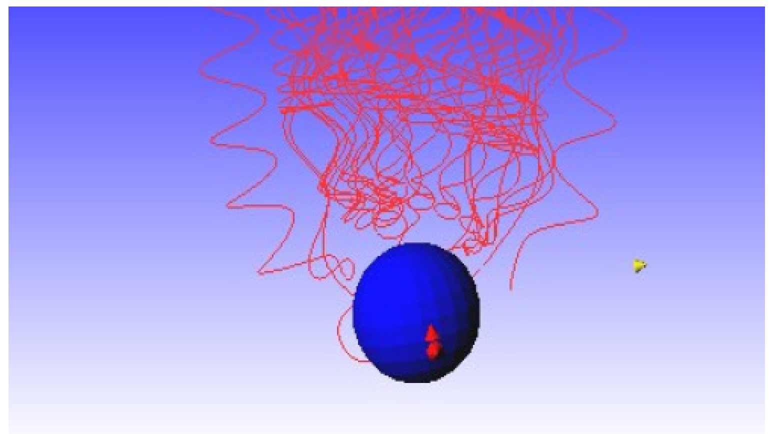
- Radiations at Europa
- Dose in Europa soil (ice)





Planetocosmics-J





P. Truscott, D. Heynderickx, R. Nartallo, Fan Lei, A. Sicard-Piet, S. Bourdarie, J. Sorensen and L.Desorgher, "Application of PLANETOCOSMICS to Simulate the Radiation Environment at the Galilean Moons", Vol. 5, EPSC2010-808, 2010

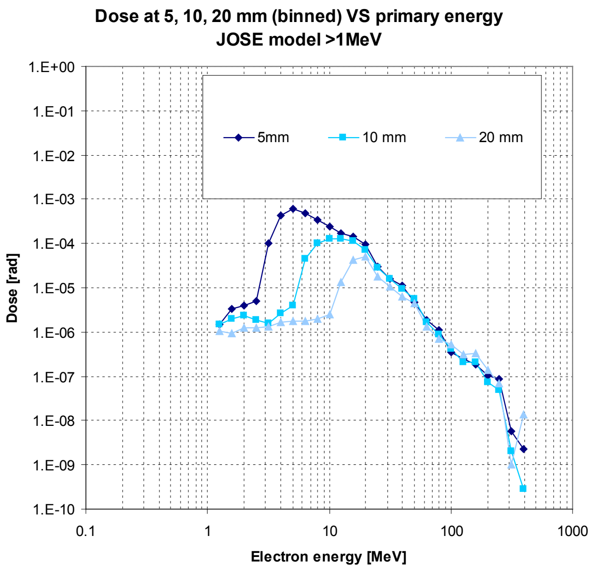
- Available in SPENVIS

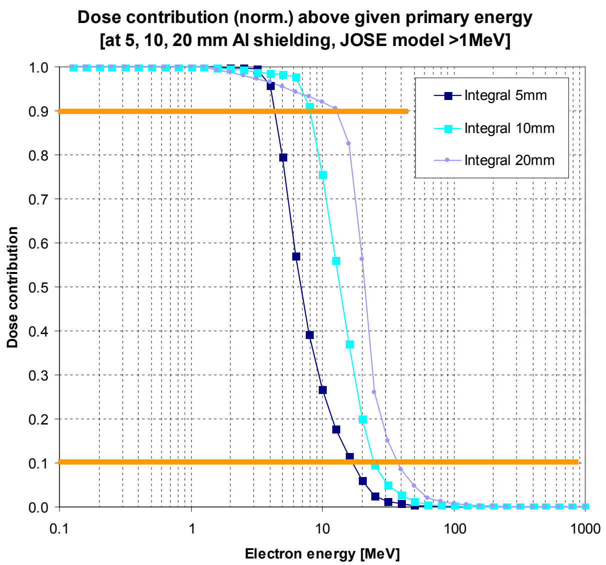
ESA JORE^{2}M^{2} project, Final Report, QinetiQ UK

Other MC tools

- FASTRAD
  - Recent addition of (TRAD-developed) Reverse and Forward MC
  - Starting collaboration for comparisons and validations
- NOVICE
  - De facto standard (until now) for reverse (adjoint) 3D simulations
- Other 3D MC tools
  - Penelope
  - EGSnrc
  - MCNPX
  - FLUKA
  - …

Dose response function (1-D)





ESA Memo TEC-EES/2011.812/GS

- JOSE model extends in energy up to 1 GeV, but impact of the highest portion of the spectrum (above 50 MeV) is rather limited for TID
- Only 10% of the dose is coming from electrons of energy
  - >~15 MeV for 5mm Al
  - > ~25 MeV for 10 mm Al
  - >~35 MeV for 20 mm Al.
- This might not apply to other radiation effects, e.g. background, where high energy tail can affect signals of deeply shielded sensors

Shielding material effectiveness
Graded shielding

MEO / GEO

Electron source
Isotropic
(cosine-law bias)

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 43, NO. 6, DECEMBER 1996

Effects of Material and/or Structure on Shielding of Electronic Devices

R. Mangeret, T. Carrière, J. Beaucour
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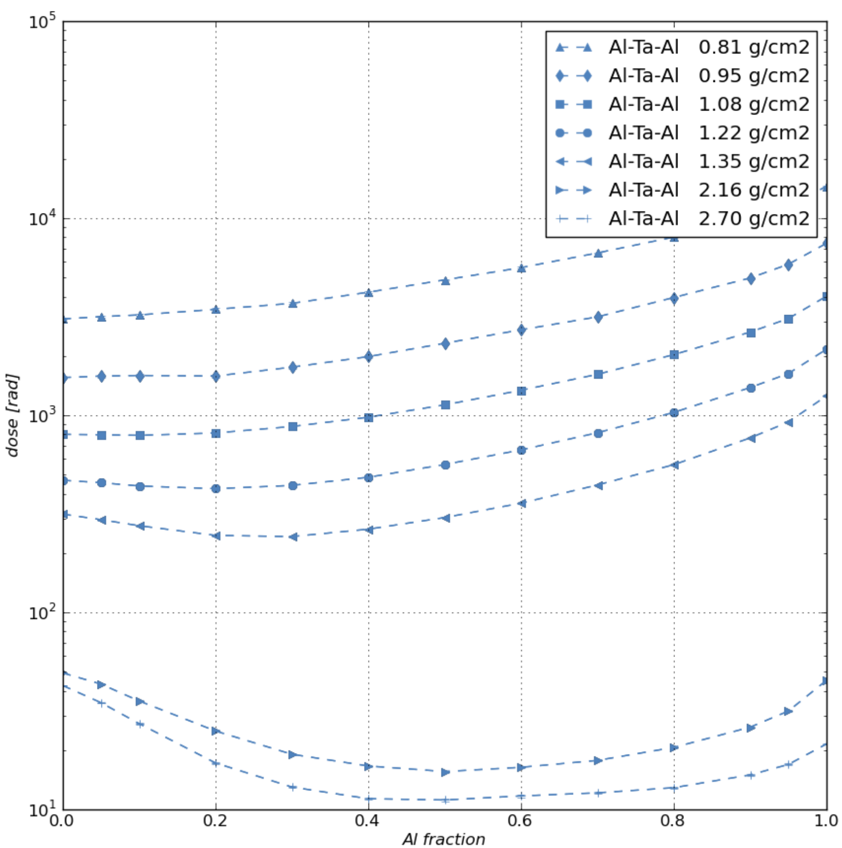
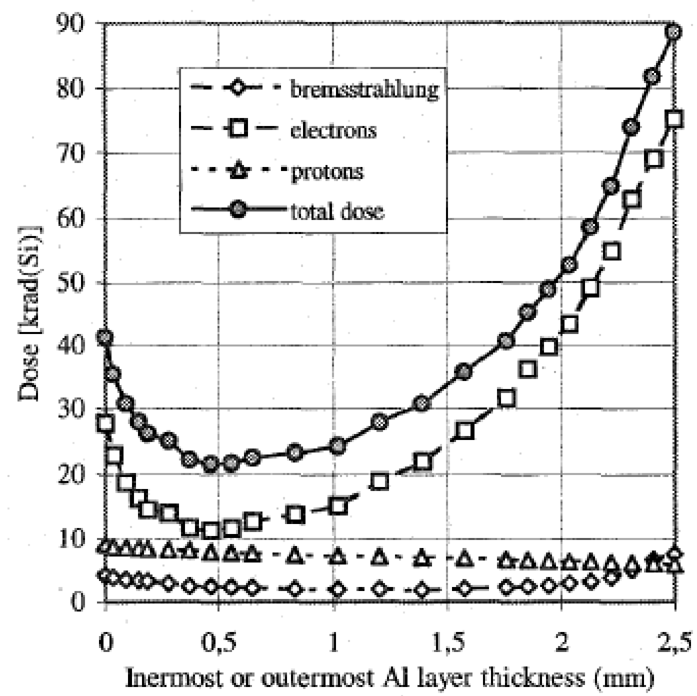


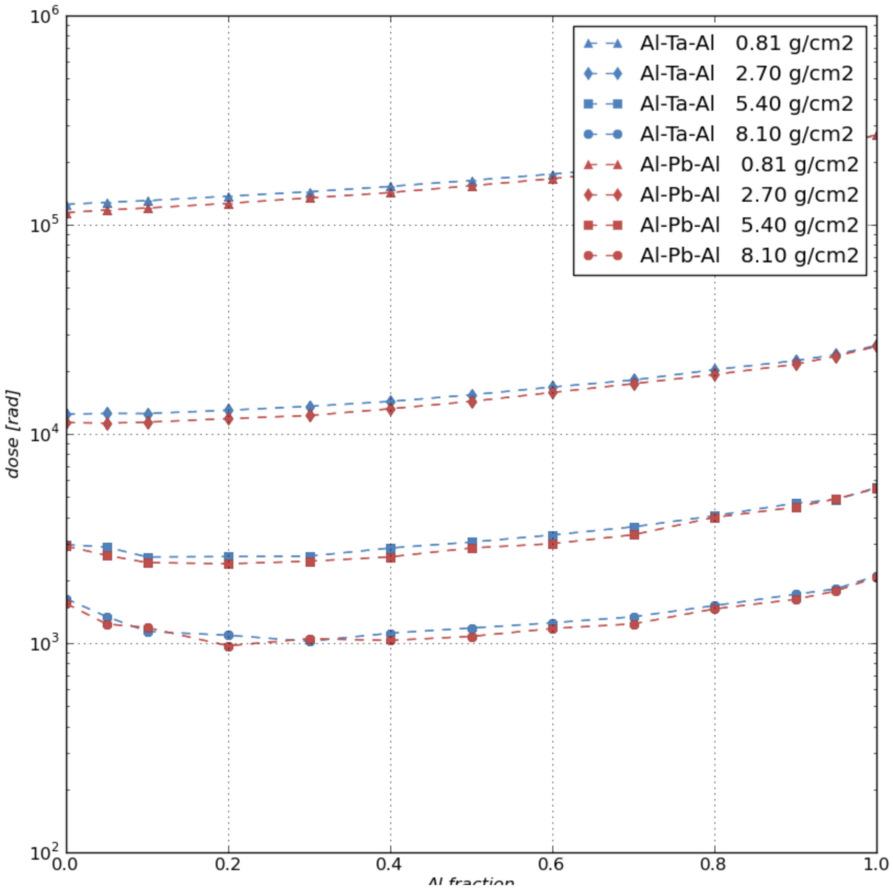


Giovanni Santin, Marie Ansart
TEC-EES/2010.613/GS/2.0

Fig. 7. Attenuated dose versus internal or external Aluminium thickness at a shield "mass thickness" of 1,35 g/cm^2.

Shielding material effectiveness
Graded shielding

Jupiter



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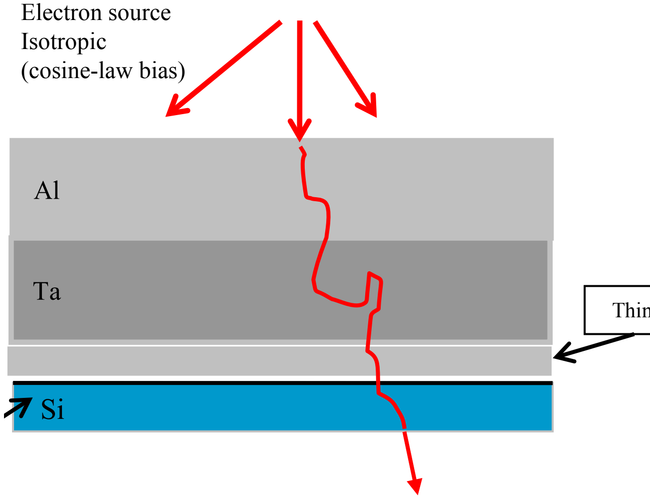
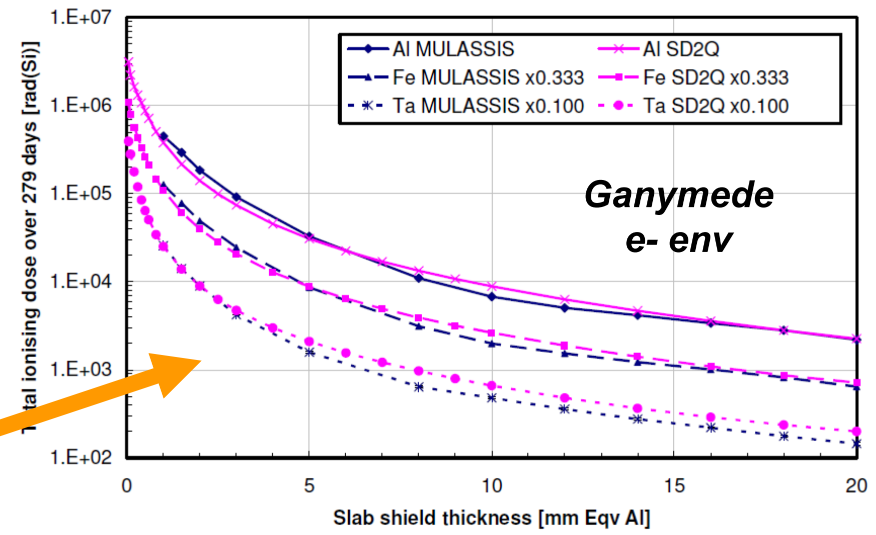
TEC-EES/2010.613/GS/2.0



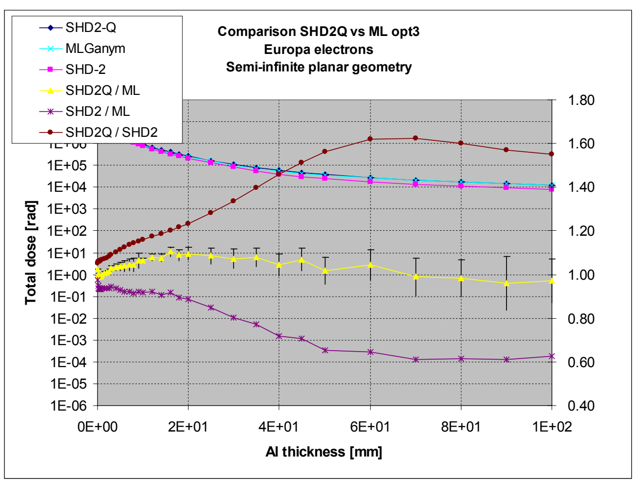
- Maximum dose reduction factor ~2
- For a given dose: mass saving for pure Ta vs. pure Al factor ~1.5
  - E.g.
    3.24 g/cm2 (Al) ~ 2.16 g/cm2 (Ta),
    and
    1.22 g/cm2 (Al) ~ 0.81 g/cm2 (Ta)
- General message:
  Rescaling to Aluminium not satisfactory

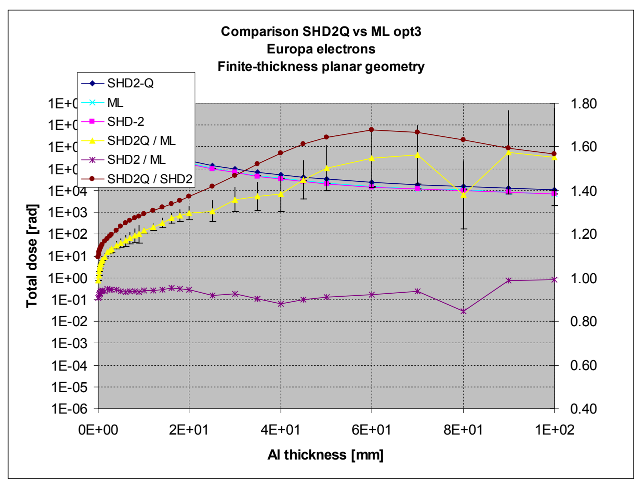
SHIELDOSE-2Q

- SHIELDOSE and SHIELDOSE-2 have been standard tools for S/C shielding analysis for over twenty years
  - Whilst not physically precise, these are much easier to use and generate results very rapidly
- SHIELDOSE-2Q extends range of shielding (including Fe, Ta, Cu-W alloy, Al-Ta bilayer) and target materials



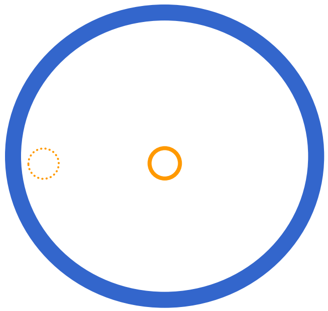
- Available in SPENVIS
- Some validation efforts at ESA



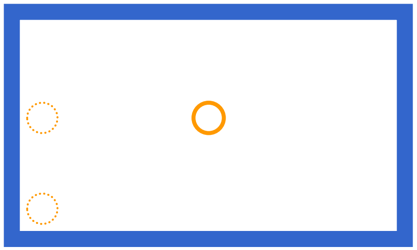


ESA JORE²M² project, Final Report, QinetiQ UK

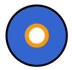
Dose in 3D simple geometries (1)



Spherical shell with detectors at the centre and close to the inner surface



Box with detectors at the centre and, close to the inner surface, at the centre of a face, next to an edge and next to a corner



"Solid sphere" with a detector at the centre

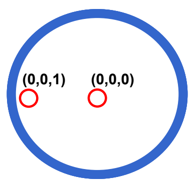
Dose at centre [krad/310d]

Shielding [mm]	**Solid sphere SHD2**	**Solid sphere** Al-Si-Vac R_Si=T/10 T_Si=10um	**Box** 2x2x3m^3 R_Si=10cm T_Si=10um	**Sphere** R=1.5m R=10cm T_Si=10um
5mm	1016	1030	345	377
10mm	266	283	83	104
20mm	62	57	18	25

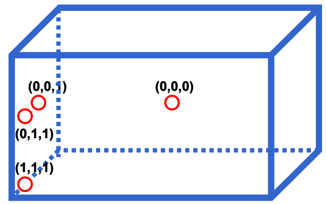
- Geant4 / GRAS 3-D Monte Carlo

ESA Memo TEC-EES/2011.812/GS

Dose in 3D simple geometries (2)



Spherical shell with detectors at the centre and close to the inner surface



Box with detectors at the centre and, close to the inner surface, at the centre of a face, next to an edge and next to a corner

"Solid sphere" with a detector at the centre

Solid sphere	Dose 310 days [krad]		
	Target 000		
5 mm	1030	+/-	1.3
10 mm	283	+/-	0.8
20 mm	57	+/-	0.4

Sphere	Dose 310 days [krad]					
	Target 000			Target 001		
5 mm	377	+/-	5	374	+/-	5
10 mm	104	+/-	3	89	+/-	2
20 mm	25	+/-	2	18	+/-	1

Box	Dose 310 days [krad]											
	Target 000			Target 001			Target 011			Target 111		
5 mm	345	+/-	5	375	+/-	5	395	+/-	5	408	+/-	5
10 mm	83	+/-	2	93	+/-	2	98	+/-	3	99	+/-	2
20 mm	18	+/-	1	18	+/-	1	21	+/-	1	22	+/-	1

Message:

- Dose-depth curve should only be taken as first order approximation of radiation environment severity
- 3-D Monte Carlo calculations mandatory
- Note: Results may be strongly dependent on geometry details

Operational radiation transport tools Development lines

Particle Physics Research

- Physics extensions
- Accuracy improvement
- Technical transport implementation
- Geometry capabilities

- Ease of use
- Engineering interfaces (CAD,…)
- Tallying options
- Computational speed
- Tool integration

Space Weather Operations

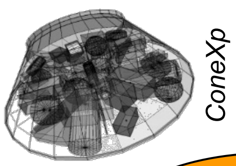
Scientific approach

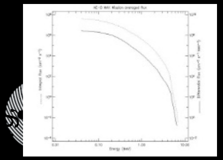
1. Accuracy
2. Usability
3. Speed

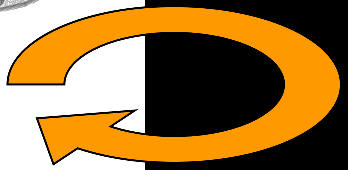
Missions support

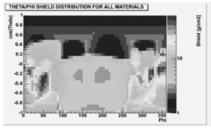
Usability
Speed
Accuracy

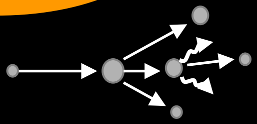
Engineering margins
Confidence in simulation results









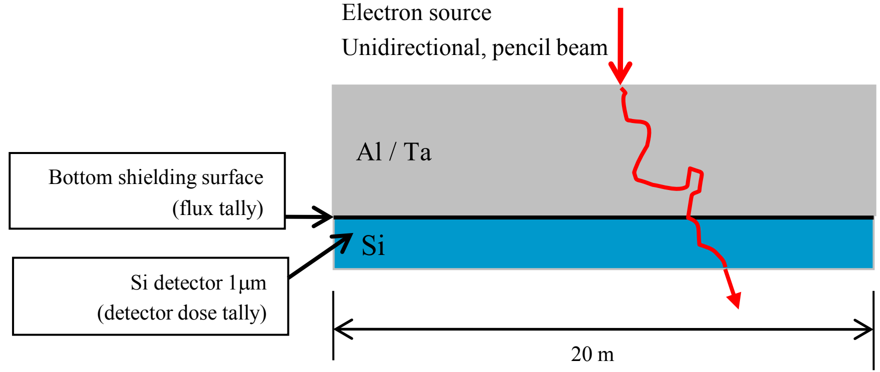


- Typical radiation analysis is iterative process with chain of calculations based on models, each with statistical and systematic uncertainties
  - Engineering margins should account for known and unknown unknowns ensure mission survival in hostile environments
  - High margins imply extra costs (e.g. from weight of thick shielding, or system redundancy) and are sometimes showstoppers in feasibility studies – should be reasonable
- 3-D Monte Carlo is assumed to be more accurate than approximations based on 1-D calculations or ray tracing
  - Lower margins imply extra risk: contributions to the global uncertainties to be monitored, MC should not be assumed as “perfect”
  - User input mistakes are generally much more dangerous than systematics from physics modelling

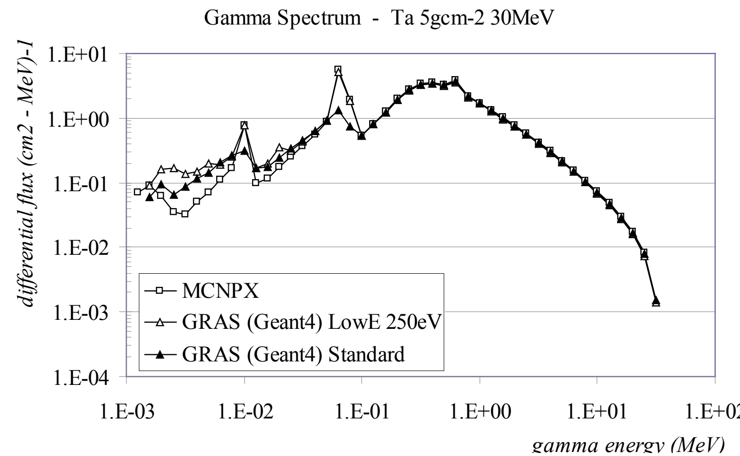
    Spectrum interpolation, biasing, cuts, response functions,

    absolute normalisation, wrong geometry, dose self shielding
  - Open interfaces for tool interoperability increases confidence
  - Significant expertise needed in the teams to increase (and quantify!) the confidence in our Monte Carlo engineering calculations

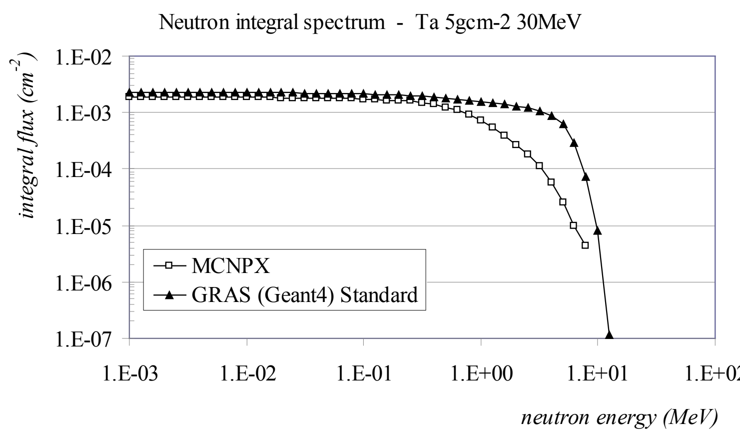
Validation efforts for EJSM

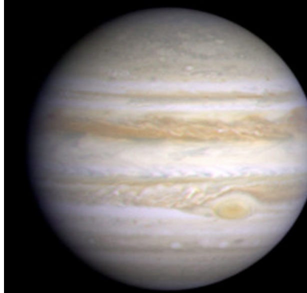


- Shared effort JPL – ESA
- Prediction capabilities of Geant4 and MCNPX
  - From single materials
    to multi-layered shielding options
  - Mono-energetic e- and realistic spectra
  - TID, electron, gamma and also neutron fluxes



- Selection of input parameters and models for Geant4 non-trivial
- Agreement generally good, with some notable differences
- Providing benchmarks for potential instrument providers to validate their own choice of transport tools





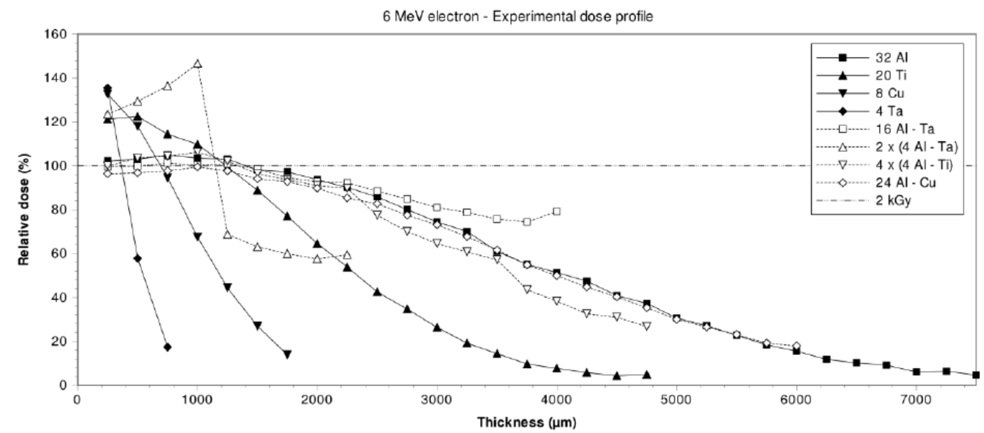
Presented at EJSM Instrument Workshop, ESTEC

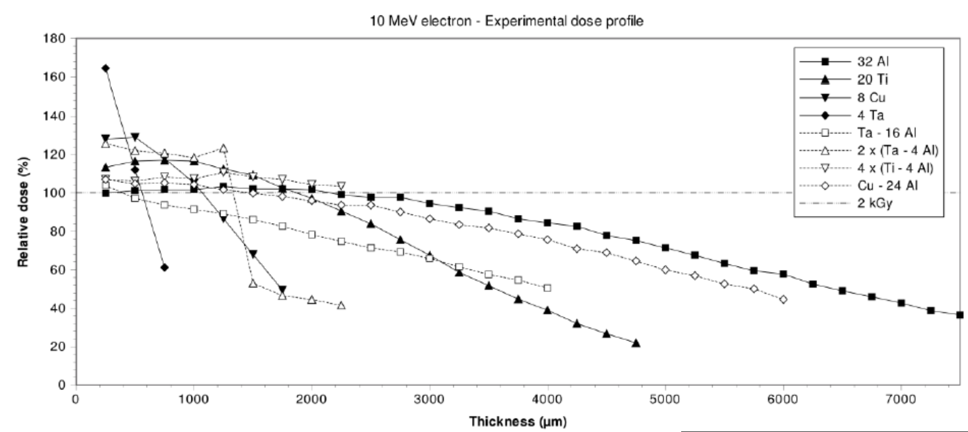
Validation efforts ELSHIELD

Energetic Electron Shielding, Charging and Radiation Effects and Margins

Experimental dose enhancement in multi-layer shielding structures exposed to high-energy electron environments

J. Eck, S. Ibarmia, V. Ivanchenko, D. Lavielle, A. Rivera, J. Cueto, G. Santin





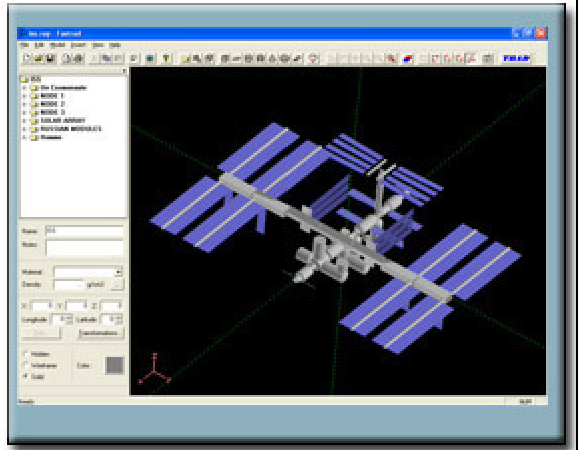
- Analysis of problem areas in energetic electron penetration and interactions in S/C and P/L
- Validation of model developments (also dedicated testing campaigns)

TAS-E led consortium
G4AI, TRAD, INTA, DHC, ONERA, Artenum, TAS France

RADECS 2012, Submitted to IEEE TNS

Modelling speed in 3-D realistic S/C

esa



Modèle de la station internationale sur FASTRAD

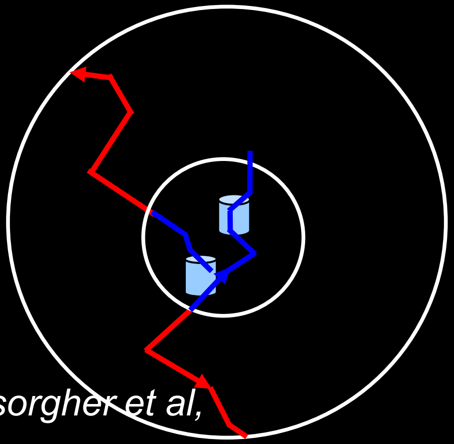
CAD geometry interface

- CAD STEP and IGES interface (and normal 3D models)
  - via external 3D modelling tools tools
  - Direct GDML output for Geant4
- FASTRAD, ESABASE2, SALOME

Speed: Reverse MC

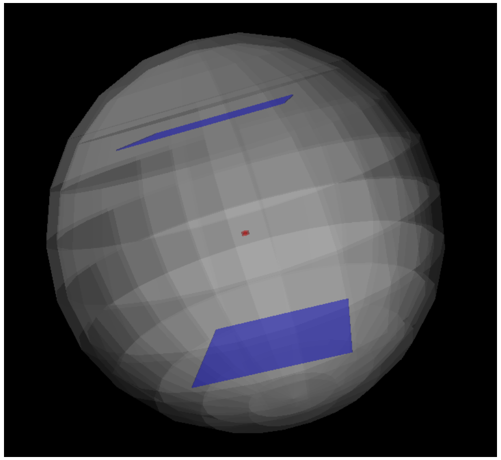
Requirement from space industry

- Tallying in sub-micron SV inside macroscopic geometries
- Reverse tracking from the boundary of the sensitive region to the external source
  - Based on "adjoint" transport equations
- Computing time focused on tracks that contribute to the detector signal

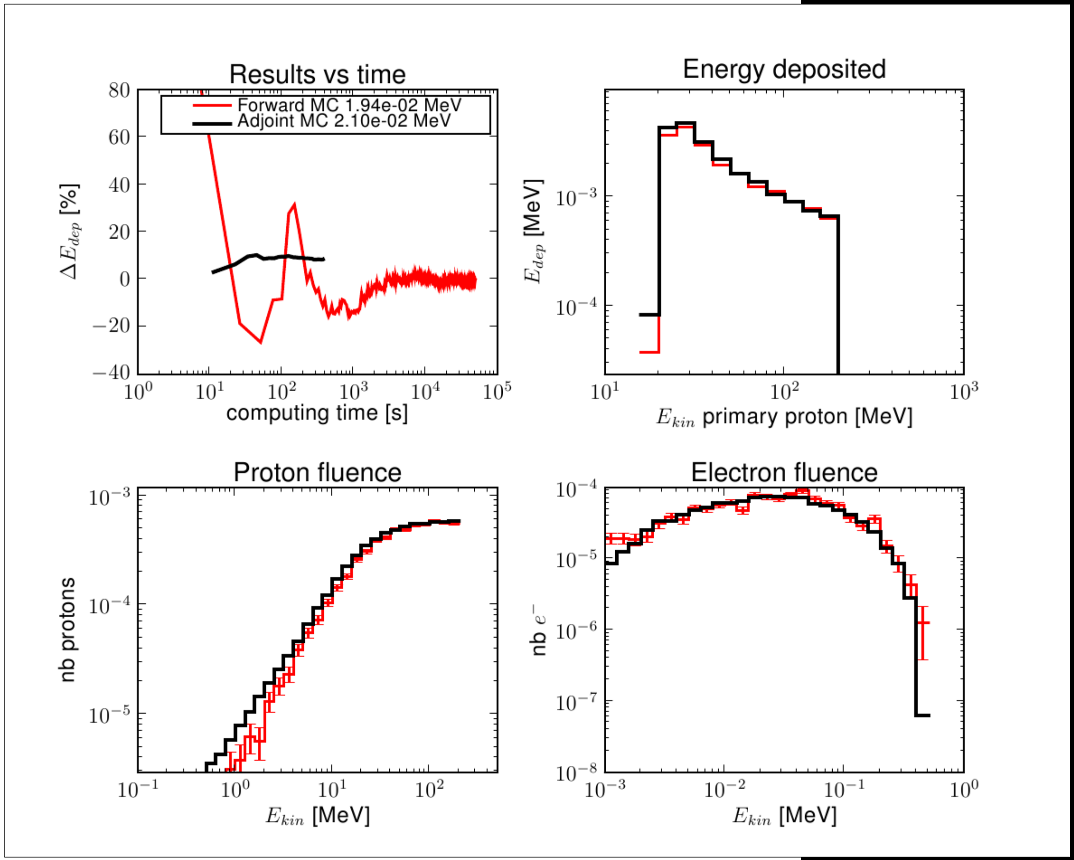


Desorgher et al, Nucl Instr Meth A, 2010

Reverse MC: comparison VS forward Protons, simple geometry



- Proton source
  - [0.1keV, 200MeV]
  - E^{-1} spectrum



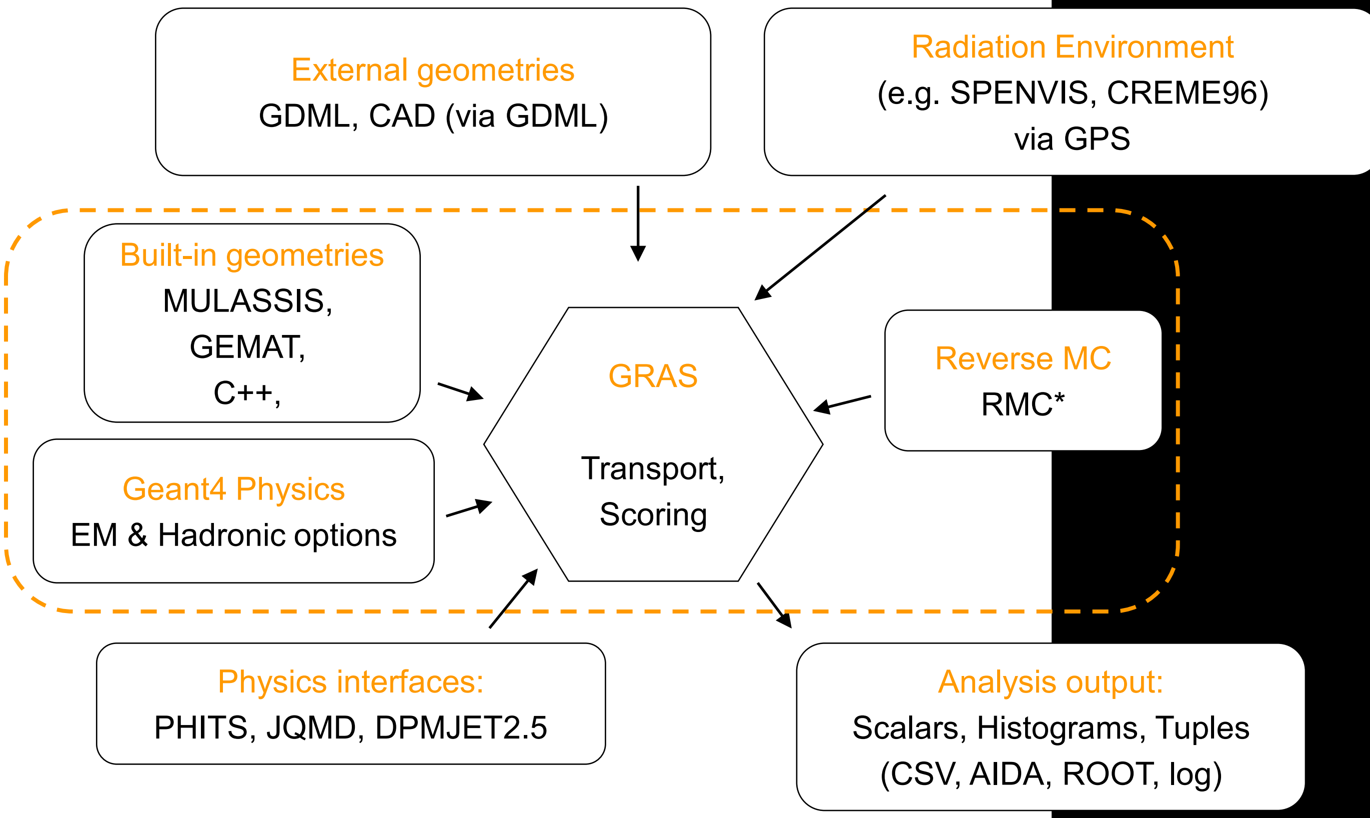
- Difference in total computed dose <~5%
- Reverse MC method more rapid than forward by orders of magnitude
- Recent observations of bigger discrepancies with electrons are being investigated

Desorgher et al, Nucl Instr Meth A, 2010

Geant4 tools integration: GRAS

Requirements:

- Ready-To-Use tool
  - Multi-mission approach
- Quick assessments
  - Ray-tracing ↔ MC
  - 1D ↔ 3D
  - EM ↔ Hadronics
  - LET ↔ SV details
- Modular progress
  - Open to collaborations and contributions
- Currently GRAS v3.1
- GRAS v3.2 in preparation
  - Jan-Feb 2012



G Santin, V Ivantchenko et al, IEEE Trans. Nucl. Sci. 52, 2005

http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

GRAS: script driven

Santin et al, RADECS, 2005

Geometry

1

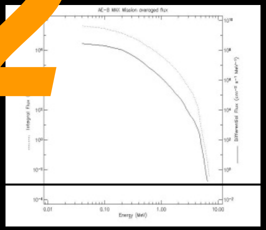
Parameters for
built-in geometries
or
External files

```
/gras/geometry/type gdml
/gdml/file geometry/conexpress.gdml
```

Source

2

RADIATION
ENVIRONMENT



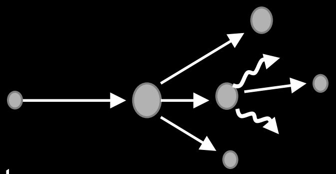
```
/gps/pos/type Surface
/gps/pos/shape Sphere
...
/gps/ang/type cos
/gps/particle e-

...
```

Physics

3

Physics lists

or single components

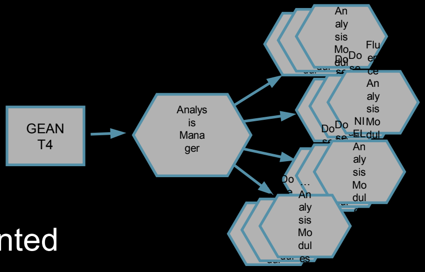


```
/gras/phys/addPhysics em_standard_opt3
/gras/phys/addPhysics QGSP_BIC_HP
/gras/phys/addPhysics raddecay

/gras/physics/setCuts 0.1 mm
/gras/physics/stepMax 0.01 mm
```

Analysis

4

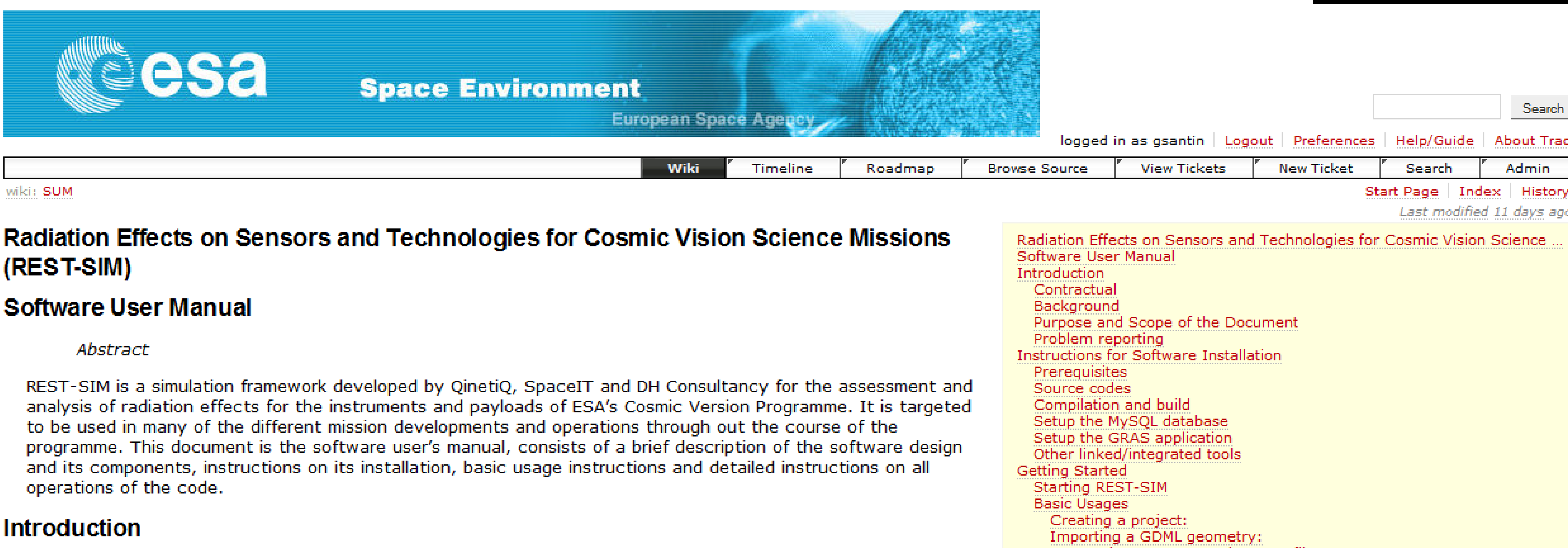
Object Oriented
scripting




```
/gras/analysis/dose/addModule doseB12
/gras/analysis/dose/doseB12/addVolume b1
/gras/analysis/dose/doseB12/addVolume b2
/gras/analysis/dose/doseB12/setUnit rad
```

GRAS
Get started (back at home)

- S/W and documentation available from
  - http://spitfire.estec.esa.int/trac/GRAS
- Temporary login / pw for the workshop:
  - juice2012 / juice2012
- Latest code version from SVN repository at
  - http://spitfire.estec.esa.int/svn/GRAS/trunk/



Radiation Effects on Sensors and Technologies for Cosmic Vision Science Missions (REST-SIM)

Software User Manual

Abstract

REST-SIM is a simulation framework developed by QinetiQ, SpaceIT and DH Consultancy for the assessment and analysis of radiation effects for the instruments and payloads of ESA's Cosmic Version Programme. It is targeted to be used in many of the different mission developments and operations through out the course of the programme. This document is the software user's manual, consists of a brief description of the software design and its components, instructions on its installation, basic usage instructions and detailed instructions on all operations of the code.

Introduction

GRAS
Releases

- Current release v3.1, Feb 2012
  - Based on Geant4 9.5.1

  Some highlights:
  - Point detector for RMC
  - New LET analysis
  - Geometry biasing interface
  - CMAKE–based installation

- GRAS 3.0 (Oct 2011) had introduced
  - Reverse MC
  - Automatic normalisation
  - Magnetic field manager
  - Improved CSV output

```
GRAS 3.1 Release Notes
------------------------

20 February 2012

Platforms and dependencies
--------------------------
        - This release has been tested on
          + Linux: SuSE10.3 (gcc-4.2.1), 64 bit
          + MacOSX Lion  64 bit
          + Windows7 32bit
        - GRAS3.1 requires the installation of
          + Geant4 9.5
        - Optional extra packages
          + Histogramming package: AIDA (not for Windows)
          + Histogramming package: ROOT (not for Windows)

Changes since previous release
------------------------------

analysis
-----------------
        -Adding of point detector in the
        -Adding of NewLET analysis module

biasing
---------
        -Adding of geometry biasing inter

physics:
--------
        -Update to geant4.9.5
        -Update list of available Phsyics
            for EM physics - em_standard,
             em_standard_opt2, em_standar
             em_standard_WVI, em_standard
             em_penelope, rmc_em_standard
            for hadronic physics: binary,
             bertini_hp, bertini_preco, F
             QGSP_BERT, QGSP_BERT_HP, QGS
             QGSP_QMD_HP, Shielding
            for ion nuclear interactions:
             binary_ion, QMD_ion, incl_ab
             jqmd_ion
        -There is a possibility to use Gea
           its name specified as 3d parame
           the environment variable MACROI


installation:
----------
        -New installation based on CMAKE
```

```
GRAS 3.0 Release Notes
------------------------

27 October 2011

Platforms and dependencies
--------------------------
        - This release has been tested on
          + Linux: SuSE10.3 (gcc-4.2.1), 64 bit
          + Linux: SuSE11.3 (gcc-4.2.1), 32 bit
        - GRAS requires the installation of
          + Geant4 9.4.p02
        - Optional extra packages
          + Histogramming package: AIDA implementation
          + Histogramming package: ROOT

Changes since previous release
------------------------------


Reverse/adjointMC
-----------------
        -The Reverse/Adjoint MC mode  available in Geant4 has been now im

         See example/reverse_mc/simple_geo (reverse_simulation.g4mac)


analysis
--------
    -Automatic normalisation. See example/normalisation/automatic_normali

        -Adding of 3D scoring with meshing  (Sergio Ibarmia Huete INTA)
    -New Reaction analysis module

physics
-------
     -Adding of reverse/adjoint physics.

histo
-----
        -Possibility of ntupling also with ROOT.
        -Improvments of GRAS CSV output (normalised unit, ...)

magnetic field modeling
-----------------------
        -Adding of the magnetic field model manager (MarsREM project, L.De
```

GRAS
Simple case

- Example distributed during the JUICE instrument AO
- S/W and documentation available from
  - http://spitfire.estec.esa.int/trac/GRAS/wiki/GRAS/JuiceSimpleCase

Space Environment

European Space Agency

Search

logged in as gsantin | Logout | Preferences | Help/Guide | About Trac

Wiki | Timeline | Roadmap | Browse Source | View Tickets | New Ticket | Search | Admin

wiki: GRAS / JuiceSimpleCase

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Last modified 3 months ago

JUICE - GRAS simple case

Description

The gzipped tar file in attachment contains geometry model and input macro text files for a simple GRAS simulation of a spacecraft in the Jupiter electron environment. Output results and the log text from the simulations are also included.

The simulated case corresponds to a configuration presented in Figure 4 from TEC-EES/2010.613/GS/2.0, 30 May 2012. This particular simulation corresponds to the 90% point of the last curve (Pb-Al), with an expected dose value of about 45 krad.

The geometry model (see Figure 1) includes a box-shaped spacecraft and 4 targets. The 2x2x3 m3 spacecraft has 2 concentric layers of different materials: the external layer is made of Lead, the internal one is made of Aluminium. The total areal mass is 2.7 g/cm2 (corresponding to 10 mm of equivalent Aluminium) split into 2.141 mm of Lead (2.43 g/cm2, or 90% in mass) and 1 mm of Aluminium (0.27 g/cm2, or 10% in mass). The 4 targets are thin but rather large Silicon spherical shells.

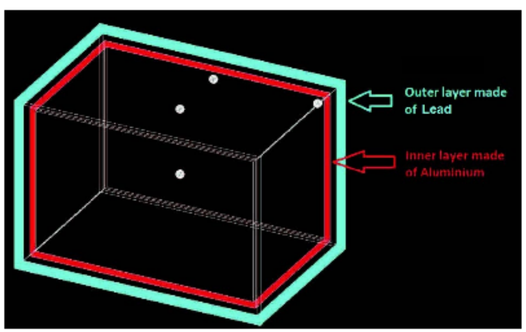
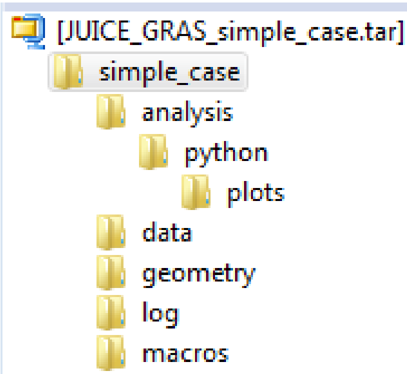


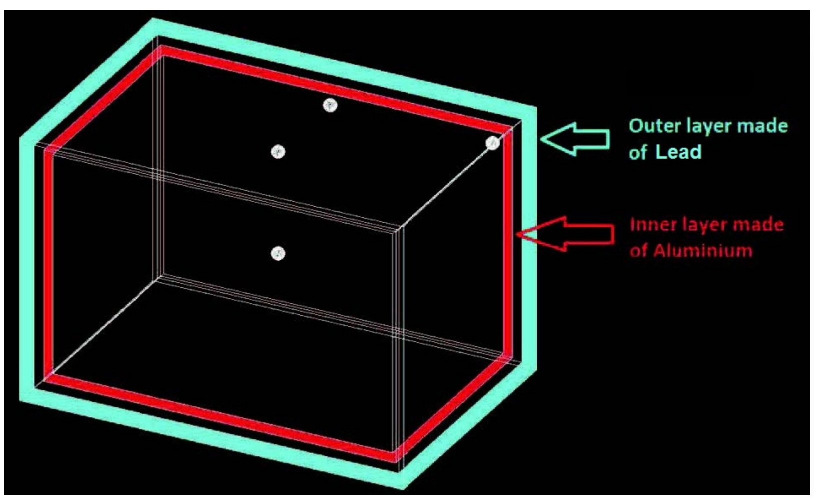
Figure 1: Geometry model (shielding thickness not to scale).

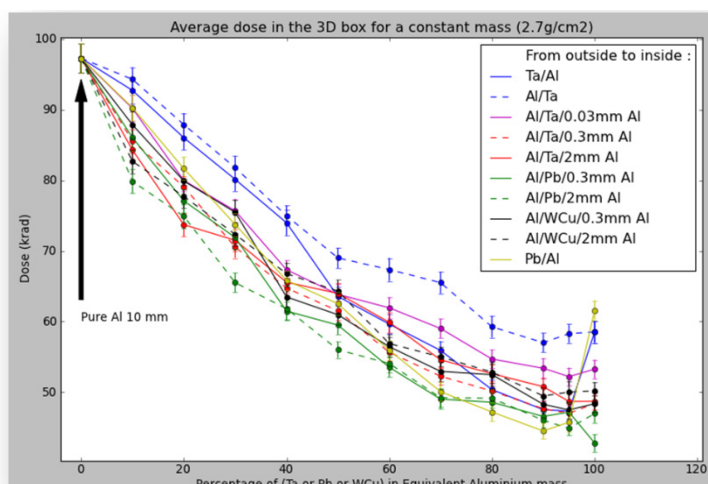
GRAS
Simple case

- Multi-layered S/C, 4 targets
- Jupiter trapped electron environment, mission averaged




```
macros/3d_box_2layers_4targets.g4mac        -->  main GRAS macro file
macros/source_e_JOSE_thr_1MeV_log.g4mac     -->  macro file containing the electron spectrum
macros/spectrum.txt                         -->  the same spectrum as in the macro above, but in simple text format
macros/vis.g4mac                            -->  macro commands for visualisation
macros/colours.g4mac                        -->  macro commands for additional user defined visualisation colours
geometry/3d_box_2layers_4targets.gdml       -->  GDML geometry model
GDMLSchema                                  -->  symbolic link pointing at the location of the GDML XML schema
Qgras.csh                                   -->  shell script to launch the GRAS simulation
log/3d_box_2layers_4targets_XXX.log         -->  log output files during execution
data/3d_box_2layers_4targets_XXX.csv        -->  main output files
analysis/python/analysis_juice_simple_case.py --> Python analysis script
analysis/python/plots/...                   --> Python analysis output plots
analysis/python/analysis_juice_simple_case_tables.txt --> Python analysis output with tables
```





GRAS
Get started (now)

- Download files from URL below or from JUICE website → AO → Q&A
  - http://spitfire.estec.esa.int/trac/GRAS/wiki/GRAS/JuiceSimpleCase
- Unpack

```
tar -zxf JUICE_GRAS_simple_case.tgz
```

- and go to the simple_case example directory

```
cd simple_case
```

- Run gras with the main macro file as input. Wait 5 minutes

```
/usr/local/applic/g4apps/bin/gras
        macros/3d_box_2layers_4targets.g4mac
```

- Look at the log on screen. Error on dose results might be unacceptably big
  - Set # of events to 100M, re-launch GRAS, have a coffee…

- Play with the project
  - Edit the main macro file to reduce the number of required events to 1M

```
gedit macros/3d_box_2layers_4targets.g4mac
```

  - Edit the GDML geometry and modify the parameters, e.g.
    - **mat_Lead → mat_Aluminium** and
    - thickness from **2.141 mm → 9.0 mm** to compensate for density

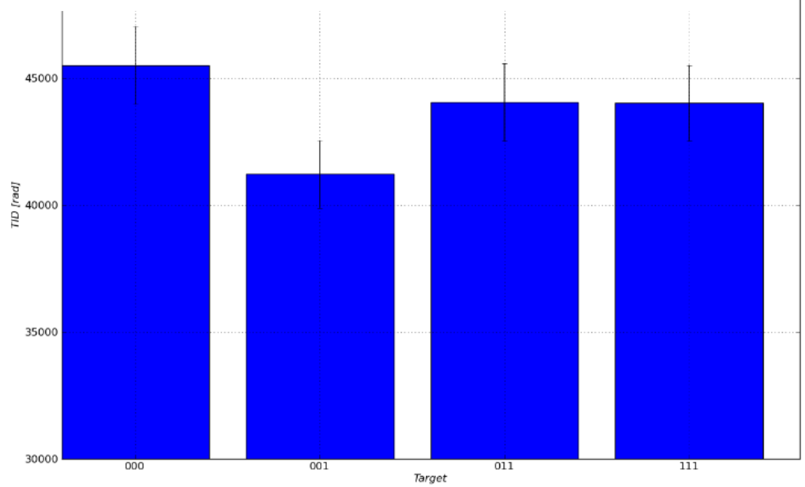
```
gedit geometry/3d_box_2layers_4targets.gdml
```

GRAS
Result analysis

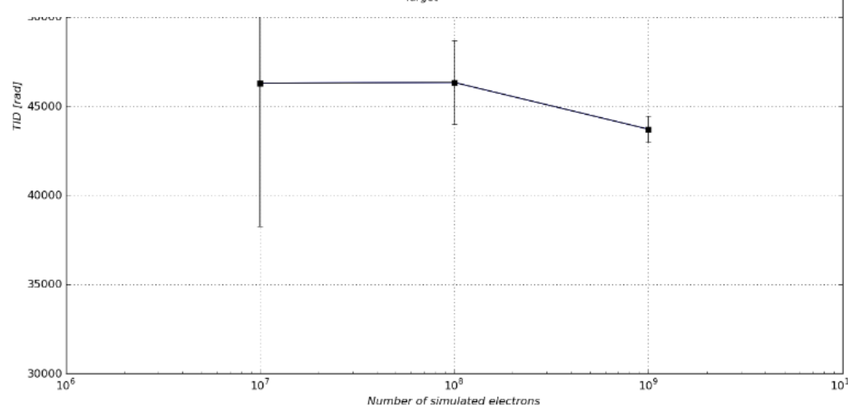
- CSV and ROOT files produced
  - CSV human readable, can be opened in Excel
- Python script (provided) extracts from CSV file relevant output and produces example tables and plots

```
#events        TID
               [rad]
1.0E+07        4.63E+04 +/- 8.04E+03
1.0E+08        4.63E+04 +/- 2.35E+03
1.0E+09        4.37E+04 +/- 7.39E+02

Target         TID
               [rad]
000            4.55E+04 +/- 1.54E+03
001            4.12E+04 +/- 1.34E+03
011            4.41E+04 +/- 1.52E+03
111            4.40E+04 +/- 1.49E+03
```



	A	B	C	D	E	F	G
1	'*'	8	0	4	0	3	3
2	'GRAS_DA	-1	'TOTAL DOSE'				
3	'GRAS_DA	-1	'STAT_DOUBLE'				
4	'GRAS_MC	-1	'doseSi'				
5	'GRAS_MC	-1	'DOSE'				
6	'Dose'	'rad'	1	'Dose/energy deposition'			
7	'Error'	'rad'	1	'Error dose/energy deposition'			
8	'Entries'	''	1	'Number of entries'			
9	43700	738.85	1.00E+09				
10	'End of Block'						
11	'*'	8	0	4	0	3	3
12	'GRAS_DA	-1	'TOTAL DOSE'				
13	'GRAS_DA	-1	'STAT_DOUBLE'				



GRAS
Beyond this simple example

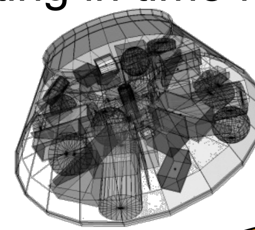
- More realistic GDML model
  - With external tools, e.g. FASTRAD or ESABASE2
    - From CAD model via STEP, IGES,… or
    - From scratch (FASTRAD and ESABASE2 are CAD tools too)
    - Speed improvements expected with G4 Tessellation in Geant4 9.6
  - Edit (by hand) the provided GDML file
    - Human readable XML format

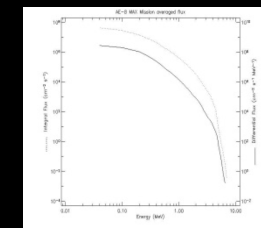
- Spectrum
  - Official mission averaged spectrum for end of mission assessment
  - Phase by phase analysis
  - Worst case electron flux
  - Cosmic ray impact

- Instrument specific analysis, e.g.
  - Ionising dose v. Displacement damage depending on technology
  - Instantaneous e-, photon, neutron flux spectrum for sensor background, SEE
  - Event-by-event analysis (ROOT format, python analysis) of energy deposition for instrument background, (anti)coincidence logics,…

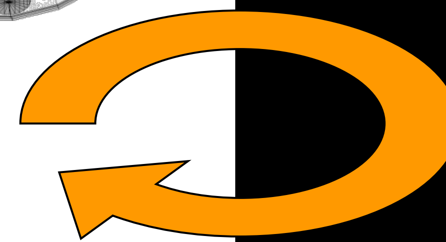
REST-SIM Radiation Effects on Sensors and Technologies for Cosmic Vision SCI Missions

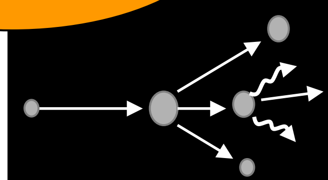
- Recurrent difficulty of efficiently establishing and iterating in time for critical radiation analyses:
  - Spacecraft / payload geometry
  - Science analysis definition (e.g. sensors)



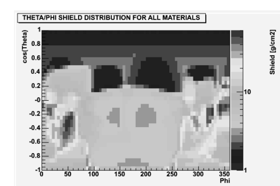


- Need for efficient front-ends
  - Analysis application definition
  - Geometry creation
  - Models I/O





- Use from earliest phases (CDF), w/ increasing details



- Continuous, smooth improvement of radiation analyses over entire mission design lifetime
  - Reducing costly margins on radiation levels
  - Extended to flight phase and ultimately to post-flight mission data analyses

Phases
A to E

REST-SIM

Radiation Effects on Sensors and Technologies for Cosmic Vision SCI Missions

Figure of Merit (risk?)

- Technology mapping & effects
- Impact on mission risk assessment

- The susceptibility of the various technologies to the specific space environments:

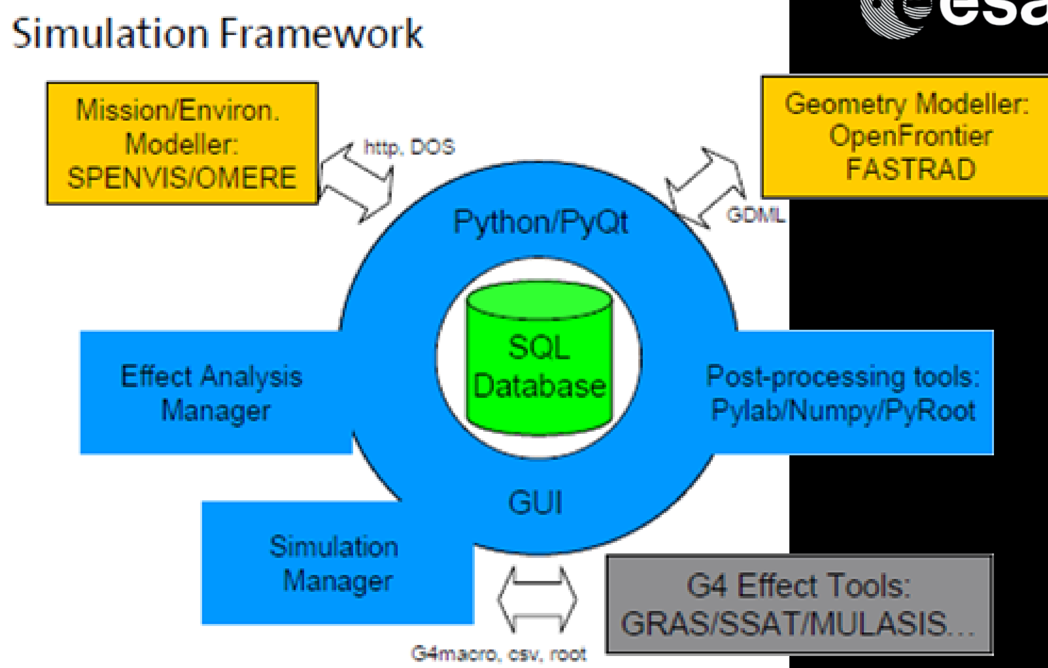
$$f = \log\left(250 \times Env \times \frac{\#effects}{8} \times \frac{1}{TRL}\right)$$

  - ***Env***: a scaling factor that takes into account the space environment (e.g. distance from the sun) and mission duration
  - ***#effects***: the number of effects a technology is susceptible to
  - ***TRL***: the technology readiness level

- Traffic-light colour coding!

		L-Class							
Technology	Effect	IXO	LISA	JGO	EUCLID	MP	PLATO	SPICA	SO
CCD	TID	1.2			0.9		1.0		
	DD	1.2			0.9		1.0		
	SEE	0.5			0.2		0.3		
Photodiodes	TID	1.2	0.9	2.2		1.1			1.9
	DD	0.8	0.5	1.5		0.7			2.1
	SEE	0.5	0.2	0.4		0.4			0.5
Si Drift Diode Array	TID	1.6							
	DD	1.2							
	SEE	0.9							
Laser Pump Diodes	TID	0.8		1.8		0.6			
	DD	0.8		1.4		0.6			
	SEE								
APS	TID	1.0		2.0		0.8			1.7
	DD	1.2		1.9		1.1			2.5
	SEE	0.8		0.7		0.7			0.8
Hybrid CMOS ROIC Multiplex	TID			1.8	0.5	0.7			1.5
	DD								
	SEE			0.7	0.5	0.7			0.8
HgCdTe	TID			1.8	0.5	0.7			1.5
	DD			1.5	0.5	0.7			2.1
	SEE			0.4	0.2	0.4			0.5
PhotoDetectors	TID		0.7	2.0					
Ga:As	DD								
	SEE		0.2	0.4					
PhotoConductors	TID							0.5	
Ge:Ga	DD								
	SEE							0.0	
Si Bolometers	TID			2.2		1.0		0.7	
	DD								
	SEE			0.5		0.5		0.2	
TES Bolometers	TID								
	DD								
	SEE	0.8						0.3	
SQUID Amplifier	TID								
	DD								
	SEE	0.8						0.3	
KID Detectors	TID								
	DD								
	SEE							0.4	
CdZnTe	TID	0.8							
CdTe	DD	0.8							
	SEE	0.5							
MCP	TID								
	DD								
	SEE			0.4		0.4			0.5
Solid State Oscillator	TID								
	DD								
	SEE								
Crystal Oscillator	TID			1.5					
	DD								
	SEE								
Glass, Fibres, Laser Rods	TID	0.5	0.2		0.2		0.3		
	DD								
	SEE								
Si Pore Optics	TID								
	DD								
	SEE								
CsI Scintillator	TID								1.2
	DD								1.8
	SEE								
Fluxgate Sensors	TID								
Search coil magnetometer	DD								
	SEE			0.4					0.5
Gas Pixel Detector	TID								
	DD								
	SEE	1.0							

REST-SIM
Simulation Framework

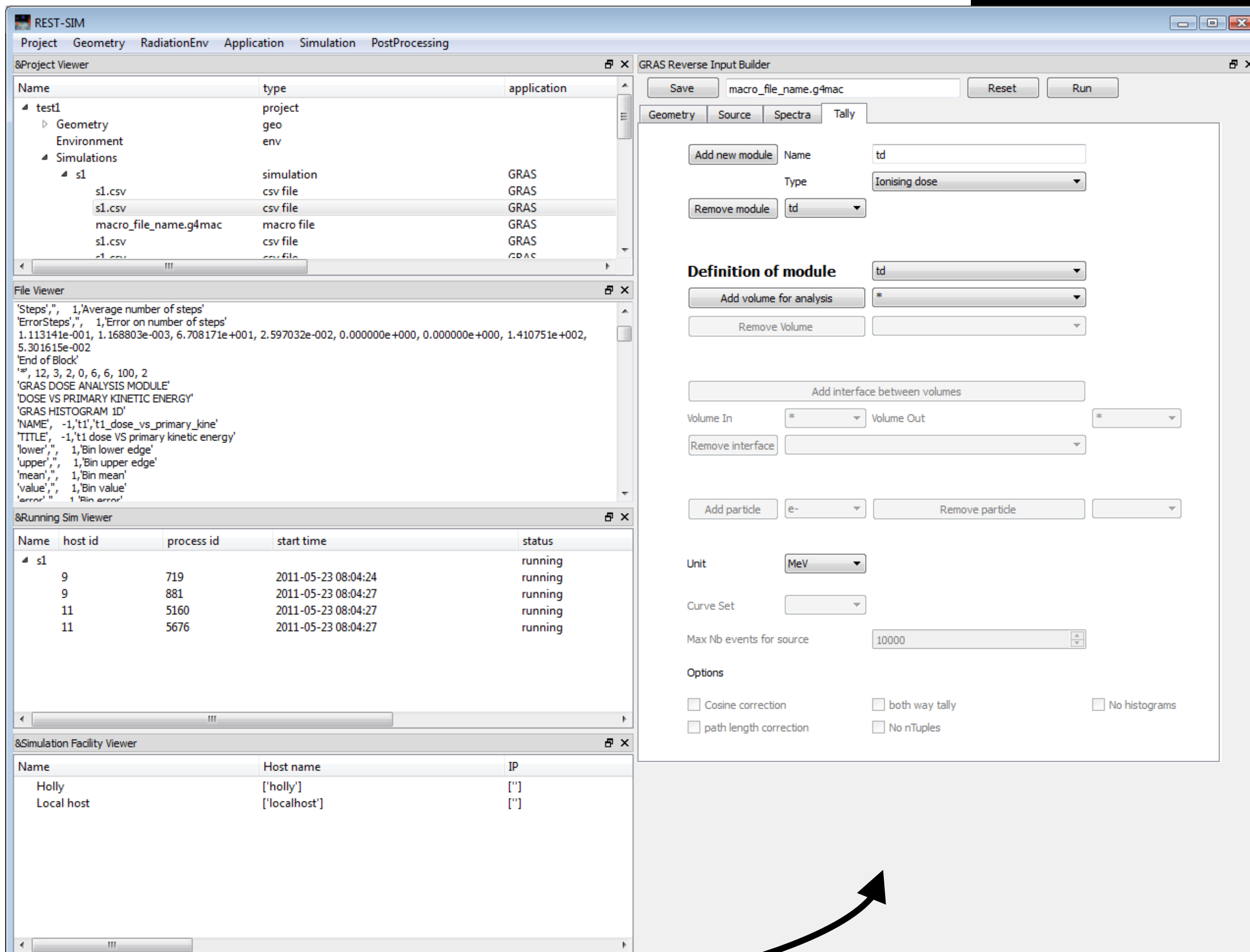


- Mission specification and environment modeller
- S/C and P/L geometry modeller
- Effects analysis tools
  - Geant4-based applications (GRAS, SSAT, MULASSIS)
- Simulation manager
- Post-processing manager
  - Visualisation, plots
  - Response matrices / formulae / algorithms

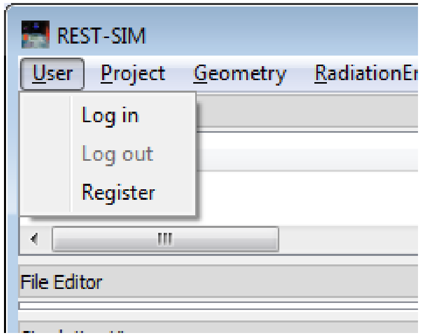
- Key s/w technologies:
  - Python and PyQT
    main programming lang. and GUI
  - GRAS/Geant4
    particle transport and effects simulation tool
  - NumPy, SciPy & Matplotlib
    post-processing
  - MySQL
    internal database

REST-SIM simulation framework
User interface

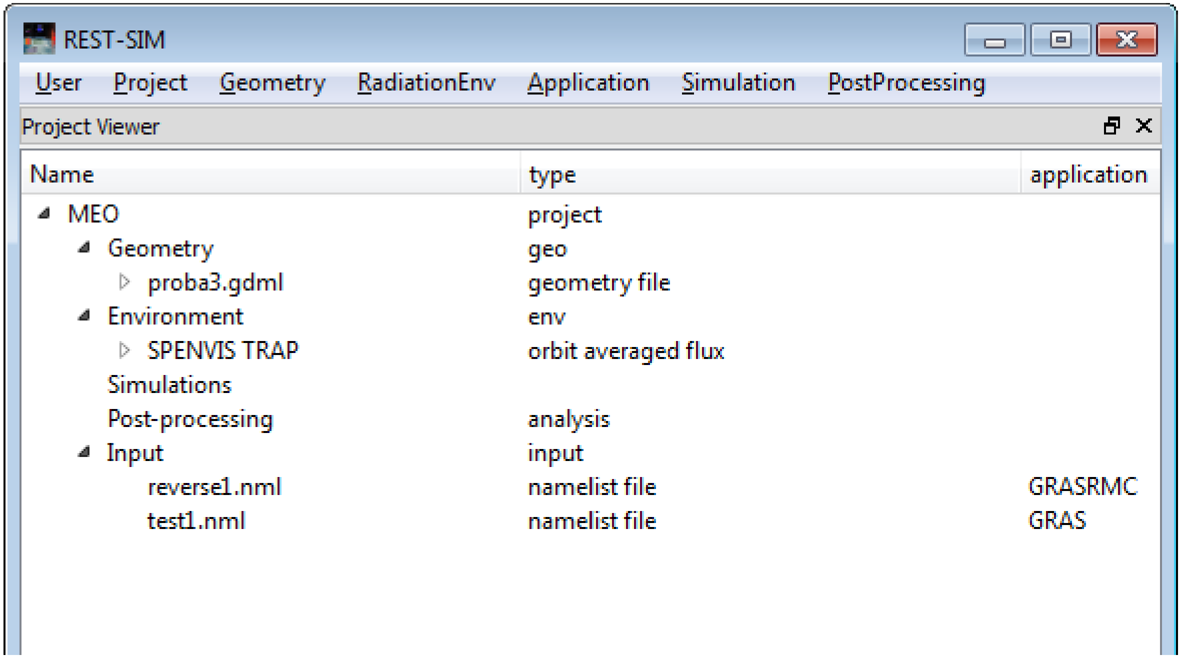
- Project management
- File details
- Simulation runs
- Parallel computing, cluster details
- Analysis input, post-processing



REST-SIM simulation framework
Project/user management

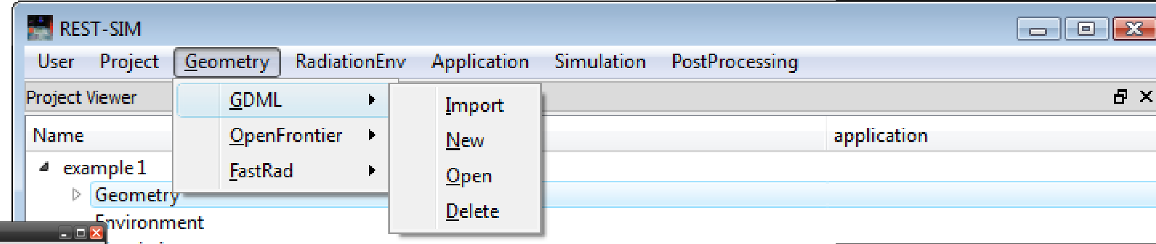


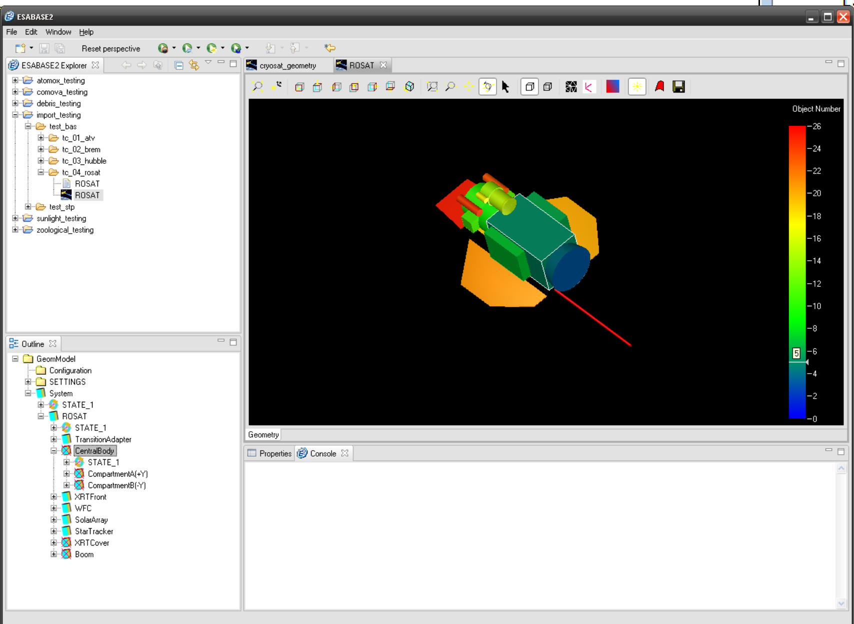
- Multiple user control
- Local MySQL database or central/remote database
- Built-in project viewer
- Import / export facilities

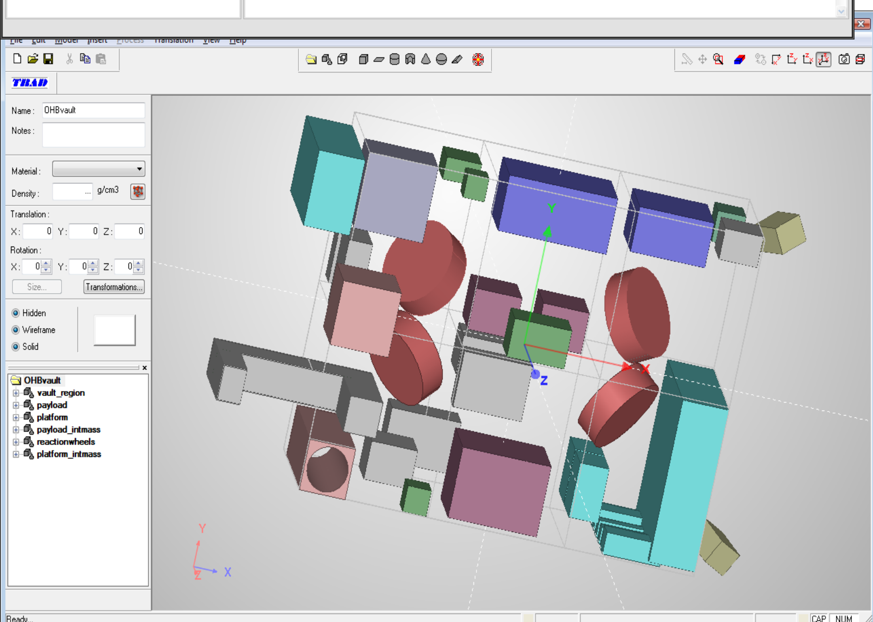


REST-SIM

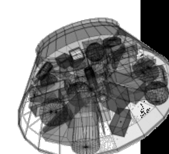
Geometry

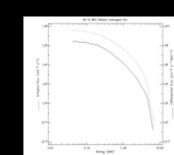


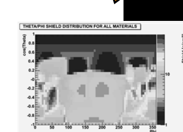


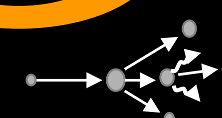


- CAD Tool -> GDML -> Geant4:
  - Stored in the database in GDML format – Geometry Description Markup Language
- Geometry modelling:
  - import or build
- Two S/W tools can be used for GMDL input into REST-SIM:
  - **FASTRAD** (TRAD)
  - **ESABASE2** (etamax)

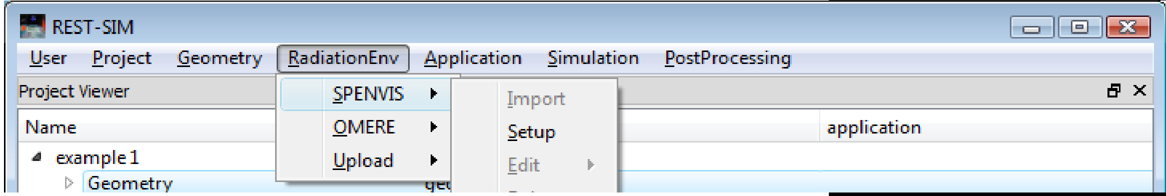




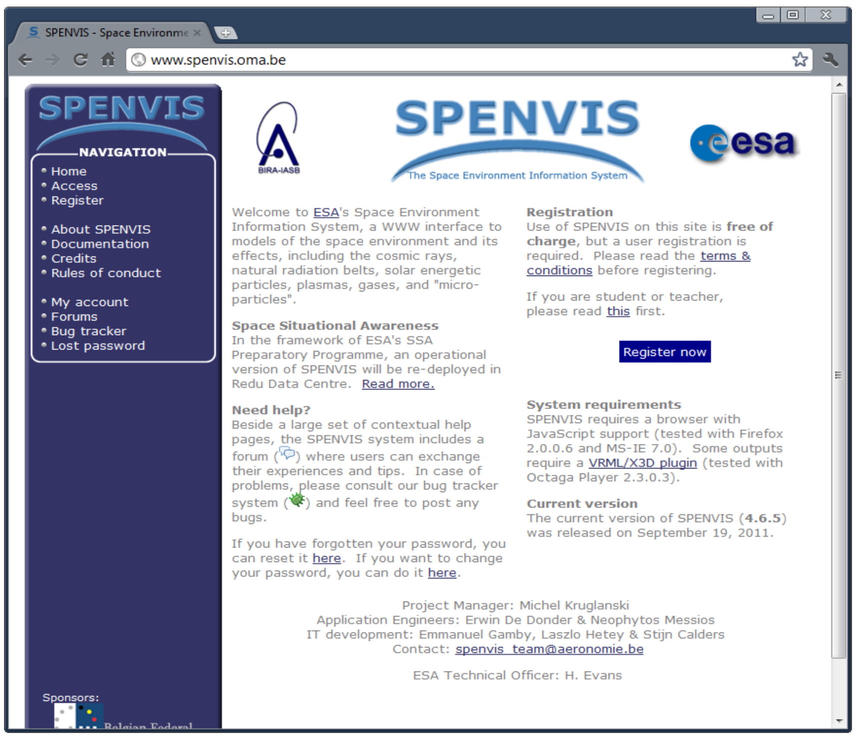


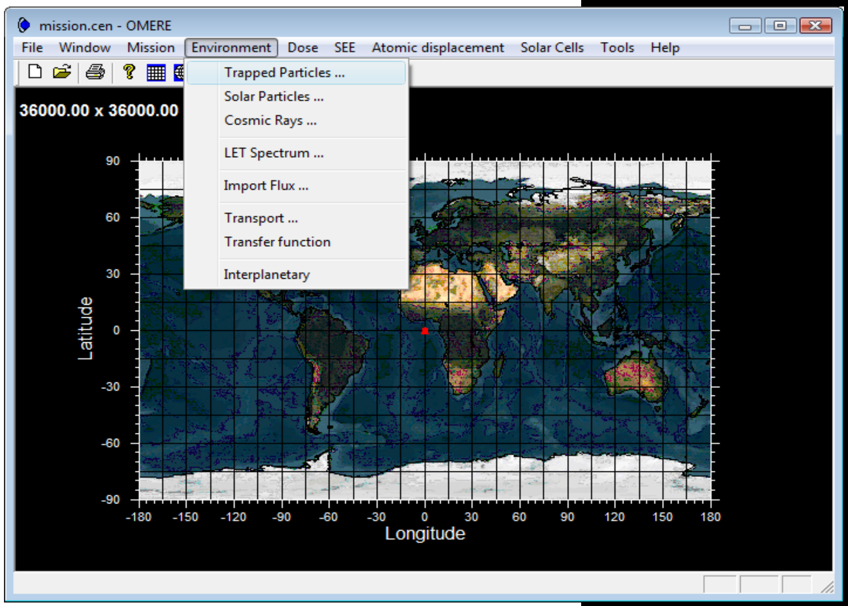


REST-SIM
Radiation environment



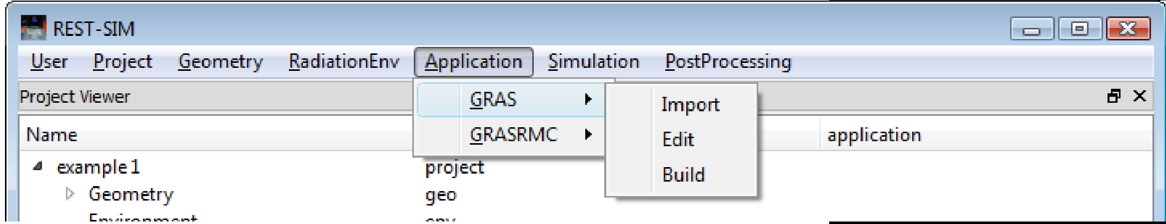
- Mission environments can be modelled using SPENVIS and OMERE
  - run from REST-SIM
  - environ. data are imported and saved in the project database
- User can also upload environ. specifications directly



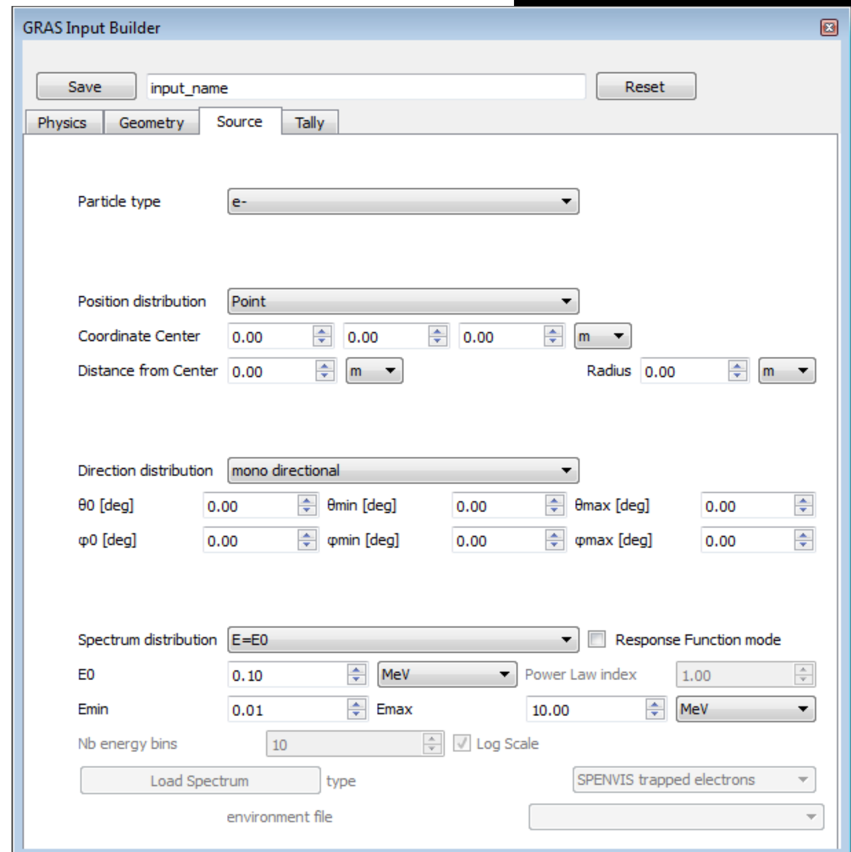


REST-SIM

Effects Analysis

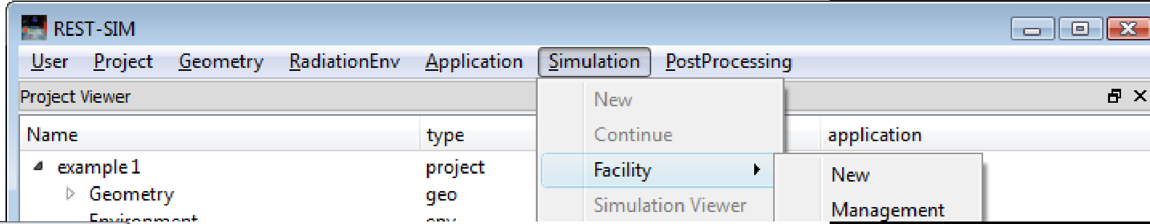


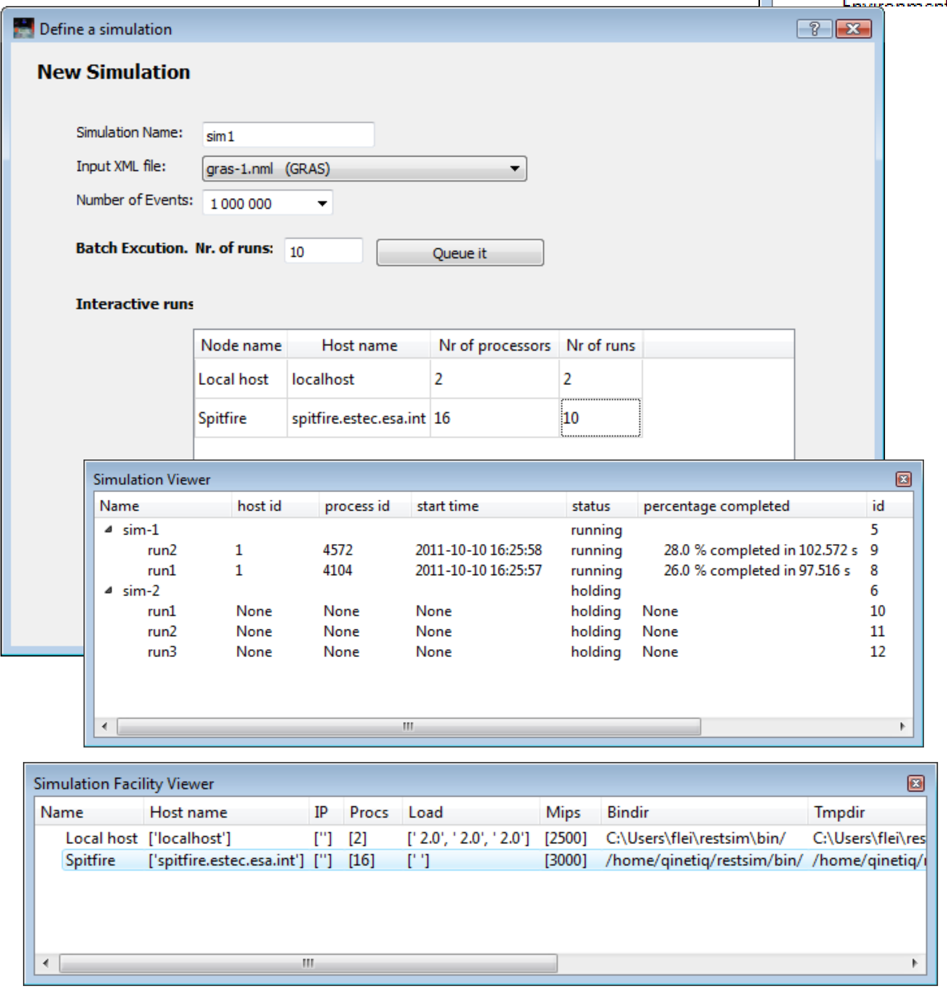
- Geant4 based analysis tools:
  GRAS (w/ Forward and Reverse MC)
- Geometry and Environment from the DB
- Full control of Geant4 physics
- Type of effects/analysis:
  - Fluence/Current -- Dose (TID)
  - Pulse height spectrum -- Dose_equivalent
  - Equivalent_dose -- LET
  - NIEL (DDD) -- Path_Length
  - Charging -- Charge_collection



REST-SIM

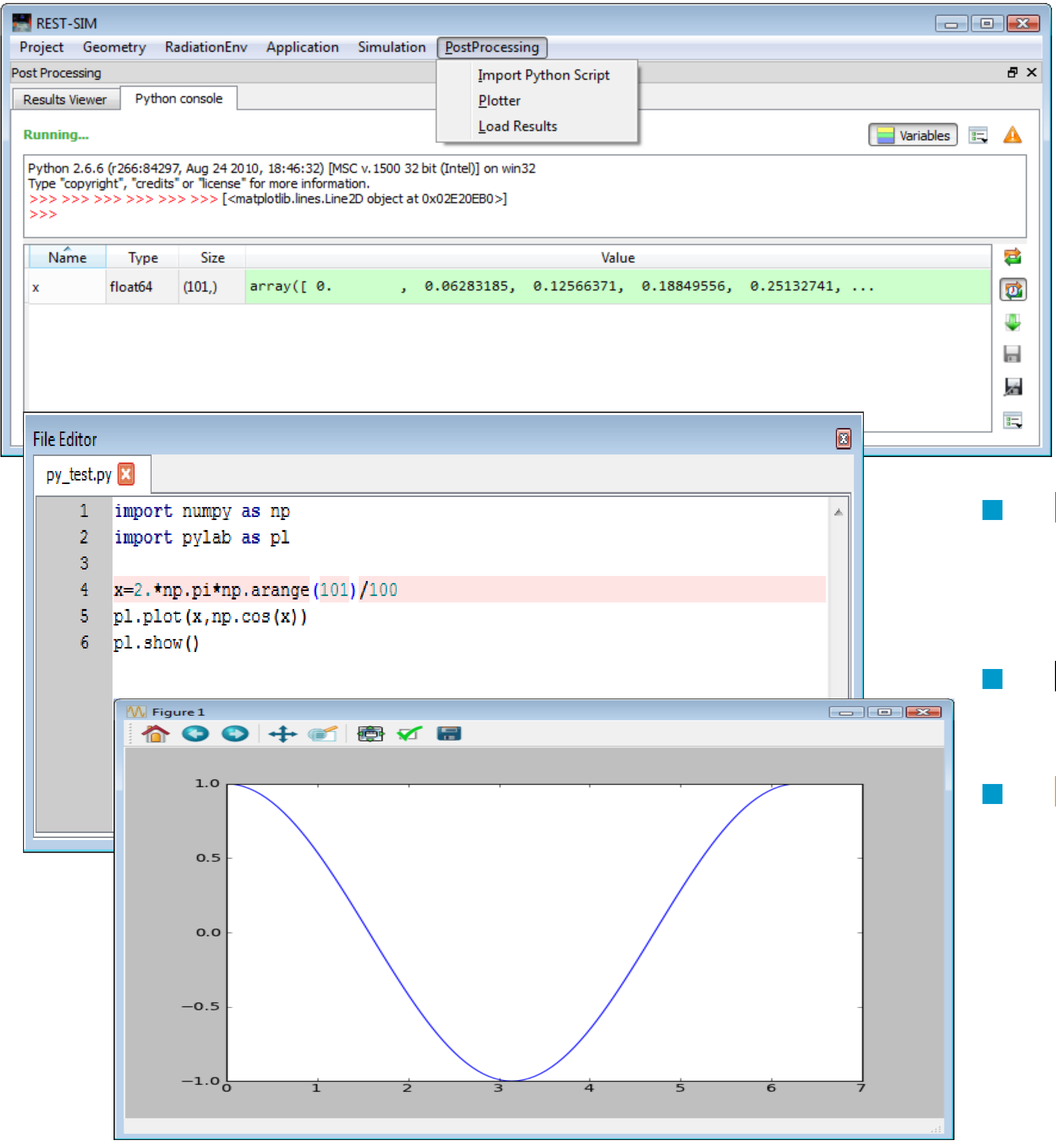
Simulation manager





- Simulation facilities:
  - Local host, or remote (SSH)
  - Linux, or Windows (local)
- Two execution modes:
  - Interactive, forced runs
  - Batch queue
- Automated parallelisation:
  - Load balance
  - Results - auto collection, merge
- Execution monitoring/management:
  - Check progress: % completed
  - Stop/Kill/Remove

REST-SIM
Post-processing



- Interactive Python scripts
  - NumPy, SciPy, Matplotlib
  - Python console and editor
- Plotting:
  - 1d/2d histograms
- Post-processing:
  - Operation on histograms
  - Derivative parameter analysis
  - Analysis based on response functions
  - …

REST-SIM
Get started (back at home)

- S/W and documentation available from
  - http://spitfire.estec.esa.int/trac/REST-SIM
  - Ask for a personal account
- Temporary login / pw for the workshop:
  - juice2012 / juice2012
- Latest code version from SVN repository at
  - http://spitfire.estec.esa.int/svn/REST-SIM/trunk/

esa Space Environment
European Space Agency

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Last modified 11 days ago

Radiation Effects on Sensors and Technologies for Cosmic Vision Science Missions (REST-SIM)

Software User Manual

Abstract

REST-SIM is a simulation framework developed by QinetiQ, SpaceIT and DH Consultancy for the assessment and analysis of radiation effects for the instruments and payloads of ESA's Cosmic Version Programme. It is targeted to be used in many of the different mission developments and operations through out the course of the programme. This document is the software user's manual, consists of a brief description of the software design and its components, instructions on its installation, basic usage instructions and detailed instructions on all operations of the code.

Introduction

REST-SIM
Get started (now)

- Start the RestSim.py client
  - Please follow the instructions provided by the organisers
- User accounts already available
  - Same as on fearless, password = username
- Defining a new project, fill it in with files e.g. from simple_case
  - Geometry (GDML file)
  - Radiation environment (from SPENVIS server, OMERE or text file)
  - Application parameters (Physics, Source, Tally for GRAS FMC and/or GRAS RMC)
- Define a simulation facility, launch some runs, have a look at the results

Advert #1

CIRSOS

ESA Intended Invitation To Tender

12.1EE.18

Title: COLLABORATIVE ITERATIVE RADIATION SHIELDING OPTIMISATION SYSTEM (CIRSOS)
Revision: 7
Program ref.: TRP
Tender Type: C
Quarter: 123
Tender Status: INTENDED
Price Range: 200-500 KEURO
Budget Ref.: E/0901-01 - TRP
Proc. Prop.: DIPC
Special Prov.: B+DK+F+D+I+NL+E+S+CH+GB+IRL+A+N+FIN+POR+GR+LUX+CZ+RO
Establishment: ESTEC
Directorate: Directorate of Technical & Quality Manag
Department: Electrical Engineering Department
Division: Electromagnetics and Space Environment D
Responsible: Eamonn Daly

The objectives of this activity are to reduce radiation shielding mass through a system that efficiently supports collaborative industry and instrument provider shielding analyses, providing configuration controlled geometry and shielding data, reliable interfaces with company (prime and unit provider) processes, and high speed validated physics simulation, implementable on low cost scalable computing resources.

- The objectives of this activity are to
  - reduce radiation shielding mass
  - through a system that efficiently supports collaborative industry and instrument provider shielding analyses,
  - providing configuration controlled geometry and shielding data,
  - reliable interfaces with company (prime and unit provider) processes,
  - and high speed validated physics simulation,
  - implementable on low cost scalable computing resources.

Advert #2

Research Fellow position at ESTEC (TEC) for JUICE

- Preparatory work in support of the JUICE mission
  - to analyse and model the effects of the interplanetary and local Jovian radiation environment on the mission, its shielding and payloads,
  - using the newly developed JOREM radiation environment models
  - together with radiation transport and analysis tools such as Geant4, GRAS, FASTRAD and NOVICE

- Contact person: Petteri Nieminen at ESTEC
  - Note: the standard ESA schedule for applications does not apply to Research Fellow positions in TEC

Summary

- Severity and new features in Jupiter radiation environment impose use of appropriate (MC-based) tools for study of countermeasures
- New tools are being made available to the community
  - GRAS v3.1 / REST-SIM
- Stress on uncertainties and impact on margins → risk / mass