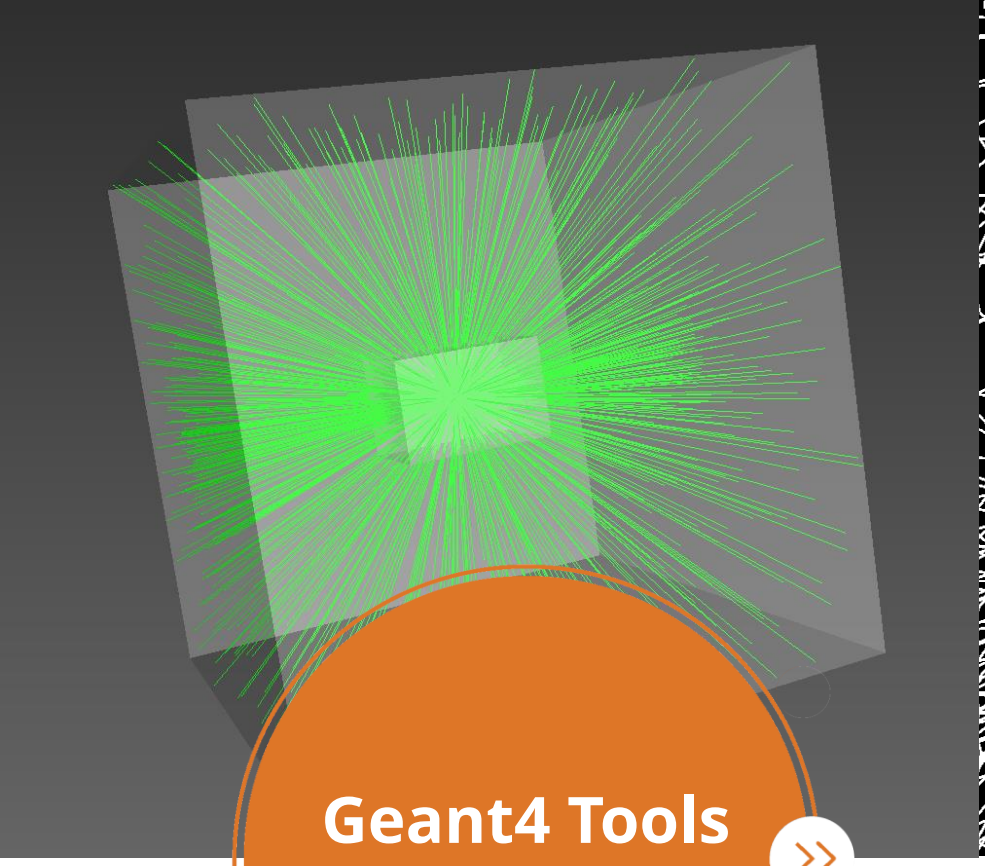
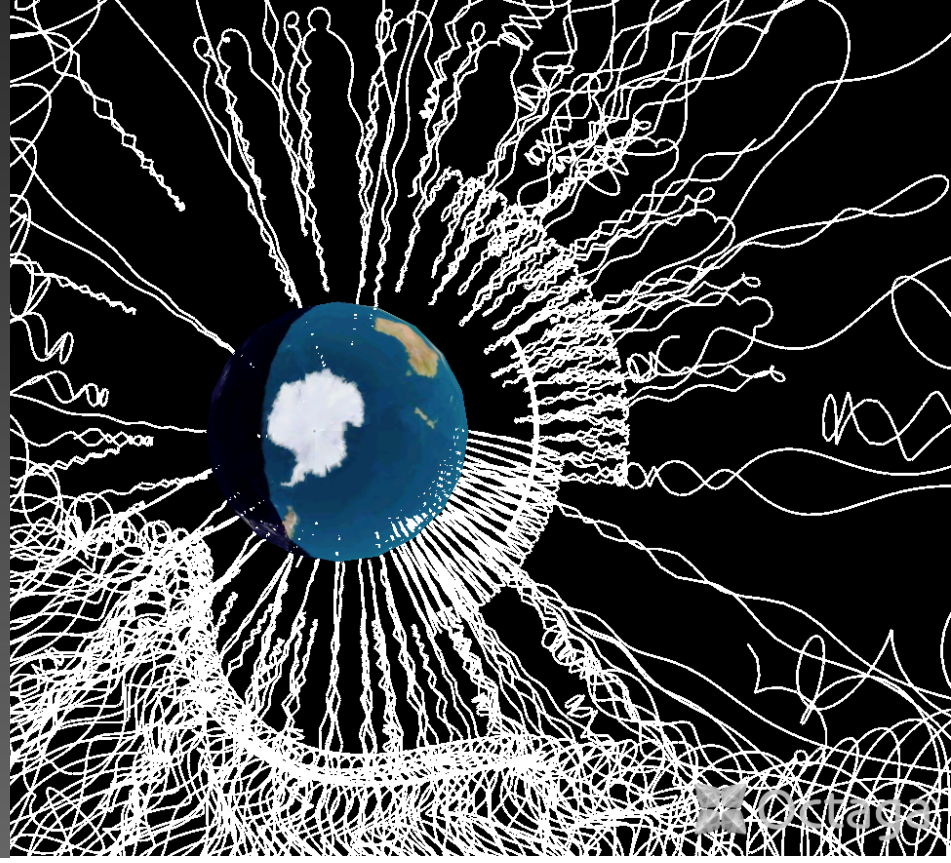




Geant4 Tools in SPENVIS

A User Perspective

Neophytos Messios

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

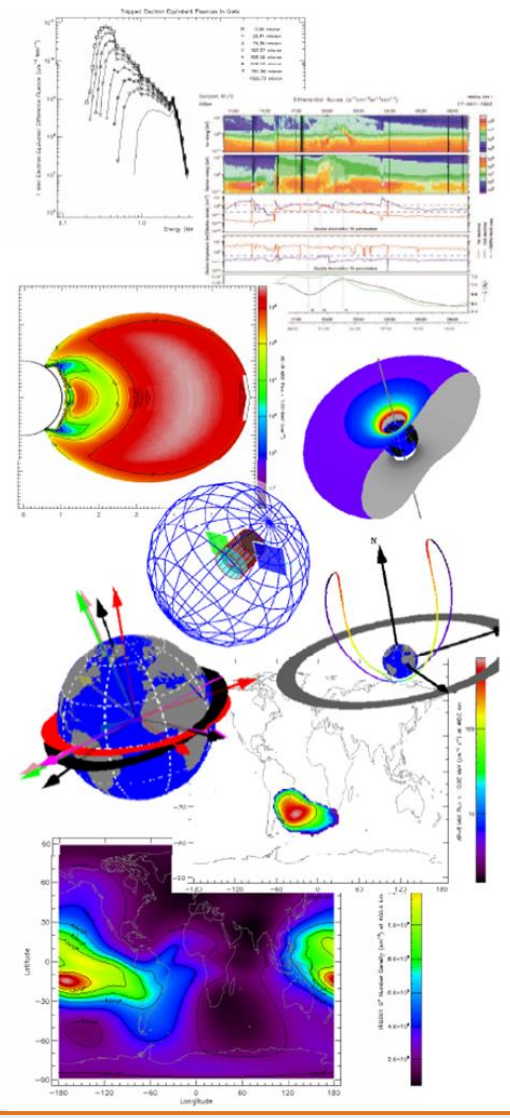
Royal Belgian Institute for Space Aeronomy

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

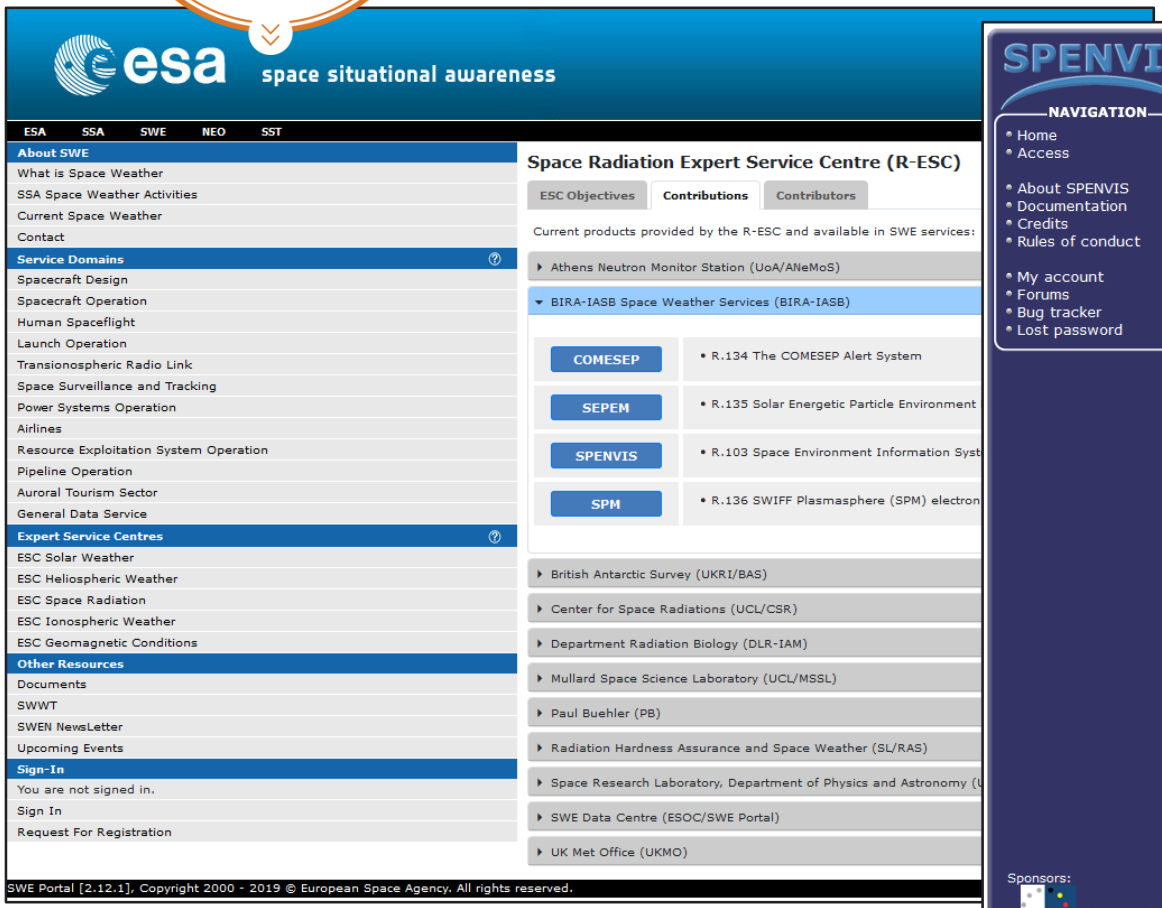
The ESA's SPENVIS system

- 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



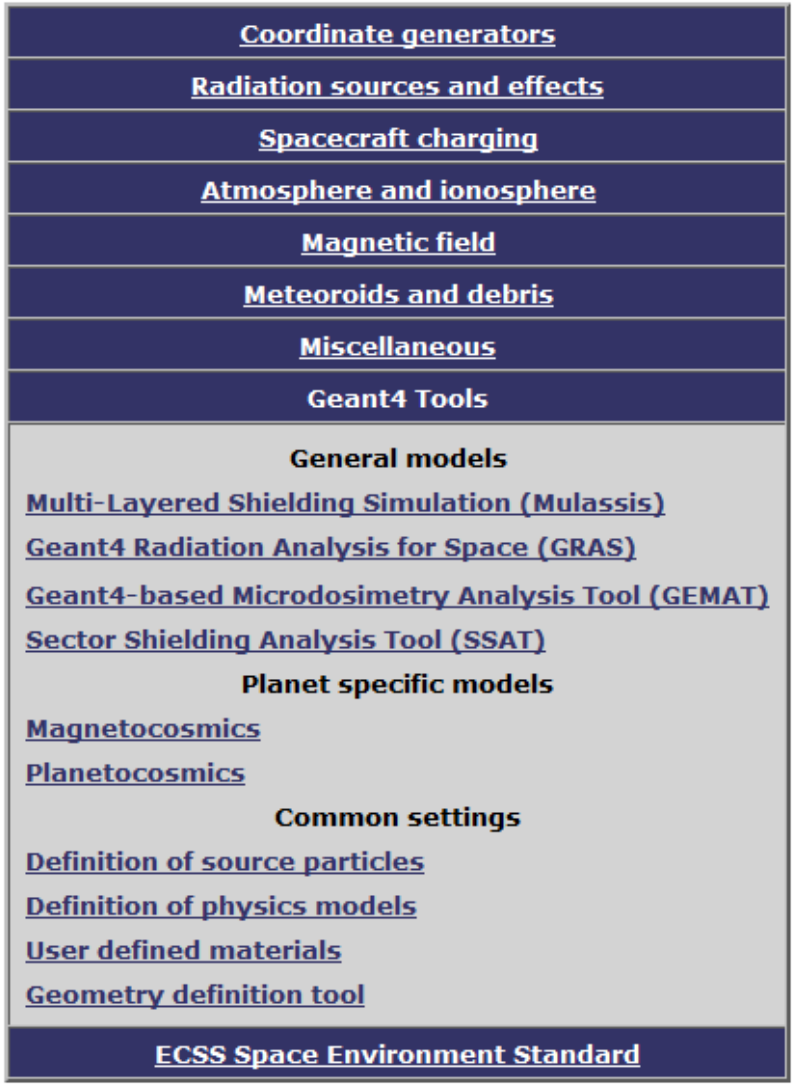
http://swe.ssa.esa.int

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



Geant4 tools in SPENVIS

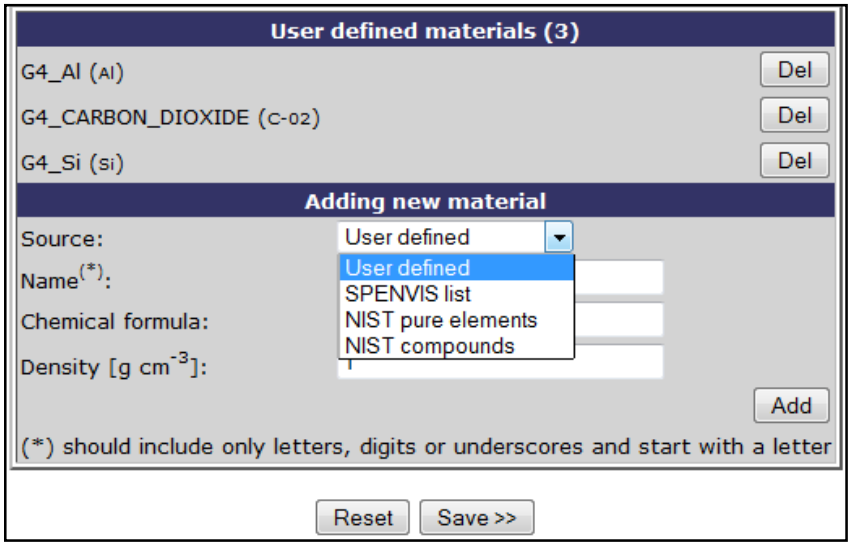
Tool name	Tool version	Geant4 version	Description
GRAS	4.0 3.1	4.10.1p3 4.9.5p02	The Geant4 Radiation Analysis for Space tool performs general space radiation studies for complex 3D geometry models
MULASSIS	1.26 1.23	4.10.1p3 4.9.5p02	The Multi-Layered Shielding Simulation Software can simulate the particle 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

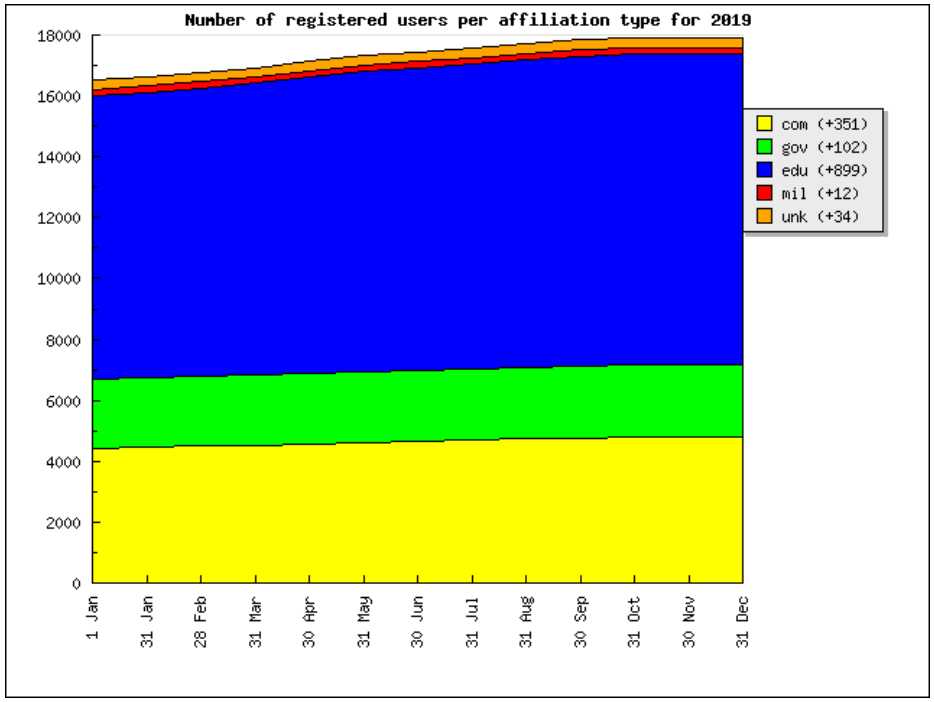
- Mission-based General Particle Source (GPS) macros
- Simple GDML geometry definition tool
- GDML upload & analysis tool
- Material definition tool
  - ✓ User defined materials
  - ✓ Selection from predefined lists
  - ✓ Available for MULASSIS, GRAS, GEMAT & PLANETOCOSMICS

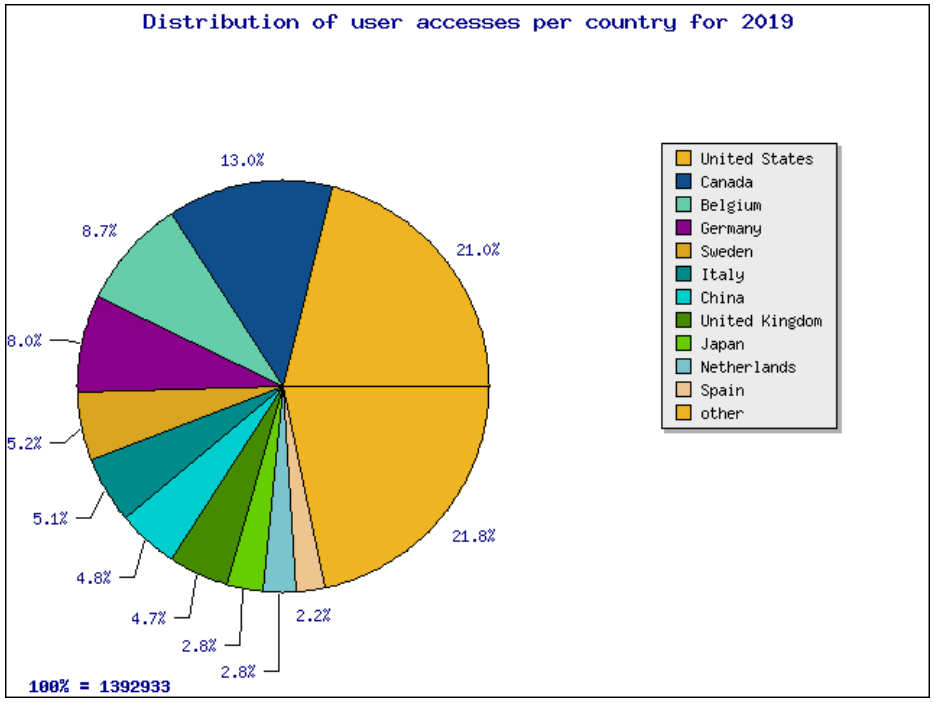


The SPENVIS users' profile

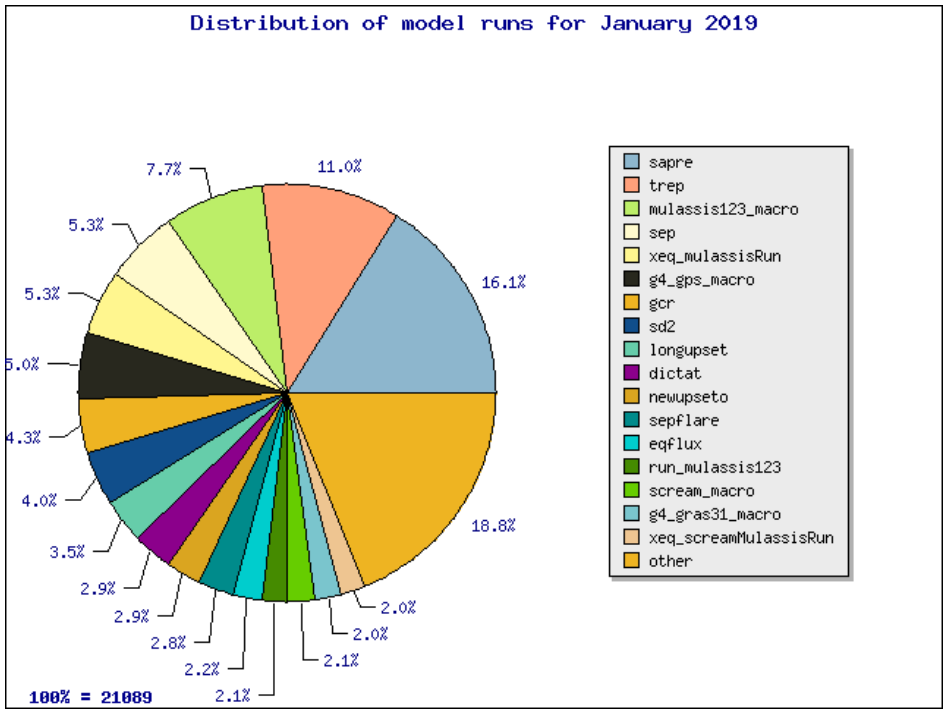
- Both experienced & inexperienced Geant4 users access SPENVIS to:
  - ✓ Characterise the space environment e.g. get mission average particle fluxes/fluences
  - ✓ Set up and run full simulations with available Geant4 tools (e.g. MULASSIS, GRAS, etc.)

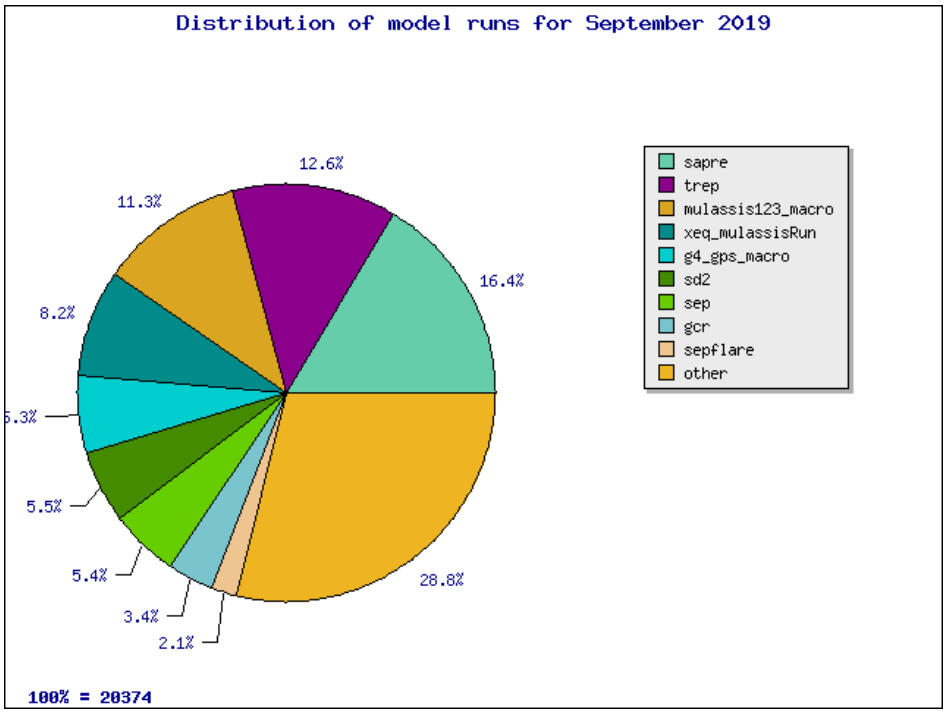
Some SPENVIS user statistics





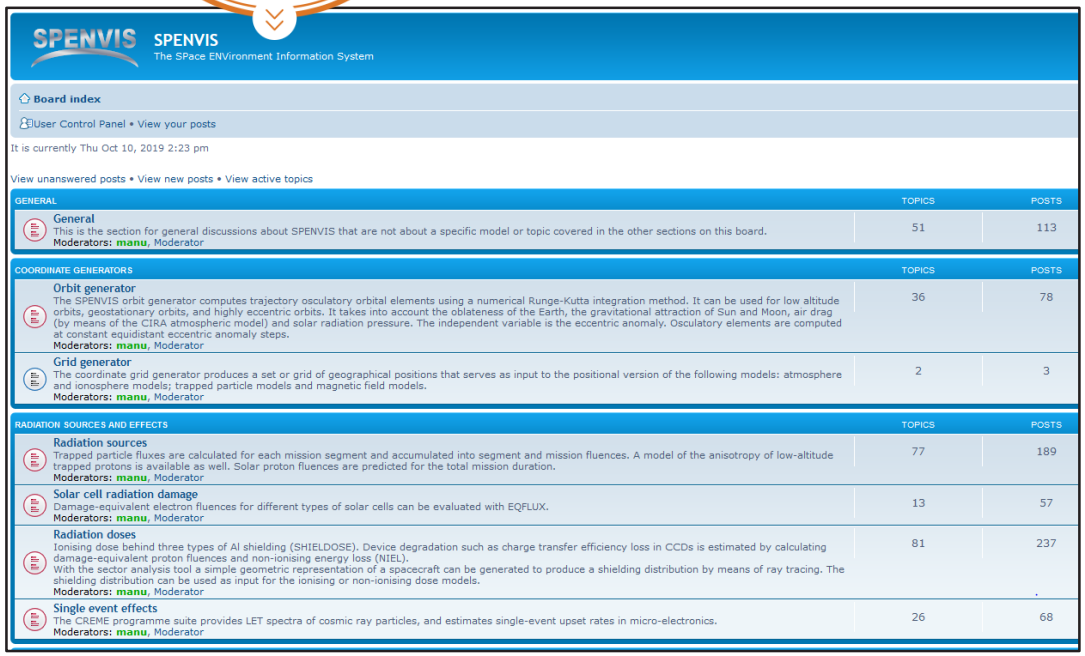
Some SPENVIS model statistics

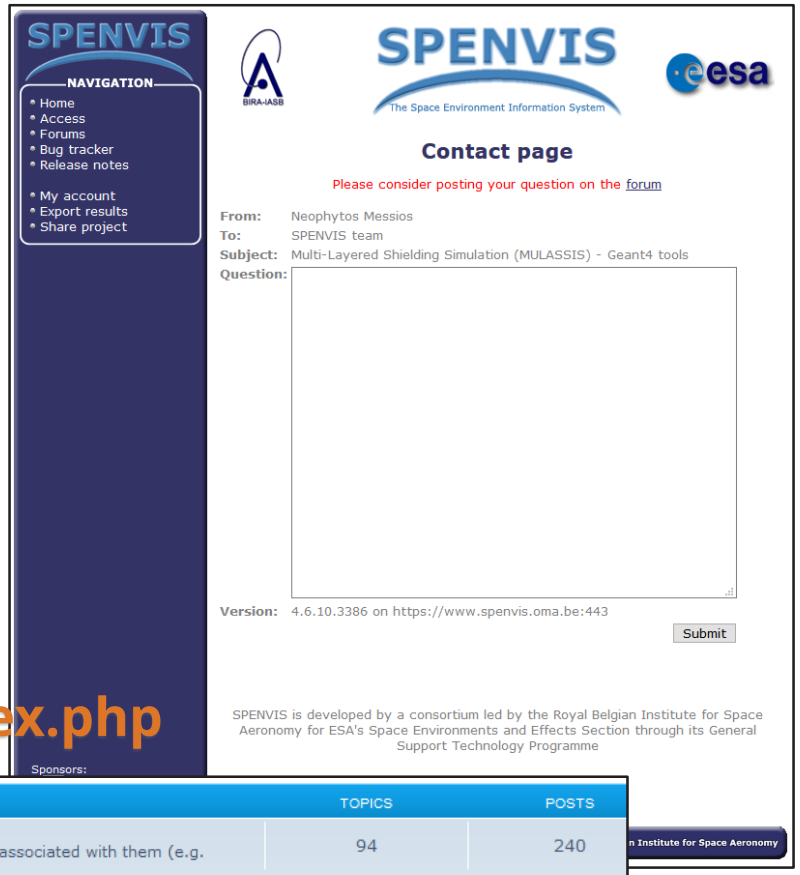




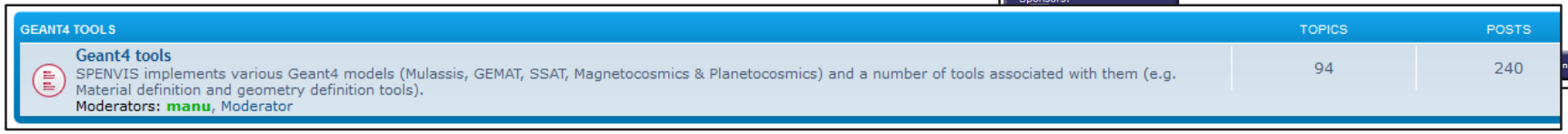
SPENVIS user support

Contact SPENVIS team: spenvis_team@aeronomie.be





SPENVIS forums: https://www.spenvis.oma.be/forum/index.php



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

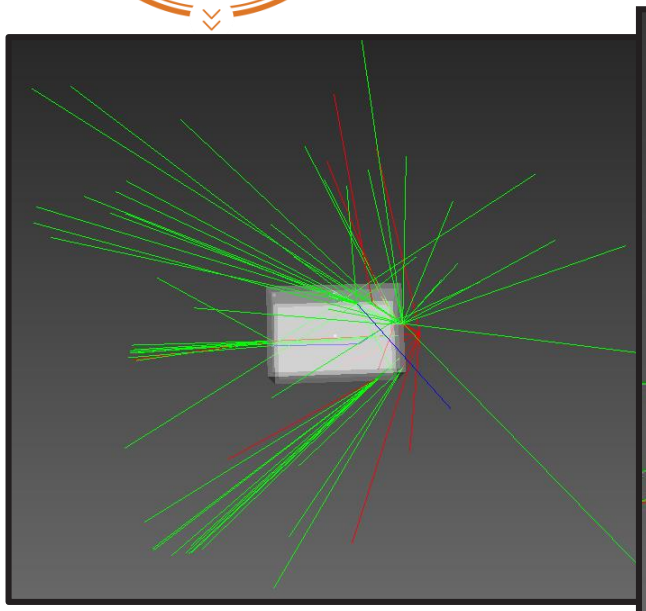
- Physical processes
  - ✓ Which Geant4 physics list should I use?
  - ✓ How can I use a specific physics model (e.g. High Precision Neutron Model)?
  - ✓ Is there available documentation that explains the different physics lists?

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).

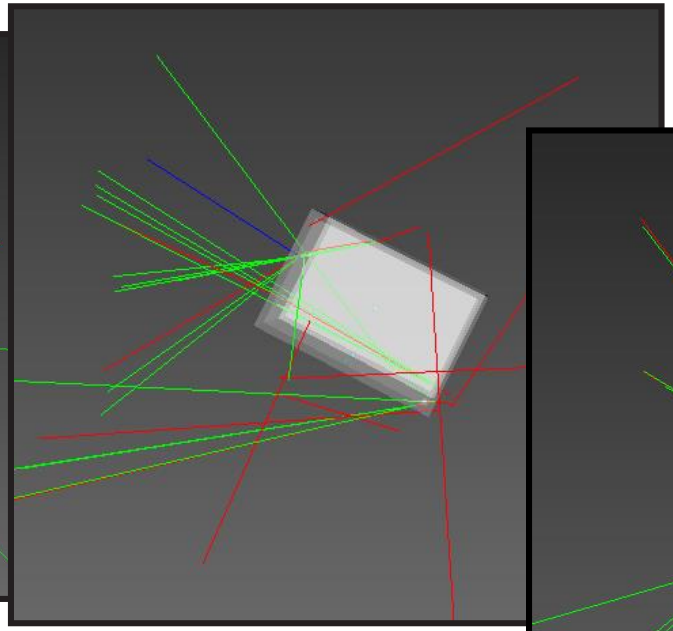
Commonly asked questions

- 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?

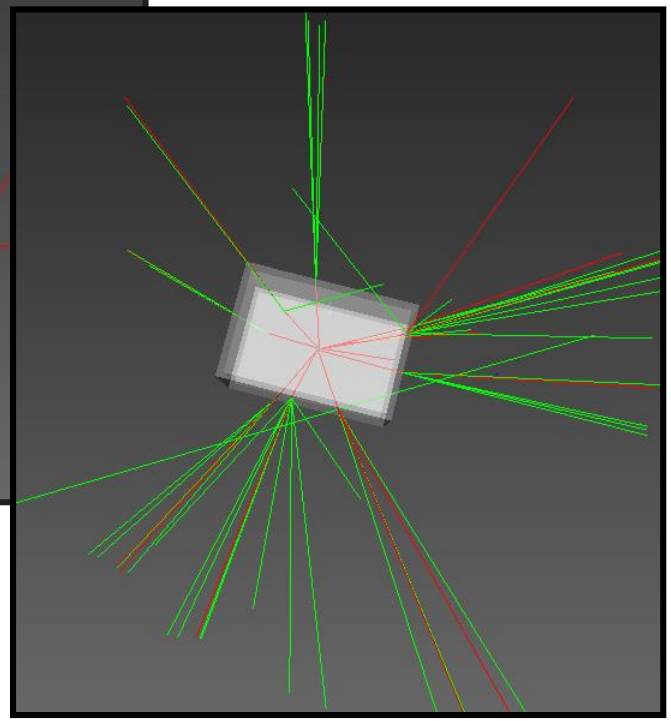
Commonly asked questions



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 it its purpose in general?
  - ✓ How does SPENVIS calculates 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. Bremmstrahlung)
- 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

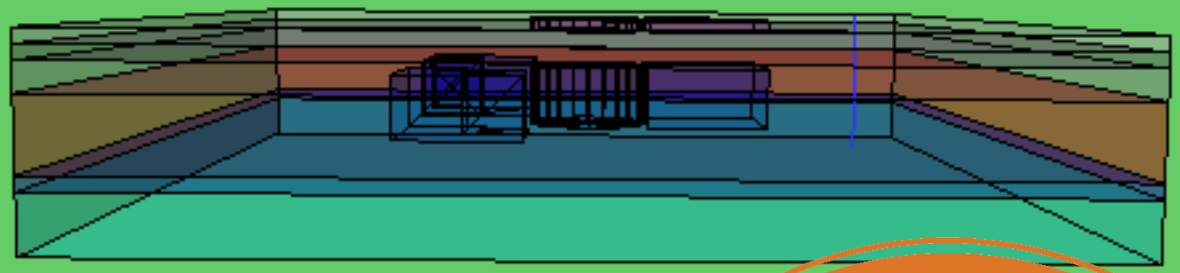
- Migrating SPENVIS to a new machine (SLES 15)

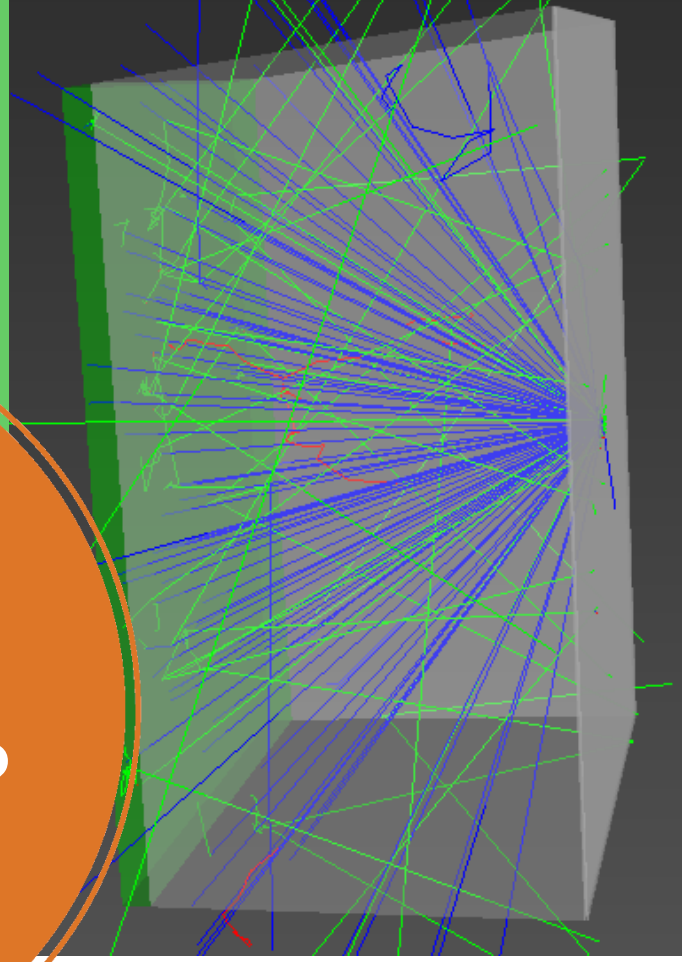
Future plans

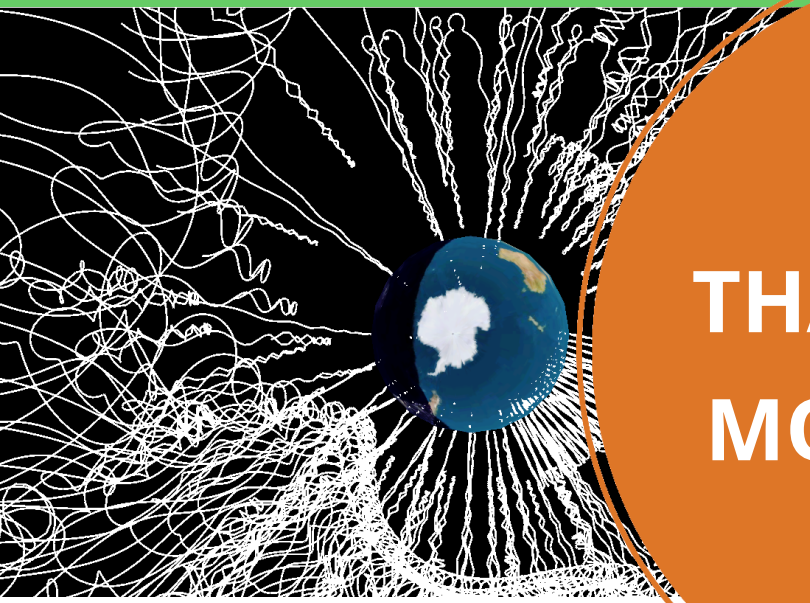
- Follow-up SPENVIS project for improving the system:
  - ✓ Redesign the existing SPENVIS front-end to improve user experience
  - ✓ Refactor existing models to increase flexibility (e.g. different models for individual trajectory segments)
  - ✓ Implement new models (e.g. IRI -2016, ATOX effects, FLUMIC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

spenvis_team@aeronomie.be

Neophytos.Messios@aeronomie.be