



Presentation of SPIS, the Spacecraft Plasma Interaction Software

SPENVIS meeting
22/05/2013

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(1) ONERA, (2) Artenum



r e t u r n o n i n n o v a t i o n

SPIS Context

- SPINE (Spacecraft Plasma Interaction Network in Europe) community setup around year 2000 (A. Hilgers, J.F. Roussel, D. Payan...):
 - Gather European efforts for SC-plasma interactions
 - Boost the development of a common simulation toolkit: ESA ITT in 2002 => SPIS
- SPIS Development (Spacecraft Plasma Interaction Software) :
 - Initial development: 2002 – 2005
 - ONERA leaded consortium
 - ESA/ESTEC TRP contract
 - Major solver enhancement: 2006 – 2009
 - Mostly ONERA
 - ESTEC ARTES contract, French funding
 - ESD triggering modelling : 2010
 - ONERA leaded consortium
 - ESA/ESTEC TRP contract
 - Others
 - Some community developments
 - Some CNES-funded enhancements (EP, ESD)

SPIS Context

- Recent SPIS activities →
 - **SPIS-GEO**: Simplified MEO/GEO tools for spacecraft charging (ESA contract: TEC-EES/4000101174)
 - **SPIS-Science**: Computational tools for spacecraft electrostatic cleanliness and payload (ESA contract: 4000102091/10/NL/AS)
 - **ElShield**: SPIS-Deep charging module (ITT ESA: TEC-EES/2008.266/PN)
 - **AISEPS**: Assessment of the Interactions between Spacecraft and Electric Propulsion Systems (ESA contract: 4200022730/09/NL/SFe, EADS Astrium led consortium)

See respective ESA technical officers for all question and/or further information:

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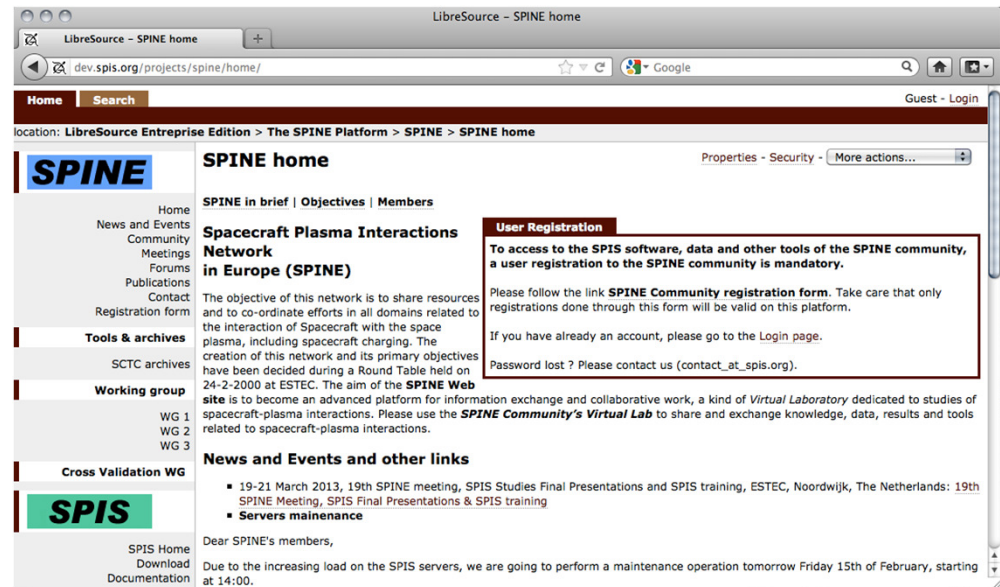
SPINE community

- SPIS is maintained and hosted in the frame of the SPINE community

- Web site and exchange platform: <http://www.spis.org>

- A dynamic life:

- More than 680 registered and active members
 - About 4 new registration by week
 - More than 6500 downloads all versions/branches includes
 - More than 80 publications related to SPIS and SPINE activities
 - Annual workshops
 - An active forum
 - A growing set of experts, including several academic and industrial entities

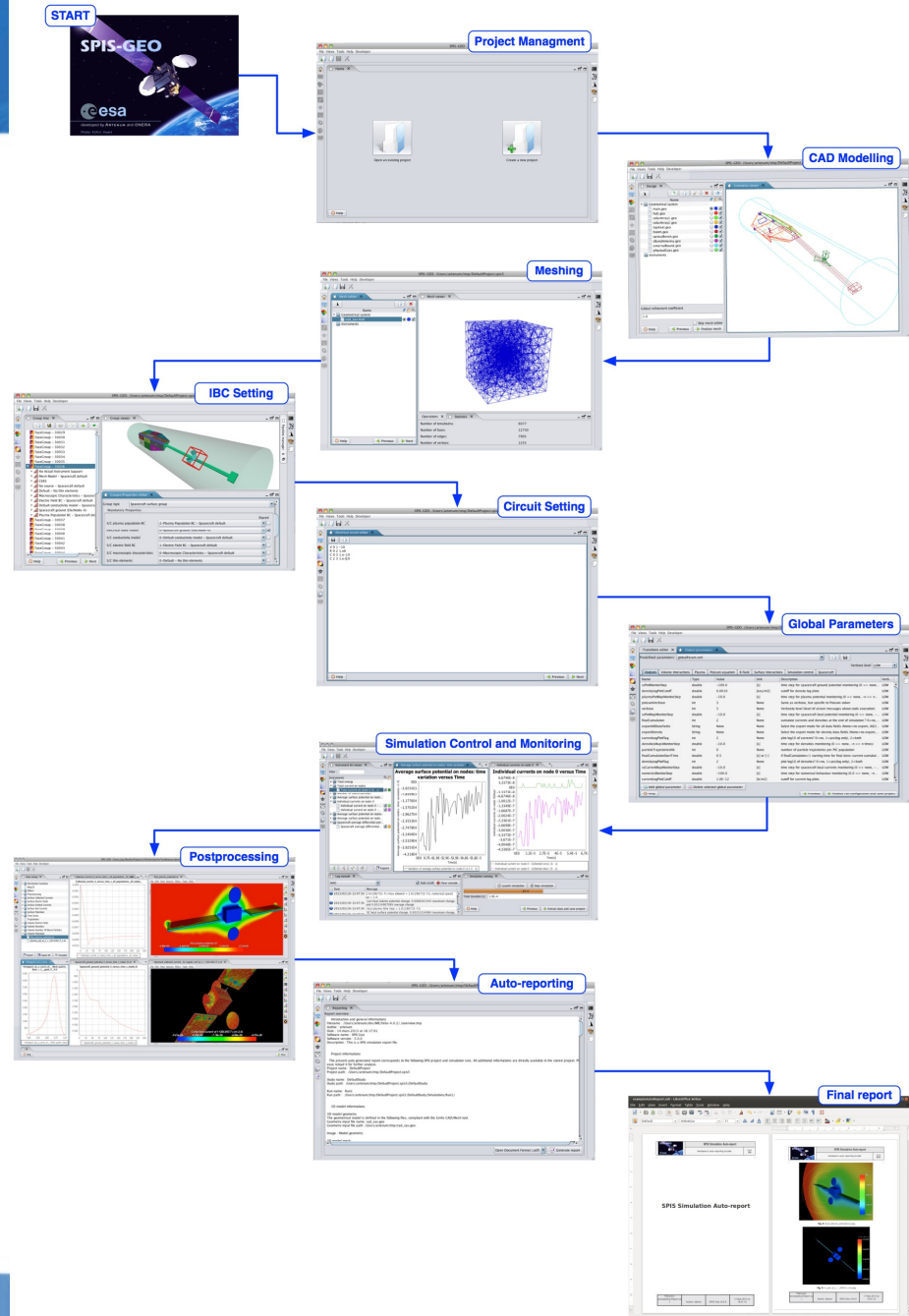


- SPIS is an open-source software freely available

- GPL-like license
 - Registration required: <http://dev.spis.org/projects/spine/home/captcha>
 - Software download: <http://dev.spis.org/projects/spine/home/spis/software/download>
 - SPIS is a Java based application and can be run on all platforms supporting JAVA

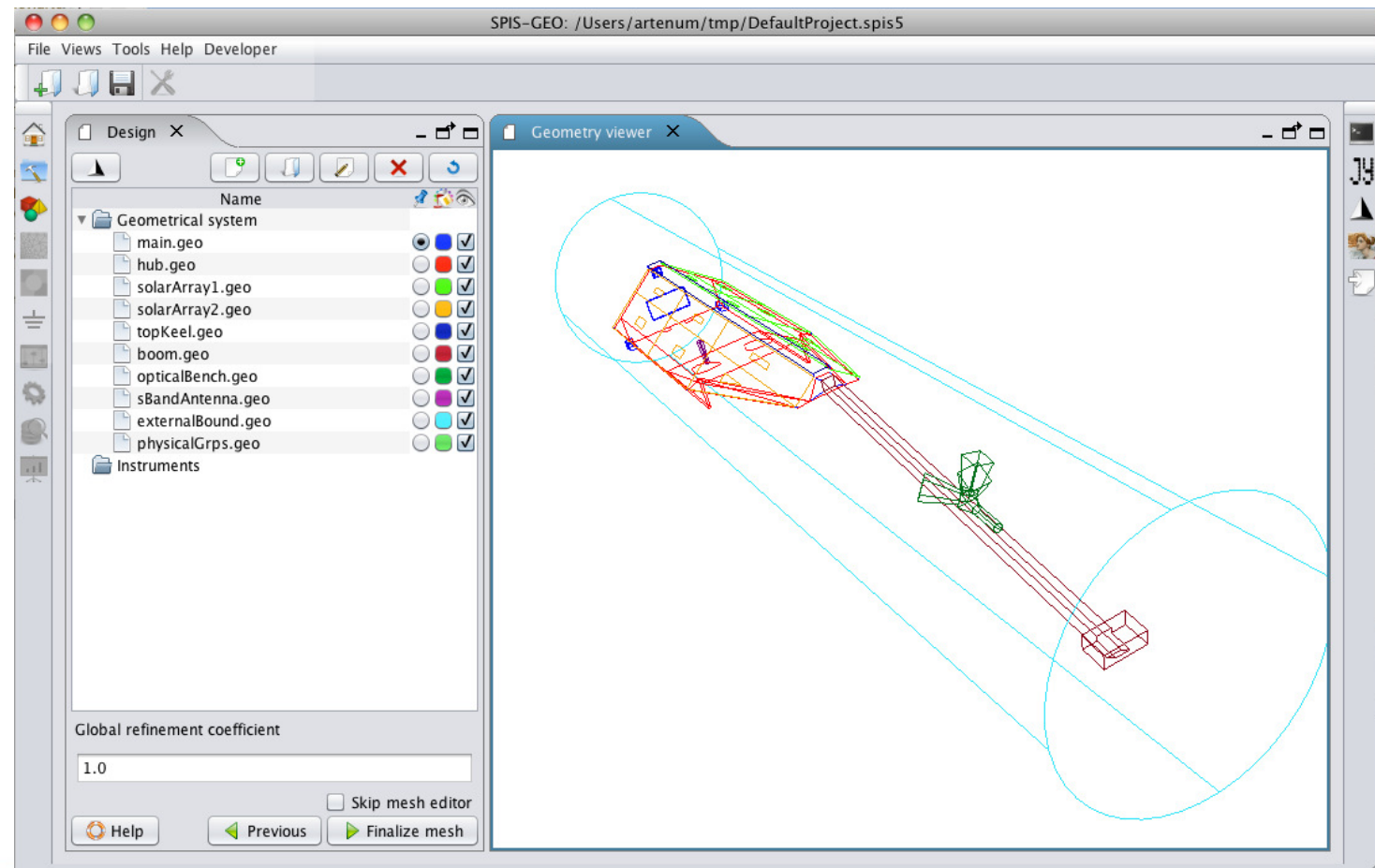
SPIS-UI

- SPIS 5 includes a new rich user interface to help the user to follow the whole modelling process while guaranteeing data consistency
 - Wizard-based GUI & batch mode
 - Integrating all needed external
 - CAD tools
 - Meshing tools
 - 2D/3D data analysis and visualization
 - Reporting
- Based on the multi-physics and open-source **Integrated Modelling Environment (IME)** Keridwen
 - Modular design for tailored declinations
 - Multi-physics
 - OSGi standard
 - Interoperability
 - Hierarchical data model



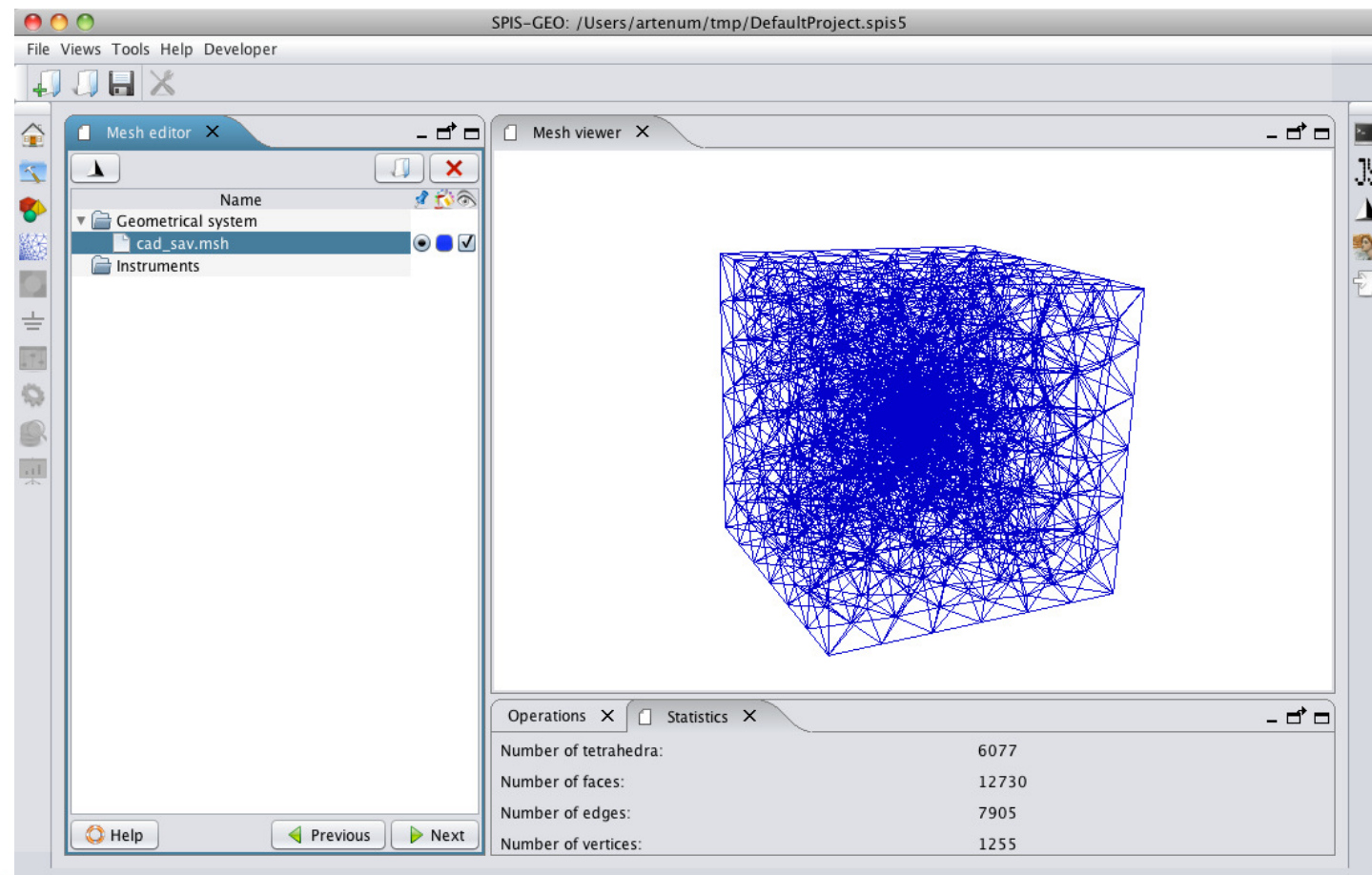
Geometry editor

- Rich CAD/geometry editor
 - Brep based approach (Gmsh model)
 - Capacity of import various CAD formats (Gmsh geo format, STEP, Brep, Iges...)



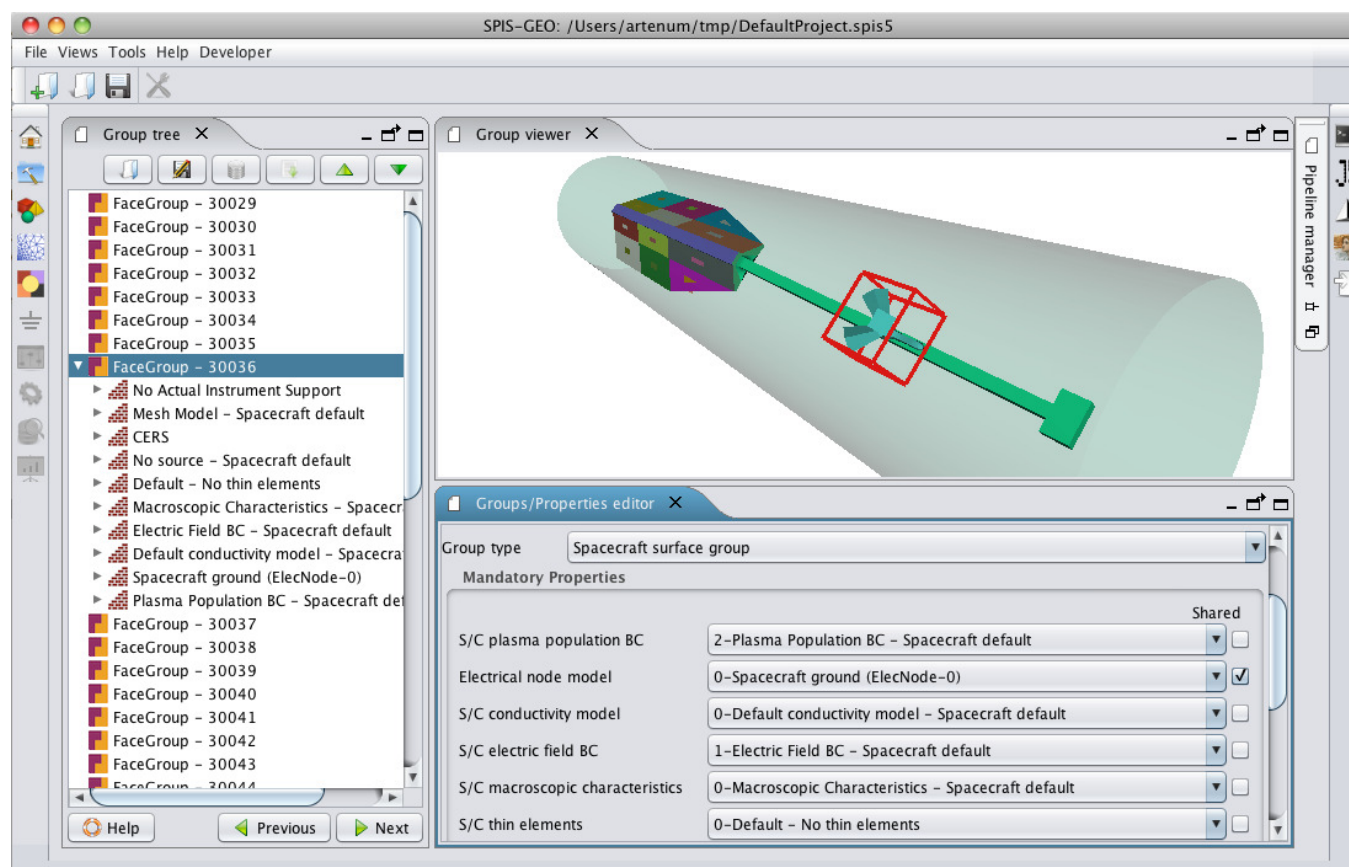
Mesh editor

- 3D unstructured mesher
 - Mesh adaptation to handle complex geometries, large range physical scales)
 - Possibility to directly import existing meshes in various formats



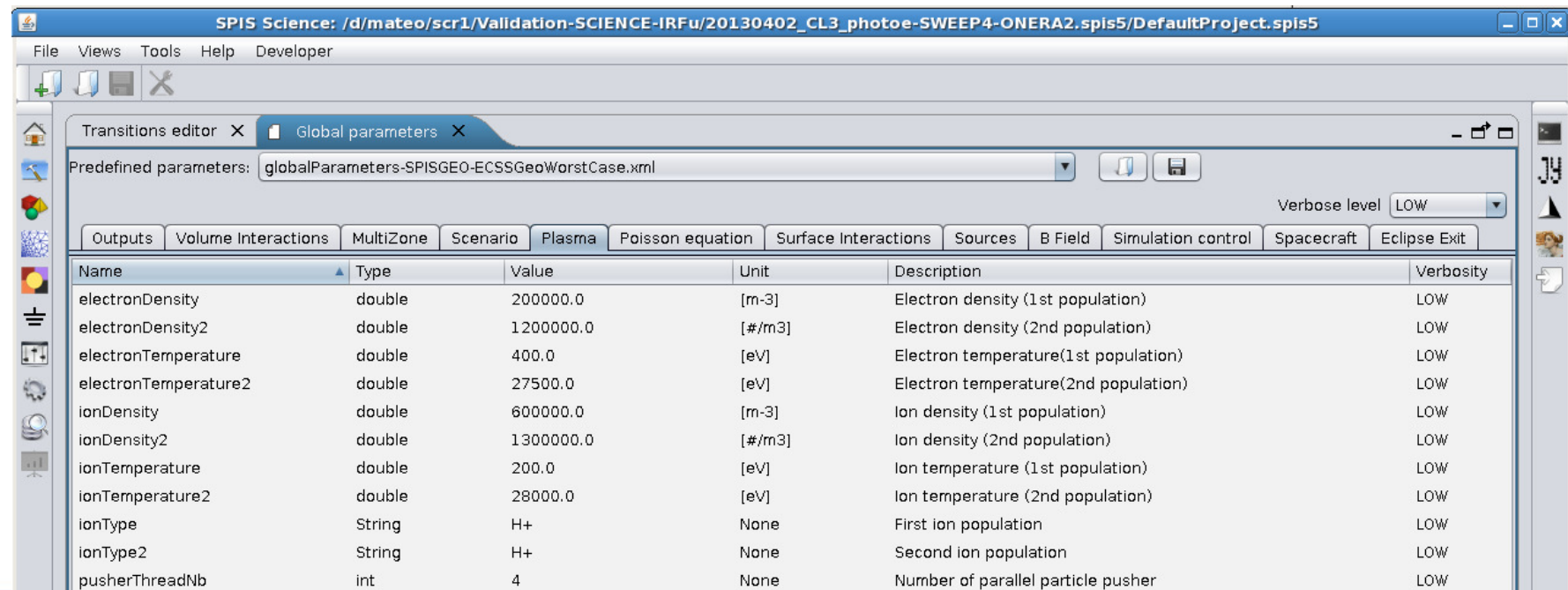
Surface and Volume properties editor

- Full refactoring of the Groups Editor
 - Attributions of complex properties of each sub-set of the modeled system
 - Initial and boundary conditions and material properties
 - Hierarchised and extensible data-model to support future evolution or physics
 - I/O capabilities
 - XML format
 - NASCAP-2K
 - Simplified GUI
 - 3D view
 - Automatic presetting

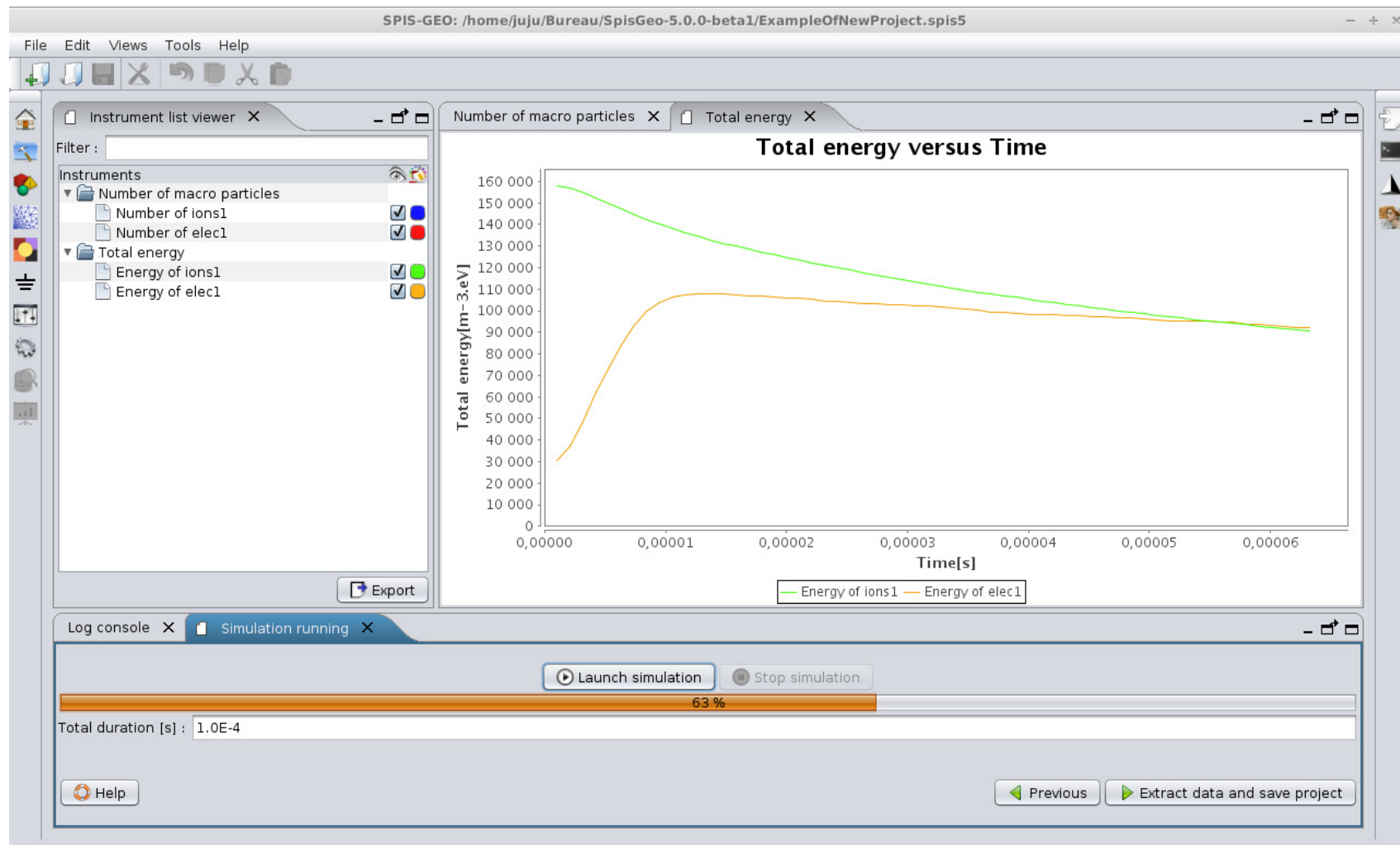


Simulation Parameters

- SPIS may include more than 200 parameters !
- New Global Parameters Editor, with:
 - Various levels of expertise (Low, advanced, expert) to simplify settings
 - Typing/field validation
 - Various formats support (XML, Excel, etc...)



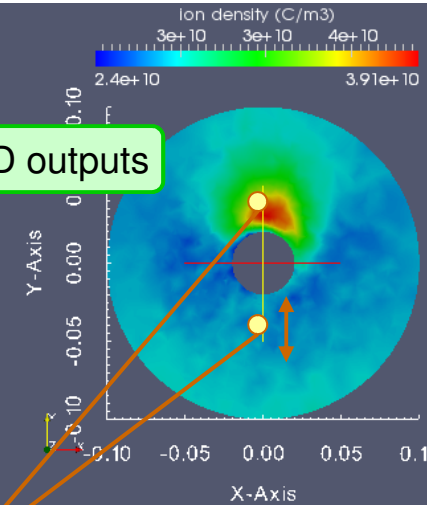
Live monitoring



Live monitoring

Live Monitoring of numerical data

Intermediate 3D outputs



New live diagnostic with interactive data (position, sampling rate, etc)

Creation of new sensors

Pause simulation (SR-SP-014)

Results accuracy level estimation

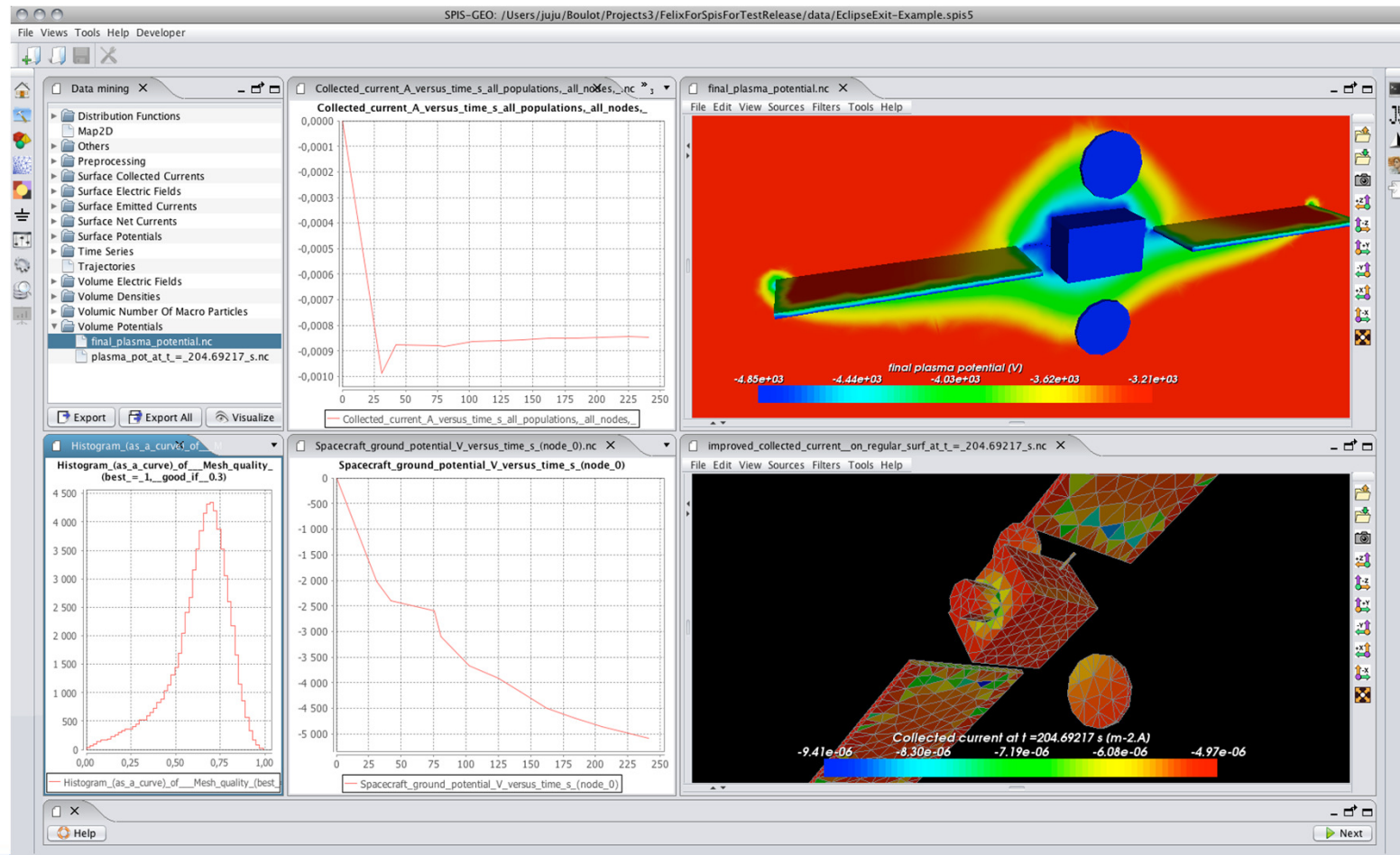
Default Live Monitoring

SPENVIS meeting, Bruxelles, 22-05-2013

Interactive live monitoring

Post-Processing

- Data miner
- Extensible 2D/3D post-processing
- Various saving/export capabilities (NetCDF, VTK...)



Automatic reporting

- OpenOffice automatic reporting

The screenshot displays the SPIS-GEO software interface, which is integrated with LibreOffice Writer for automatic reporting. The interface is divided into several panels:

- Reporting Overview Panel (Left):**
 - Report overview:**
 - Introduction and general informations:
 - Filename: /Users/artenum/dev/IME/Felix-4.0.2
 - Author: artenum
 - Date: 14.mars.2013 at 16:17:01
 - Software name: SPIS Geo
 - Software version: 5.0.0
 - Description: This is a SPIS simulation report file.
 - Project informations:
 - The present auto generated report correspond to the simulation results. Please reload it for further analysis.
 - Project name: DefaultProject
 - Project path: /Users/artenum/tmp/DefaultProject
 - Study name: DefaultStudy
 - Study path: /Users/artenum/tmp/DefaultProject
 - Run name: Run1
 - Run path: /Users/artenum/tmp/DefaultProject
 - 3D model informations:
 - 3D model geometry: The geometrical model is defined in the following input file.
 - Geometry input file name: cad_sav.geo
 - Geometry input file path: /Users/artenum/tmp/DefaultProject
 - Image: Model geometry
 - 3D model mesh
- Main Report Content (Center):**
 - SPIS Simulation Auto-report:**
 - Keridewen's auto-reporting bundle
 - 6. Outputs
 - The outputs of the simulation run. Including time series for simulation duration and 2D/3D map data. Images may have been resized during report generation, full size versions are still stored in project.
 - Fig. 6: Spacecraft ground potential V versus time s (node 0)**
 - Fig. 8: final plasma potential ac.png**
 - Fig. 9: sc_pot_at_t=-2000.0_s.nc.png**
- Footer (Bottom):**
 - Page 2 / 28
 - Words: 2135
 - Default
 - French (France)
 - 75%

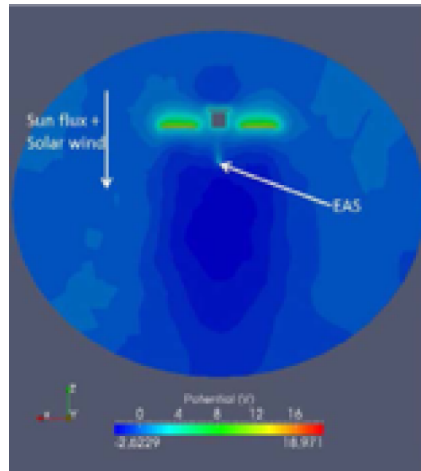


General Modelling Capabilities



return on innovation

SPIS simulation principle

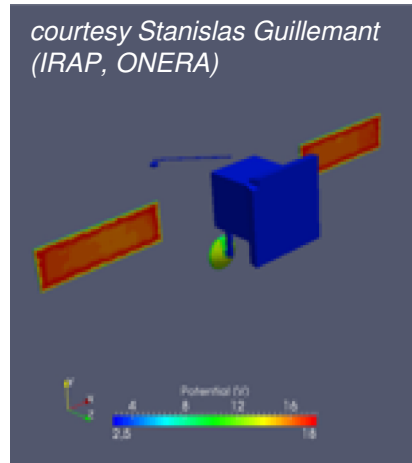


①

Electric field from:
-Particle densities
-Boundary conditions

④

Potential on S/C:
-Current balance
-RLC circuit between
S/C elements

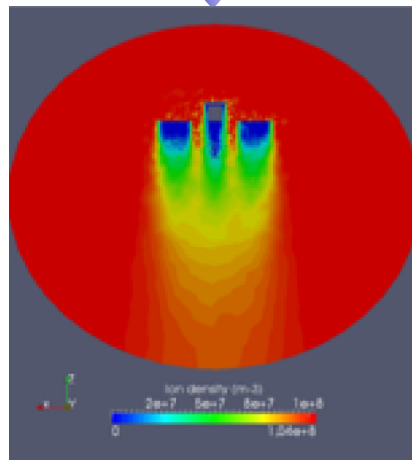
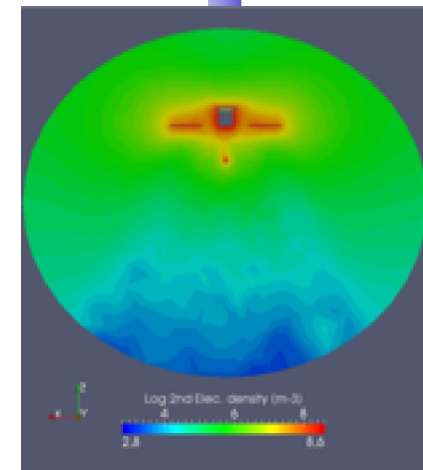


②

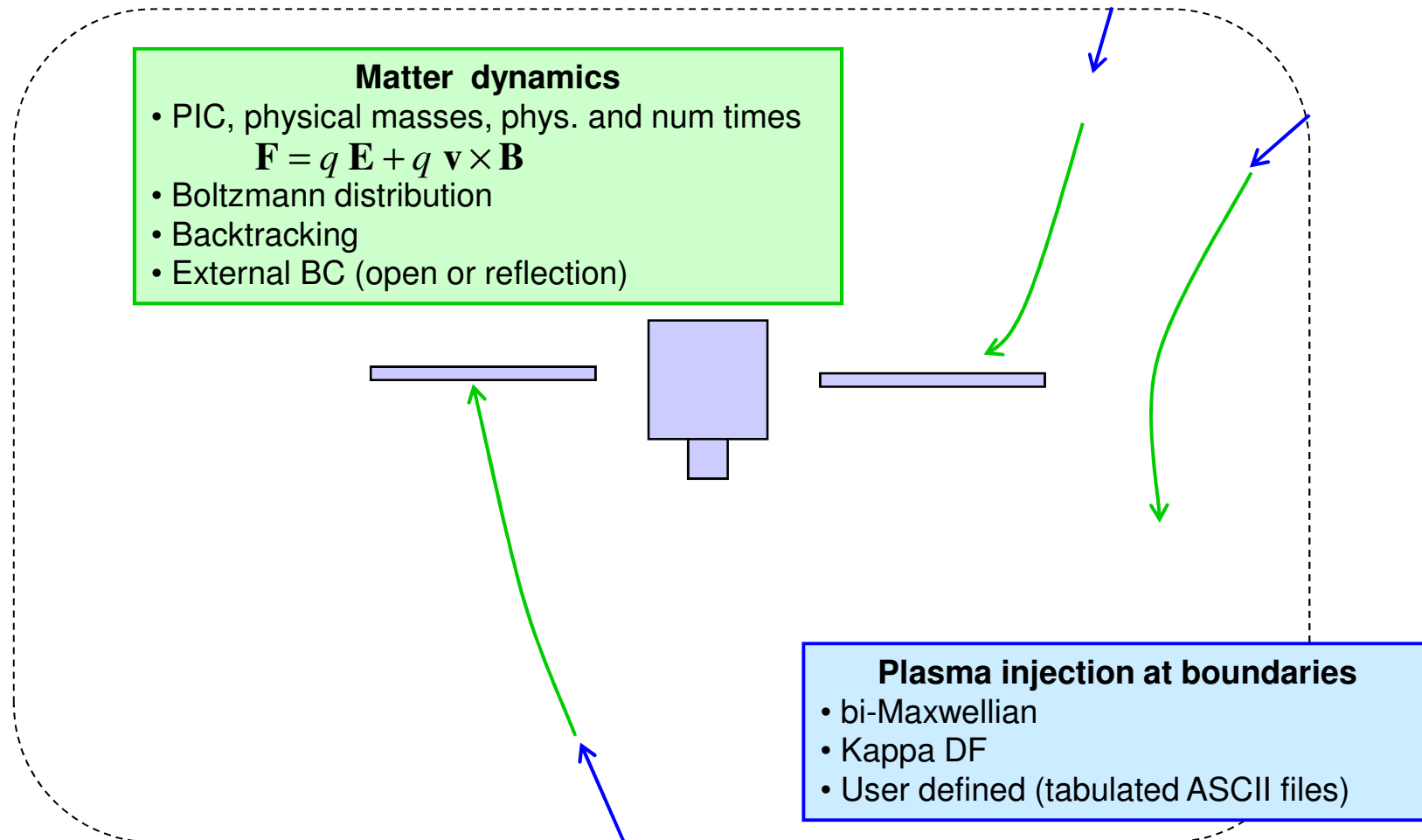
Particle Transport:
-Space environment
-Secondaries or
Sources from S/C

③

Interaction with S/C:
-SEE by electrons
-SEE by protons
-Photo-emission
-Sources



Matter model



Field model

Poisson Boundary condition

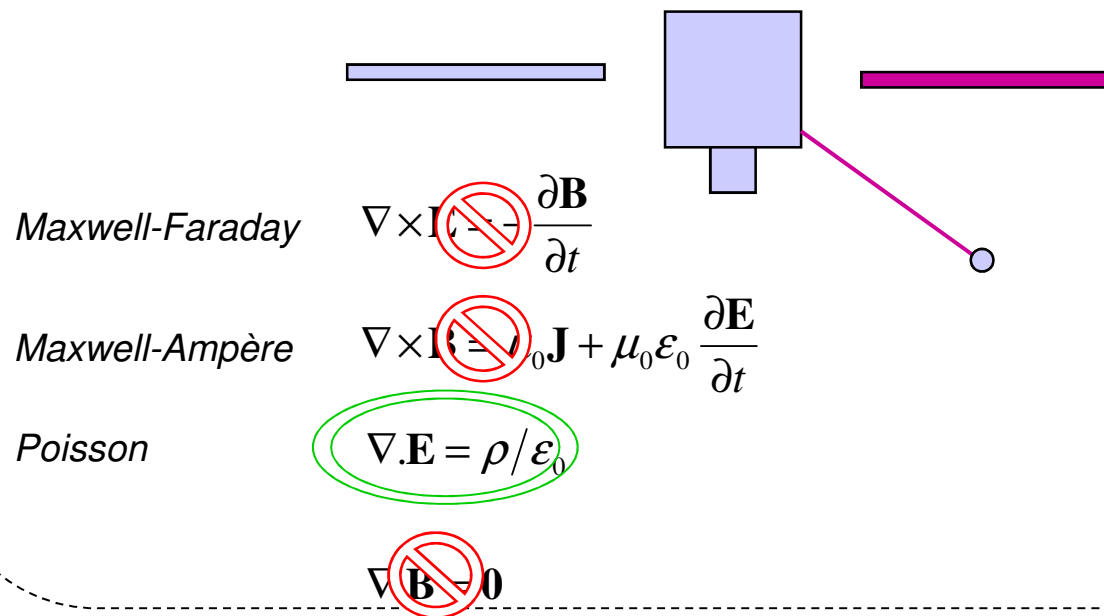
- Dirichlet
- Neumann
- Robin

Electric Field model

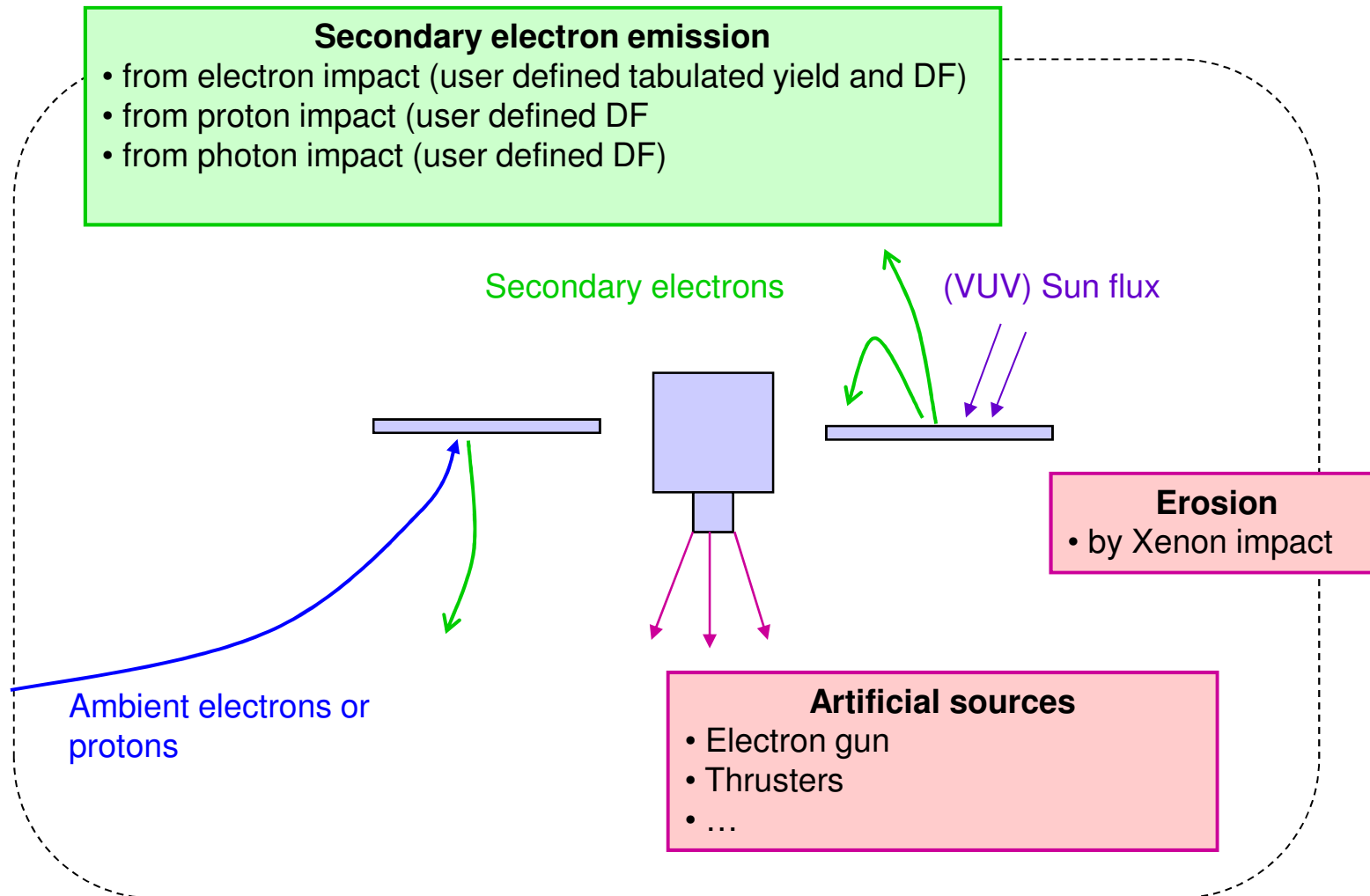
- Conjugate gradient solver for Poisson eq.
- Implicit solver for non-linear Poisson eq.
- SC singularities (*thin wires, panels*)

Magnetic Field model

- Uniform
- Constant



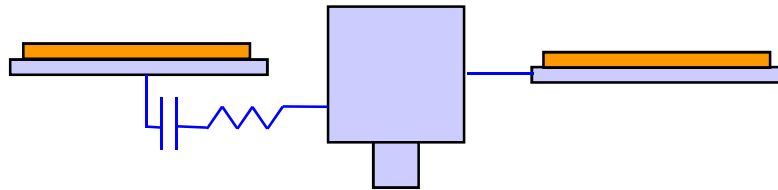
Surface interactions and sources



Surface potentials

Dielectric coatings

- thickness
- capacitance
- bulk, surface, radiation induced conductivity



SC equivalent electrical circuit

- net currents on each SC element → potential evolution
- SC ground → absolute charging
- diel coatings → differential charging
- discrete electrical components (R-C-V)



Some Illustrations

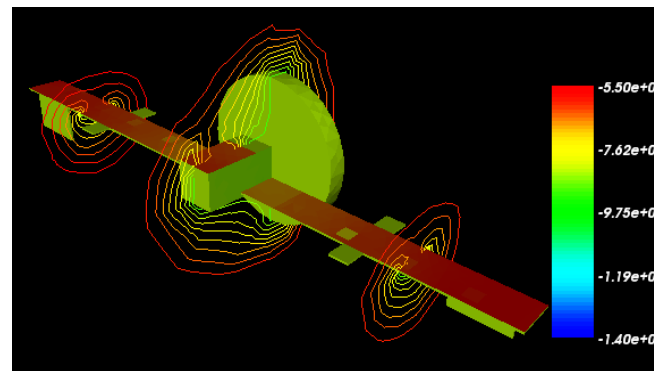
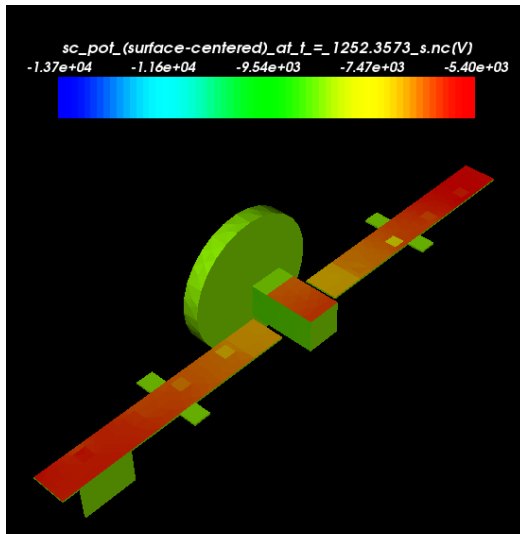


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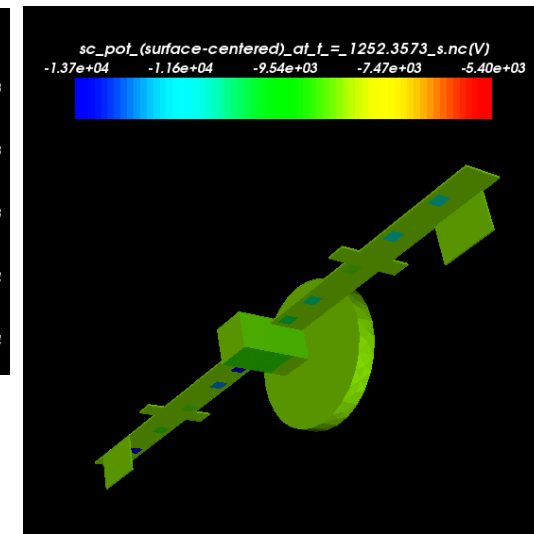
GEO spacecraft charging

ESA activity

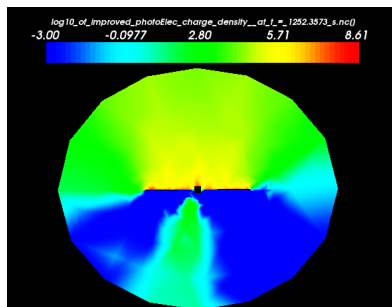
- EADS E3000 spacecraft



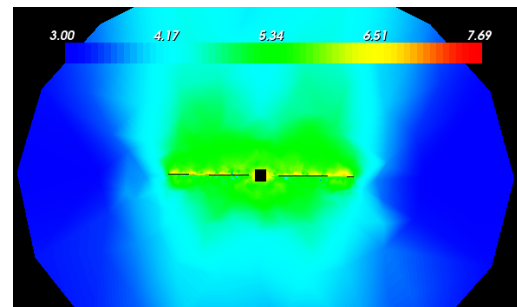
Surface potentials at $t = 1250$ s



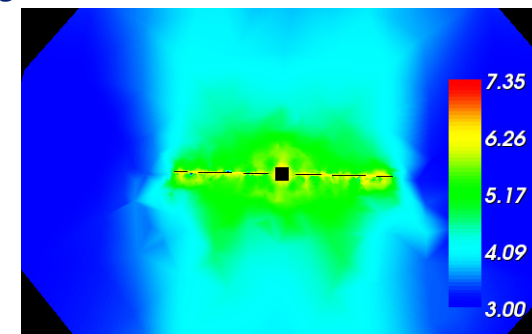
SEE densities (log10) at $t = 1250$ s



Impacting photons



Impacting electrons



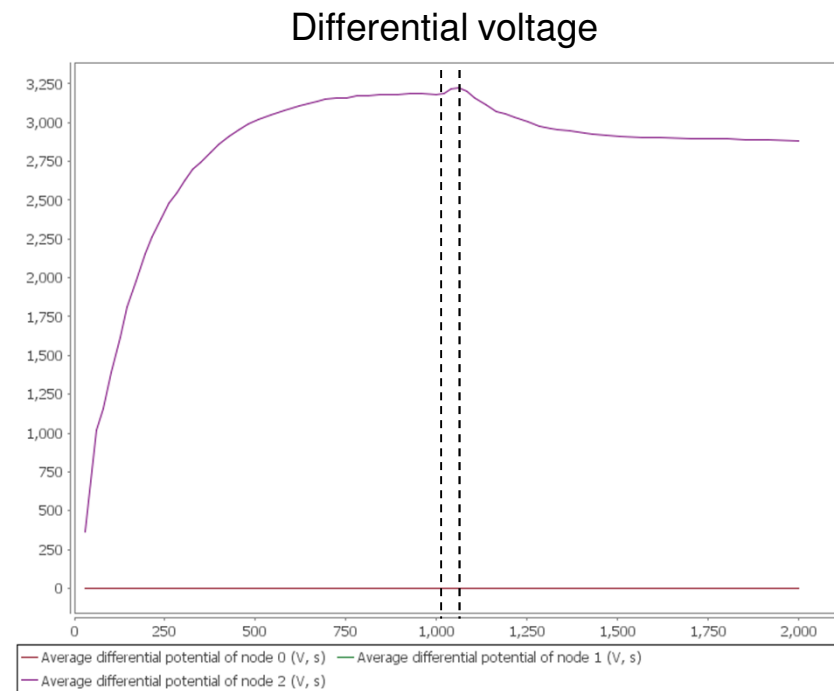
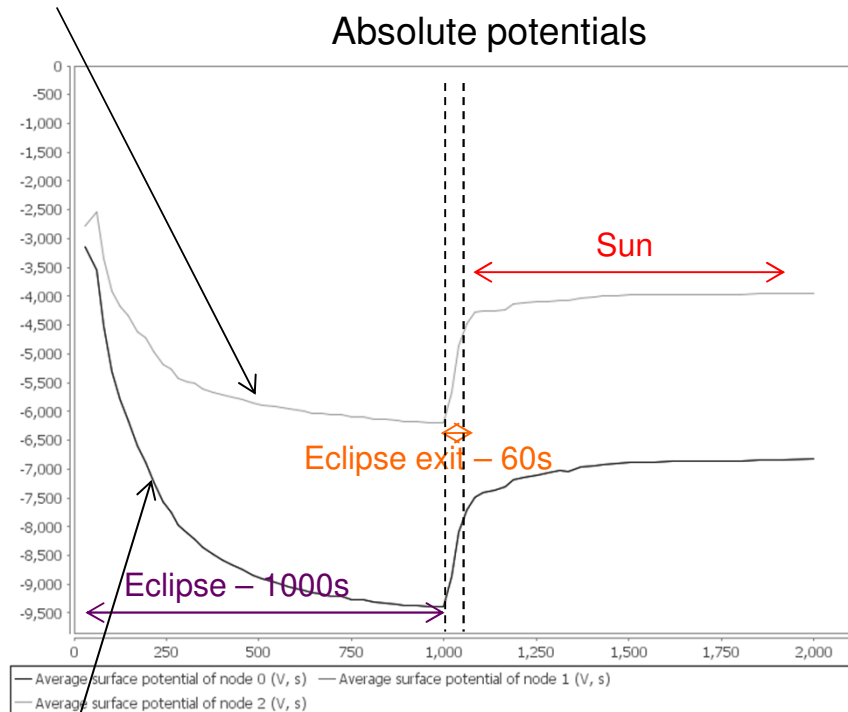
Impacting protons

GEO spacecraft charging

ESA activity

- Eclipse exit dynamics

Cover Glass

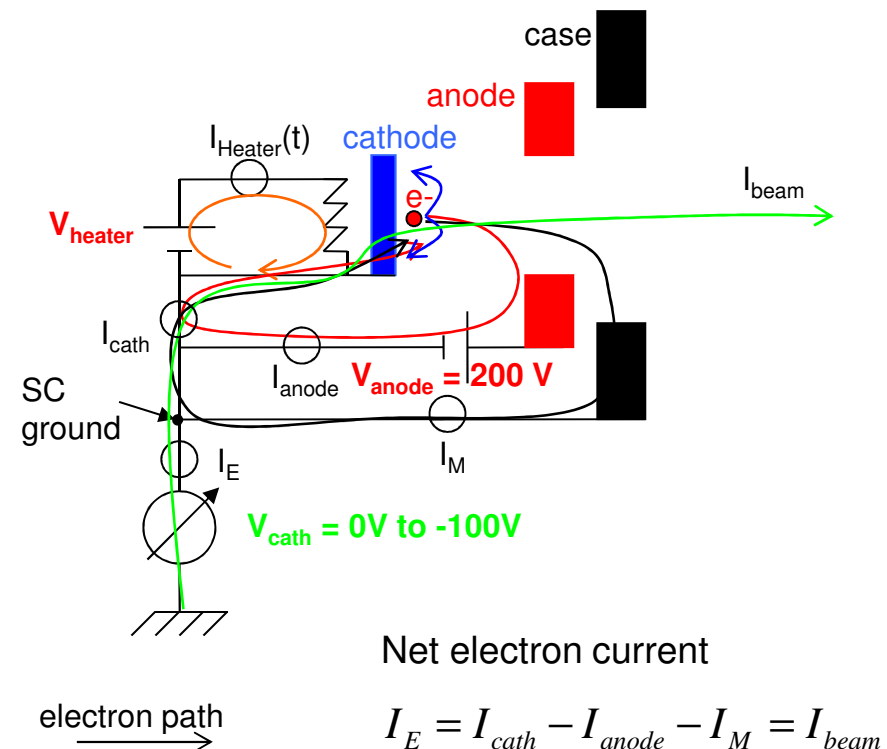
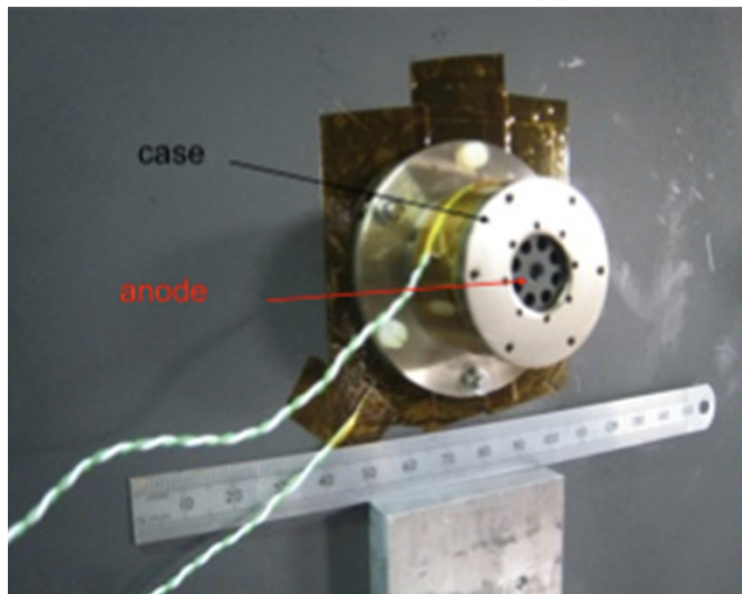


S/C ground

Simulation of an electron emitter

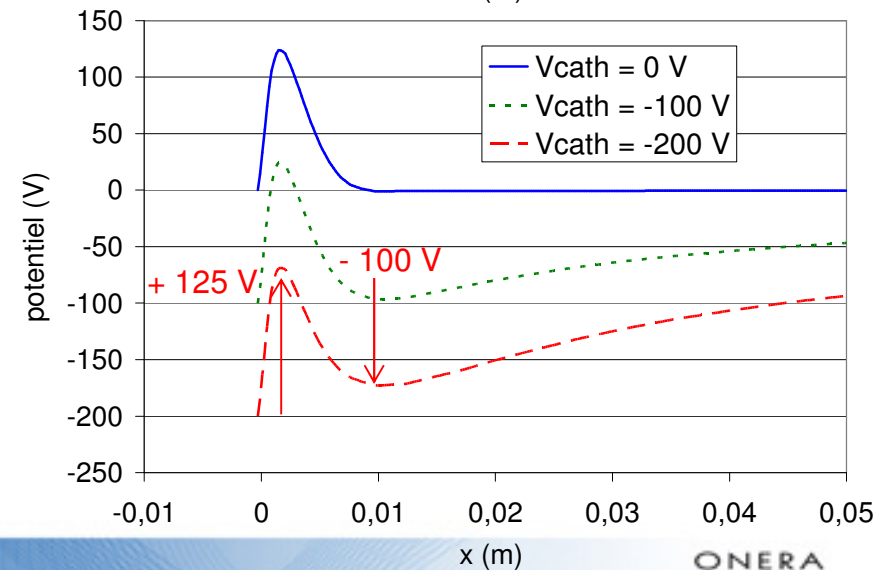
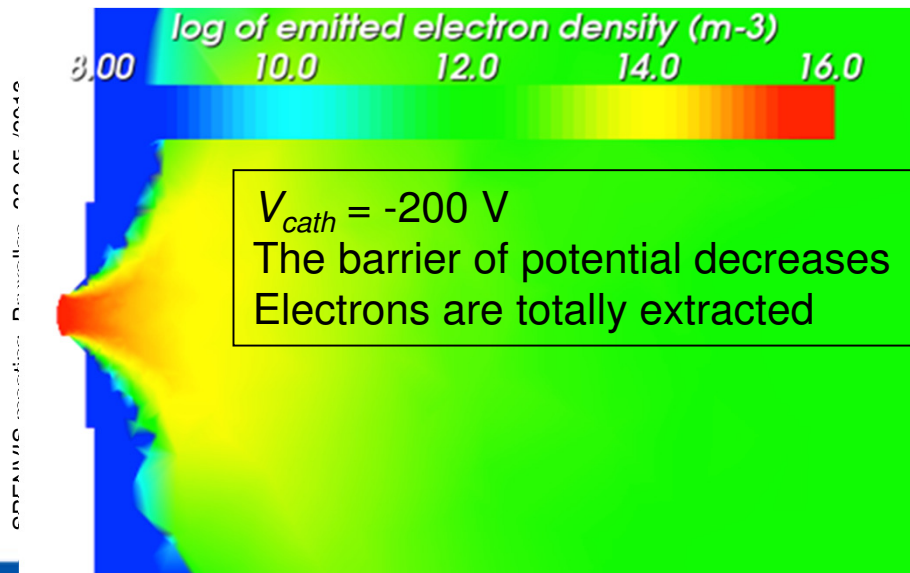
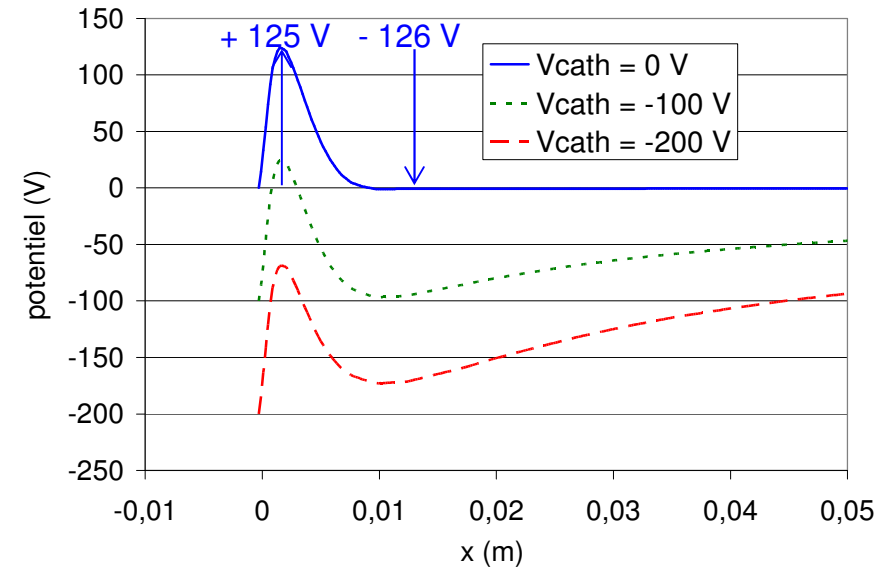
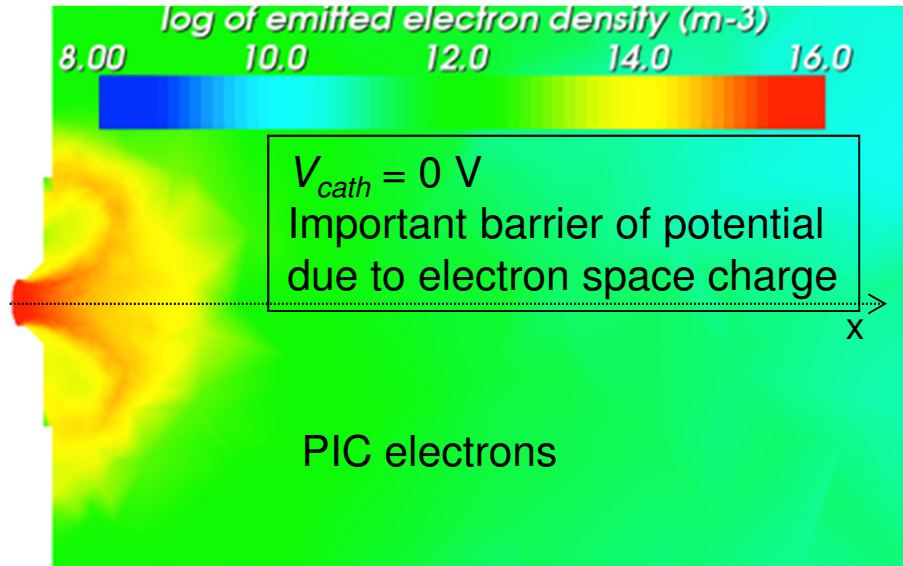
CNES activity

- TAS neutralizer
 - Heated impregnated cathode
 - Extractor electrode (anode)



Simulation of an electron emitter

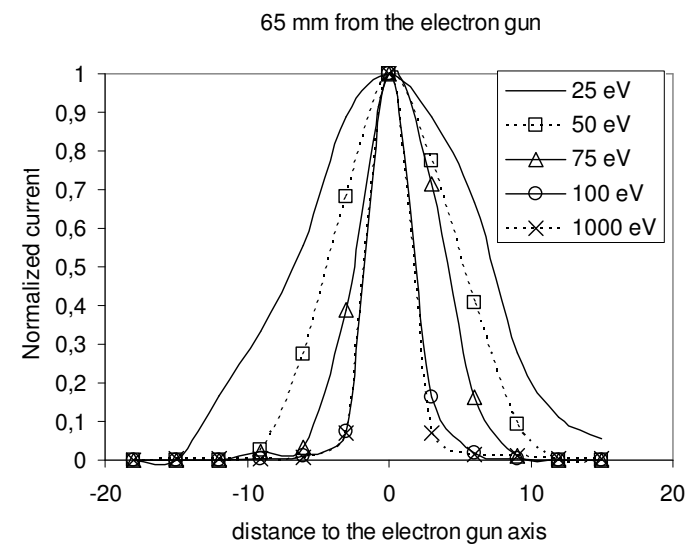
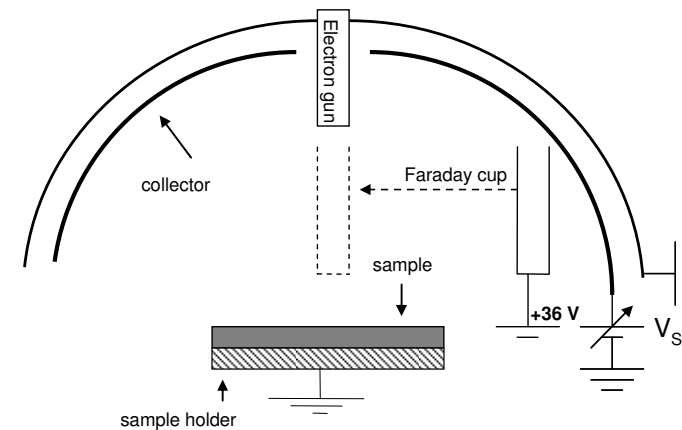
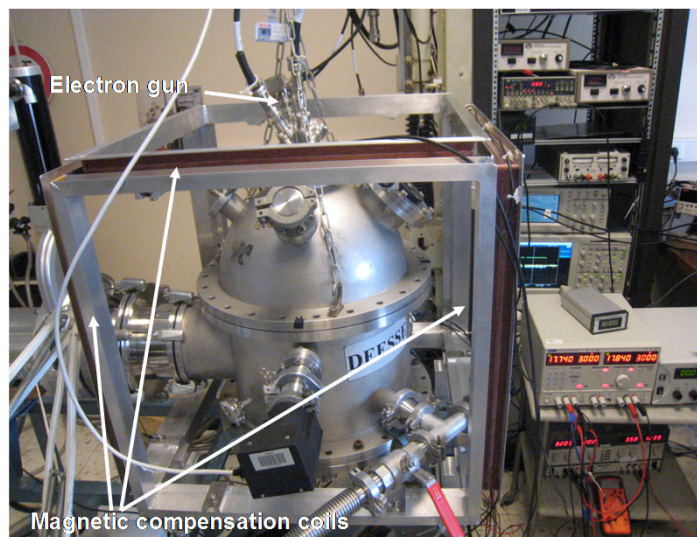
CNES activity



DEESSE chamber simulation

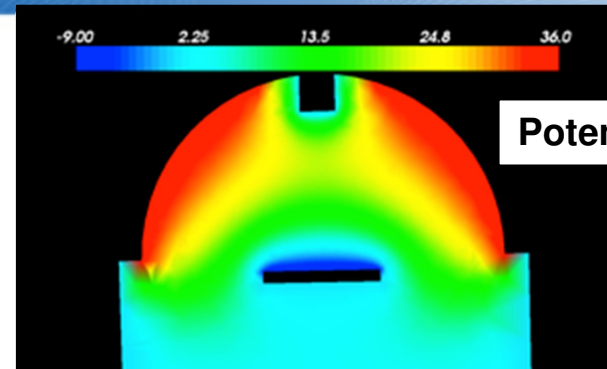
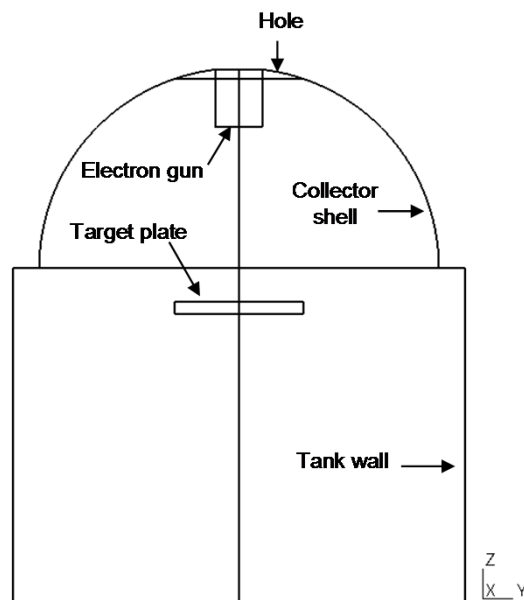
CNES activity

- Experimental setup assessment by numerical simulation

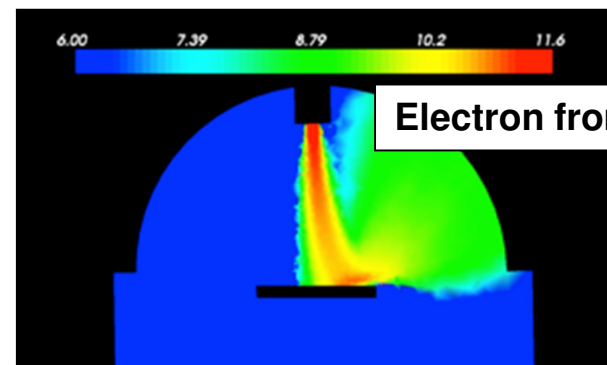


DEESSE chamber simulation

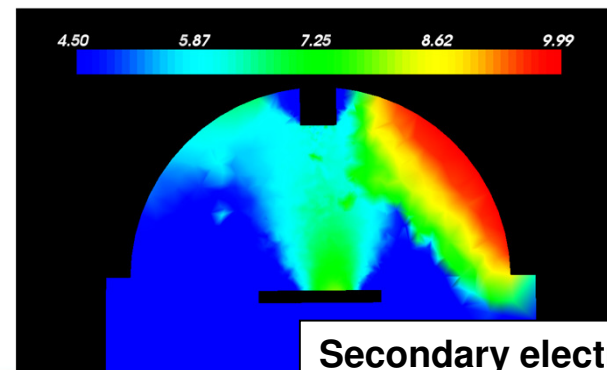
CNES activity



Potential (V)



Electron from gun (m-3, log)

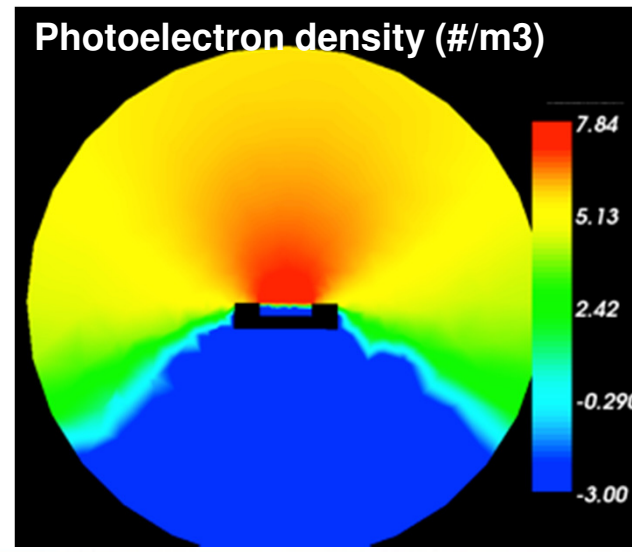
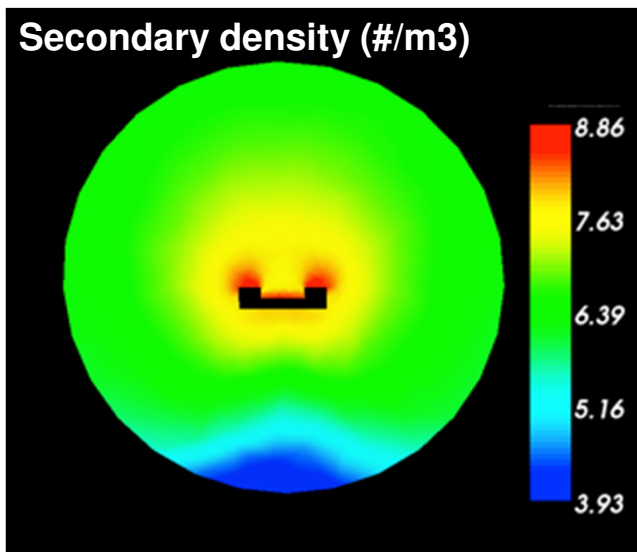
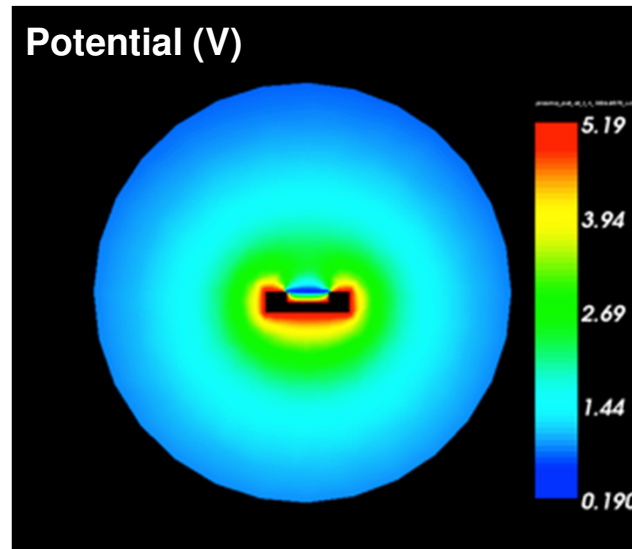
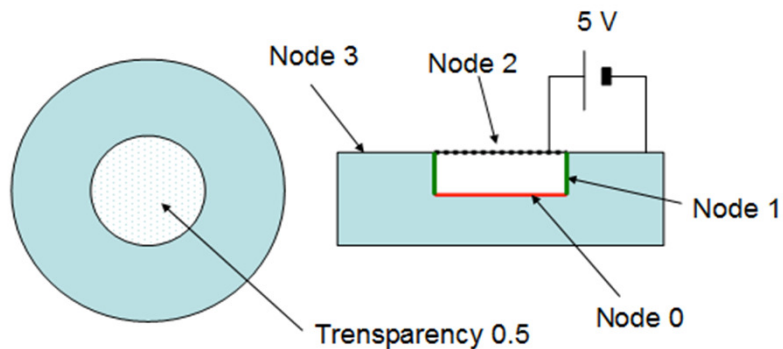


Secondary electrons (m-3, log)

Semi-Transparent Grids

ESA activity

- Aperture not meshed $\rightarrow$ transparency coefficient

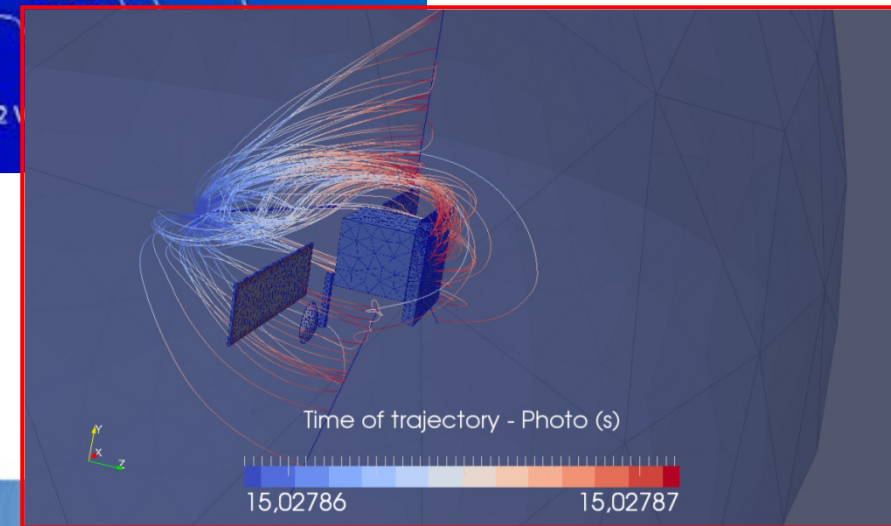
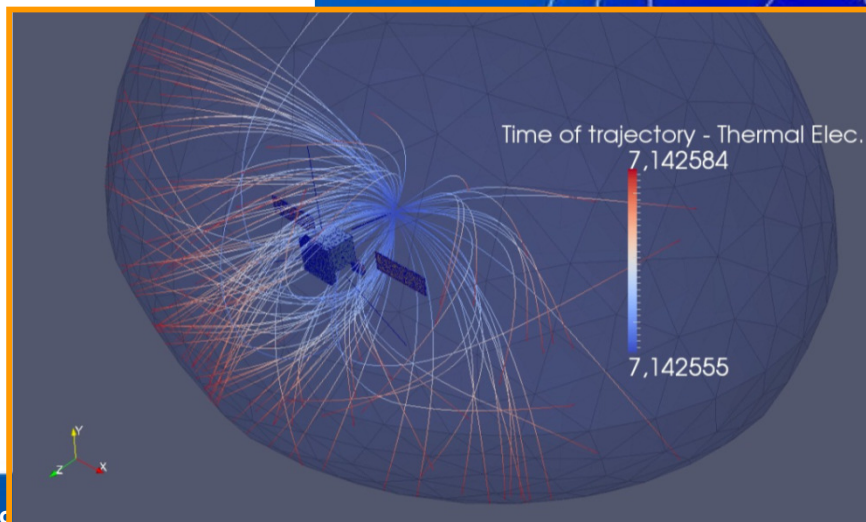
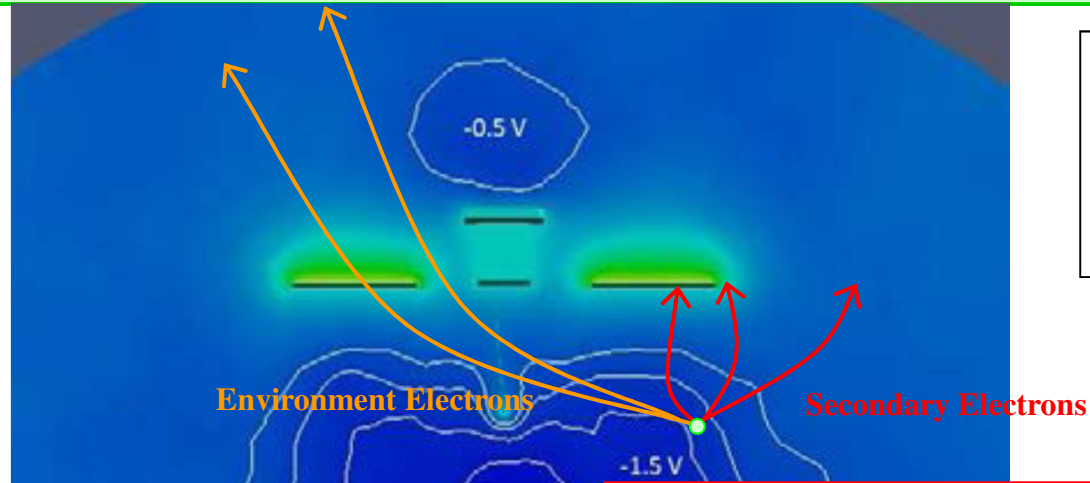


Scientific instruments

Advanced method for instruments

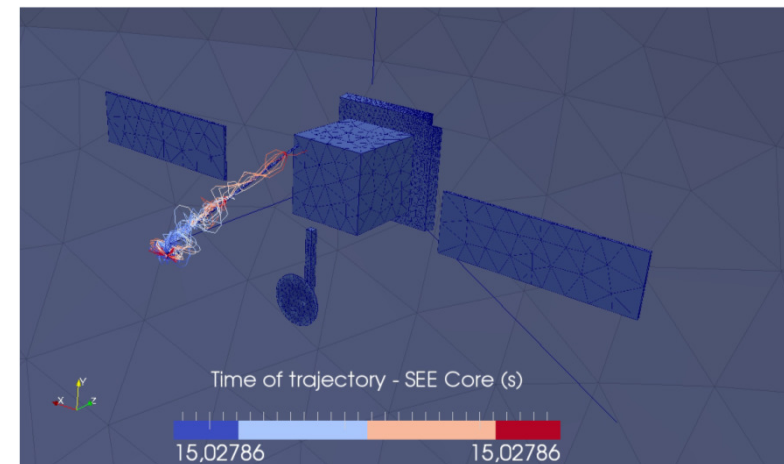
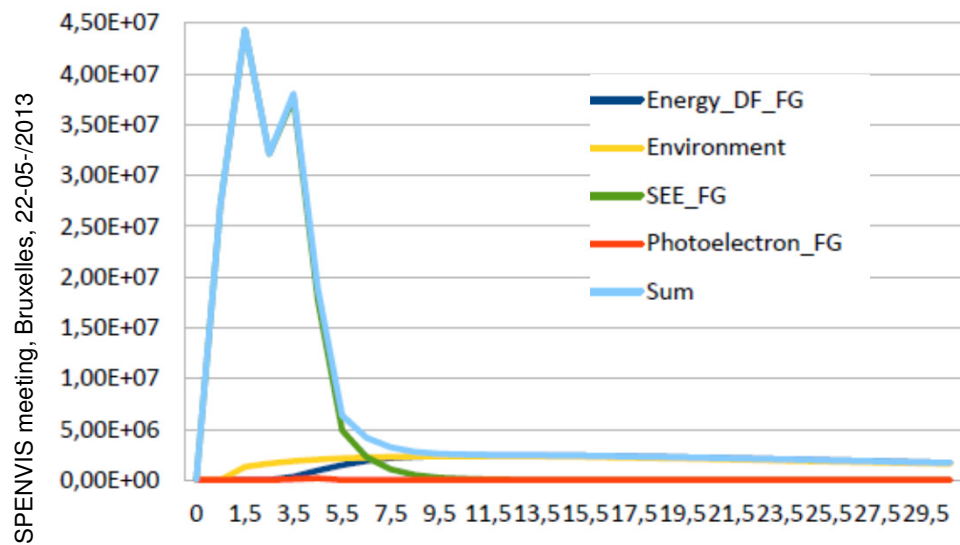
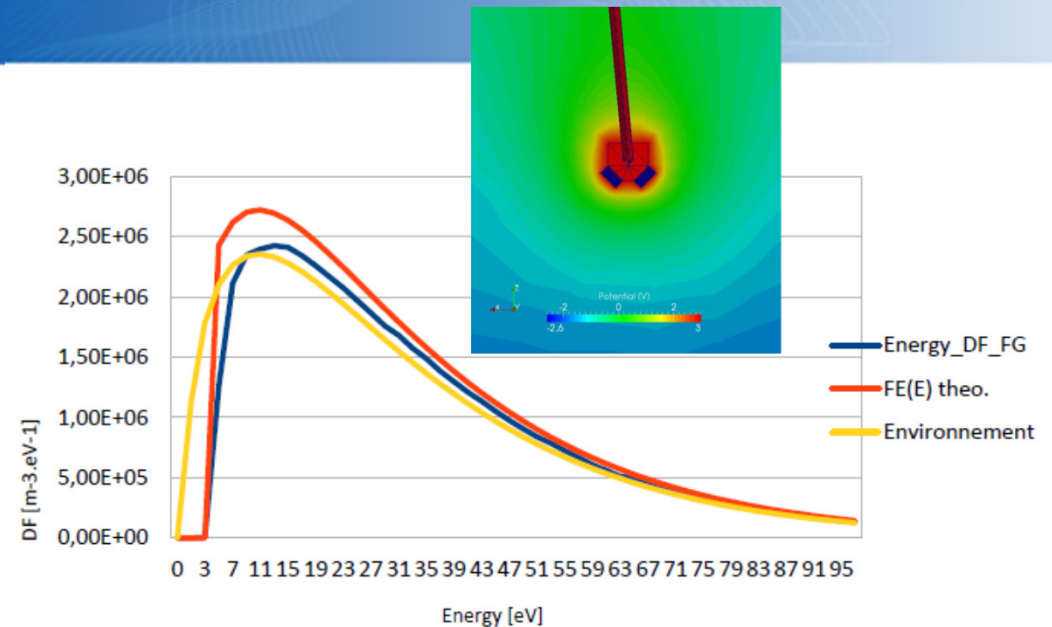
- Backtracking instead of forward tracking Based on Liouville's theorem and discretization of DF in phase space
- Increase drastically the precision
- Also for electrons coming from thin wires !!

Illustrated in S. Guillemant PhD (ONERA, IRAP) & ESA activity SPIS activity



Instrument outputs

- Energy DF
- Differential flux
- Angular DF
- Origin of particles
- ...



Summary

- SPIS has been deeply refactored recently
 - New Integrated Modelling Environment (IME)
 - Improved simulation kernel and new models
 - Large extension of modelling capabilities
 - Better integration into industrial contexts and high interoperability
 - Has proven validity for spacecraft surface potential estimations
 - Also adapted to ground experiments with low energy particles
 - Ready to be extended / interfaced with other tools and physics
-
- Next steps
 - Maintenance
 - Propulsion
 - Dust
 - Internal charging (continuation of activities not illustrated here)