

# Using SPENVIS within Space Mission Operations

**Alexi Glover**

*ESA SSA Programme-Space Weather Segment  
ESA-ESAC, Madrid, Spain (RHEA System SA)*

**On behalf of**

**Gareth Lawrence and Simon Reid**

*Rhea System SA, Louvain-la-Neuve, B-1348, Belgium*

**Michel Kruglanski**

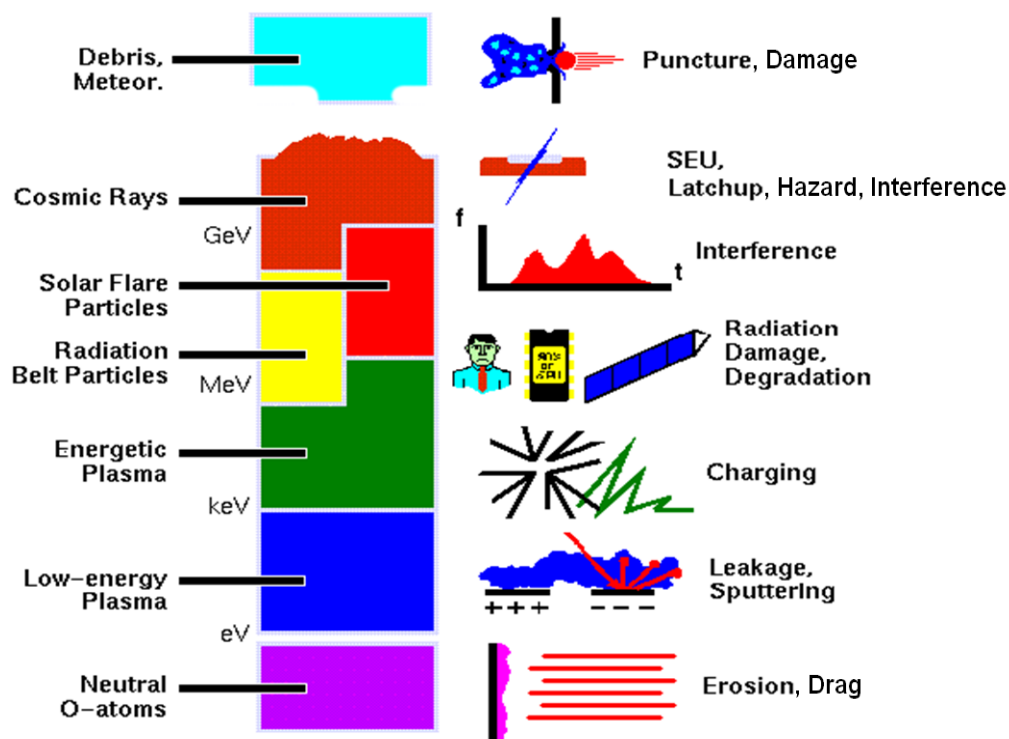
*Belgian Institute for Space Aeronomy, Uccle, B-1180, Belgium*

*Supporting material courtesy **Eamonn Daly** (ESA-ESTEC)*



# Space Environments Effects: Project Support

## Overview of Space Environment



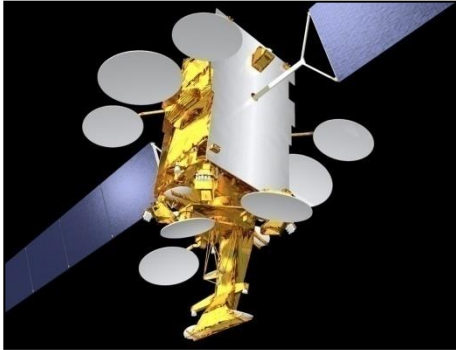
## Evaluation of space environments and effects

- Starts pre-phase A
  - Environment specifications
  - Tailoring of standards
  - Concurrent Design
- More detailed support in later phases
- In-orbit behaviour evaluations

## Supporting activities

- R&D
- Standardisation
- Collaboration

# Commercial, Applications & Earth Obs Missions



## **Telecommunications** spacecraft in GEO:

- environment dominated by energetic  $e^-$  of the outer radiation belt;
- High lifetime dose

## Low altitude constellations (e.g. Globalstar at 1400km)

- Mixed environment; High lifetime dose



## **Earth observation** and Earth science:

- "sun-synchronous" polar orbit  $\sim 600$ -900 km; Mixed environment
- Many ESA Earth Science and "Sentinel" projects

## **Navigation** systems

- medium altitude, highly inclined, circular orbits.
- Galileo at  $\sim 25000$ km and  $\sim 55^\circ$  incl.  $\rightarrow$  heart of the radiation belts.

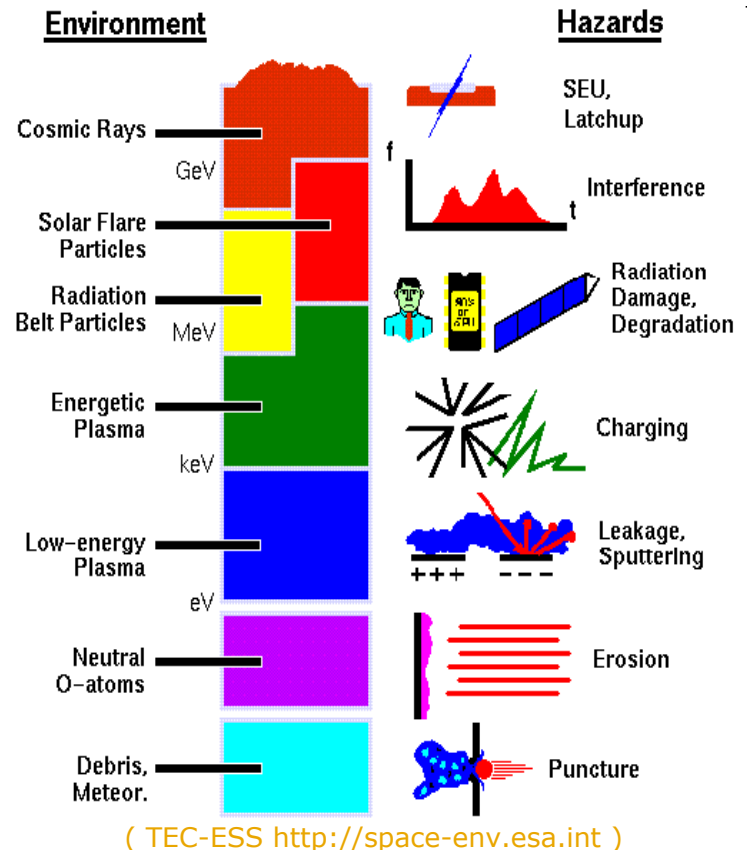
## **Trends** have major radiation implications:

- $\uparrow$  complexity of on-board systems;
- $\uparrow$  spacecraft size in GEO;
- $\uparrow$  power in GEO  $\rightarrow$  large lightweight solar arrays,
- $\downarrow$  procurement costs;
- minimization of operations;
- $\uparrow$  on-board processing;
- long-term reliability;
- extensive use of commercial off-the-shelf components (COTS):
  - $\downarrow$  radiation hard or poorly characterized
  - $\uparrow$  on-chip complexity.



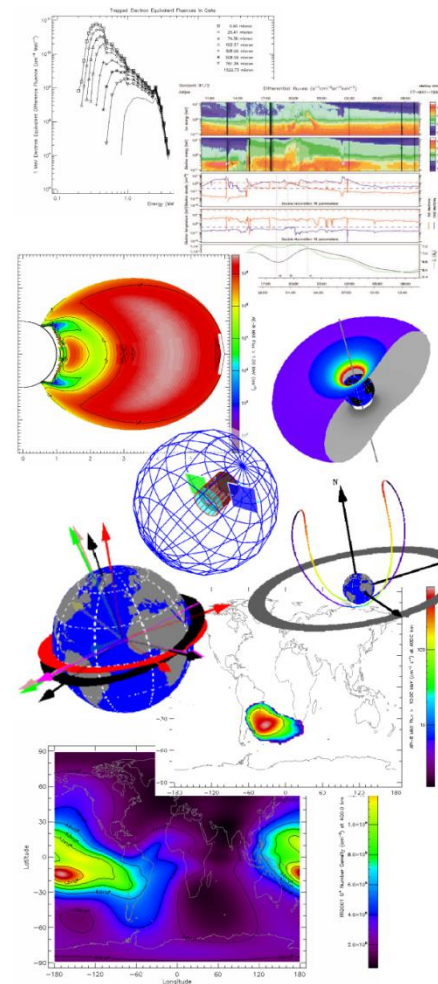
# SPENVIS in short

- ESA operational software
  - developed and maintained at BIRA-IASB from 1996
  - Support through ESA GSTP programme
  - H Evans TEC-EES, ESA responsible
- User-friendly human interface to models of the space environment and its effects
  - web interface, default values, contextual help, user workspace (inputs, outputs), reports, graphical utilities,...
- Allows rapid analysis of
  - cosmic rays
  - solar energetic particles
  - natural radiation belts
  - magnetic fields
  - space plasmas
  - upper atmosphere
  - meteoroids and debris

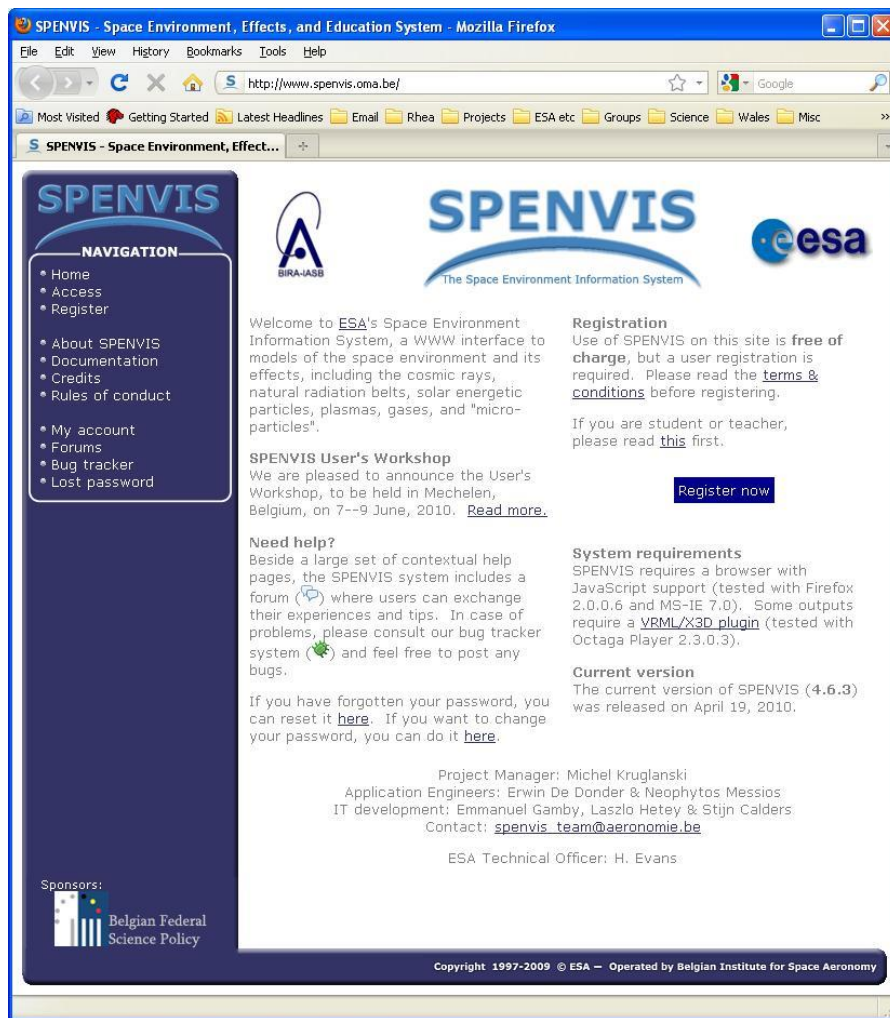


# SPENVIS Overview

- Tour of SPENVIS models  
(including focus on new and upcoming items)
  - Coordinate generators
  - Space environment
  - Environment effects
- Geant4-based tools (GRAS, Mulassis, GEMAT)
- Current developments
  - Planetary environment
  - Third party development toolkit
  - On-line help; user forum; bug-tracker
- Conclusions



# SPENVIS: Space Environment Information System



www.spenvis.oma.be



# Introduction > How to start?

1. Create an account → Register
2. Login in → Access
3. Create a new project (user workspace)
4. “Coordinate generators”

A screenshot of the "Project management" web interface in a Mozilla Firefox browser. The browser address bar shows "http://localhost/spenvis/htbin/spenvis.exe/FIRST?%23resettoPrevious(project.html)". The page has a dark blue header with "Project management" and "Create a new project" in white. There are "UP", "Output", and "Help" buttons. Below the header is a "Project action" section with a list of actions: create new project (selected), switch to another project, delete project(s), zip and download project(s), change current project settings, and delete current project results. Below this is a "Project name" field with "g4suw" and a "Project title" field with "Geant4 Space Users Workshop". There is a "Project abstract" section with a text area containing "How to start ?". At the bottom, there is an "Import model parameters from another project:" dropdown menu set to "no import" and an "Execute" button.A screenshot of the "Model packages" web interface in a Mozilla Firefox browser. The browser address bar shows "http://localhost/spenvis/htbin/spenvis.exe/FIRST". The page has a dark blue header with "SPENVIS DEVELOPER Project: G4SUW" and "Model packages" in white. There are "UP", "Output", and "Help" buttons. Below the header is a list of model packages: Coordinate generators, Radiation sources and effects, Spacecraft charging, Atmosphere and ionosphere, Magnetic field, Meteoroids and debris, Data base queries, Miscellaneous, and ECSS Space Environment Standard. Below the list, there is a paragraph of text explaining the models implemented in SPENVIS and how they are combined in the packages listed above. It mentions that clicking on a package name will expand the table with a list of models and that some model suites have to be executed in a prescribed order. It also mentions that most models run on both a spacecraft trajectory and a geographical coordinate grid. Below this paragraph is another paragraph explaining that the model pages have deliberately been kept as concise as possible and that a navigation bar is figured at the top of each SPENVIS page. It mentions that the "Help" link in the bottom right hand corner of this bar points to context sensitive help pages, which in turn contain their own navigation system, including access to guidelines on model usage and background information on the space environment. Below this paragraph is a final paragraph asking users not to use their browser's Back or Forward buttons (except for navigating in the help pages) and to contact the SPENVIS team for additional assistance.

# Coordinate generators

- Coordinate grid
- Spacecraft trajectories
  - Next Release → other trajectories (hyperbolic, user upload)

Orbit generator: Mission definition - Mozilla Firefox  
http://localhost/spenvis/htbin/spenvis.exe/G4SUW

**SPENVIS DEVELOPER Project: G4SUW**  
Orbit generator  
Mission definition (Earth)

UP Output Help

Trajectory generation: use orbit generator  
Number of mission segments: use orbit generator  
Mission end: total mission duration  
Mission duration: 3.0 years  
Satellite orientation: one axis parallel to the velocity vector  
Account for solar radiation pressure: no  
Account for atmospheric drag: no

Reset Next >>

Tool developed by

esa ESOC

© BIRA-IASB

Orbit generator: Parameters for segment NULL - Mozilla Firefox  
http://localhost/spenvis/htbin/spenvis.exe/G4SUW

**SPENVIS DEVELOPER Project: G4SUW**  
Orbit generator  
Parameters for segment 1

UP Output Help

Segment title: first segment

Orbit type: general  
Orbit speed: general  
19 May 2000  
Representative: heliosynchronous  
near Earth interplanetary  
two-line elements

Altitude specification: perigee and apogee altitudes  
Perigee altitude [km]: 300  
Apogee altitude [km]: 36000

Inclination [deg]: 0.0  
R. asc. of asc. node [deg w.r.t. gamma50]: 0  
Argument of perigee [deg]: 0  
True anomaly [deg]: 0

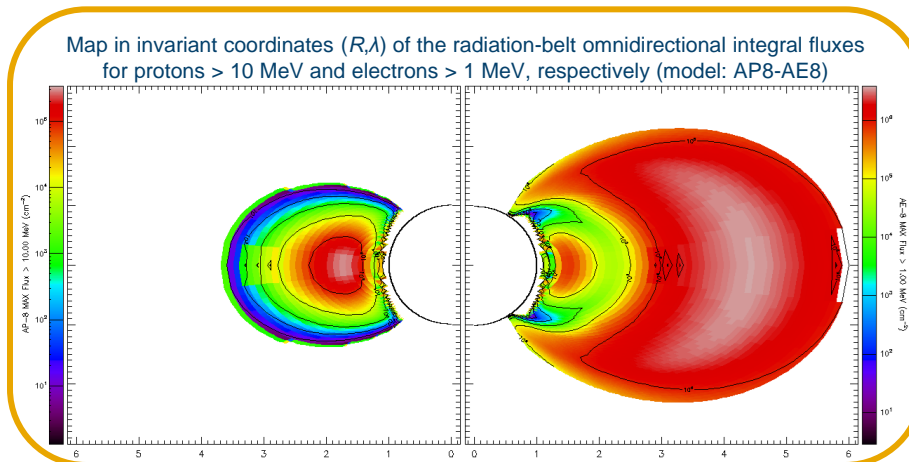
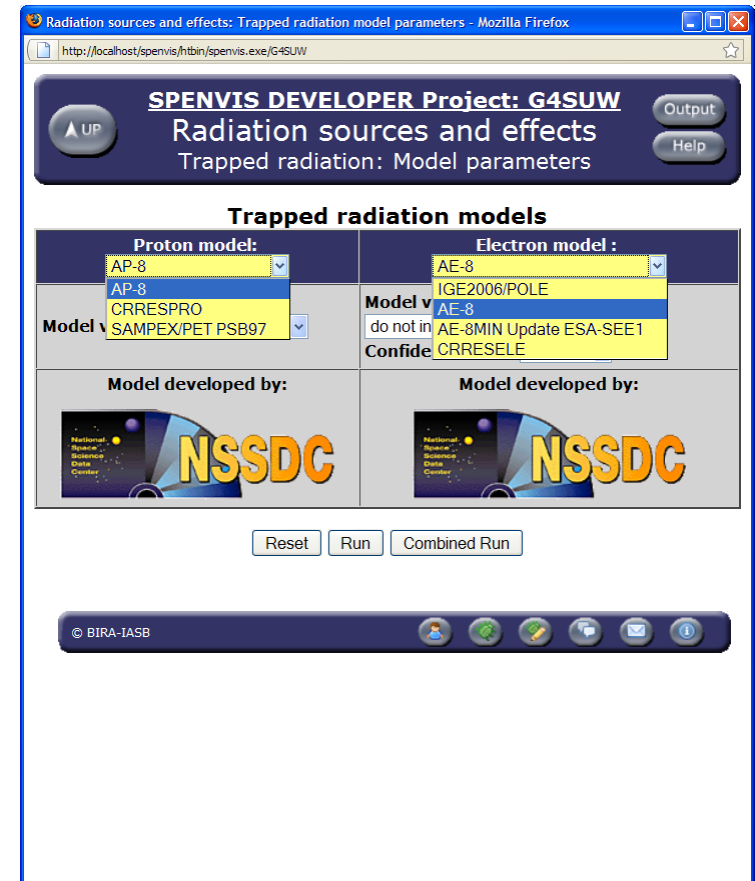
Output resolution

1.	60.0	s below	20000.0	km
2.	240.0	s below	80000.0	km
3.	3600.0	s elsewhere		

<< Back Next >>

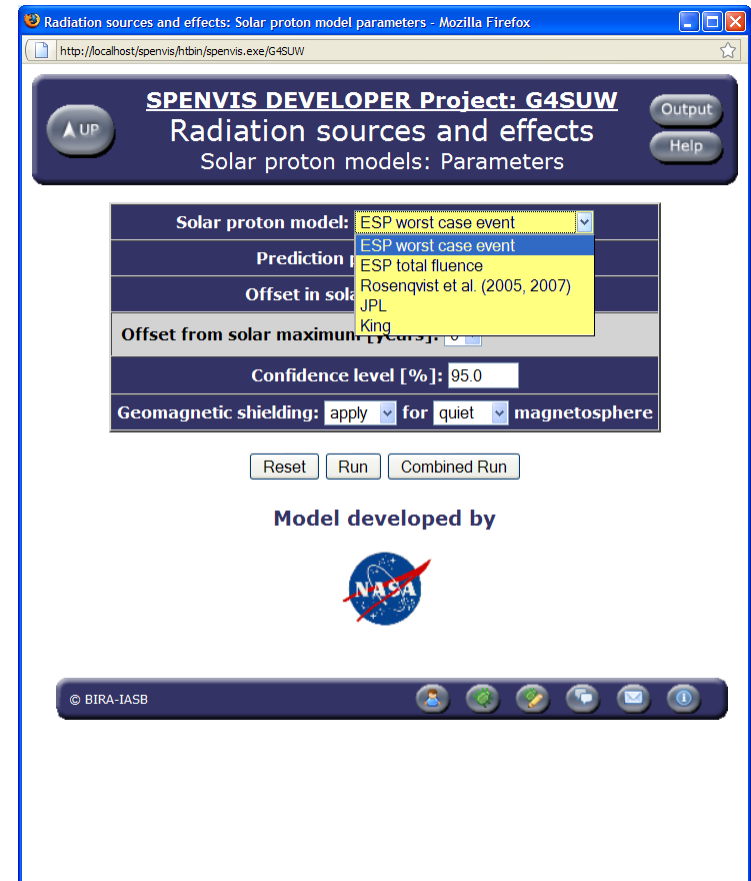
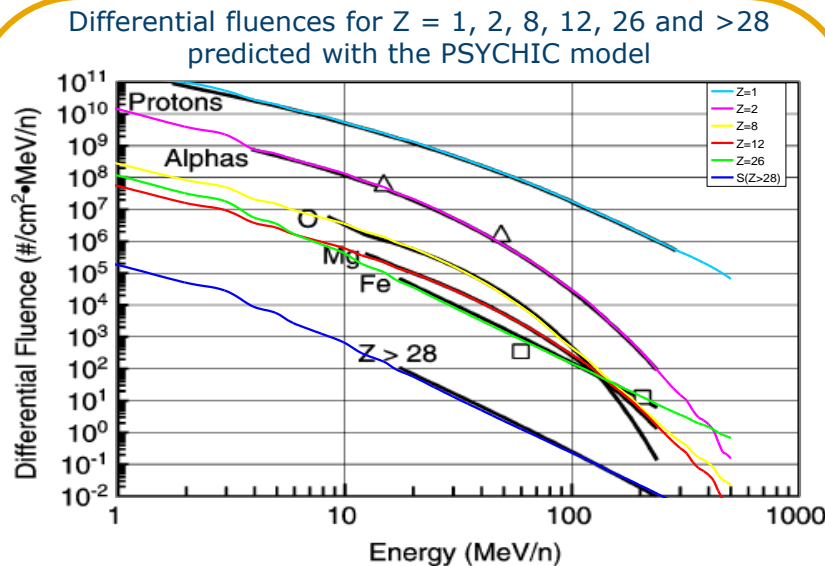
# > Space environment > Radiation belts

- Trapped electron/proton fluxes along spacecraft trajectories or maps (coordinate grids)
- new → IGE2006/POLE (e<sup>-</sup> geostationary orbit)
- new → Sampex/PET (p<sup>+</sup> low altitudes)
- next → Jovian models (Divine and Garret, JIRE, ONERA/Salammbô)



# > Space environment > Solar Energetic Particles

- new → Particle fluence
- new → PSYCHIC incl. ions  
(Xapsos et al. 2007)



# > Space environment > GCR

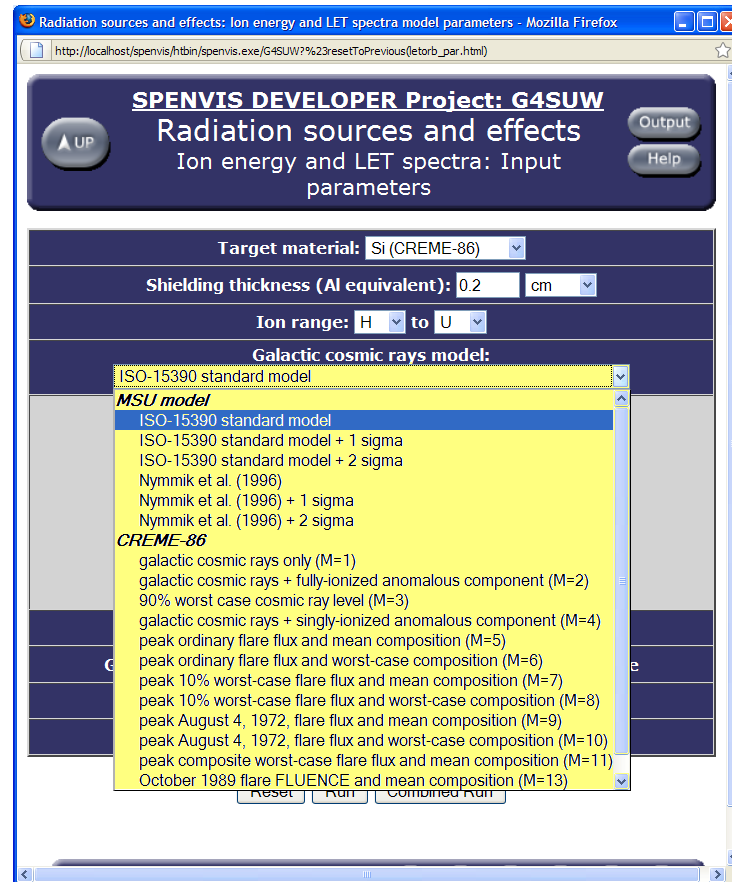
## Cosmic rays

(inside LET spectrum model)

- new → ISO-15390
- new → Nymmik et al 1996

## SEP & GCR > Magnetic shielding

- Størmer approach (= dipole)
- new → Upgrade based on Magnetocosmics

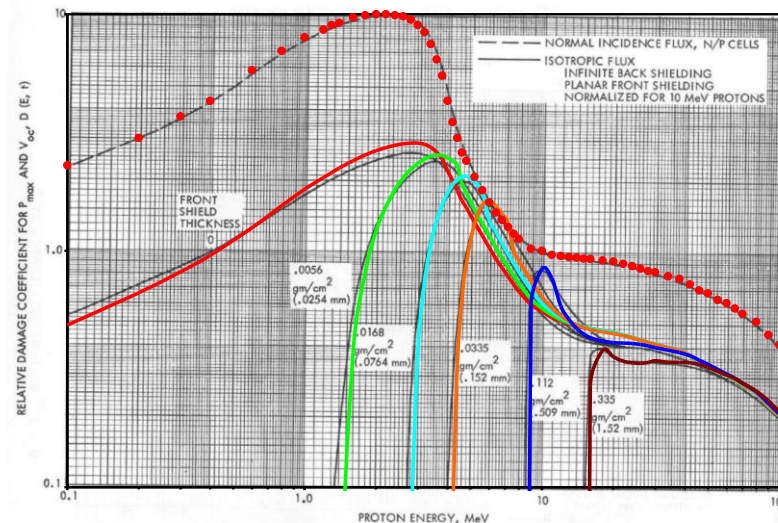
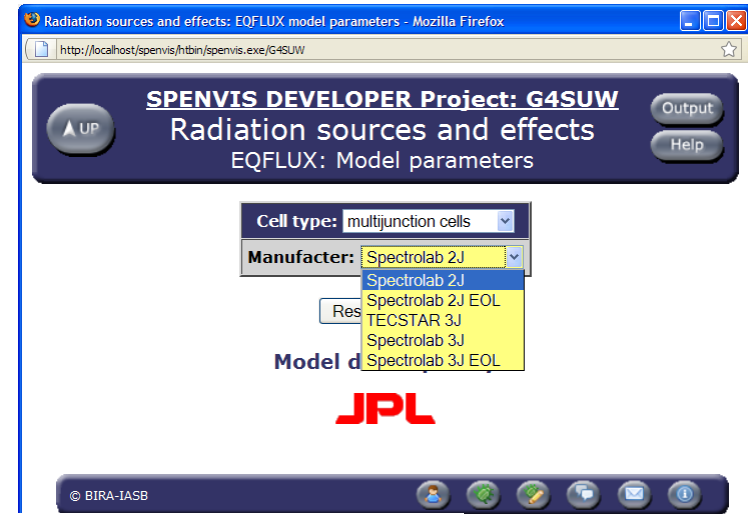


# > Environment effects > Solar cell

## Solar cell damage equivalent fluences

← trapped  $e^-$ , trapped & solar  $p^+$

- new → RDC (Relative Damage Coefficient)  
converter Tada et al. (1982)  
Input= uncovered unidirectional RDC  
Output= covered omnidirectional RDC
- next → additional RDC data  
(Emcore, Azur solar cells)
- new → NIEL-based degradation  
calculations (MC-SCREAM)

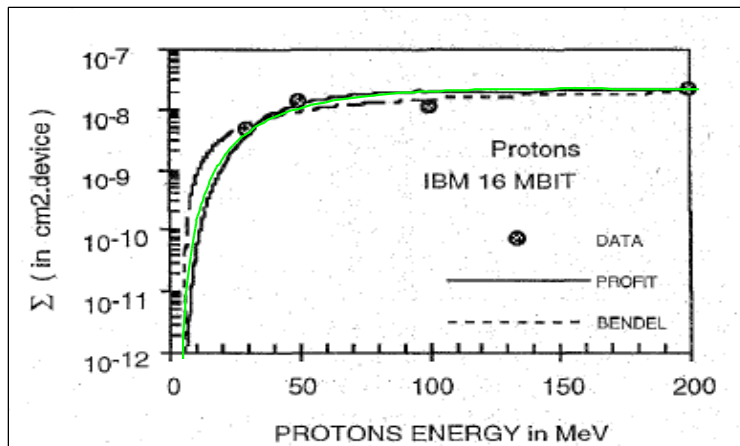


# > Environment effects > SEU

## Single Event Upset

← LET spectra ← trapped  $p^+$  & GCR

- new → GaAs device
- new → Profit algorithm  
Multiple devices  
Path length distr.



- next → Upgrade of  
slowing/stopping ions

Radiation sources and effects: SEU rate model parameters - Mozilla Firefox

http://localhost/spenvis/htbin/spenvis.exe/G4SUW?%23resetToPrevious(upseto\_par.html)

**SPENVIS DEVELOPER Project: G4SUW**

Radiation sources and effects

SEU rates: Input parameters

Output

Help

**Direct ionisation upset rates**

**Sensitive volume**

Material: Silicon (Si)

Dimension [μm]: 38.7 x 38.7

x 2.0

**Cross-section method:**

critical charge

Critical charge [pC]: critical charge

Weibull function

experimental data

**Proton induced upset rates**

**Cross-section method:** Bendel function

A [MeV]: Bendel data fit

B [MeV]: Weibull function

σ<sub>lim</sub> [cm²/bit]: 1.87E-10

Reset Run Combined Run

Model developed by

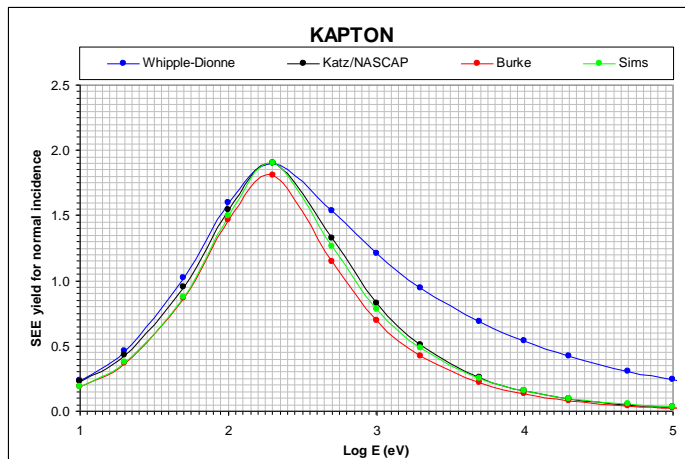
BIRA-IASB

# > Environment effects > Charging

## Surface charging

← space plasma

- new → Burke's equation (1980)  
(secondary electron emission)



- new → auroral environment  
(Davis & Duncan, 1992)

## Deep dielectric charging

← trapped  $e^-$

- new → DICTAT v3

Spacecraft charging: EQUIPOT parameters - Mozilla Firefox

http://localhost/spenvis/htbin/spenvis.exe/G4SUW

### SPENVIS DEVELOPER Project: G4SUW

Spacecraft charging  
EQUIPOT parameters

UP

Output  
Help

#### Spacecraft environment

Spacecraft is in:

Incident distribution:

Environment type:

Ram/wake effects:

Environment specification:

Material parameters. Caution: the default values for the material parameters are given for reference only. The results of the simulation critically depend on the values of the input parameters.

Structure:	Patch:
<input type="text" value="aluminium"/>	<input type="text" value="Kapton"/>
Atomic number: <input type="text" value="13"/>	Relative permittivity: <input type="text" value="3"/>
Photoelectric current [A m <sup>-2</sup> ]: <input type="text" value="4.0E-5"/>	Thickness [m]: <input type="text" value="2.5E-5"/>
SEE yield for 1 keV protons: <input type="text" value="0.244"/>	Conductivity [ohm <sup>-1</sup> m <sup>-1</sup> ]: <input type="text" value="1.0E-15"/>
Proton energy for maximum SEE yield [keV]: <input type="text" value="230"/>	Atomic number: <input type="text" value="5"/>
SEE formula: <input type="text" value="Katz"/>	Photoelectric current [A m <sup>-2</sup> ]: <input type="text" value="2.0E-5"/>
Maximum SEE yield for electrons: <input type="text" value="0.97"/>	SEE yield for 1 keV protons: <input type="text" value="0.455"/>
Electron energy for	Proton energy for maximum SEE yield [keV]: <input type="text" value="140"/>



- Geant4 Library Developed by the Geant4 Collaboration, members include CERN, SLAC, ESA, ...
- Physics-based and semi-empirical
- Study interactions of Radiation and Matter at all scales and energies
- Subset relevant to Space Science optimised to reflect nature of problem:
  - Omni-directional radiation
  - Specific species ( $e^-$ ,  $p^+$ , He ions, heavier ions etc ...)
  - Materials commonly used
  - Typical geometries
  - Shielding
- Applications (Mulassis, SSAT, GEMAT) fully integrated within SPENVIS (user friendly!)

# Current developments



## Geant4-based tools

### New Applications

new → Magnetocosmics  
Planetocosmics  
MC-SCREAM  
GRAS (later)

### Existing Applications

now → GEMAT, Mulassis, SSAT

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

# User Support: Bug Tracker

New → Tool bar:

- Tracking of issues reported by users (bug, feature,...)

0000058: SHIELDSE returns zeroes when given only one thickness - SPENVIS Bug Tracker - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://dev.spennis.oma.be/tracker/view.php?id=58

spennis-tracker

Logged in as: michel (Michel Kruglanski - developer) 2009-05-18 19:03 CEST

My View | View Issues | Report Issue | SPENVIS | Forum | Other | Help

Recently Visited: 0000058, 0000052

Search: [ ] Apply Filter [ ]

Reset Filter [ ] Save Current Filter [ ]

Viewing Issue Simple Details [ Jump to Notes ] [ >> ] [ Issue ]

ID	Category	Severity	Reproducibility	Date Submitted	Reporter	Assigned To	Priority	Resolution	Status	Product Version
0000058	[SPENVIS] Package: Radiation Doses	minor	always	2009-05-15 21:12	Christopher Dieck	Michel Kruglanski	normal	fixed	resolved	4.6

Reporter: Christopher Dieck View Status public

Assigned To: Michel Kruglanski

Priority: normal Resolution: fixed

Status: resolved Product Version: 4.6

Summary: 0000058: SHIELDSE returns zeroes when given only one thickness

Description: In SHIELDSE and SHIELDSE-2, when including only one value in the user input table of values, the output regardless of the value of the single input, is 0.00 for all calculated columns.

Additional Information: The problem only appears in the case of the "solid sphere" geometry for which the both models require at least two thicknesses (the spherical results are derived from the planar results). The problem has been fixed by adding some thicknesses to the user values. These additional values are not model outputs. See note for an example how the results are affected by the number of thicknesses.

Tags: No tags attached.

Attach Tags: (Separate by ',') [ ] Existing tags [v] Attach [ ]

Attached Files: [ ]

Change Status To: new [v] Reopen Issue [ ]

Relationships: [ ]

There are no users monitoring this issue.

Find: neop [ ] Next [v] Previous [v] Highlight all [ ] Match case [ ]



View Issues - SPENVIS Bug Tracker - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://dev.spennis.oma.be/tracker/view\_all\_bug\_page.php

spennis-tracker

Logged in as: michel (Michel Kruglanski - developer) 2009-05-18 19:01 CEST

My View | View Issues | Report Issue | SPENVIS | Forum | Other | Help

Issue # [ ] Jump [ ]

Recently Visited: 0000058, 0000052

Search: [ ] Apply Filter [ ]

Reset Filter [ ] Save Current Filter [ ]

Viewing Issues (1 - 34 / 34) [ Print Reports ] [ CSV Export ]

	P	ID	#	Category	Severity	Status	Updated	Summary
<input type="checkbox"/>		0000058	1	Package: Radiation Doses	minor	resolved (Michel Kruglanski)	2009-05-18	SHIELDSE returns zeroes when given only one thickness
<input type="checkbox"/>		0000057		Package: Radiation Sources	feature	new	2009-05-15	Add input for threshold flux for exposure
<input type="checkbox"/>		0000056		Add-on: Development Tools	feature	new	2009-03-31	Would be nice to have ViewVC integrated into the SVN as an http based source code browser
<input type="checkbox"/>		0000054	1	Package: Spacecraft Charging	minor	resolved (Michel Kruglanski)	2009-03-30	Fraction of solar cycle
<input type="checkbox"/>		0000055		System: Documentation	text	assigned (Michel Kruglanski)	2009-03-30	Links to TREND-3 web site point to http://www.magnet.oma.be/trend4/public/trend3/index.html [v]
<input type="checkbox"/>		0000052	2	Package: Radiation Sources	major	resolved (Erwin De Donder)	2009-03-19	results from IGE-2006 model are several orders of magnitude too high
<input type="checkbox"/>		0000053	4	Package: Radiation Sources	minor	resolved (Michel Kruglanski)	2009-03-19	TREP: Differential fluence to be checked
<input type="checkbox"/>		0000051	2	Package: Radiation Sources	major	resolved (Erwin De Donder)	2009-03-17	No results obtained from the IGE-2006 model
<input type="checkbox"/>		0000001	1	Package: Coordinate Generators	crash	resolved (Michel Kruglanski)	2009-03-06	Orbit Generator, Two Line Elements
<input type="checkbox"/>		0000019		Other	feature	resolved	2009-03-06	(Technical: Kernel) changing behaviour the #runModel() action
<input type="checkbox"/>		0000032		Package: Spacecraft Charging	minor	resolved	2009-03-06	DICTAT: compilation warning (version 3)
<input type="checkbox"/>		0000048		Package: Spacecraft	minor	resolved	2009-03-06	number of input lines of DICTAT user-defined

Find: neop [ ] Next [v] Previous [v] Highlight all [ ] Match case [ ]

# User Support: User Forum

**SPENVIS** • Index page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.spenvis.oma.be/forum/index.php

SPENVIS • Index page

**SPENVIS** The Space ENVironment Information System

Search... Search Advanced search

Board index

User Control Panel (0 new messages) • View your posts

FAQ Members

It is currently Fri Apr 23, 2010 3:11 pm

Last visit was: Tue Feb 02, 2010 3:03 pm

View unanswered posts • View new posts • View active topics

Mark forums read

GENERAL	TOPICS	POSTS	LAST POST
<b>General</b> 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: <b>manu</b> , Moderator	17	29	by <b>stijn</b> on Mon Apr 19, 2010 7:41 am

COORDINATE GENERATORS	TOPICS	POSTS	LAST POST
<b>Orbit generator</b> 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: <b>manu</b> , Moderator	5	11	by hugh on Tue Mar 16, 2010 7:20 pm
<b>Grid generator</b> 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: <b>manu</b> , Moderator	1	1	by janw on Mon Aug 13, 2007 11:04 am

RADIATION SOURCES AND EFFECTS	TOPICS	POSTS	LAST POST
<b>Radiation sources</b> 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: <b>manu</b> , Moderator	11	18	by michel on Tue Feb 02, 2010 1:36 pm
<b>Solar cell radiation damage</b> Damage-equivalent electron fluences for different types of solar cells can be evaluated with EQFLUX. Moderators: <b>manu</b> , Moderator	0	0	No posts
<b>Radiation doses</b> Ionising dose behind three types of Al shielding (SHIELDDOSE). 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. The Multi-Layered Shielding Simulation tool 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. Moderators: <b>manu</b> , Moderator	46	121	by pisacane on Tue Apr 20, 2010 5:10 pm

Response by SPENVIS team member normally within 3 working days.

All advanced users are encouraged to use the forum particularly as respondents to posted questions.

# Third Party Development

## New → Third party development toolkit

### Development of SPENVIS

applications by third parties

1. Dedicated repository (SVN)

@ developer side:(win32 or linux)

2. Reduced version of SPENVIS

3. Application development

4. Testing on reduced version

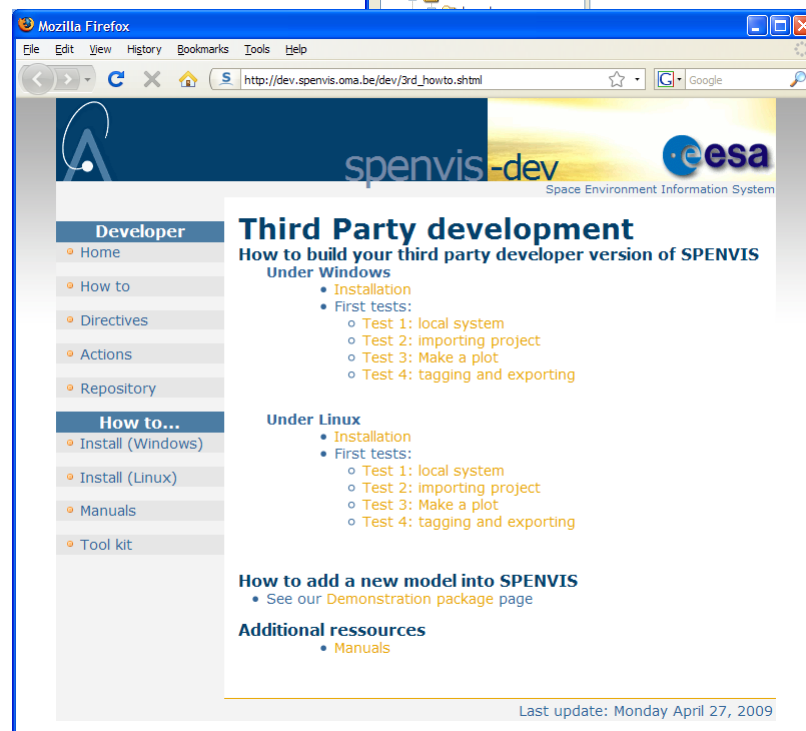
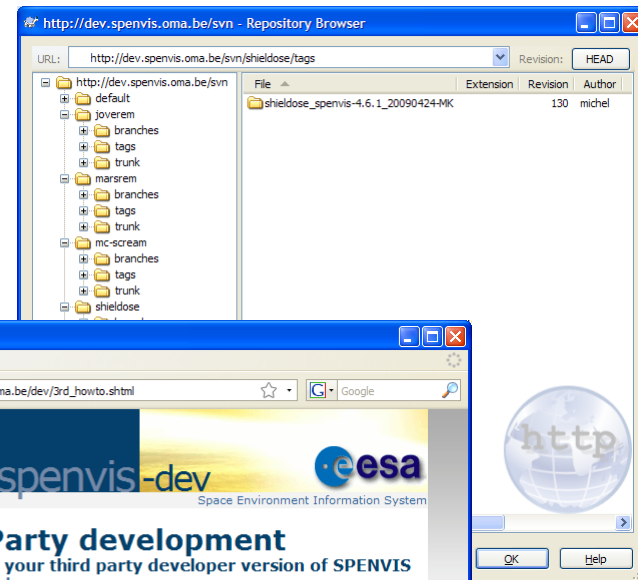
@ dev.spenvis.oma.be:

5. Export & installation of the application on full version

6. Testing & demonstration

SPENVIS team:

7. Final integration in SPENVIS





- Study radiation environments and likely effects during mission design
- Analyse long term radiation dose for the final orbit, especially for sensitive components (eg., processors, detectors, solar panels)
- Optimise shielding – materials and quantity – to reduce margins



- Core applications are used with other SWE products (eg SWENET, SEISOP ...) to routinely describe space environment for a given mission and orbit
- often used alongside in-situ data from INTEGRAL, XMM, PROBA, Giove-A, Giove-B, etc..
- Predict likely impact from anticipated SWE events
- Use pre-launch to define thresholds etc to reduce both failures and safe downtime during routine operations
- Under consideration for redeployment within ESA's SSA framework in 2010

# SPENVIS: Further Information



[www.spenvis.oma.be](http://www.spenvis.oma.be)

[g.lawrence@rheagroup.com](mailto:g.lawrence@rheagroup.com)  
[spenvis\\_team@areonomie.be](mailto:spenvis_team@areonomie.be)

SPENVIS User Workshop to be held on the  
7<sup>th</sup> → 9<sup>th</sup> June, 2010 in Mechelen, Belgium.

<http://www.spenvis.oma.be/workshop2010.php>