Geant4 based tools at ESA

MULASSIS
GRAS

Giovanni Santin, *ESA / ESTEC and Rhea System SA*

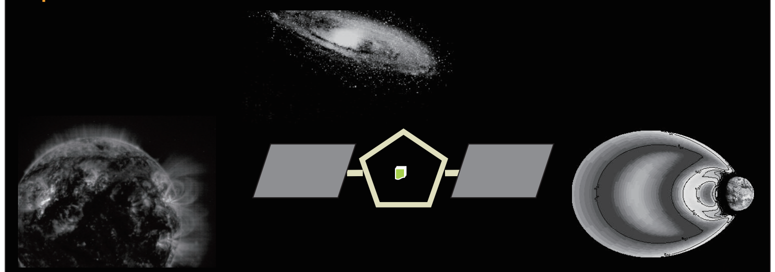
5th Geant4 Space Users' Workshop
Tokyo University, 13-15 Feb 2008

Outline

- ESA Geant4-based tools for space radiation analysis
  - Ray-tracing, 1D-MC (MULASSIS), SEE, adjoint MC, CAD interface
- MULASSIS demo
- GRAS
  - Main features
  - Example applications

Simulations of the Space Radiation Environment

Simulations of the Space Radiation Environment



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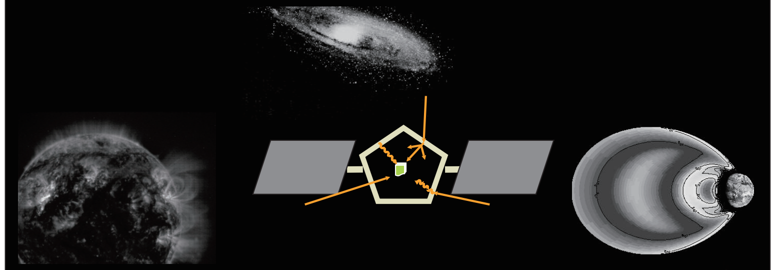

Effects

Effects in components	Effects to science detectors	Threats to life
Single Event Effects Degradation	Signal, Background Charging …	Dosimetry for manned space flights Radiobiological effects

3

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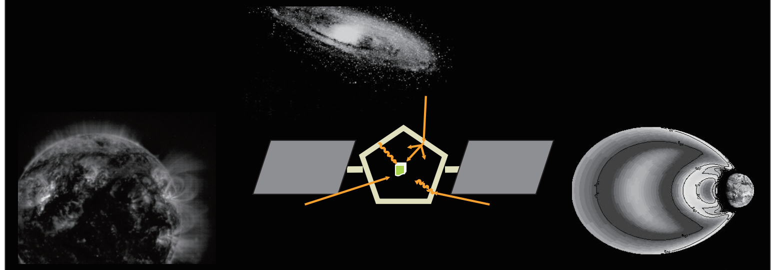

Tasks

Mission design	Science analyses	Anomaly study
Fast "engineering" radiation analysis Detailed subsystem analysis Ground tests and extrapolation to space	Particle signal extraction Background Degradation	Actual space environment Detailed geometry Actual electronic details

Effects

Effects in components	Effects to science detectors	Threats to life
Single Event Effects Degradation	Signal, Background Charging …	Dosimetry for manned space flights Radiobiological effects

3

Geant4-based tools for space Requirements and ESA role

Scientific approach	Real life in S/C development
1. Accuracy	Usability
2. Usability	Speed
3. Speed	Accuracy

Usability issues
- User Interface (scripting, GUI, web access, Windows)

Enabling technologies
- Exchange formats:
  - Geometry (GDML, CAD/TCAD)
  - Data I/O (e.g. Space Environment, Histogramming, Analysis)

Accuracy
- Physics (secondaries from inelastic, ion interactions)

Better understanding of engineering practices and margins
- Wide application of too simple approaches in S/C radiation analysis
- Need to identify problems, quantify uncertainties

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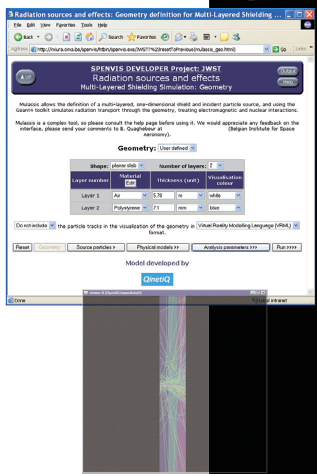
QinetiQ

Multi Layered Shielding Simulation Software MULASSIS

- Geometry definition
  - Multiple layer geometry via macro
  - 1D (slab / sphere)
  - Materials by chemical formula
- Physics list choice
- Primary particle spectrum and fluences from SPENVIS
  - Trapped protons
  - Solar protons
  - Trapped electrons
- Analysis options
  - Pulse Height Spectrum
  - Ion. Dose
  - Dose equivalent
  - NIEL
- First Geant4 application with web interface (in SPENVIS)
  - User success
  - Raised the standard level of radiation shielding analysis in the space community (both academia and industry)



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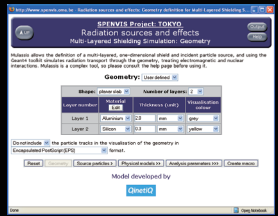
QinetiQ MULASSIS in SPENVIS — esa

1. Orbit input parameters
   – E.g. LEO circular, 500 km, 28 deg incl
2. Radiation environment models
   – Trapped proton and electron fluxes
   – Solar proton fluence
3. MULASSIS interface
- Layered Geometry
- 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
- Run in SPENVIS



6

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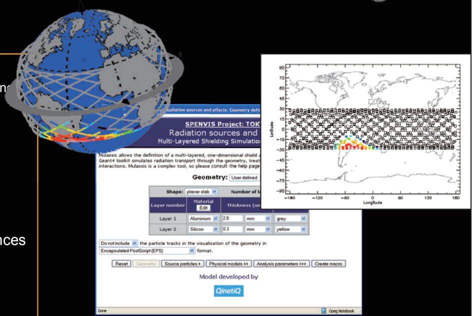

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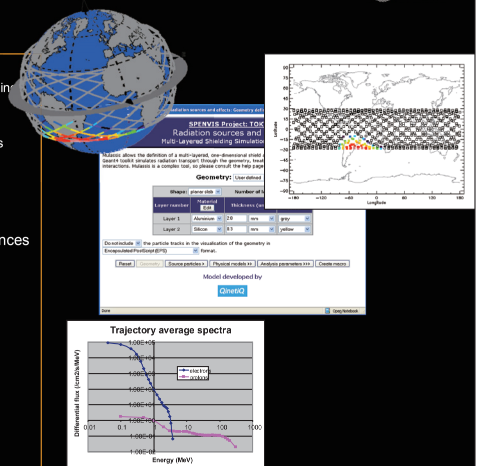

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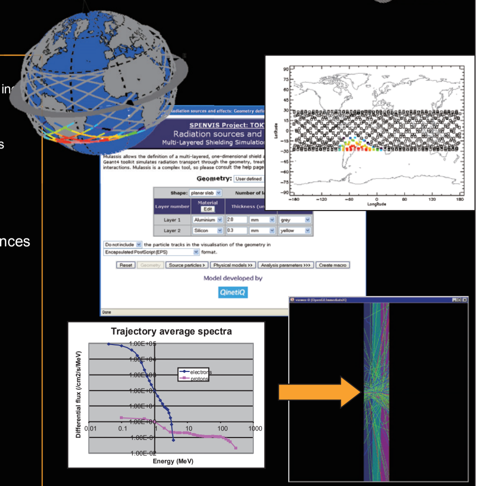
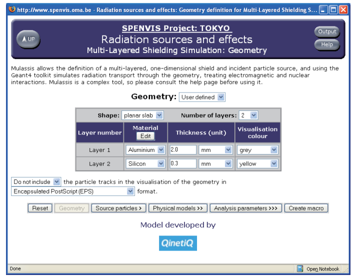


MULASSIS
Demo

- http://www.spenvis.oma.be
  or see related presentation



QinetiQ Single Event Effects: GEMAT

Geant4-based Microdosimetry Tool

- Microdosimetry in geometries representing features of a semiconductor device (transistor/junction geometries)
- Analysis includes
  – Single Event Effects (SEE)
  Charge collection analysis similar to REAC approach
  – Simultaneous energy deposition in several sensitive regions (MBU)
- Has been recently integrated into SPENVIS

→ see related talk by Daniel Heynderickx

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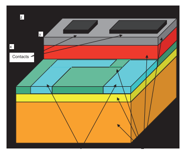

Sector Shielding Analysis Tool SSAT

- Ray tracing: from a user-defined point within a Geant4 geometry
- 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
- Results:
  - Total dose
  - Dose-Depth profile
  - Dose directionality

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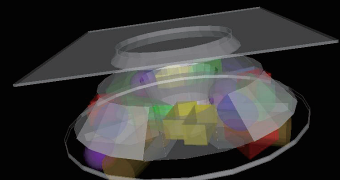

ConeXpress model: R.Lindberg, ESA

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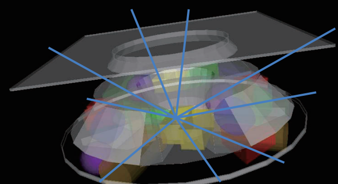

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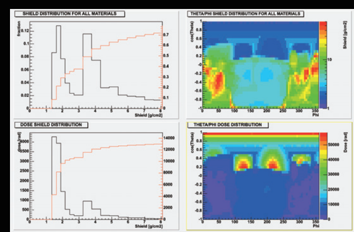

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QinetiQ · esa

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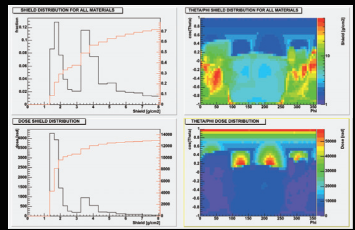

- Potential shortcomings
  - Dose-depth curves (often SHIELDOSE2)
  - Transport in complex geometries

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Geant4 Reverse MC

esa

See talk by Laurent Desorgher

Space IT and Uni. Bern

"Adjoint" technique [Kalos 1968]

- New transport eq., "adjoint" to the "forward" transport eq.
- Transport analogous to the forward one, but backward
  - successive points are higher in energy, earlier in time
- Suitable for Monte Carlo calculations
- Simulation starts at detector and scores at source
- Possibility of computing doses at a point!

ESA contract REAT-MS

Feasibility study (phase 1) and full implementation (phase 2) for electrons and photons

- RMC in G4 for fast e- dose computation, by L.Desorgher
- Backward simulation of :
  - e- ionisation with delta production, continuous energy loss and multiple scattering
  - Bremstrahlung
  - compton scattering, photo-electric effect

Proposed to be included in Geant4 release

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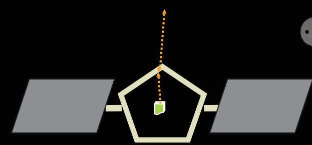

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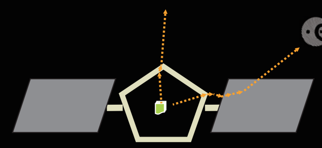

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Proposed to be included in Geant4 release

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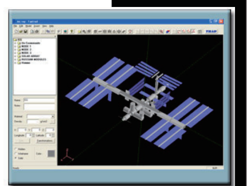
CAD geometry interface
(and 3D modelling GUI)

- ESA REAT-MS contract
- CAD
  - Using G4TessellatedSolid by P.Truscott (ESA REAT-MS-1)

    [Old prototype used to require ST-Viewer commercial S/W
    - GDML module to read ST-Viewer files]
  - New: CAD STEP interface (and normal 3D models)
    via external 3D modelling tools tools
    (ESA contract REAT-MS-2)
    Direct GDML output

    Tools: FASTRAD and ESABASE2
- GDML upgrade (Witek Pokorski, CERN)
  - Tetrahedron and Tessellated volumes, modular models, loops
- FASTRAD, ESABASE2
  - GUI for 3D modelling
  - GDML output


Modèle de la station internationale sur FASTRAD

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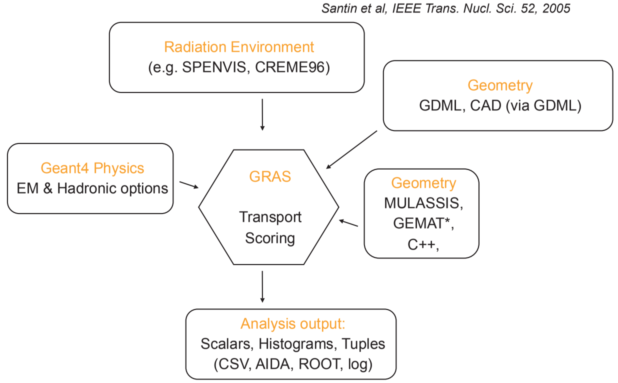
Geant4 Radiation Analysis for Space
GRAS – Motivation

- Widening of Geant4 application domain → multiplication of tools
  - Offer framework for coordinated extension and development
- Issues to address on geometry and transport
  - Ray-tracing VS MC
  - 1D VS 3D
  - EM VS EM+Hadronics
  - LET approach VS Actual energy deposition in microvolumes
- Analysis
  - Common tallies for standard support to engineering and scientific design
  - Human dosimetry for ESA exploration initiative
  - More detailed analysis for in depth studies
- Ready-To-Use tool
  - “Multi-mission” approach
  - Different analyses and geometries set without re-compilation
  - Integrated into SPENVIS

Santin et al, IEEE Trans. Nucl. Sci. 52, 2005

GRAS tool description

Santin et al, IEEE Trans. Nucl. Sci. 52, 2005



* *in progress*

http://space-env.esa.int/R_and_D/gras

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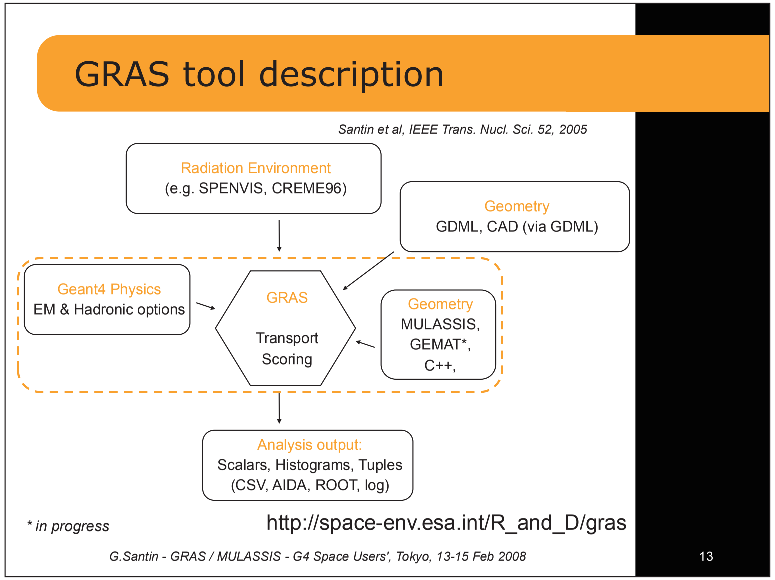
GRAS tool description
Santin et al, IEEE Trans. Nucl. Sci. 52, 2005
Radiation Environment
(e.g. SPENVIS, CREME96)
Geometry
GDML, CAD (via GDML)
Geant4 Physics
EM & Hadronic options
GRAS
Transport
Scoring
Geometry
MULASSIS,
GEMAT*,
C++,
Analysis output:
Scalars, Histograms, Tuples
(CSV, AIDA, ROOT, log)
* in progress
http://space-env.esa.int/R_and_D/gras
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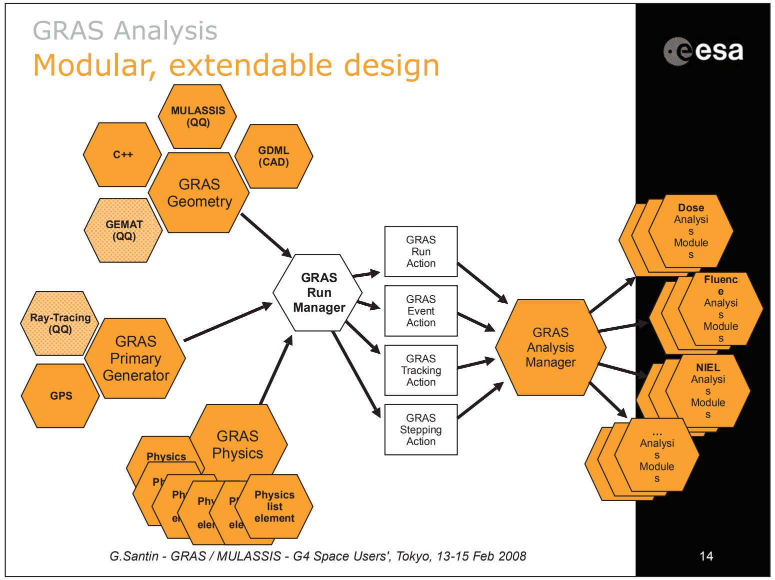
GRAS Analysis
Modular, extendable design
esa
MULASSIS
(QQ)
C++
GDML
(CAD)
GRAS
Geometry
GEMAT
(QQ)
GRAS
Run
Manager
GRAS
Run
Action
GRAS
Event
Action
GRAS
Tracking
Action
GRAS
Stepping
Action
GRAS
Analysis
Manager
Ray-Tracing
(QQ)
GRAS
Primary
Generator
GPS
GRAS
Physics
Physics
Physics
list
element
Dose
Analysis
Modules
Fluence
Analysis
Modules
NIEL
Analysis
Modules
...
Analysis
Modules
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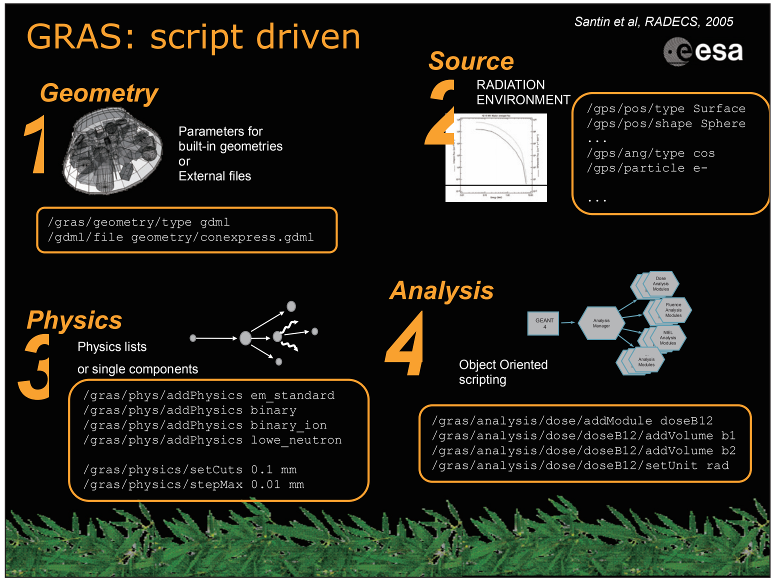
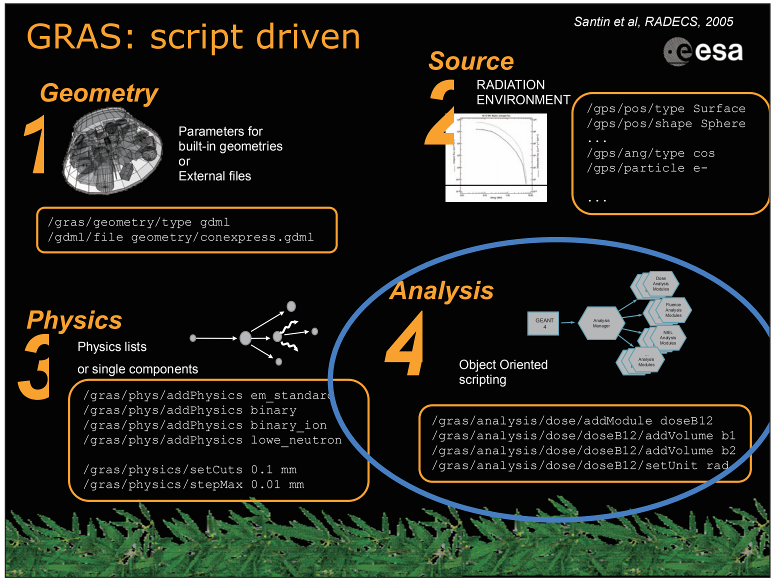

GRAS: script driven
Santin et al, RADECS, 2005
esa
Geometry
1
Parameters for
built-in geometries
or
External files
/gras/geometry/type gdml
/gdml/file geometry/conexpress.gdml
Source
2
RADIATION
ENVIRONMENT
/gps/pos/type Surface
/gps/pos/shape Sphere
...
/gps/ang/type cos
/gps/particle e-
...
Physics
3
Physics lists
or single components
/gras/phys/addPhysics em_standard
/gras/phys/addPhysics binary
/gras/phys/addPhysics binary_ion
/gras/phys/addPhysics lowe_neutron
/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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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
/gras/phys/addPhysics binary
/gras/phys/addPhysics binary_ion
/gras/phys/addPhysics lowe_neutron
/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 Analysis modules:
Component degradation, background

- Total Ionizing Dose
  - Total accumulated dose
  - Also event Pulse Height Spectrum (signal in detectors / devices)
  - Also per "incident" particle type (with user choice of interface)
  - Units: MeV, rad, Gy
- Current / Fluence
  - Particle type, energy, direction, time, etc at surfaces
  - One/Both ways
- NIEL
  - Based on NIEL coeff.
  - Several curve sets available
    - CERN/ROSE (p, e-, n, pi)
    - SPENVIS/JPL (p)
    - Messenger Si (p, e-)
    - Messenger GaAs (p, e-)
  - Easy to add coeff. curves
  - Units: 95MeVmb, MeVcm2/g MeVcm2/mg, keVcm2/g

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GRAS Analysis modules:
Human Exploration Initiatives

GRAS Biological effects modules

- Dose equivalent
  - ICRP-60 and ICRP-92 LET-based coefficients
  - Units:
  - MeV, Sv, mSv, Gy, rad
- Equivalent Dose
  - ICRP-60 weights
  - User choice of weight interface
  - Units:
  - MeV, Sv, mSv, Gy, rad

GRAS Analysis modules
SEE in microelectronics

- LET
  - Based on Geant4 dE/dx tables
  - Computed at surface
  - Units:
    - MeV/cm
- Path length
  - Event distribution of particle path length in a given set of volumes
  - If used with "geantinos", it provides the geometrical contribution to the energy deposition pattern change
    - In a 3D model w.r.t. a 1D planar irradiation model
- CC (Charge Collection)
  - Based on REAC approach
  - QinetiQ development for GEMAT (ESA REAT-MS contract)

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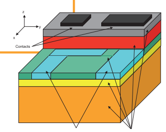
esa

18

GRAS Analysis modules
SEE in microelectronics

- LET
  - Based on Geant4 dE/dx tables
  - Computed at surface
  - Units:
    - MeV/cm
- Path length
  - Event distribution of particle path length in a given set of volumes
  - If used with "geantinos", it provides the geometrical contribution to the energy deposition pattern change
    - In a 3D model w.r.t. a 1D planar irradiation model
- CC (Charge Collection)
  - Based on REAC approach
  - QinetiQ development for GEMAT (ESA REAT-MS contract)



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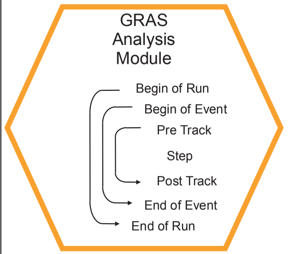
18

Analysis Module

- Easy to implement:
  Self contained analysis element
  - Initialization, event processing, normalization, printout
- Only one class to create/derive in case a new type of analysis is needed
  - No need to modify Run+Event+Tracking +Stepping actions
- AIDA histogramming available "per module"
- G4 UI commands "per module"
  - Automatic module UI tree
  - *à la GATE*



```
/gras/analysis/dose/addModule doseCrystal
/gras/analysis/dose/doseCrystal/setUnit MeV
```

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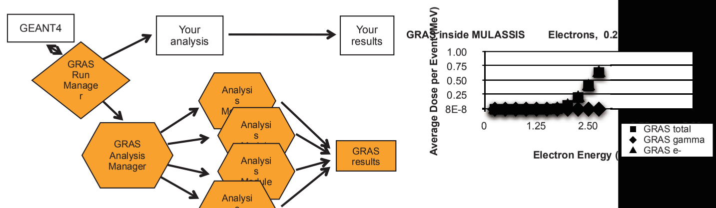
GRAS in existing applications

- 2 ways of adding GRAS output without discarding previous work
  A. Inserting C++ Geometry, Physics and/or Primary Generator classes inside GRAS
     - In the main gras.cc
  B. Inserting GRAS into your existing applications



R.Lindberg (ESA) IEEE-Trans Nucl Sci 53, 6 (2006)

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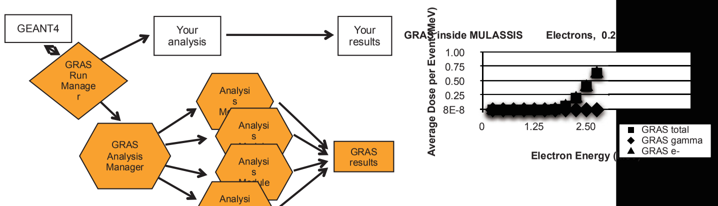

R.Lindberg (ESA) IEEE-Trans Nucl Sci 53, 6 (2006)

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GRAS used by G4-SESS

Space Environment Support System

SESS
- Monitoring, analysis, warning
- Operators, project teams, development engineers and scientists
- "Space-Weather" application

G4SESS
- GRAS-based module (new GRAS module developed at INTA)
- Response matrix for radiation effects in sensors / electronics
- Near real-time computation based on external environment spectra
  - Python scripts (scipy, numpy) for GRAS data processing
- G4-SESS features
  - Multiplatform
  - Coded with Open Source Software
  - Modular structure
  - Geant4 and GRAS as radiation interaction and effects tools
  - Radiation effects data provider for SESS

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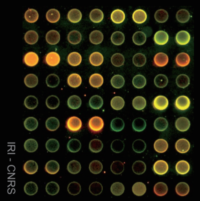
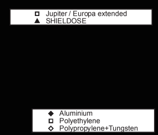
GRAS for planetary exploration



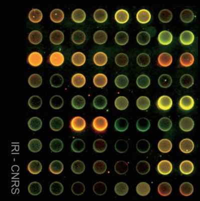
Biochip development
- Biological systems (ligands) to detect biomarkers
- Detection by fluorescence
- Radiation analysis for mission to Mars
- See talk by A. LePostollec

- Jupiter / Europa mission study
  - Internal ESA feasibility study
  - Divine-Garrett, GIRE and Salammbo-3D models



22

GRAS for planetary exploration



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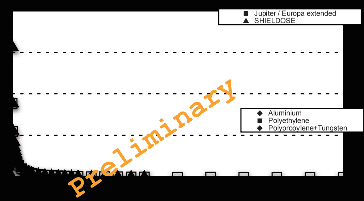
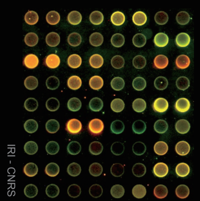


22

GRAS for planetary exploration



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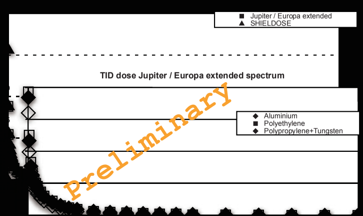
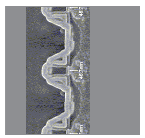


22

GRAS as ground testing aid
Facilities, simulation tools, data harmonisation

- *A. Javanainen et al., IEEE TNS 54, 2007, p.1158*
  LET values are determined differently at different irradiation facilities
  Some use "SRIM", some "LET Calculator"
  No common guidelines
  → inconsistent characterization of tested electronics.
- Radiation Effects Facility (RADEF)
  - JYFL Accelerator Laboratory, Jyväskylä, Finland
    One of the ESA's European Component Irradiation Facilities (ECIF)
  - Heavy ion cocktail (7 ion species from N to Xe)
  - Energy of < 9.3 MeV/nuc
  - LET in Si from ~2 to 60 MeV/(mg/cm²)
  - Differences up to 12% !



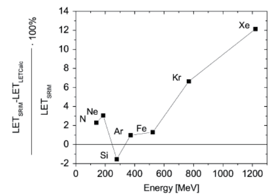


Fig. 1. Percentage difference in LET values in Si calculated with SRIM and LET Calculator for different ions as a function of energy.

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GRAS as ground testing aid
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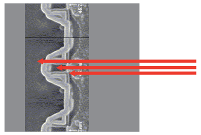

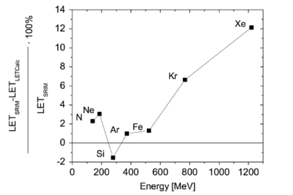

Fig. 1. Percentage difference in LET values in Si calculated with SRIM and LET Calculator for different ions as a function of energy.

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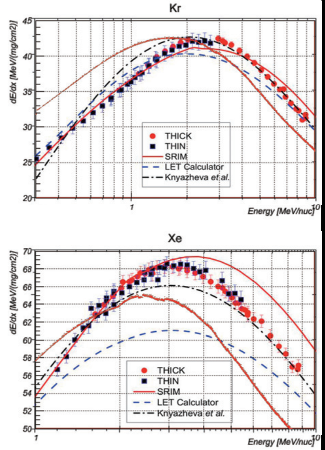
GRAS as ground testing aid
Work in progress

- Ion ionisation tables
- ^{82}Kr, ^{131}Xe
- E < 10 MeV/nuc
- Comparison to
  - SRIM 2003
  - LET calculator
  - Exp data
  - Data: *A. Javanainen et al., IEEE TNS 54, 2007*
- New LET data taking by 2008.
  Direct inclusion of new dE/dx data would enable use of Geant4 (e.g. via GRAS) in ESA component SEE testing procedure
- Foreseen (2008, ESA contract) implementation in Geant4 of
  - *ICRU73*
  - *Direct data assimilation option*



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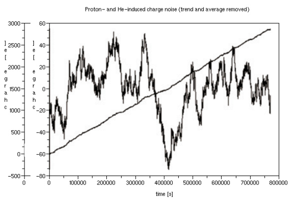
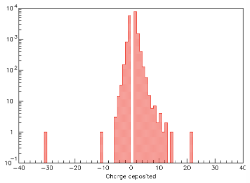
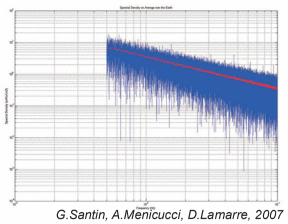
GRAS for GOCE
Gravity field and steady-state Ocean Circulation Explorer

- Impact of electrode contact discontinuity on accelerometer performance
- Assessment of charging level and noise frequency content induced on the gold electrodes by cosmic-rays







G.Santin, A.Menicucci, D.Lamarre, 2007

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Summary, perspectives

- Usability of Geant4 greatly increased by development of friendly applications – SSAT, MULASSIS, GEMAT
- As a result, several space missions (more that we think) benefit from Geant4, for S/C design or science payload analyses
- Usability, speed and accuracy are still an issue
- GRAS is providing a framework for coordinated development of Geant4-based applications for space
  - User-friendly, ready-to-use, general-purpose tool
  - Script driven
  - Analysis types cover needs of both engineering and science
  - Used at ESA & external institutes and industry
  - Available for download (and collaborations)

MULASSIS in SPENVIS
Demo

Giovanni Santin, ESA / ESTEC and Rhea System SA

5th Geant4 Space Users' Workshop
Tokyo University, 13-15 Feb 2008

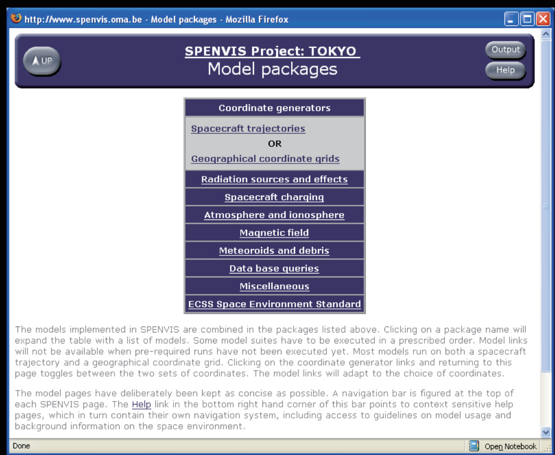
G.Santin - GRAS / MULASSIS
G4 Space Users', Tokyo, 13 Feb 2008

Outline

- SPENVIS intro
- SPENVIS demo
  - Mission definition
  - Mission radiation environment
  - MULASSIS configuration
  - MULASSIS output

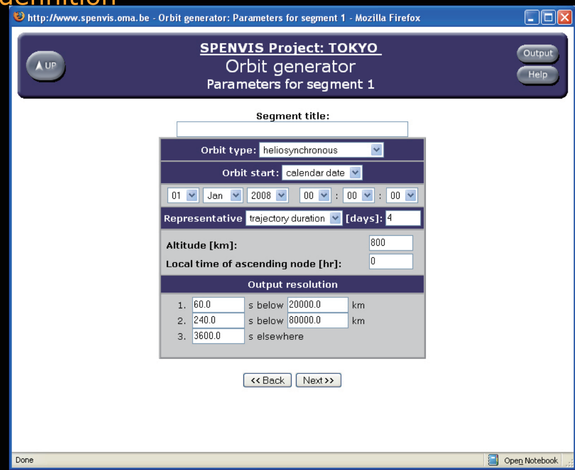
2

SPENVIS
Intro

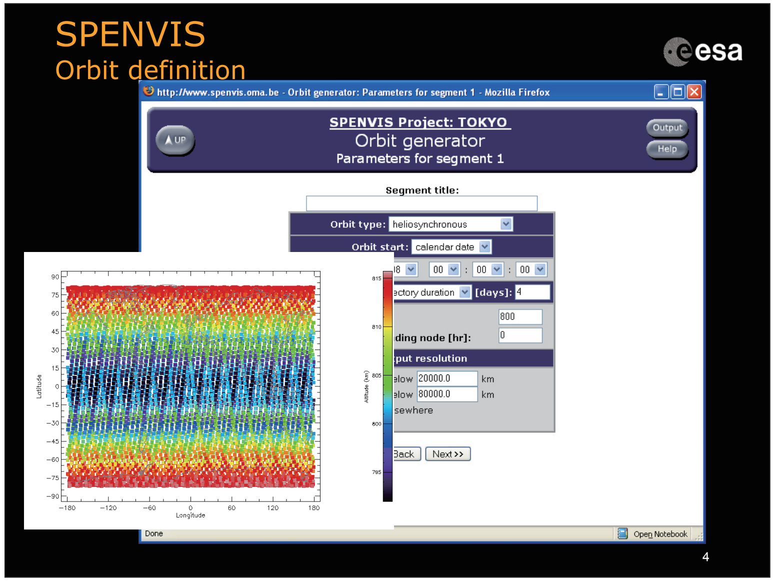


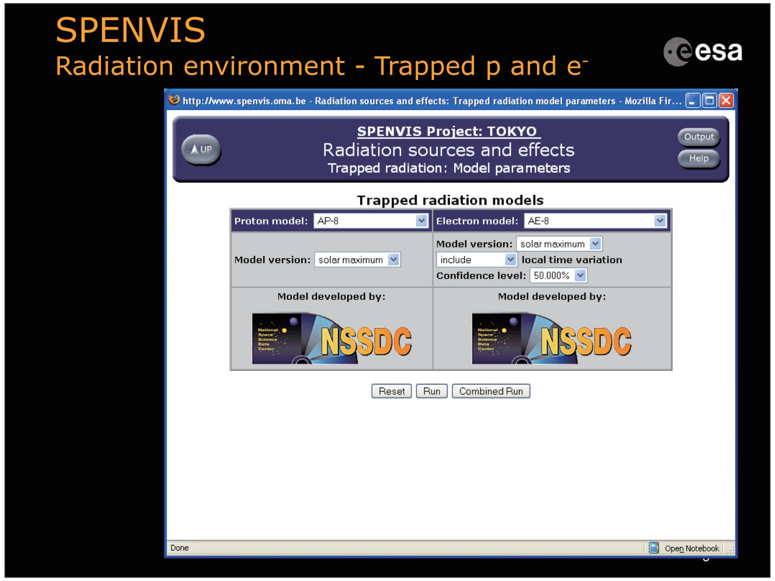
3

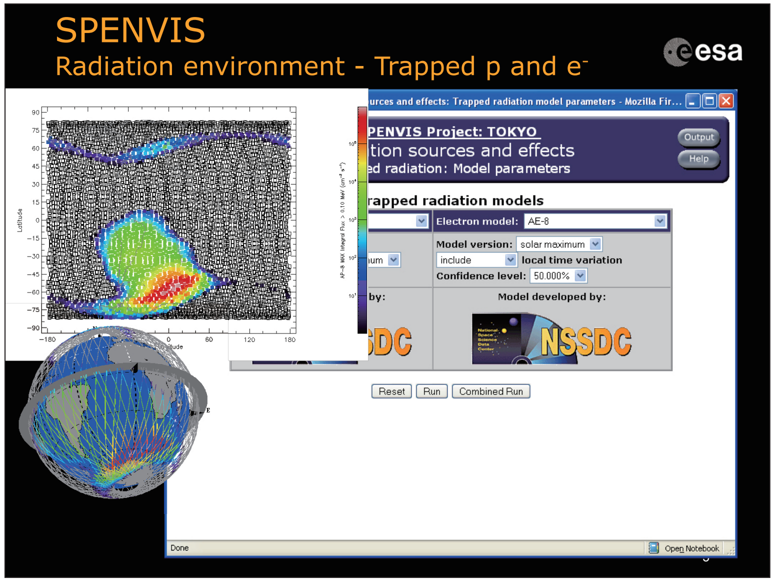
SPENVIS
Orbit definition

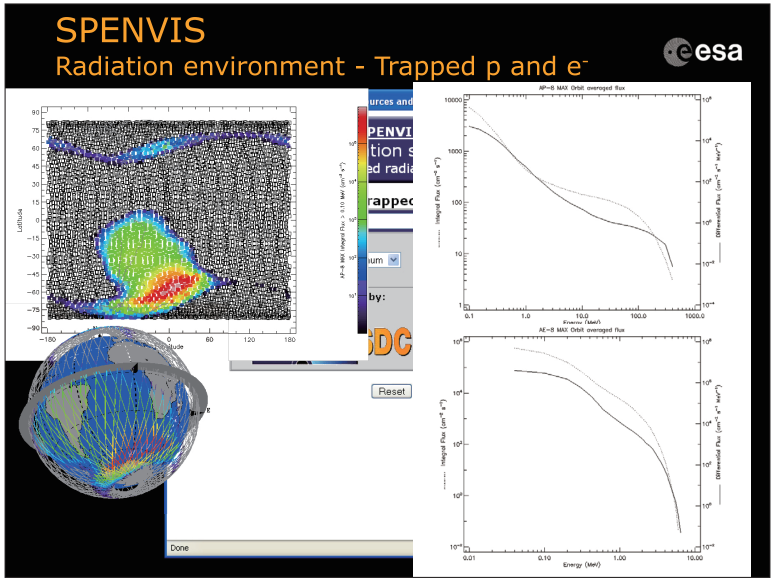


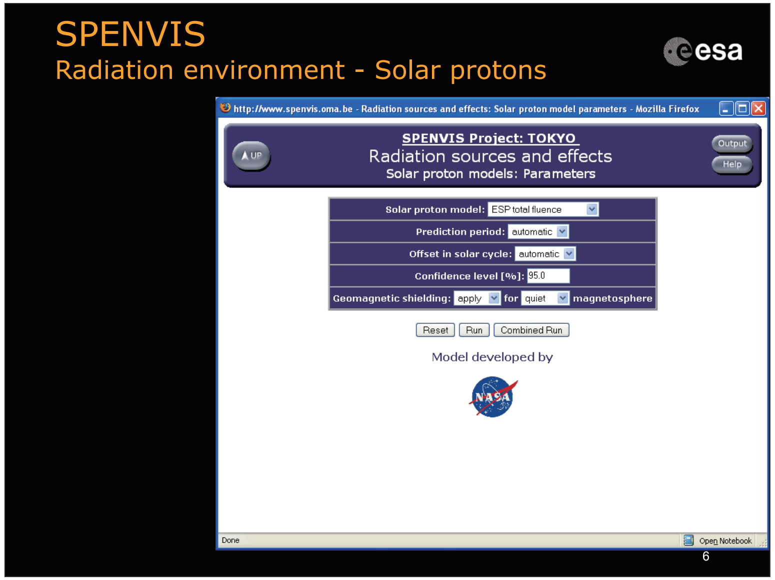
4

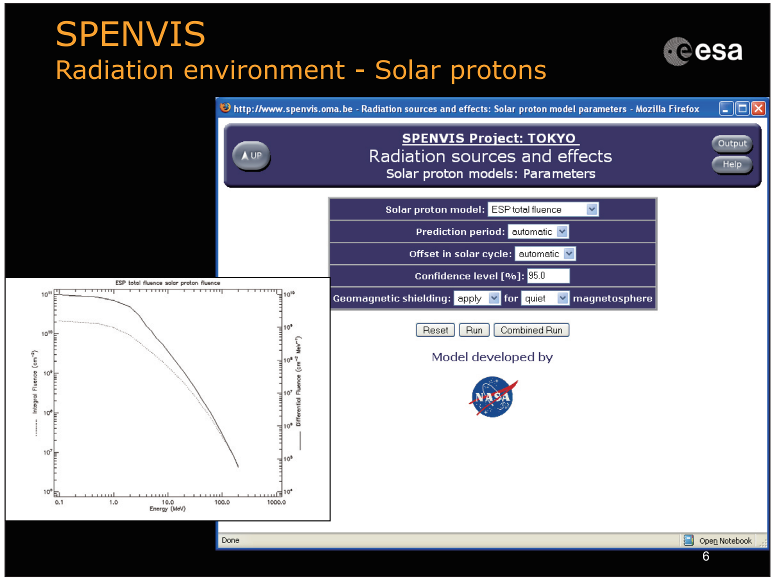

SPENVIS
Orbit definition
esa
http://www.spenvis.oma.be - Orbit generator: Parameters for segment 1 - Mozilla Firefox
SPENVIS Project: TOKYO
Orbit generator
Parameters for segment 1
Output
Help
Segment title:
Orbit type: heliosynchronous
Orbit start: calendar date
[days]: 4
800
0
km
km
Next >>
Done
Open Notebook
Latitude
Longitude
4

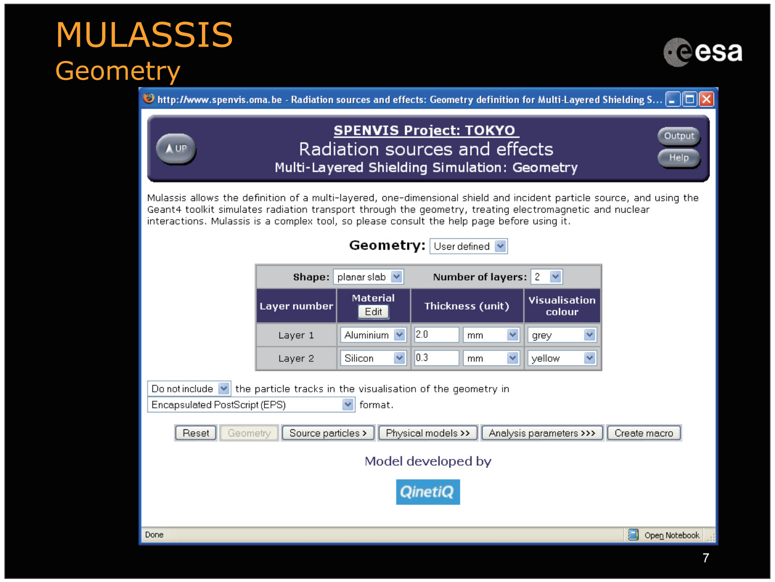

SPENVIS
Radiation environment - Trapped p and e-
esa
http://www.spenvis.oma.be - Radiation sources and effects: Trapped radiation model parameters - Mozilla Fir...
SPENVIS Project: TOKYO
Radiation sources and effects
Trapped radiation: Model parameters
Output
Help
Trapped radiation models
Proton model: AP-8
Electron model: AE-8
Model version: solar maximum
Model version: solar maximum
include
local time variation
Confidence level: 50.000%
Model developed by:
Model developed by:
NSSDC
NSSDC
Reset
Run
Combined Run
Done
Open Notebook

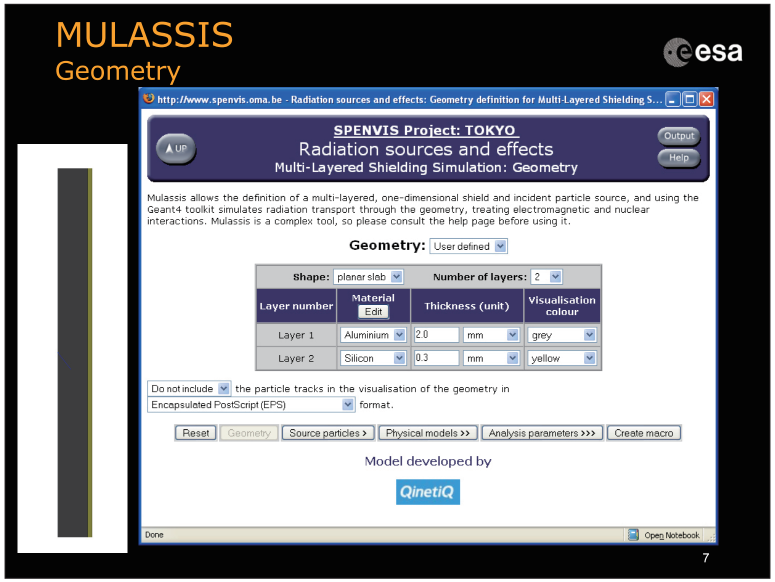

SPENVIS
Radiation environment - Trapped p and e-
esa
Trapped radiation model parameters - Mozilla Fir...
SPENVIS Project: TOKYO
Radiation sources and effects
Trapped radiation: Model parameters
Output
Help
Trapped radiation models
Electron model: AE-8
Model version: solar maximum
include
local time variation
Confidence level: 50.000%
Model developed by:
NSSDC
Reset
Run
Combined Run
Done
Open Notebook
Latitude


SPENVIS
Radiation environment - Trapped p and e-
esa
AP-8 MAX Orbit averaged flux
AE-8 MAX Orbit averaged flux
Energy (MeV)
Reset
Done


SPENVIS
Radiation environment - Solar protons
esa
http://www.spenvis.oma.be - Radiation sources and effects: Solar proton model parameters - Mozilla Firefox
SPENVIS Project: TOKYO
Radiation sources and effects
Solar proton models: Parameters
Solar proton model: ESP total fluence
Prediction period: automatic
Offset in solar cycle: automatic
Confidence level [%]: 95.0
Geomagnetic shielding: apply for quiet magnetosphere
Reset Run Combined Run
Model developed by
NASA
6


SPENVIS
Radiation environment - Solar protons
esa
http://www.spenvis.oma.be - Radiation sources and effects: Solar proton model parameters - Mozilla Firefox
SPENVIS Project: TOKYO
Radiation sources and effects
Solar proton models: Parameters
Solar proton model: ESP total fluence
Prediction period: automatic
Offset in solar cycle: automatic
Confidence level [%]: 95.0
Geomagnetic shielding: apply for quiet magnetosphere
Reset Run Combined Run
Model developed by
NASA
ESP total fluence solar proton fluence
Energy (MeV)
6


MULASSIS
Geometry
esa
http://www.spenvis.oma.be - Radiation sources and effects: Geometry definition for Multi-Layered Shielding S...
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Geometry
Mulassis allows the definition of a multi-layered, one-dimensional shield and incident particle source, and using the Geant4 toolkit simulates radiation transport through the geometry, treating electromagnetic and nuclear interactions. Mulassis is a complex tool, so please consult the help page before using it.
Geometry: User defined
Shape: planar slab Number of layers: 2
Layer number Material Thickness (unit) Visualisation colour
Layer 1 Aluminium 2.0 mm grey
Layer 2 Silicon 0.3 mm yellow
Do not include the particle tracks in the visualisation of the geometry in Encapsulated PostScript (EPS) format.
Reset Geometry Source particles > Physical models >> Analysis parameters >>> Create macro
Model developed by
QinetiQ
7


MULASSIS
Geometry
esa
http://www.spenvis.oma.be - Radiation sources and effects: Geometry definition for Multi-Layered Shielding S...
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Geometry
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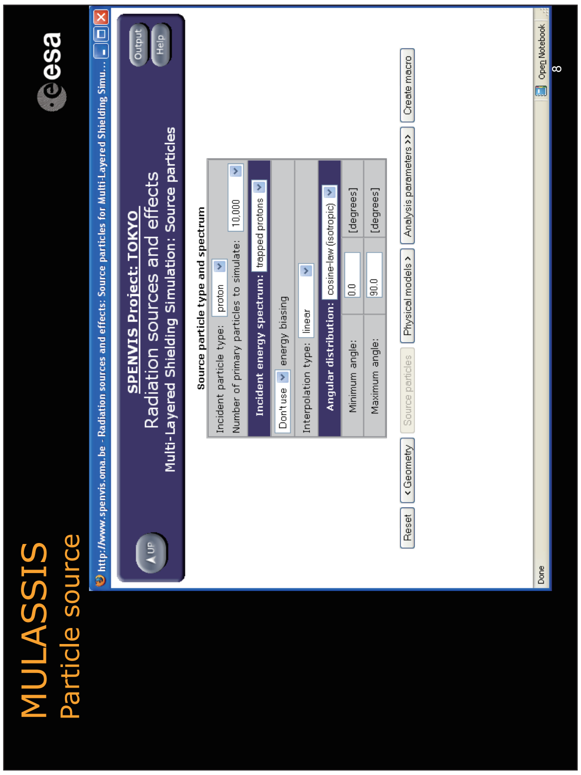
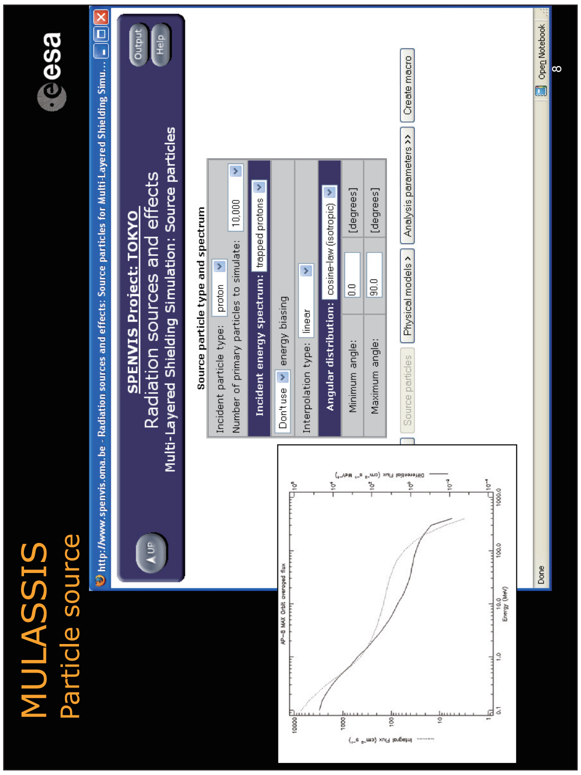
Reset Geometry Source particles > Physical models >> Analysis parameters >>> Create macro
Model developed by
QinetiQ
7


MULASSIS
Particle source
esa
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Source particles
Source particle type and spectrum
Incident particle type: proton
Number of primary particles to simulate: 10,000
Incident energy spectrum: trapped protons
Don't use energy biasing
Interpolation type: linear
Angular distribution: cosine-law (isotropic)
Minimum angle: 0.0 [degrees]
Maximum angle: 90.0 [degrees]
Reset
< Geometry
Source particles
Physical models >
Analysis parameters >>
Create macro


MULASSIS
Particle source
esa
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Source particles
Source particle type and spectrum
Incident particle type: proton
Number of primary particles to simulate: 10,000
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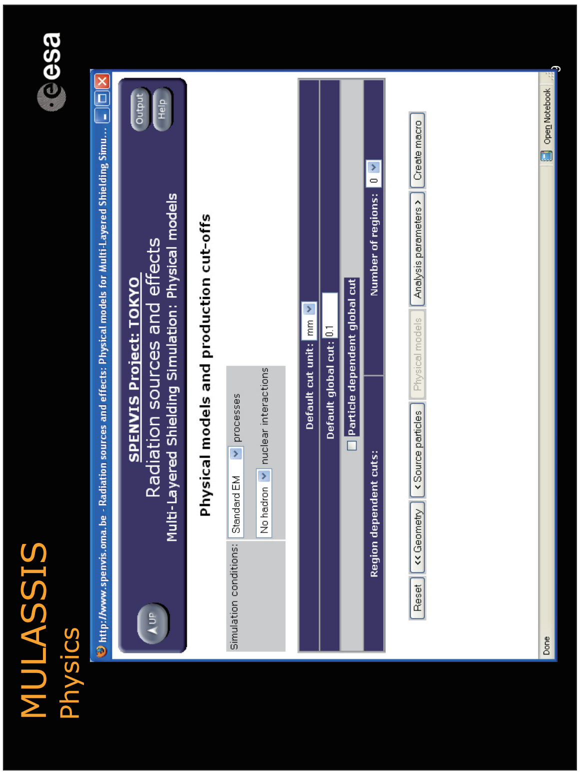
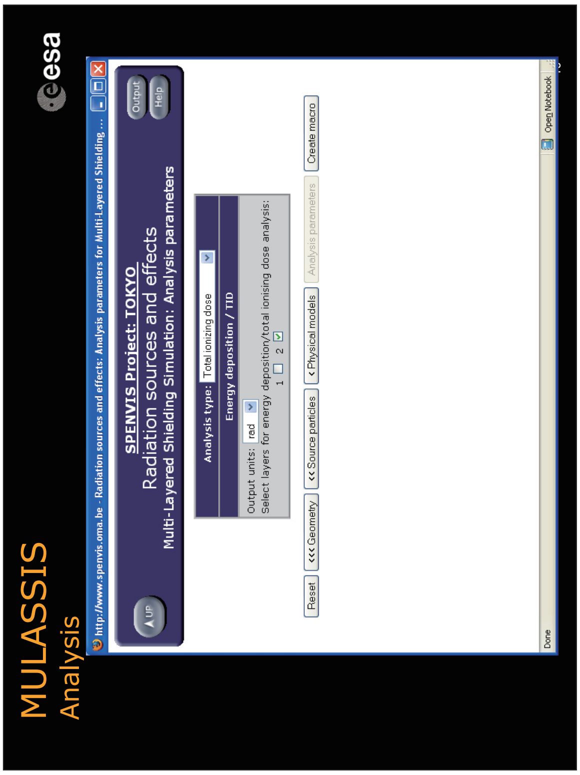
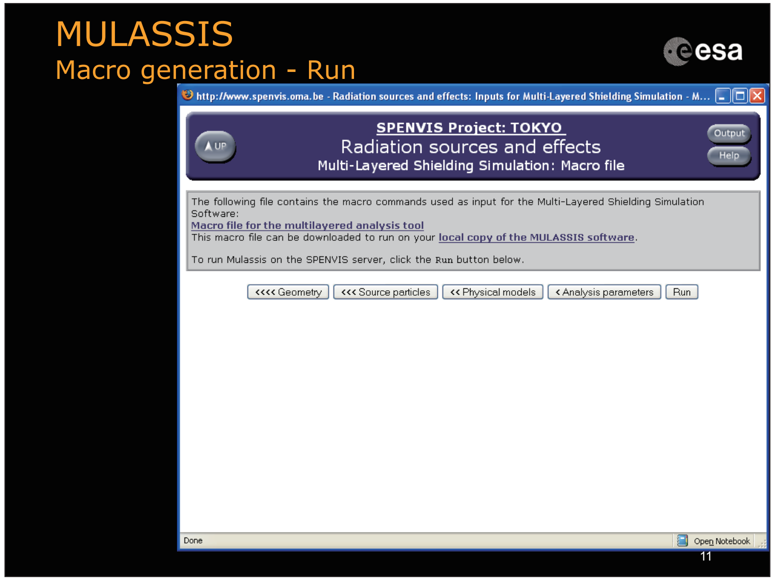
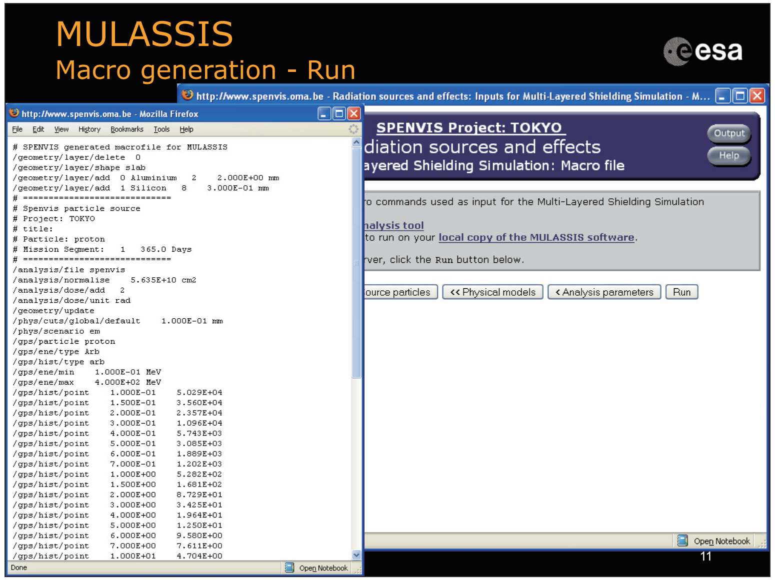
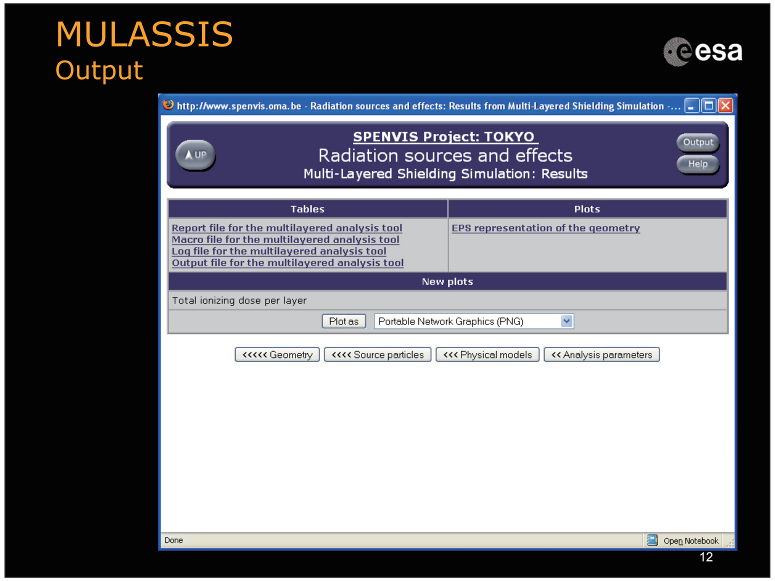
Angular distribution: cosine-law (isotropic)
Minimum angle: 0.0 [degrees]
Maximum angle: 90.0 [degrees]
Physical models >
Analysis parameters >>
Create macro

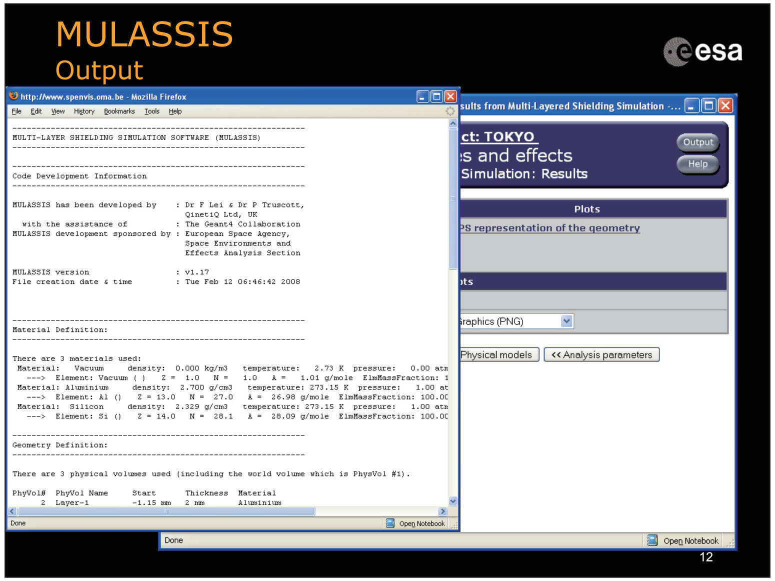

MULASSIS
Physics
esa
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Physical models
Physical models and production cut-offs
Simulation conditions: Standard EM processes
No hadron nuclear interactions
Default cut unit: mm
Default global cut: 0.1
Particle dependent global cut
Region dependent cuts:
Number of regions: 0
Reset
<< Geometry
< Source particles
Physical models
Analysis parameters >
Create macro

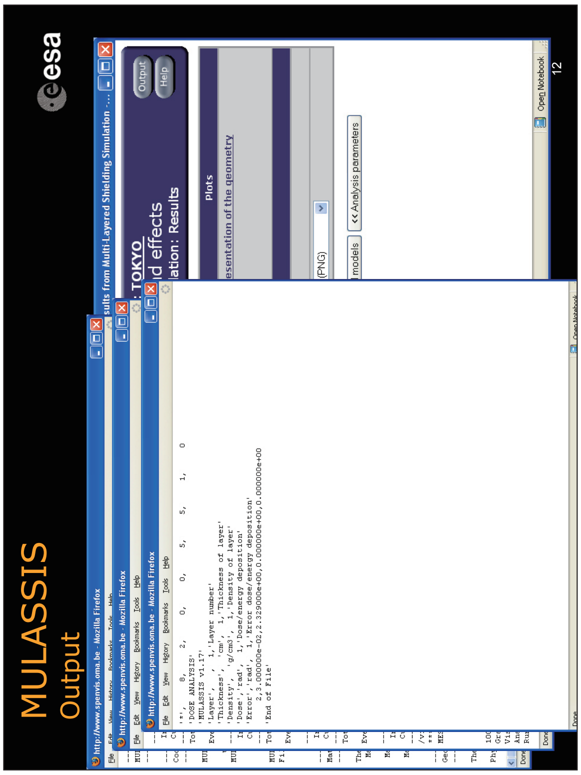

MULASSIS
Analysis
esa
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Analysis parameters
Analysis type: Total ionizing dose
Energy deposition / TID
Output units: rad
Select layers for energy deposition/total ionising dose analysis:
Reset
<<< Geometry
<< Source particles
< Physical models
Analysis parameters
Create macro

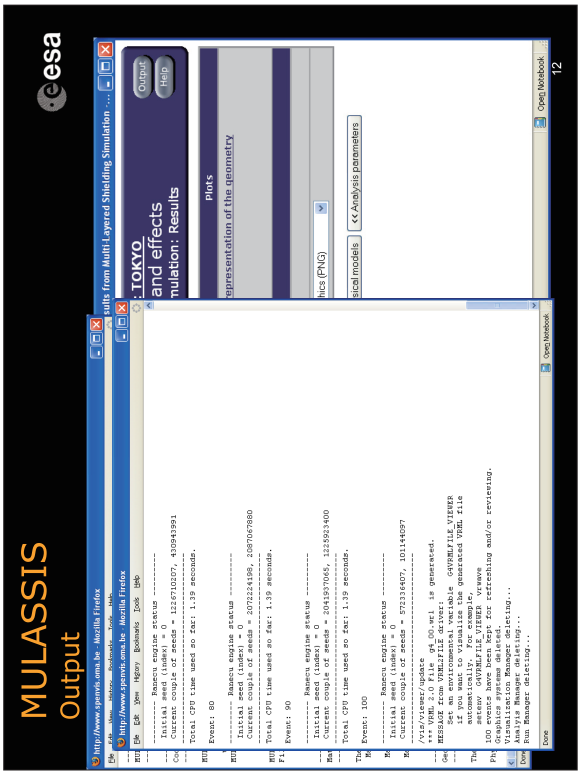

MULASSIS
Macro generation - Run
esa
http://www.spenvis.oma.be - Radiation sources and effects: Inputs for Multi-Layered Shielding Simulation - M...
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Macro file
UP
Output
Help
The following file contains the macro commands used as input for the Multi-Layered Shielding Simulation Software:
Macro file for the multilayered analysis tool
This macro file can be downloaded to run on your local copy of the MULASSIS software.
To run Mulassis on the SPENVIS server, click the Run button below.
<<<< Geometry
<<< Source particles
<< Physical models
< Analysis parameters
Run
Done
Open Notebook
11


MULASSIS
Macro generation - Run
esa
http://www.spenvis.oma.be - Mozilla Firefox
SPENVIS generated macrofile for MULASSIS
/geometry/layer/delete 0
/geometry/layer/shape slab
/geometry/layer/add 0 Aluminium 2 2.000E+00 mm
/geometry/layer/add 1 Silicon 8 3.000E-01 mm
Spenvis particle source
Project: TOKYO
Particle: proton
Mission Segment: 1 365.0 Days
/analysis/file spenvis
/analysis/normalise 5.635E+10 cm2
/analysis/dose/add 2
/analysis/dose/unit rad
/geometry/update
/phys/cuts/global/default 1.000E-01 mm
/phys/scenario em
/gps/particle proton
/gps/ene/type Arb
/gps/hist/type arb
/gps/ene/min 1.000E-01 MeV
/gps/ene/max 4.000E+02 MeV
SPENVIS Project: TOKYO
Output
Help
11


MULASSIS
Output
esa
http://www.spenvis.oma.be - Radiation sources and effects: Results from Multi-Layered Shielding Simulation - ...
SPENVIS Project: TOKYO
Radiation sources and effects
Multi-Layered Shielding Simulation: Results
UP
Output
Help
Tables
Plots
Report file for the multilayered analysis tool
Macro file for the multilayered analysis tool
Log file for the multilayered analysis tool
Output file for the multilayered analysis tool
EPS representation of the geometry
New plots
Total ionizing dose per layer
Plot as
Portable Network Graphics (PNG)
<<<<< Geometry
<<<< Source particles
<<< Physical models
<< Analysis parameters
Done
Open Notebook
12


MULASSIS
Output
esa
http://www.spenvis.oma.be - Mozilla Firefox
MULTI-LAYER SHIELDING SIMULATION SOFTWARE (MULASSIS)
Code Development Information
MULASSIS has been developed by : Dr F Lei & Dr P Truscott, QinetiQ Ltd, UK
with the assistance of : The Geant4 Collaboration
MULASSIS development sponsored by : European Space Agency, Space Environments and Effects Analysis Section
MULASSIS version : v1.17
File creation date & time : Tue Feb 12 06:46:42 2008
Material Definition:
There are 3 materials used:
Geometry Definition:
There are 3 physical volumes used (including the world volume which is PhysVol #1).
Done
Open Notebook
12


MULASSIS
Output
12


MULASSIS
Output
12