



Geant4 Tools in SPENVIS



A User Perspective

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14th Geant4 Space Users' Workshop
Xylokastro, Greece, 22 October 2019



ROYAL BELGIAN INSTITUTE
FOR SPACE AERONOMY



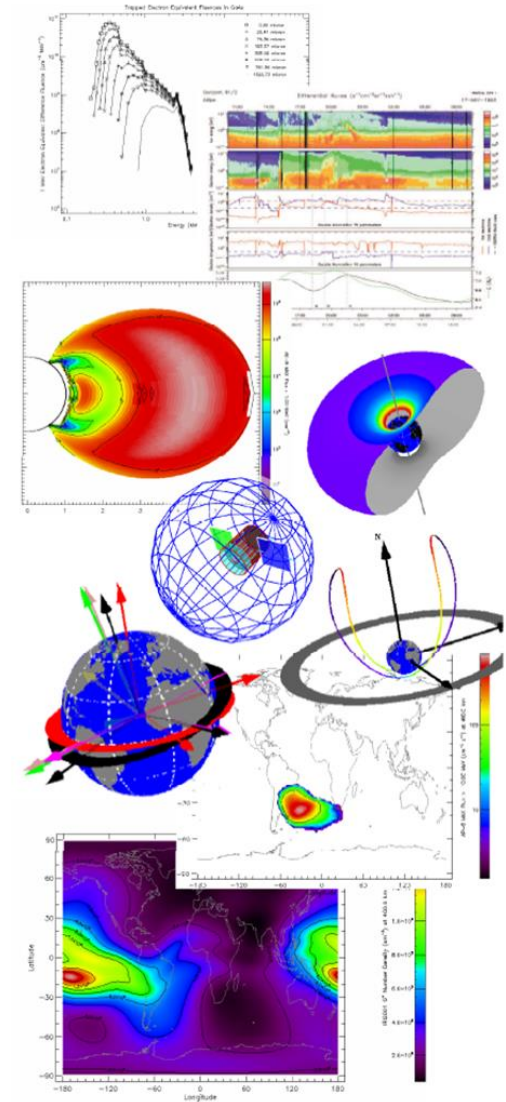
Outline

- ❑ A brief introduction to SPENVIS
- ❑ Geant4 tools in the SPENVIS system
- ❑ SPENVIS users & Geant4 tools
 - ✓ Profile & needs
 - ✓ User support
 - ✓ Commonly asked questions & feedback
- ❑ Selected examples
- ❑ Current status and future plans



The ESA's SPENVIS system

- Operational software with large user community
- Web interface to models of the space environment & its effects
- Developed & maintained by BIRA-IASB since 1996
- Publicly available since 1998





How to access SPENVIS

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

esa space situational awareness

ESA SSA SWE NEO SST

About SWE

- What is Space Weather
- SSA Space Weather Activities
- Current Space Weather
- Contact

Service Domains

- Spacecraft Design
- Spacecraft Operation
- Human Spaceflight
- Launch Operation
- Transionospheric Radio Link
- Space Surveillance and Tracking
- Power Systems Operation
- Airlines
- Resource Exploitation System Operation
- Pipeline Operation
- Auroral Tourism Sector
- General Data Service

Expert Service Centres

- ESC Solar Weather
- ESC Heliospheric Weather
- ESC Space Radiation
- ESC Ionospheric Weather
- ESC Geomagnetic Conditions

Other Resources

- Documents
- SWWT
- SWEN Newsletter
- Upcoming Events
- Sign-In
- You are not signed in.
- Sign In
- Request For Registration

Space Radiation Expert Service Centre (R-ESC)

ESC Objectives Contributions Contributors

Current products provided by the R-ESC and available in SWE services:

- Athens Neutron Monitor Station (UoA/AlMeoS)
- BIRA-IASB Space Weather Services (BIRA-IASB)
- COMESEP • R.134 The COMESEP Alert System
- SEPEN • R.135 Solar Energetic Particle Environment
- SPENVIS • R.103 Space Environment Information System
- SPM • R.136 SWIFF Plasmasphere (SPM) electron

British Antarctic Survey (UKRI/BAS)

Center for Space Radiations (UCL/CSR)

Department Radiation Biology (DLR-IAM)

Mullard Space Science Laboratory (UCL/MSSL)

Paul Buehler (PB)

Radiation Hardness Assurance and Space Weather (SL/RAS)

Space Research Laboratory, Department of Physics and Astronomy (U)

SWE Data Centre (ESOC/SWE Portal)

UK Met Office (UKMO)

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<http://swe.ssa.esa.int>

SPENVIS

The Space Environment Information System

NAVIGATION

- Home
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- Rules of conduct
- My account
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Welcome to SPENVIS

SPENVIS is **ESA's** Space ENVIRONMENT Information System, a WWW interface to models of the space environment and its effects; including cosmic rays, natural radiation belts, solar energetic particles, plasmas, gases, and "micro-particles".

REGISTER **SIGN IN**

Use of SPENVIS on this site is free of charge, but a user registration is required.

[forgot password](#)
[change password](#)

[Terms and Conditions](#)
[Teacher or Student?](#)

Current version
The current version of SPENVIS (**4.6.10**) was **released** on May 4, 2018.

System requirements
SPENVIS requires a browser with JavaScript support (tested with Firefox 23 and MS-IE 9). Some outputs require a [VRML/X3D plugin](#) (tested with Octaga Player 2.3.0.3).

Need help?
Beside a large set of contextual help pages, the SPENVIS system includes a forum (🗨️) where users can exchange their experiences and tips. In case of problems, please consult our bug tracker system (🐛) and feel free to post any bugs.

The SPENVIS system is developed by a consortium led by the Royal Belgian Institute for Space Aeronomy (BIRA-IASB) for ESA's Space Environments and Effects Section through its **General Support Technology Programme (GSTP)**. The system is maintained by the development team at BIRA-IASB.

Current development team: Stijn Calders (project manager), Erwin De Donder, Michel Kruglanski & Neophytos Messios.

ESA Technical Officer: H. Evans (ESA/ESTEC/TEC-EPS)

Sponsors:
 Belgian Federal Science Policy

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SPENVIS Next Generation

- Complete re-design of the SPENVIS system developed in the frame of ESA's GSTP
 - ✓ Web-based service oriented framework
 - ✓ Modular architecture allowing distributed deployment
 - ✓ Plug-in of models
 - ✓ Machine-to-machine interface
- Project ended in December 2018





Geant4 tools in SPENVIS

- Easy to use interface
- 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> |



Geant4 tools in SPENVIS

| Tool name | Tool version | Geant4 version | Description |
|-----------------|--------------|----------------------|--|
| GRAS | 4.0 3.1 | 4.10.1p3 4.9.5p02 | The Geant4 Radiation Analysis for Space tool performs general space radiation studies for complex 3D geometry models |
| MULASSIS | 1.26 1.23 | 4.10.1p3 4.9.5p02 | The Multi-Layered Shielding Simulation Software can simulate the particle transport in one-dimensional planar or spherical shields |
| GEMAT | 2.8 | 4.9.5p02 | The Geant4 Microdosimetry Analysis Tool can be used to study dosimetry effects of space radiation on micro-electronics and micro-sensors |
| SSAT | 2.1 | 4.9.0 | The Sector Shielding Analysis Tool Ray determines shielding levels and shielding distributions from a user defined point within a given geometry |



Geant4 tools in SPENVIS

| Tool name | Tool version | Geant4 version | Description |
|-------------------------|--------------|----------------|---|
| MAGNETOCOSMICS | 2.0 | 4.7.1 | Computes cut-off rigidities as a function of position for different types of magnetic field models for Earth. Also, visualises charged particle trajectories and magnetic field lines |
| PLANETOCOSMICS | 2.0 | 4.8.1 | Allows the definition of a planetary magnetic field, atmosphere & soil and it simulates the interactions of energetic particles with the planetary environment |
| PLANETOCOSMICS-J | - | 4.9.2p02 | Update of version 2.0 of the PLANETOCOSMICS code for simulating the Galilean Moon (Io, Europa, Ganymede & Callisto) radiation environment |
| dMEREM | - | 4.9.1p03 | Detailed Mars Energetic Radiation Environment Model for simulating interactions of e.g. GCRs and SEP with Martian atmosphere and soil |



Geant4 supporting tools

- Mission-based General Particle Source (GPS) macros
- Simple GDML geometry definition tool
- GDML upload & analysis tool
- Material definition tool
 - ✓ User defined materials
 - ✓ Selection from predefined lists
 - ✓ Available for MULASSIS, GRAS, GEMAT & PLANETOCOSMICS

User defined materials (3)

| | |
|--------------------------|-----|
| G4_Al (Al) | Del |
| G4_CARBON_DIOXIDE (C-O2) | Del |
| G4_Si (Si) | Del |

Adding new material

Source: User defined

Name (*): User defined

Chemical formula:

Density [g cm⁻³]:

Add

(*) should include only letters, digits or underscores and start with a letter

Reset **Save >>**



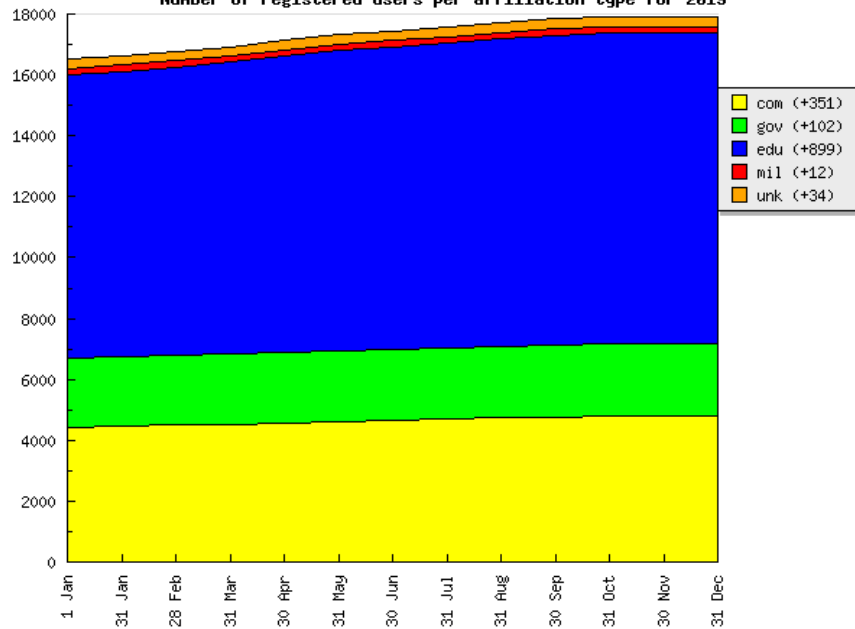
The SPENVIS users' profile

- Both experienced & inexperienced Geant4 users access SPENVIS to:
 - ✓ Characterise the space environment e.g. get mission average particle fluxes/fluences
 - ✓ Set up and run full simulations with available Geant4 tools (e.g. MULASSIS, GRAS, etc.)

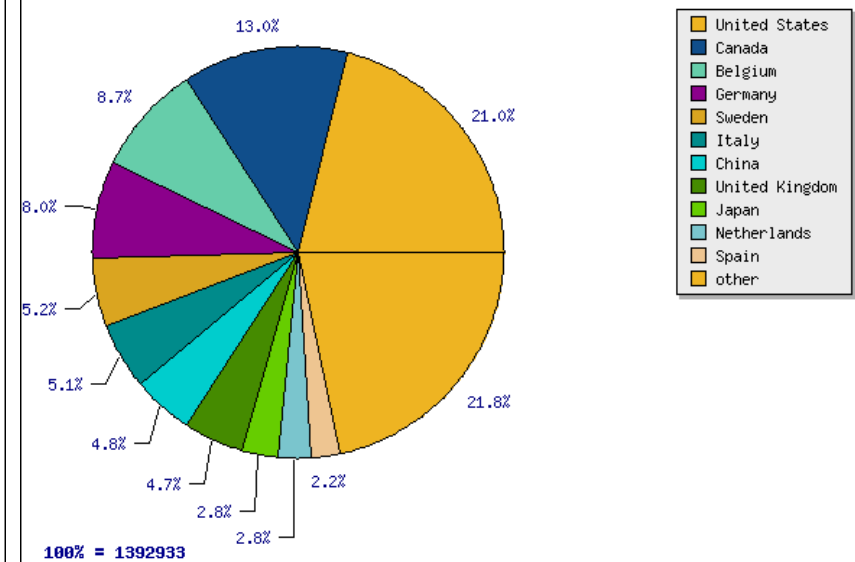


Some SPENVIS user statistics

Number of registered users per affiliation type for 2019



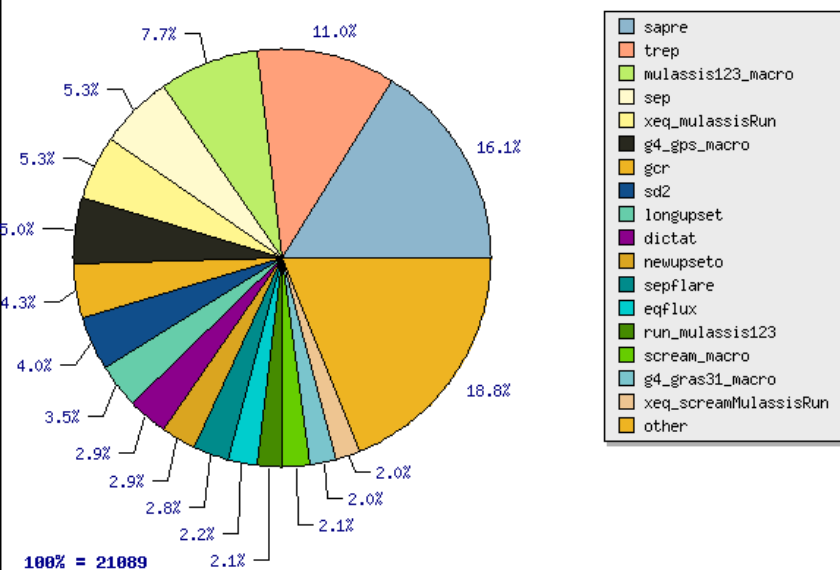
Distribution of user accesses per country for 2019



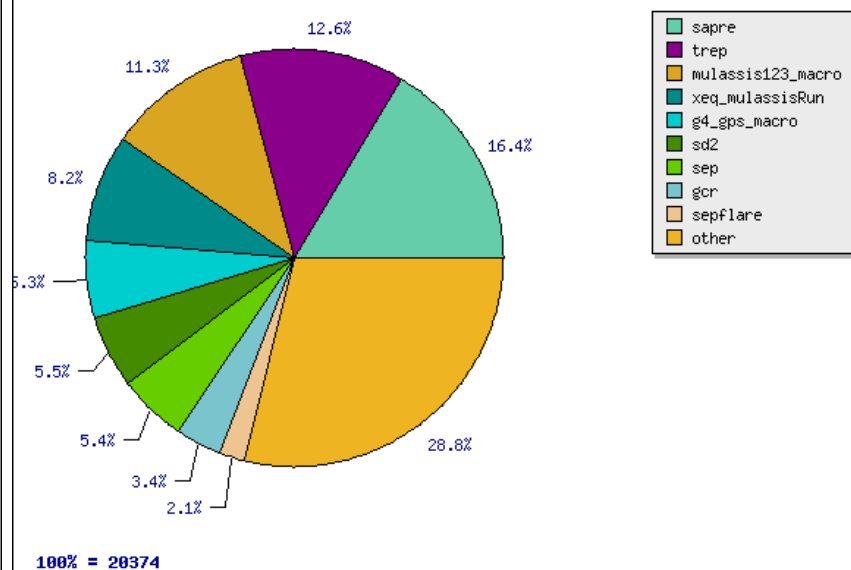


Some SPENVIS model statistics

Distribution of model runs for January 2019



Distribution of model runs for September 2019





SPENVIS user support

Contact SPENVIS team:
spenvis_team@aeronomie.be

| SPENVIS The Space ENvironment Information System | | |
|--|--------|-------|
| Board index | | |
| User Control Panel • View your posts | | |
| It is currently Thu Oct 10, 2019 2:23 pm | | |
| View unanswered posts • View new posts • View active topics | | |
| GENERAL | TOPICS | POSTS |
| General This is the section for general discussions about SPENVIS that are not about a specific model or topic covered in the other sections on this board. Moderators: manu , Moderator | 51 | 113 |
| COORDINATE GENERATORS | TOPICS | POSTS |
| Orbit generator The SPENVIS orbit generator computes trajectory osculatory orbital elements using a numerical Runge-Kutta integration method. It can be used for low altitude orbits, geostationary orbits, and highly eccentric orbits. It takes into account the oblateness of the Earth, the gravitational attraction of Sun and Moon, air drag (by means of the CIRA atmospheric model) and solar radiation pressure. The independent variable is the eccentric anomaly. Osculatory elements are computed at constant equidistant eccentric anomaly steps. Moderators: manu , Moderator | 36 | 78 |
| Grid generator The coordinate grid generator produces a set or grid of geographical positions that serves as input to the positional version of the following models: atmosphere and ionosphere models; trapped particle models and magnetic field models. Moderators: manu , Moderator | 2 | 3 |
| RADIATION SOURCES AND EFFECTS | TOPICS | POSTS |
| Radiation sources Trapped particle fluxes are calculated for each mission segment and accumulated into segment and mission fluences. A model of the anisotropy of low-altitude trapped protons is available as well. Solar proton fluences are predicted for the total mission duration. Moderators: manu , Moderator | 77 | 189 |
| Solar cell radiation damage Damage-equivalent electron fluences for different types of solar cells can be evaluated with EQFLUX. Moderators: manu , Moderator | 13 | 57 |
| Radiation doses Ionising dose behind three types of Al shielding (SHIELDOSE). Device degradation such as charge transfer efficiency loss in CCDs is estimated by calculating damage-equivalent proton fluences and non-ionising energy loss (NIEL). With the sector analysis tool a simple geometric representation of a spacecraft can be generated to produce a shielding distribution by means of ray tracing. The shielding distribution can be used as input for the ionising or non-ionising dose models. Moderators: manu , Moderator | 81 | 237 |
| Single event effects The CREME programme suite provides LET spectra of cosmic ray particles, and estimates single-event upset rates in micro-electronics. Moderators: manu , Moderator | 26 | 68 |

SPENVIS forums:

<https://www.spenvis.oma.be/forum/index.php>

| GEANT4 TOOLS | TOPICS | POSTS |
|---|--------|-------|
| Geant4 tools SPENVIS implements various Geant4 models (Mulassis, GEMAT, SSAT, Magnetocosmics & Planetocosmics) and a number of tools associated with them (e.g. Material definition and geometry definition tools). Moderators: manu , Moderator | 94 | 240 |

SPENVIS
NAVIGATION

- Home
- Access
- Forums
- Bug tracker
- Release notes
- My account
- Export results
- Share project



Contact page

Please consider posting your question on the [forum](#)

From: Neophytos Messios
To: SPENVIS team
Subject: Multi-Layered Shielding Simulation (MULASSIS) - Geant4 tools
Question:

Version: 4.6.10.3386 on <https://www.spenvis.oma.be>:443

SPENVIS is developed by a consortium led by the Royal Belgian Institute for Space Aeronomy for ESA's Space Environments and Effects Section through its General Support Technology Programme

Sponsors:





Commonly asked questions

- Space environment & source particles
 - ✓ Which source geometry (disc, sphere, etc.) should I select for my 3D GRAS simulations?
 - ✓ Which angular distribution?
 - ✓ How do I use biasing?



Commonly asked questions

- Physical processes
 - ✓ Which Geant4 physics list should I use?
 - ✓ How can I use a specific physics model (e.g. High Precision Neutron Model)?
 - ✓ Is there available documentation that explains the different physics lists?



SPENVIS sets automatically the Geant4 physics list based on the primary particle choice (Geant4 **option 3** for pure EM processes or **QBBC** for EM + hadronic processes).

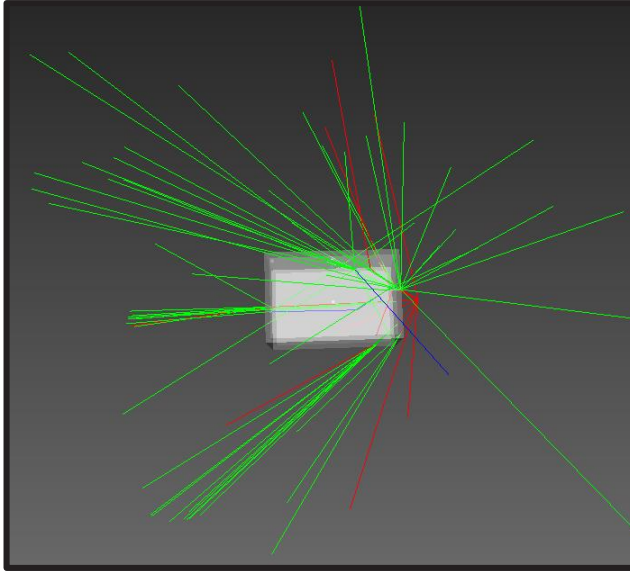


Commonly asked questions

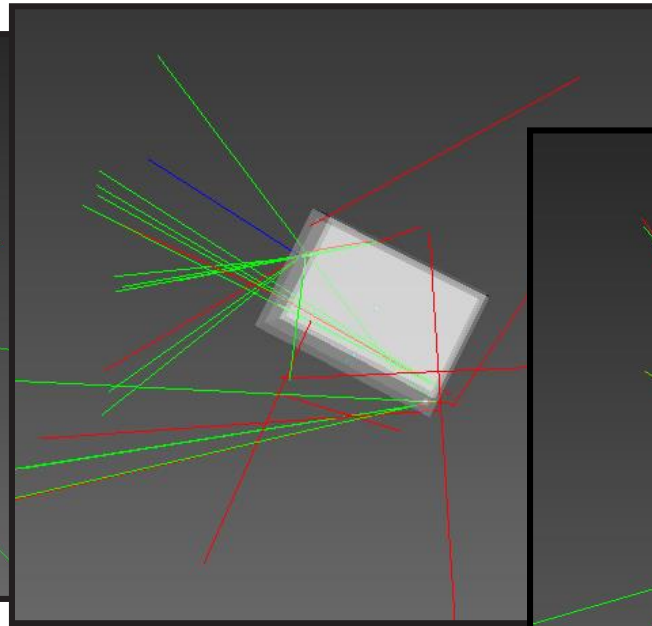
- Geometry
 - ✓ Is my GRAS simulation geometry correct (e.g. position of source & target volumes)?
 - ✓ MULASSIS 1D Vs GRAS 3D simulations! How do I compare these with SHIELDOSE(-2/2Q)?
 - ✓ How can I define my own material? Is there a way to define a mixture of gases?



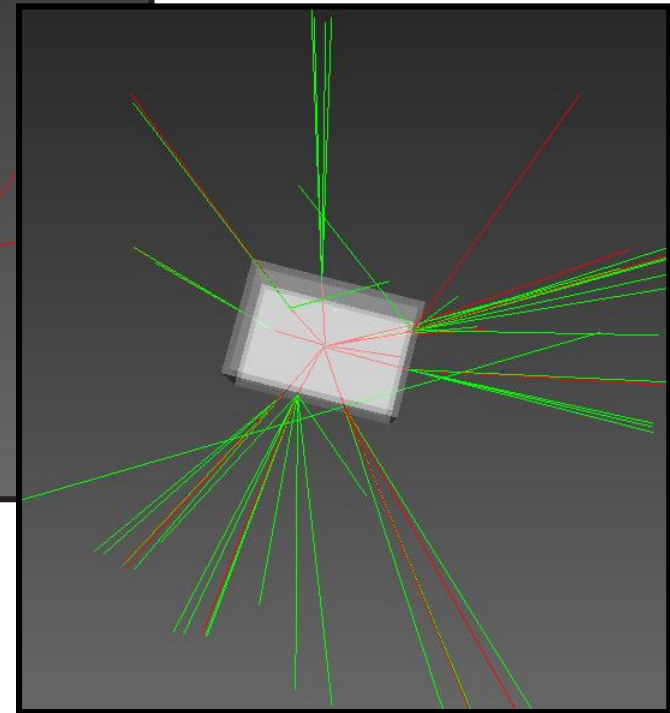
Commonly asked questions



Disk source of
20 mm radius



Spherical source
of 2 m radius



Spherical source
of 20 mm radius

All sources are positioned w.r.t world



Commonly asked questions

- Other simulation settings
 - ✓ How many primary particles should I choose (impact on my result e.g. dose, good statistics Vs heavy simulations)?
 - ✓ Is it possible to specify a maximum execution duration (SPENVIS links this to user CPU quota)?



Commonly asked questions

- Normalisation factor
 - ✓ What is its purpose in general?
 - ✓ How does SPENVIS calculate its normalisation factors for number of particles in the energy range & angular distribution?
 - ✓ Is there any difference in normalisation for SPENVIS based mission and user-defined spectra?



Commonly asked questions

- Geant4 tools output
 - ✓ Can you help me understand the output file (CSV structure, meaning of a specific result etc.)?
 - ✓ Is the result listed in the output file normalised?
 - ✓ How do I post-process some output e.g. convert the electron fluence/flux output of MULASSIS (i.e. binned spectrum) into a differential electron flux?



Commonly asked questions

- Local copy of Geant4 tools
 - ✓ How can I obtain a local copy of MULASSIS or GRAS?
 - ✓ When MULASSIS or GRAS code will be available for non-ESA member (mostly from US) users?



Users from ESA member countries can request the MULASSIS & GRAS source code from ESA's European Space Software Repository (<https://essr.esa.int/>)



Some user feedback

- Would be nice to have some well-tested cases for GRAS simulations to run through SPENVIS
- Update Geant4 tools (e.g. MULASSIS) for distinguishing between primary and secondary particles (e.g. Bremsstrahlung)
- Allow the definition of multiple sources in SPENVIS GPS tool



Some user feedback

- The execution report could be improved in some cases (e.g. warnings, error messages etc.)



Selected examples

- **A. Emmanuel et al.**, “A comparison of radiation shielding effectiveness of materials for highly elliptical orbits”, Adv. Space Res. 53 (7), 1143–1152, 2014
- **A. Emmanuel & J. Raghavan**, “Experimental validation of simulations of radiation shielding effectiveness of materials by MULASSIS” Adv. Space Res. 58, 2376–2384, 2016



Selected examples

- **W. Suparta & S. K. Zulkeple**, “Simulation of major space particles toward selected materials in a near-equatorial low earth orbit” *Astrophys Space Sci.*, 362, 104, 2017
 - SPENVIS space environment for RazakSAT-1 mission
 - Simplified 3D geometry (GDML format)
 - TID & NIEL calculations with GRAS
 - Comparison with MULASSIS simulations



Selected examples

- **M. L. Lund**, “High-performing Simulations of the Space Radiation Environment for the International Space Station and Apollo Missions”, MSc. in Nuclear Engineering, University of Utah, Salt Lake City, US, 2016
- **L. M. Martinez**, “Space Radiation Analysis: Radiation Effects and Particle Interaction outside Earth Magnetosphere using GRAS and GEANT4”, MSc. in Space Science and Technology, Luleå University of Technology, Kiruna, Sweden, 2009



Current status

- SPENVIS 4. 6.10 coupled to SPENVIS-NG
 - ✓ SPENVIS contains scripts to drive execution of models on SPENVIS-NG remote node
 - ✓ Used for IRENE v1.50, GRAS v4.0 & MULASSIS v1.26
- Migrating SPENVIS to a new machine (SLES 15)



Future plans

- Follow-up SPENVIS project for improving the system:
 - ✓ Redesign the existing SPENVIS front-end to improve user experience
 - ✓ Refactor existing models to increase flexibility (e.g. different models for individual trajectory segments)
 - ✓ Implement new models (e.g. IRI -2016, ATOX effects, FLUMIC updates etc.)



Closing remarks

- Some Geant4 tools are important for many SPENVIS users
- SPENVIS team will continue supporting the users & model developers
- Interaction with Geant4 model developers and expert users is always welcome (new physics lists, reverse MC, etc.)



**THANK YOU!
MORE INFO?**



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