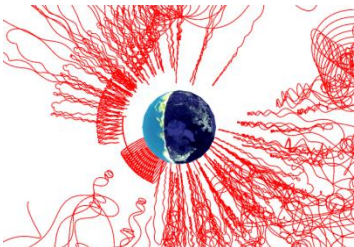


Geant4-based tools in SPENVIS

N. Messios , S. Calders, V. Letocart, M. Kruglanski
Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

H. Evans
ESA Space Environments & Effects (ESTEC/TEC-EPS)



Outline

❑ A brief introduction to SPENVIS

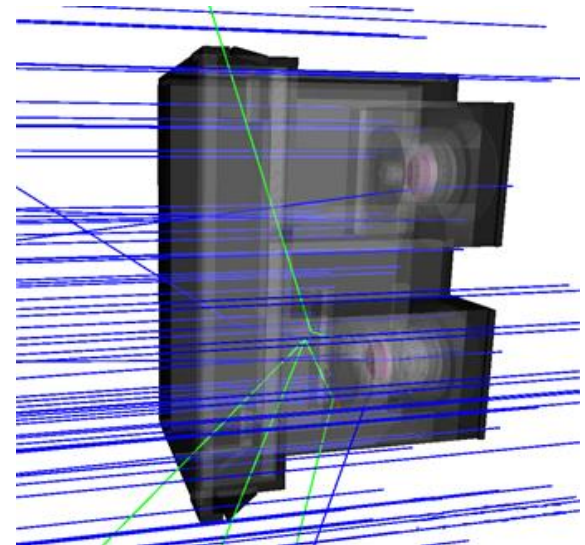
❑ Geant4 and SPENVIS

- motivation
- overview of available Geant4 tools

❑ The SPENVIS Next Generation

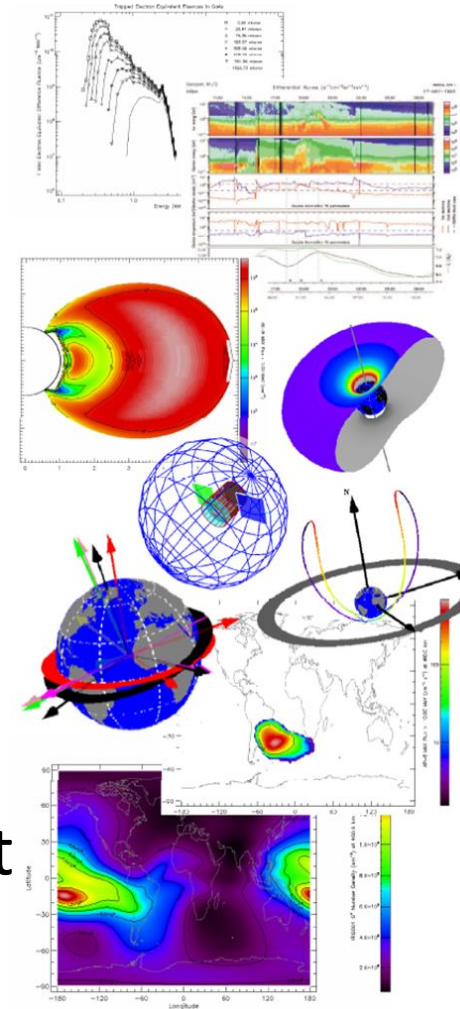
- basic concepts
- model developers support
- status

❑ Current & future developments



Space Environment Information System

- ESA Operational software with large user community, publicly available since 1998
- Developed & maintained by BIRA-IASB since 1996
- WWW interface to models of the space environment and its effects on spacecraft components and astronauts



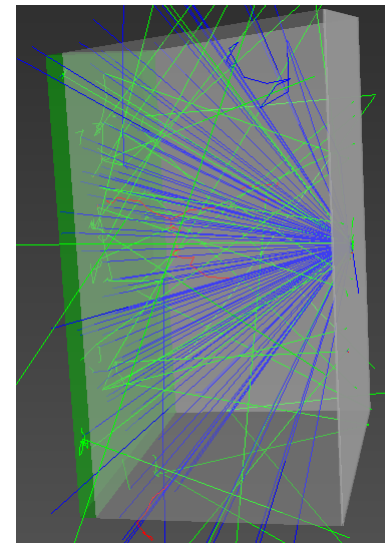
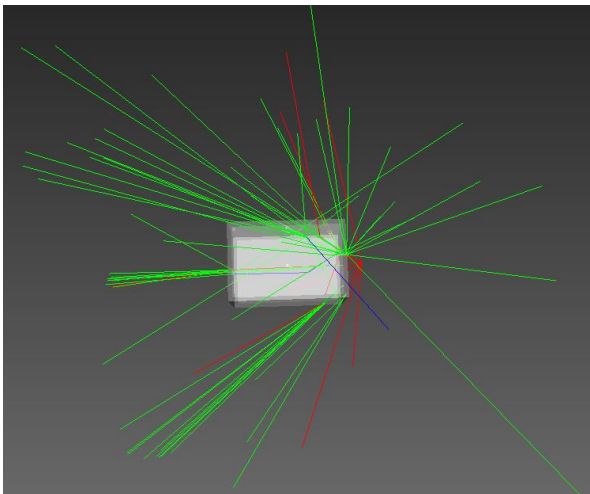
Geant4 tools in SPENVIS

- Easy to use
 - ✓ User friendly interface
 - ✓ No prior knowledge of Geant4
- Interaction with other SPENVIS models & tools
- Macro files can be used outside SPENVIS

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

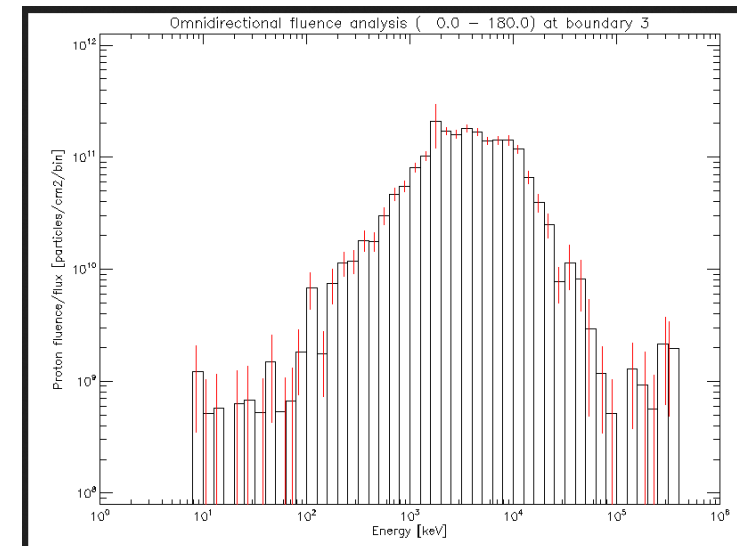
GRAS & MULASSIS

- Definition of a multi-layered (slab or sphere), one-dimensional geometry (**MULASSIS** & **GRAS**) or a **multi-volume 3D** (GDML) geometry (**GRAS**)
- Simulation of radiation transport through geometry, treating electromagnetic & nuclear interactions



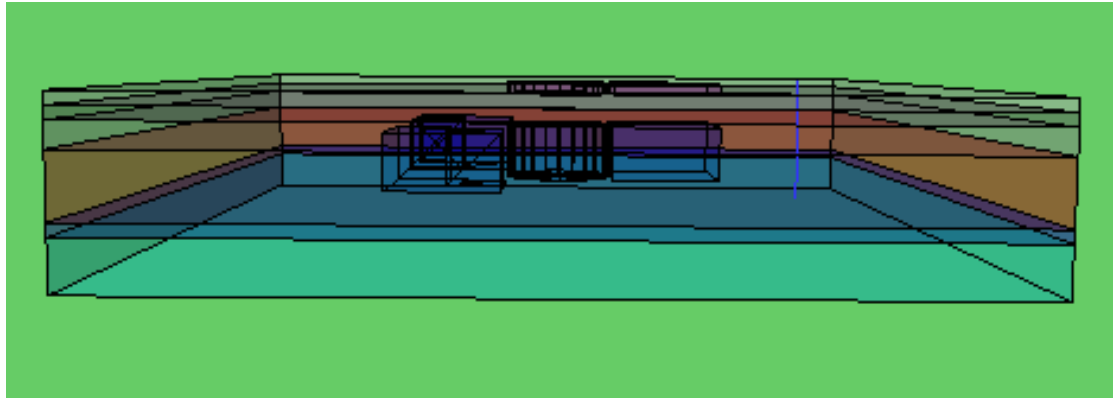
○ Various analysis types:

- Fluence analysis
- Non ionizing dose/energy loss
- Energy deposition/total ionizing dose
- Dose equivalent & Equivalent dose analysis
- Linear Energy Transfer (MeV/cm)
 - SEU rate estimates
- Path length → useful for SEU analysis
- Charging → total charge balance passing through user defined boundaries



GEMAT

- Geant4-based Micro-dosimetry Analysis Tool (GEMAT) is a computer code used for studying dosimetry effects of space radiation on micro-electronics and micro-sensors
- Has its own geometry builder → simulation geometry constructed in terms of layers, contact and depletion volumes

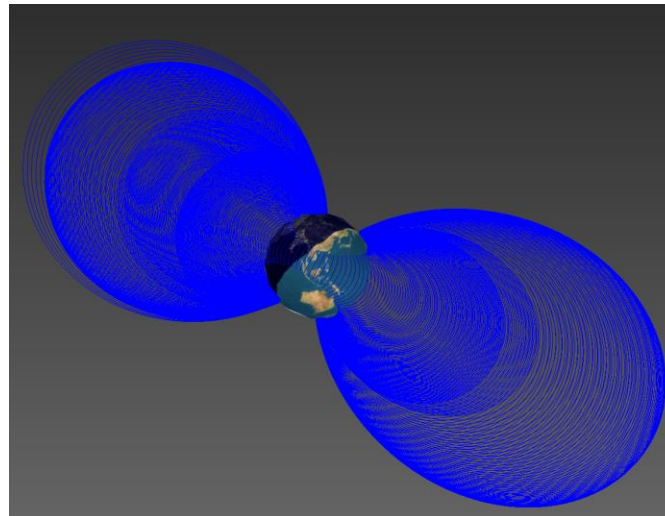


SSAT

- Sector Shielding Analysis Tool (SSAT) performs ray tracing from a user defined point within the geometry to determine
 - fraction of solid angle for which the shielding is within a defined interval (**shielding levels**)
 - mean shielding level as a function of look direction (**shielding distribution**)
- Geantino particle (no physical interactions) flags boundary crossings along its straight trajectory
- Positions of boundary crossings together with material density can be used to profile the shielding for given point within the geometry

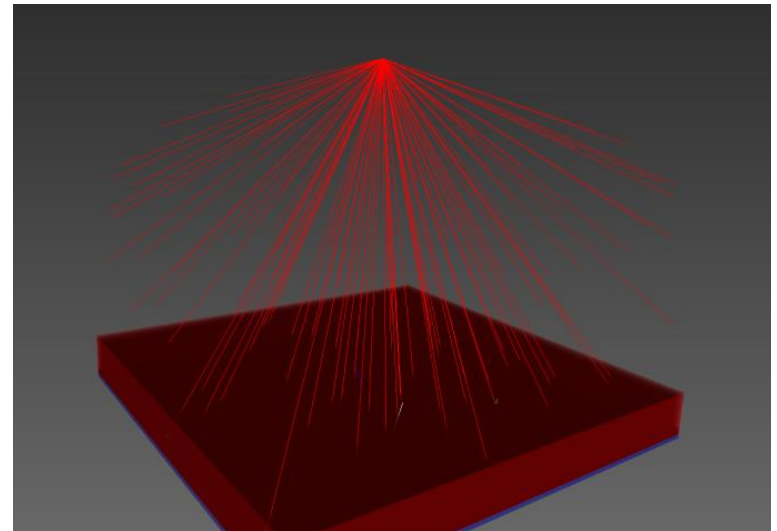
MAGNETOCOSMICS

- Computation and visualisation of charged particle trajectories and magnetic field lines
- Computation of cut-off rigidities (min momentum per charge a particle must have in order to reach a certain location) as a function of position, for different types of magnetic field models



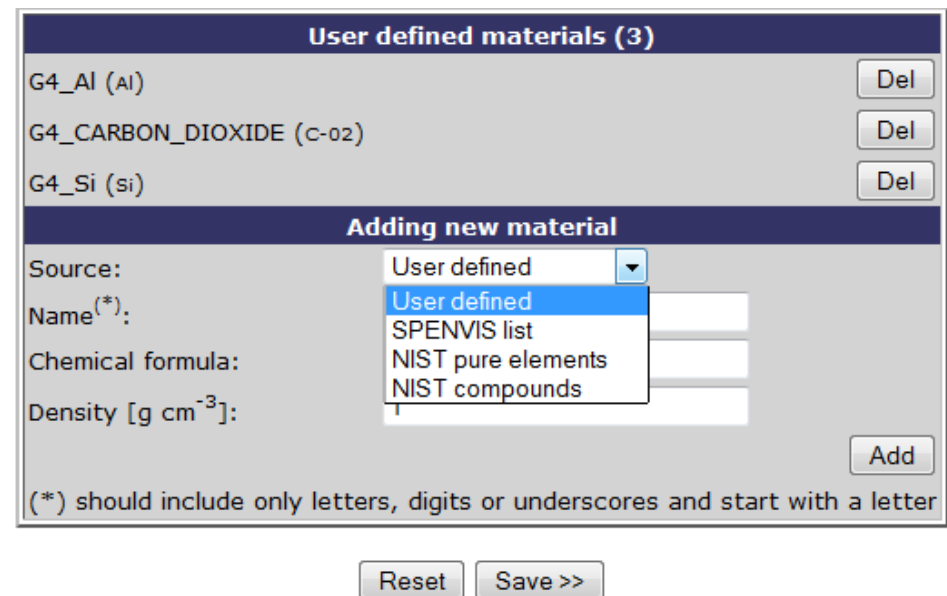
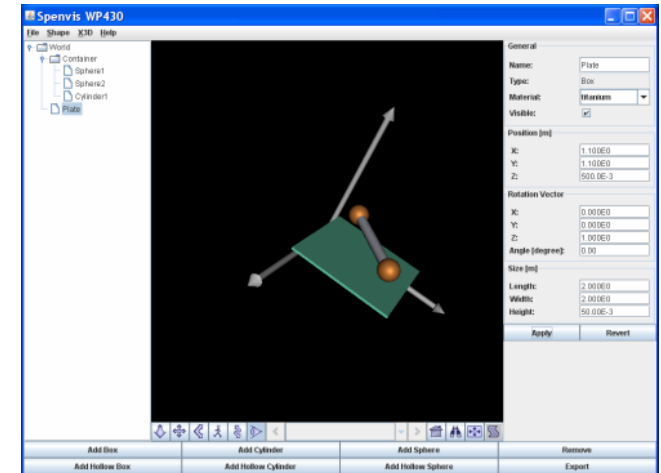
PLANETOCOSMICS

- Simulation of shielding effects of magnetic field, atmosphere and soil
 - Forward propagation: particle flux and energy deposition analysis
 - Backward propagation: rigidity cut-off analysis
- Geant4 particles & materials
- Mercury, Earth and Mars



Supporting tools

- Mission based Geant4 General Particle Source macros
- GDML (JAVA) geometry definition tool
- GDML analysis tool
- Material definition tool
 - ✓ user defined materials
 - ✓ selection from predefined lists



Other

- Detailed Mars Energetic Radiation Environment Model (dMEREM)



- PLANETOCOSMICS-J (update of PLANETOCOSMICS 2.0 code) and Genetic Algorithm Radiation Shield Optimiser (GARSO) for MULASSIS (JOREM)



- MC-SCREAM: NIEL based damage equivalent fluences for solar cell (using MULASSIS)



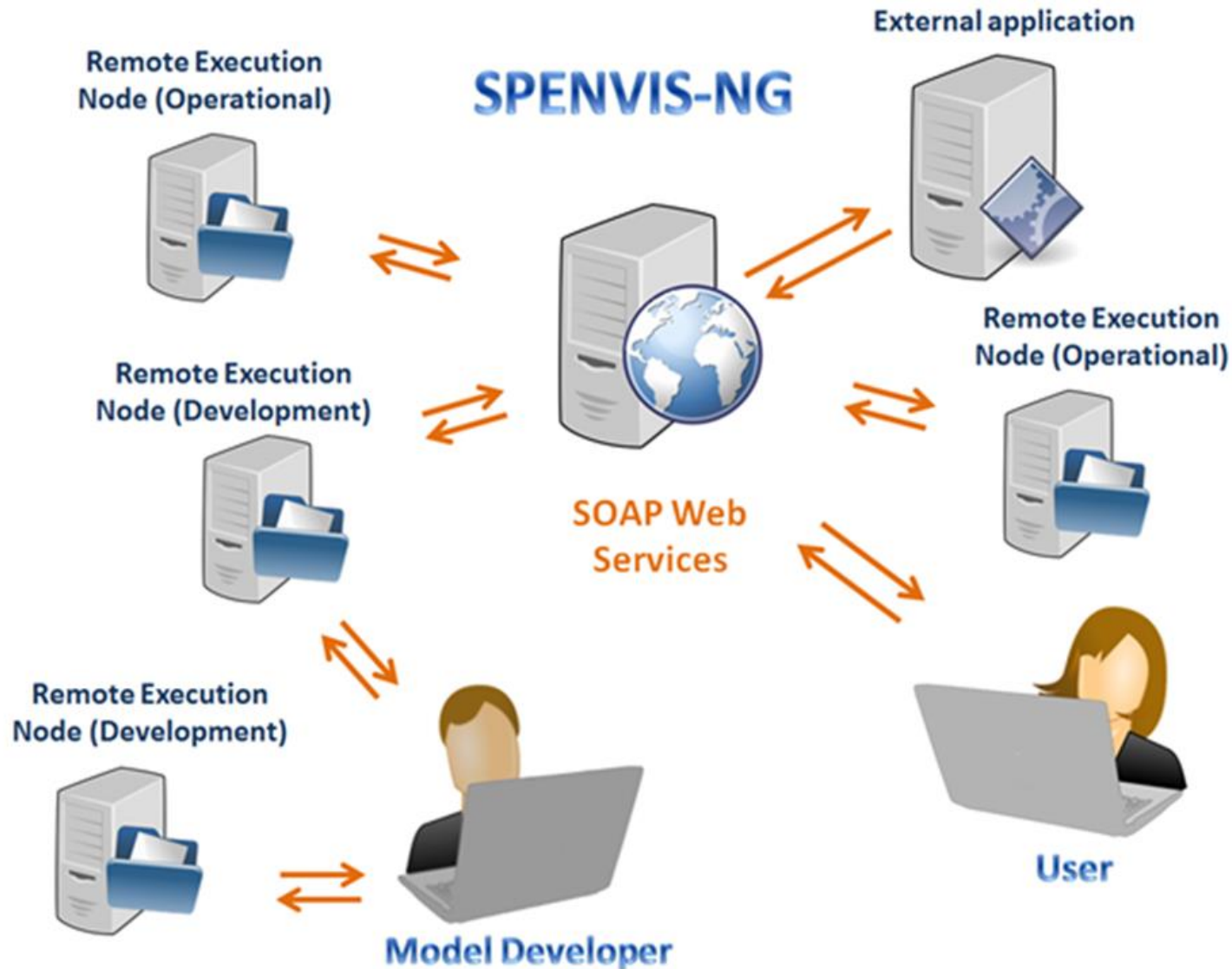
The SPENVIS Next Generation

Complete re-design of the current SPENVIS system
funded by ESA's General Support Technology
Programme, GSTP-5

- ✓ web-based service oriented distributed framework supporting plug-in of models
- ✓ allows machine-to-machine interface for interoperability with other software



The SPENVIS Next Generation




The basic concepts

- Models and tools are embedded into **bundles**
 - ✓ binaries & execution script (ANT)
 - ✓ manifest
- Bundles can be easily plugged into the system (deployed on an execution node)
- Deployed models and tools are seen as consumers/producers of data streams (resources)


The basic concepts

- SPENVIS-NG is task oriented → **workflows**
- A workflow describes how
 - ✓ the various models interact
 - ✓ the input interface shown to the user
 - ✓ the execution output is displayed
- Different types of workflows are supported
 - ✓ simple or complex (e.g. loops)
 - ✓ atomic: single model, parent/child
 - ✓ “All-in-one”
 - ✓ ECSS workflows


The SPENVIS-NG interface




BIRA-IASB
aeronomie.be




deimos
spaceapplications



DH
CONSULTANTS



etamax



SPENVIS

Next Generation

- HOME
- ABOUT
- PROJECTS
- WORKFLOWS
- DOCUMENTATION
- HELPDESK
- BUG REPORTING
- EDIT ACCOUNT
- TEAM (0)
- SHARING
- CONTACT US
- RULES OF CONDUCT

PROJECT: **ecss13**

Project list

| Workflow executions | | Project history | | | |
|---------------------|-------------------|--------------------|---------------------------------------|-------------------------------|---------------------|
| ID | NAME | STATUS | WORKFLOW | LAST ACTION | ACTION |
| 11,570 | atomic_geo | FINISHED | /neos/workflows/atomic_geo | 2016-11-07T15:30:28.498+01:00 | Delete Duplicate VO |
| 11,586 | atomic_ige2006 | FINISHED | /neos/workflows/atomic_ige2006 | 2016-11-07T16:55:51.203+01:00 | Delete Duplicate VO |
| 11,603 | atomic2_ige2006 | FINISHED | /neos/workflows/atomic_ige2006 | 2016-11-10T12:24:24.414+01:00 | Delete Duplicate VO |
| 11,612 | atomic_ecliptic01 | FINISHED | /neos/workflows/atomic_Earth_ecliptic | 2016-11-10T14:44:21.070+01:00 | Delete Duplicate VO |
| 11,615 | atomic_ap8 | FINISHED | /neos/workflows/atomic_ap8 | 2016-11-10T14:49:37.725+01:00 | Delete Duplicate VO |
| 11,618 | atomic_sd2q | WAITING_FOR_INPUTS | /neos/workflows/atomic_sd2q | | Delete Set input |

Count: 6

Create execution Refresh list

Models details Inputs Outputs Report Log Plots

“All-in-one” workflows

Set execution input

Execution input for execution: ssat

SSAT

GDML definition

Shielding distribution scheme

Dose calculation

Angular window

Ray tracing

Source position

Visualisation

Angular window parameters

Angular window

Angular window units: radians * ?

Minimum theta angle: 0.0 * ?

Maximum theta angle: 180.0 * ?

Minimum phi angle: 0.0 * ?

Set execution input

Execution input for execution: ECSS

ECSS

Mission & representative trajectory

Orbital parameters

Solar radiation pressure

AP-8 model

IGE-2006 model

GCR-ISO model

Solar activity data

Magnetic shielding

ECSS recommendations

This interface allows someone to specify the space environment for a GEO based on the ECSS-E-ST-10-04C recommendations:

- The NASA AP-8 model for calculating trapped proton spectra
 - for a conservative scenario the AP-8 solar minimum mode should be selected
 - for an open scenario the selection should be based on the mission epoch
- The International Geostationary Electron model (IGE-2006) for calculating trapped electron spectra
 - for a conservative scenario the IGE-2006 flux mode should be set to the upper flux option
 - for an open scenario the mean flux option should be selected

Atomic workflows

Set execution input

Execution input for execution: LEO-02

Add

Remove

Segment # 1 input

Selected: 1

Segment #1 input

LEO segment mission definition

Starting date of mission segment: 01/01/2011

Mission segment duration: P1Y

Define representative trajectory duration using number

Number of orbits: 1.0

Set execution input

Execution input for execution: AP-8

integral proton fluxes in the energy range 0.1 MeV to 400 MeV for protons in the Earth's radiation belt. The fluxes are stored as functions of energy, L-value, and B/B0 ($B_0=0.311653/L^3$). The maps are based on data from more than 20 satellites from the early sixties to the mid-seventies.

AP-8 parameters

Exposure threshold flux [$\text{cm}^{-2} \cdot \text{s}^{-1}$]: 1.0

AP-8 mode: solar maximum

Select a finished parent execution from the same project: LEO-01

Orbit segment # 1

Selected: 1

Send

LEO-01
GEO-01
LEO-02

Supporting the model developers

❑ Software Development Kit (SDK)

- “Software Development Kit and Remote Execution Node Manual”
 - ✓ Tutorials & “Hints and tips” section
 - ✓ Installation & configuration of remote execution node
- Tool for interacting with a remote execution node
- Additional tools (extension): Saxon-HE package, STIL Tool Set (STILTS), wrappers for transforming CSV files into VOTables and vice versa, Python VOTable parser

Supporting the model developers

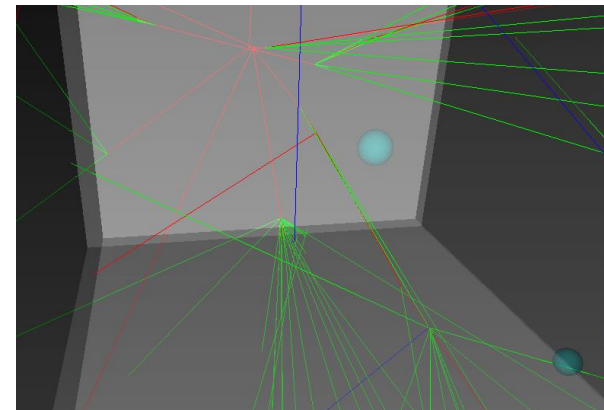
- ❑ XML Validation tool for manifests & workflows
- ❑ Semi-automatic creation of manifests (work in progress..)
- ❑ Python API

The status of SPENVIS-NG

- System development has been completed
- Busy with implementation of the model & tools (new + SPENVIS-4 migration)
- Some issues remain
 - ✓ not easy enough to implement models
 - ✓ user interface improvement
 - ✓ additional monitoring tools

Current & future developments

- Installation of Geant4.10 on a dedicated SPENVIS-NG execution node (geant4-10-01-patch-03)
- Successful compilation of MULASSIS (1.26) and GRAS (3.4) with Geant4.10 & SPENVIS-NG installation
- Installation of GEMAT and SSAT on SPENVIS-NG remote node



Current & future developments

- Complete the implementation of model in SPENVIS-NG
- Introduce a minimum set of public workflows
- Continue supporting SPENVIS users and model developers.

Geant4 tools in SPENVIS

| Model | Version | Description |
|----------------|----------------------------------|--|
| GRAS | 3.1 (4.9.5p02), 2.3 (4.9.2) | Geant4 Radiation Analysis for Space → General space radiation analysis for 3D geometry models |
| MULASSIS | 1.23 (4.9.5p02), 1.19 (4.9.2) | Multi-Layered Shielding Simulation Software → Radiation analysis for one-dimensional layered shield |
| GEMAT | 2.8 (4.9.5p02), 2.4 (4.9.0) | Dosimetry effects of space radiation on micro-electronics and micro-sensors |
| SSAT | 2.1 (4.9.0) | Ray tracing from user defined point within geometry to determine shielding levels and shielding distributions |
| MAGNETOCOSMICS | 2.0 (4.7.1) | <ul style="list-style-type: none">- Charged particle trajectories & magnetic field lines- Cut-off rigidities as a function of position |
| PLANETOCOSMICS | 2.0 (4.8.1) | <ul style="list-style-type: none">- Definition of a planetary magnetic field, atmosphere & soil- Interactions of cosmic rays with planetary environment |

Geant4 tools in SPENVIS

| Model | Version | Description |
|------------------|--------------------------|--|
| dMEREM | (4.9.1p03) | Detailed Mars Energetic Radiation Environment Model |
| PLANETOCOSMICS-J | (4.9.2p02) | Galilean Moon (Io, Europa, Ganymede & Callisto) Environment Tool → Update of version 2.0 of the PLANETOCOSMICS code |
| MC-SCREAM | MULASSIS 1.19 (4.9.2) | NIEL based damage equivalent fluences for solar cell (using MULASSIS) |
| SMUL | MULASSIS 1.19 (4.9.2) | Uses Pelliccioni conversion coefficients for converting the MULASSIS output into effective dose or ambient dose equivalent |
| | | |