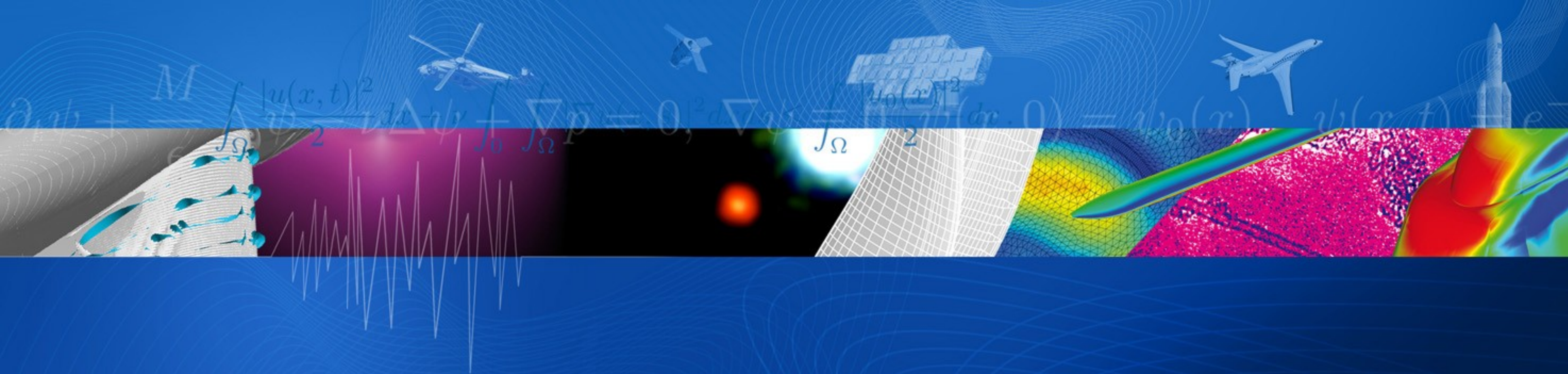

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www.onera.fr

SPIS current status and achievements

S. Hess, J-C Matéo-Vélez, P Sarrailh

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Zoom on most recent activities

SPIS – GEO

- ESTEC/ESA contract
- Technical officer: David Rodgers
- Consortium: Artenum, ONERA, EADS-Astrium, OHB-Sweden
- Adaptation to industrial needs, in particular to GEO/MEO
  - Industrial user needs
  - Simplified user interface adapted to engineering applications
  - Physical models adaptated to GEO/MEO)
  - Tested software against in-flight observations and existing codes
- Finalized in March 2013
- Maintenance phase till September 2013

SPIS-SCIENCE

- ESTEC/ESA contract
- Technical officer: Alain Hilgers
- Consortium: ONERA, Artenum, IRF-U, IRAP
- Long-term scientific program of ESA : missions dealing with plasma measurements (Solar Orbiter, Juice)
- SPIS new capabilities
  - Electrostatic cleanliness assessment
  - SPIS adapted to relatively low energy (few eV) plasma measurements with a large number of physical models implemented
  - Tested on Solar Orbiter (particle instruments), Cluster (particle & electric field), Rosetta (electric field) and Cassini (electric field)
- Finalized in November 2013
- Maintenance phase till September 2014

Software improvements

- Global precision improvements
  - Injection at the environment boundary conditions
  - User define and not limited number of environment population
  - Pusher method in presence of magnetic field
  - Optimization method for injection
- Performance:
  - UI to NUM refactoring
  - Multi thread pusher
- Instruments:
  - Particle detector
  - Virtual probes
  - Langmuir probes
- Unmeshed element

  Thin wire modeling with a very small radius in comparison to the mesh size (booms, antenna, RPW)

  Thin panels modeling with a very small thickness in comparison to the mesh size (e.g. solar array)

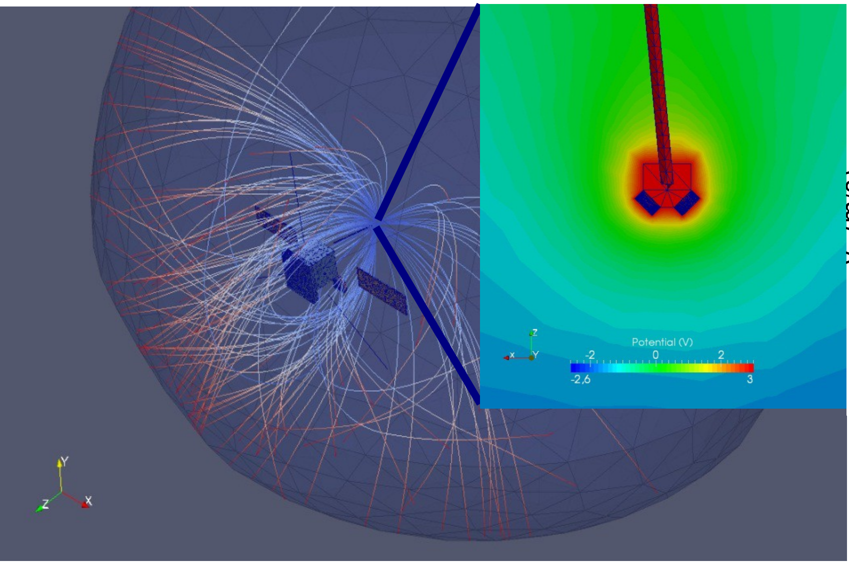
  SA interconnectors modeling with a very small size in comparison to the mesh size

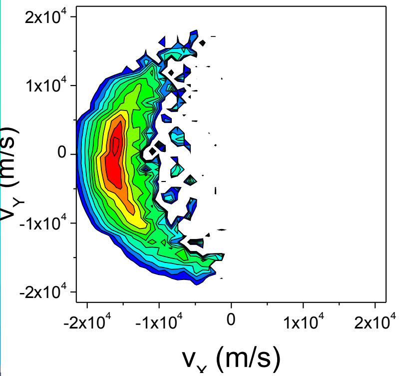
  Virtual instrument not interacting with the simulation

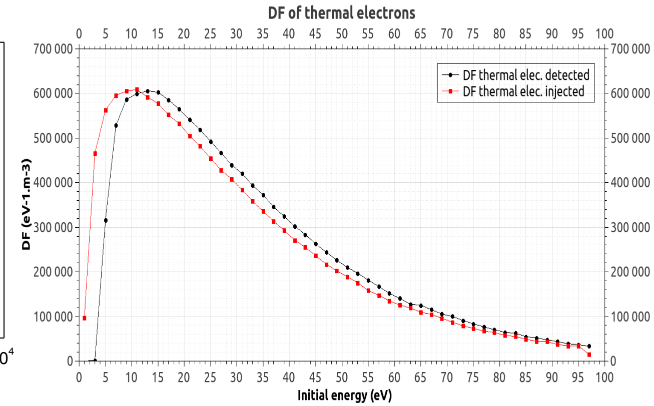
  Semi-Transparent Grid (STG) without meshing the aperture

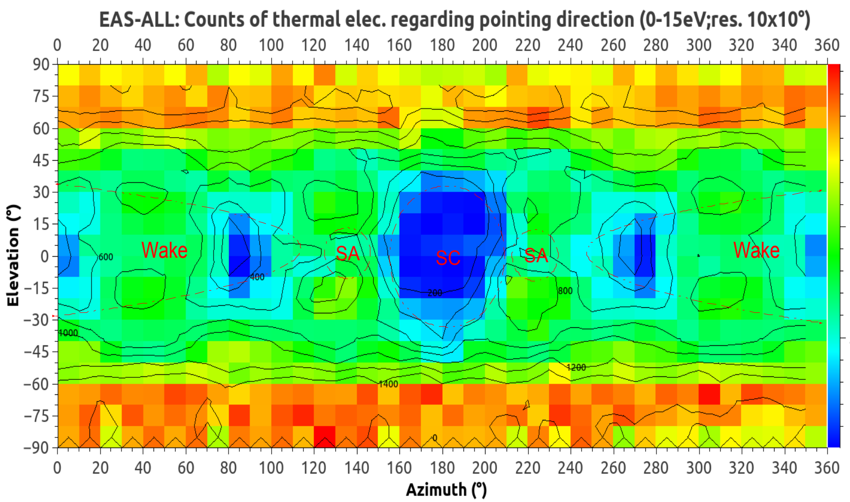
Delivered to ESA as 5.1 versions, include SPIS-GEO, SPIS-SCIENCE and some elements from AISEPS (EP)

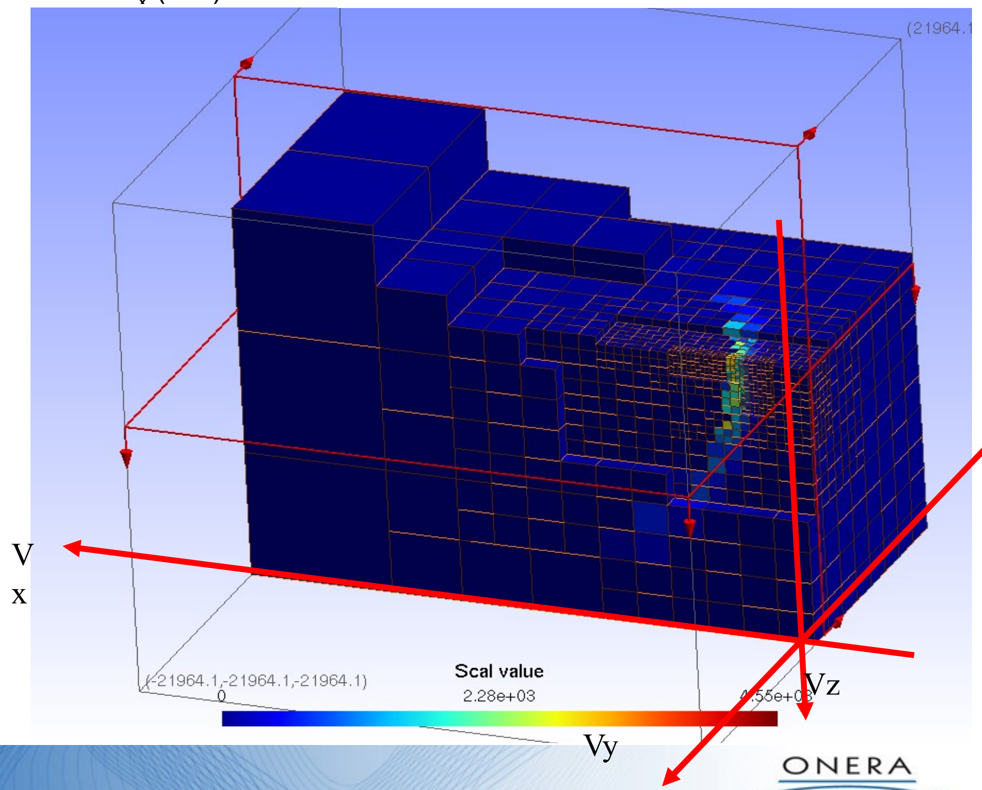
Particle Detectors – Example of DF results



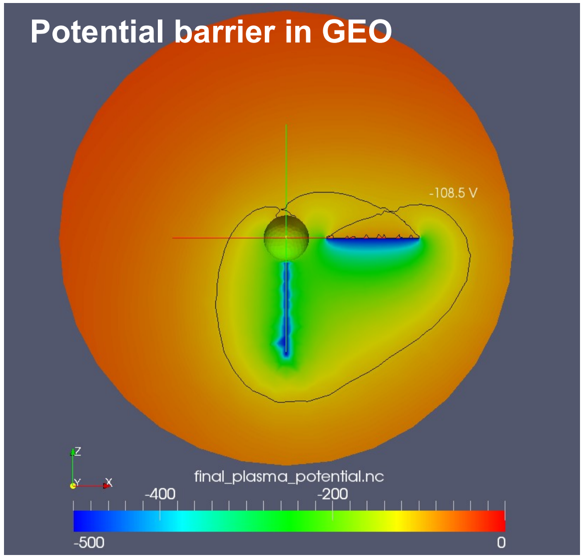




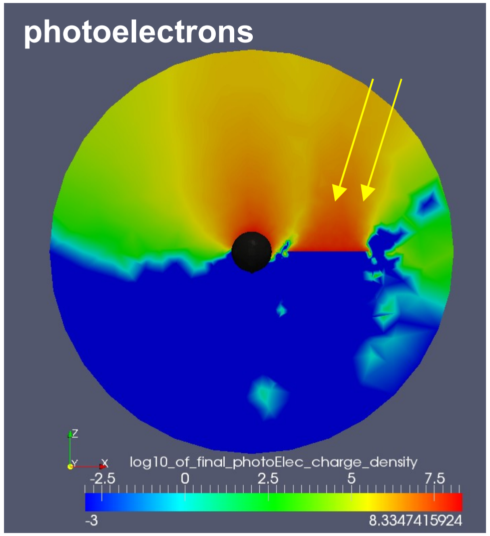


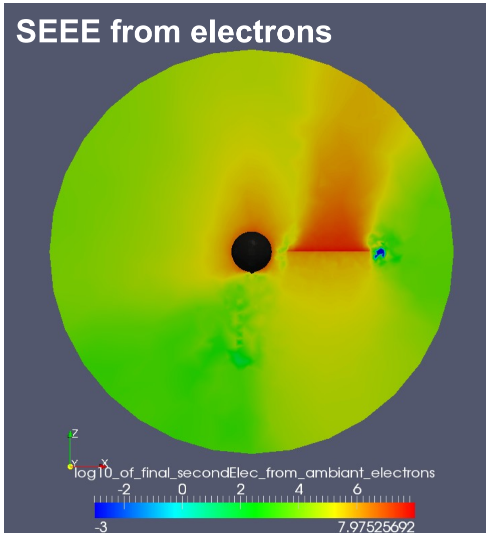


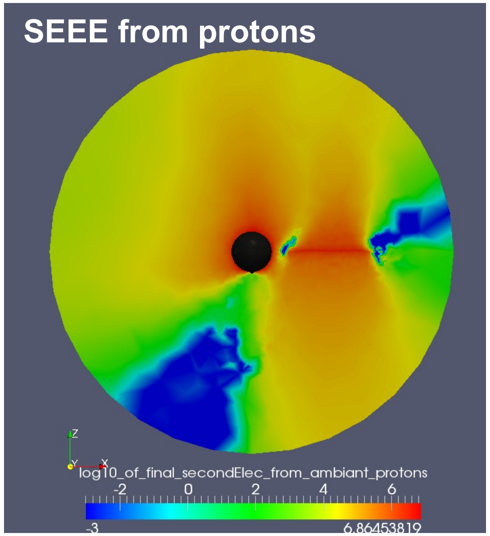
Unmeshed elements – Thin wires/Thin Panels



- Potential map:
  - Smooth potential jump → good description of the potential barrier
  - Potential effect of the wire
- Emission and collection:
  - On the wire → small effect because small radius
  - On the thin panel → standard surface (face A dielectric and face B conductor)
- Shading effect of the SC on the wire
- Wire → intensively used in the validation cases

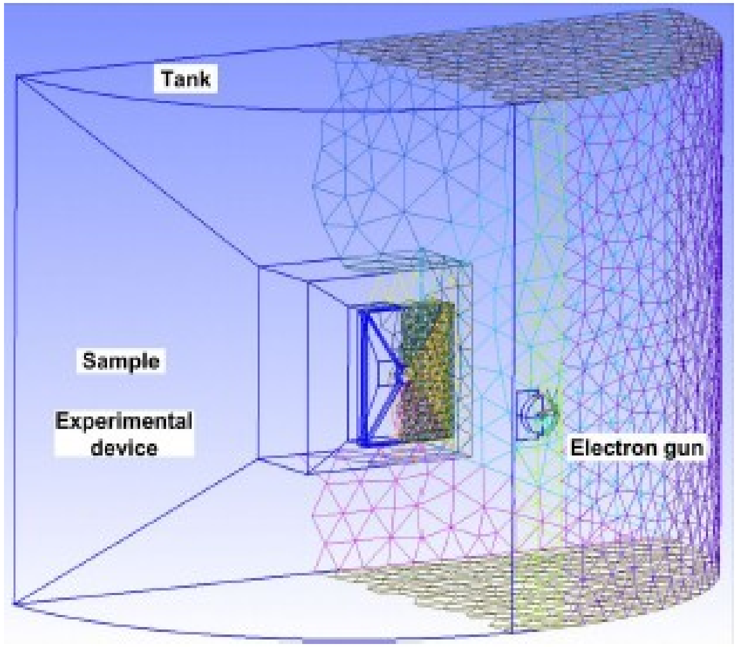


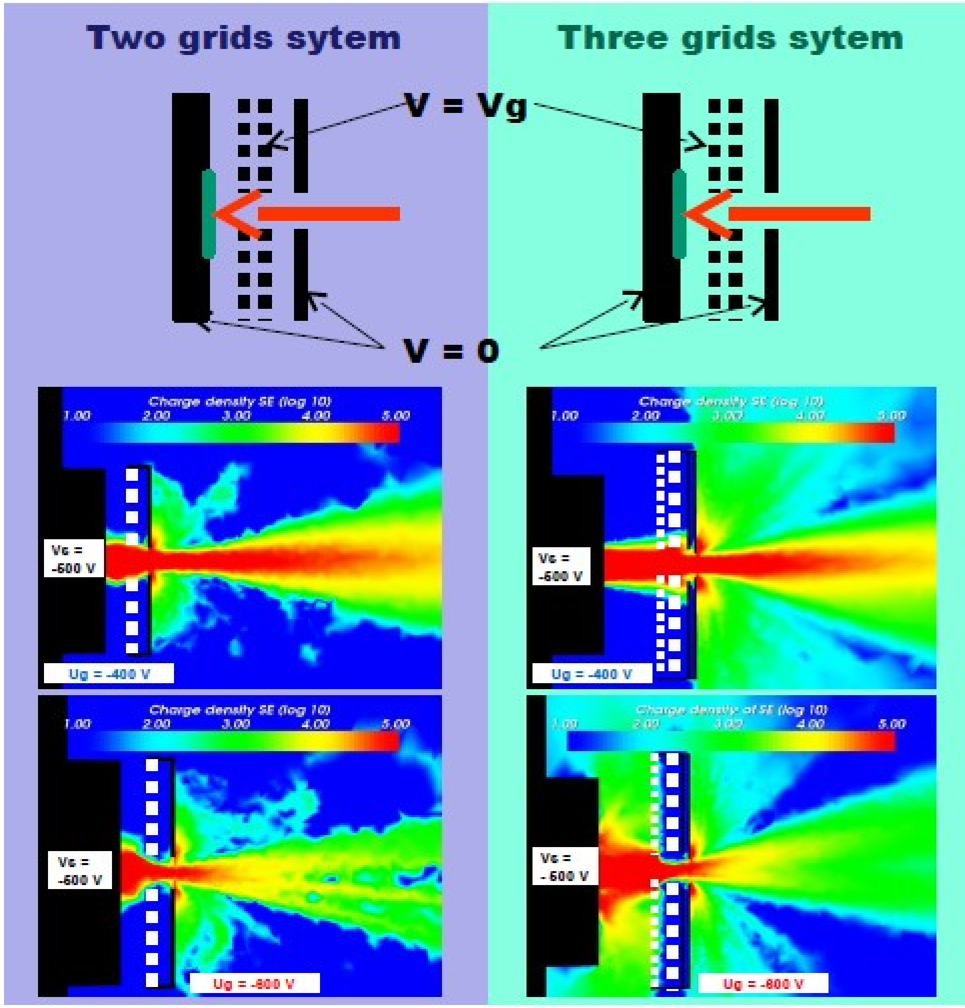




Semi transparent grid :
Repulsive Electron Potential Analyzer – REPA

- Measurement of the surface voltage of a material during continuous electron irradiation in CEDRE facility
- Grid analyser system based on the attraction or repulsion of the secondary electrons





- Paper by K. Guerch to be published

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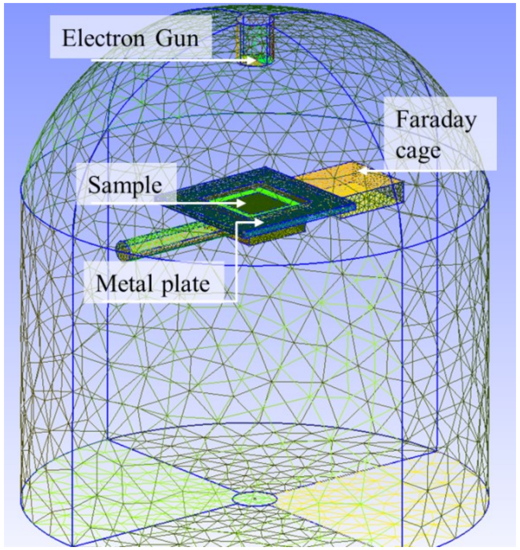
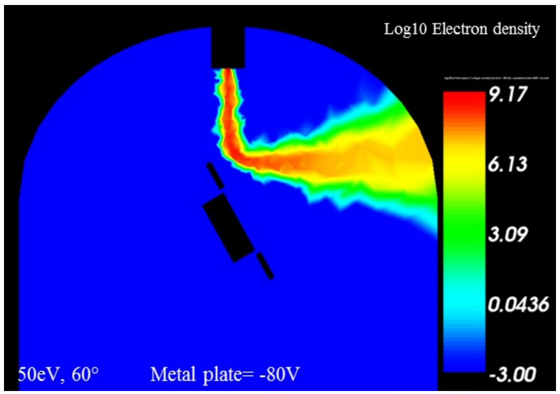
SPIS : testing new experimental setup for electron backscattering yield measurements

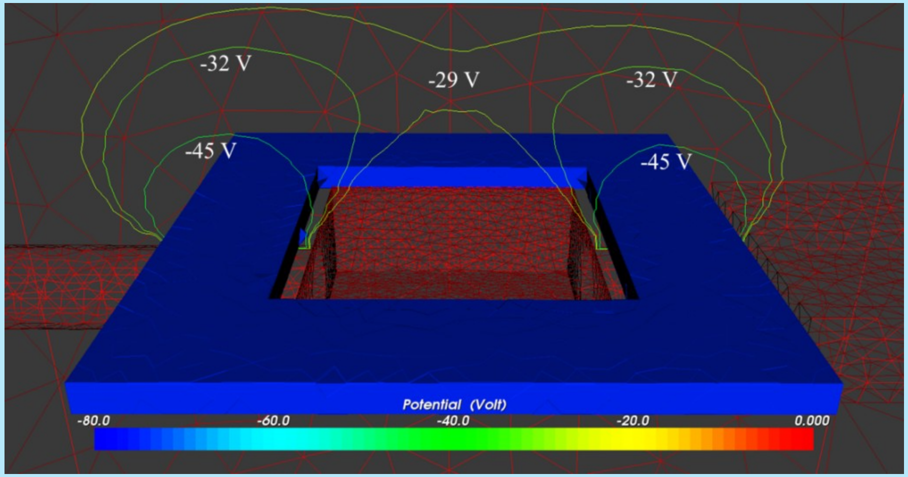
1 Modeling of experimental setup



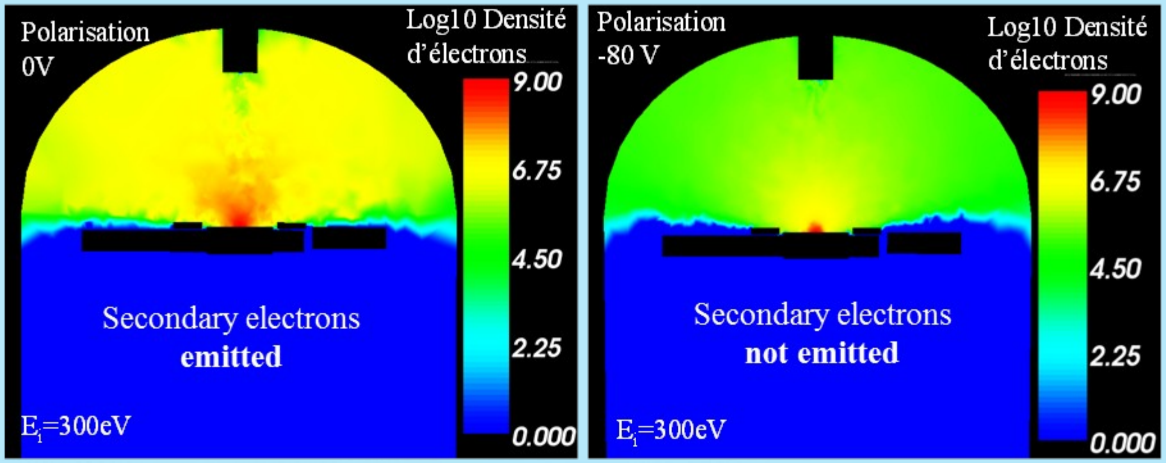
2 Testing experimental limits, ➲ Electron Beam deflection



3 Checking volume potential

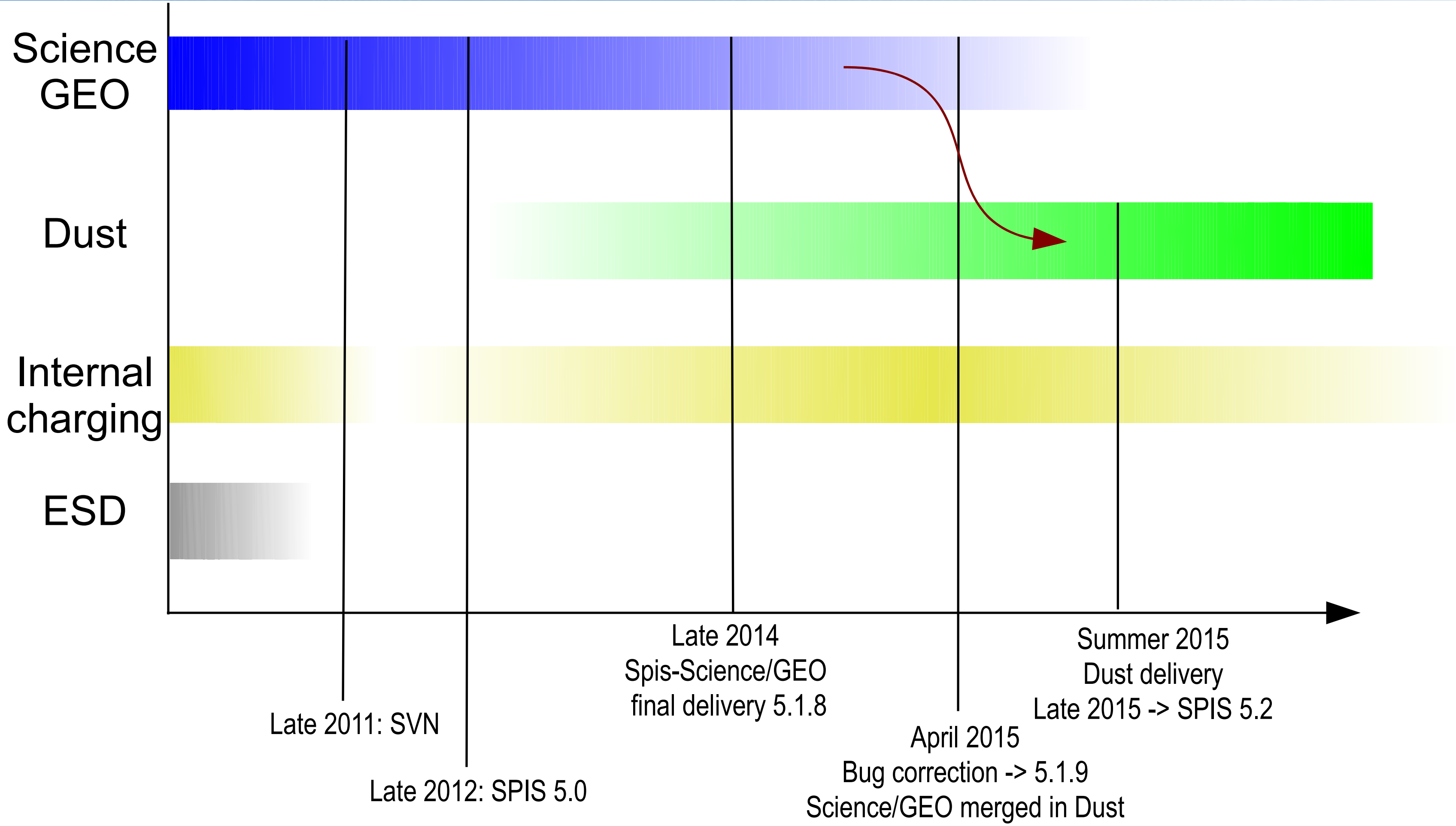


4 Simulate new setup under electron beam



ONERA

SPIS evolution



Several branches of SPIS are co-existing and / or are referenced on the official website.

→ difficulty to maintain all versions

→ some versions became obsolete before being merged in a maintained version

SPIS-Dust

Version of SPIS developed by ONERA and ARTENUM under ESA contracts.

It introduces the physics of dusts in space plasma, and their interaction with spacecraft.

particles with dust characteristics (radius, ...)
new forces in the plasma: photon pressure, gravity and on surface: vibration, cohesion,...
dust-plasma interaction: charge collection and emission, charge evolution
physical model of the dust charging on surface and subsequent dust grain emission
new models: 1D plasma sheath boundary conditions, dipole magnetic field,...
new diagnostics instruments: distributions, trajectory sensors, risk matrix,...

It also benefits from new UI capabilities:

geometry generation from DTM
merging of objects/spacecraft
global and local parameters can be lists/matrices
live monitoring of complex instruments

For users that are not interested by dusts:

The new capabilities **do not complicate the use of SPIS**

if you do not need it, you probably will not even see it

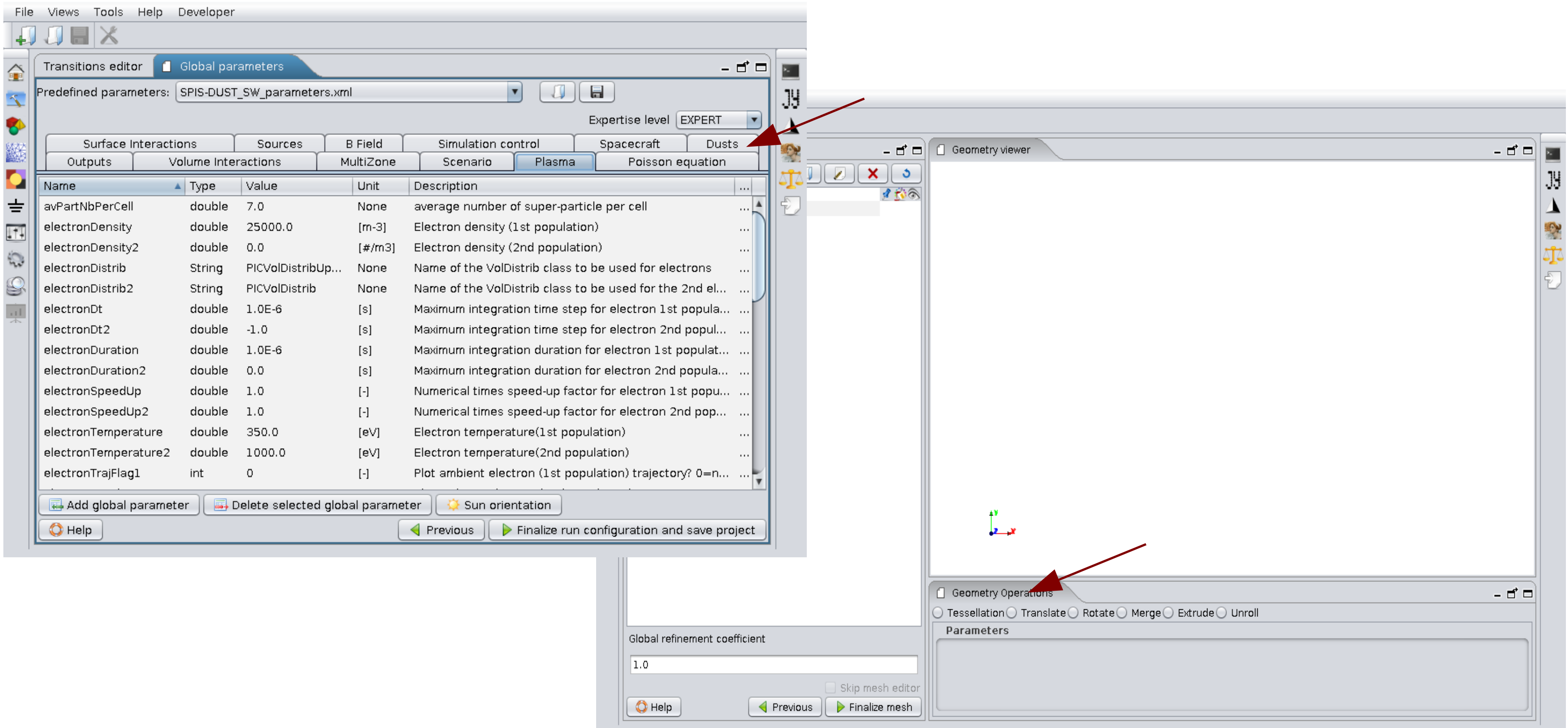
The **efficiency of SPIS for non-dusty simulations is not impacted**

memory usage is smaller and execution speed increased by ~10%

SPIS-Dust

The new capabilities **do not complicate the use of SPIS**

if you do not need it, you probably will not even see it



All of the SPIS SCIENCE and SPIS GEO capabilities are included in SPIS DUST.

It passed successfully the non-regression tests.

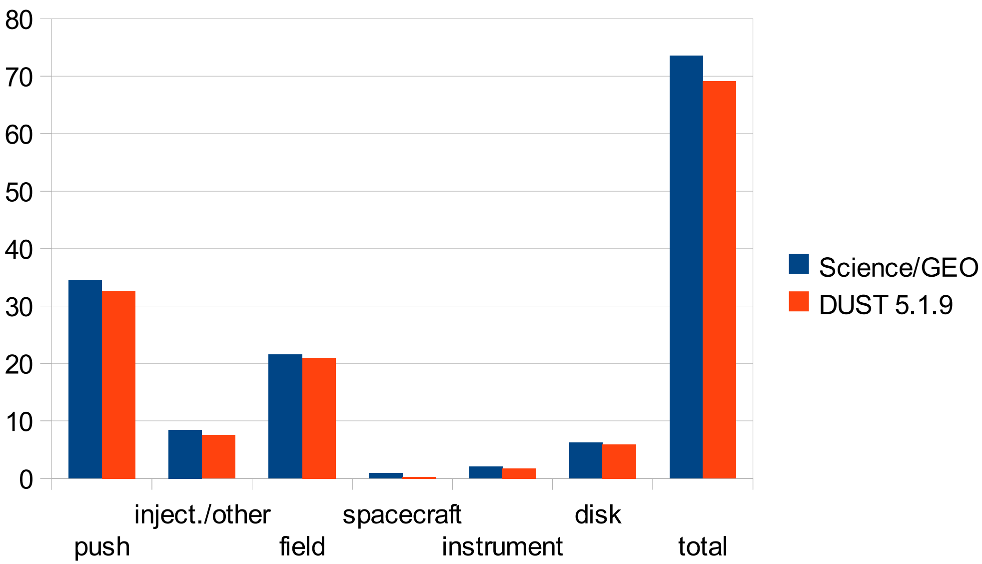
Performances

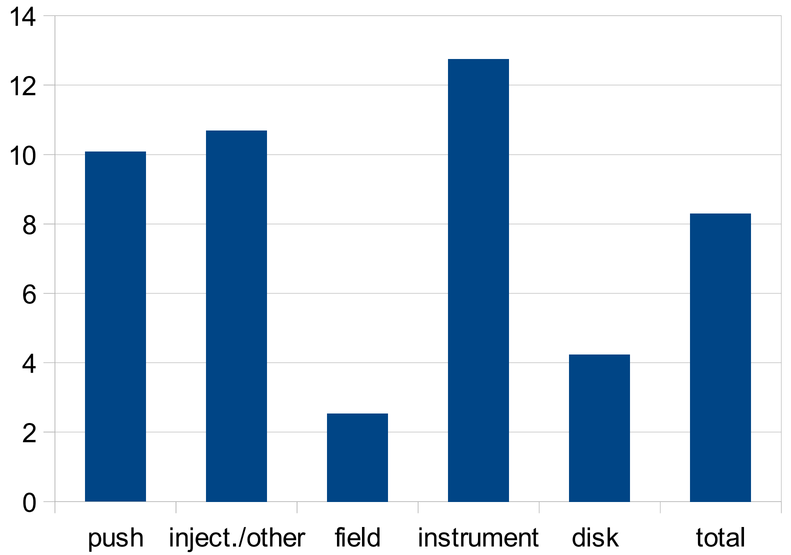
*The **efficiency of SPIS for non-dusty simulations is not impacted***

memory usage is smaller and execution speed increased by ~10%

Execution time: Non-regression cases

gain %

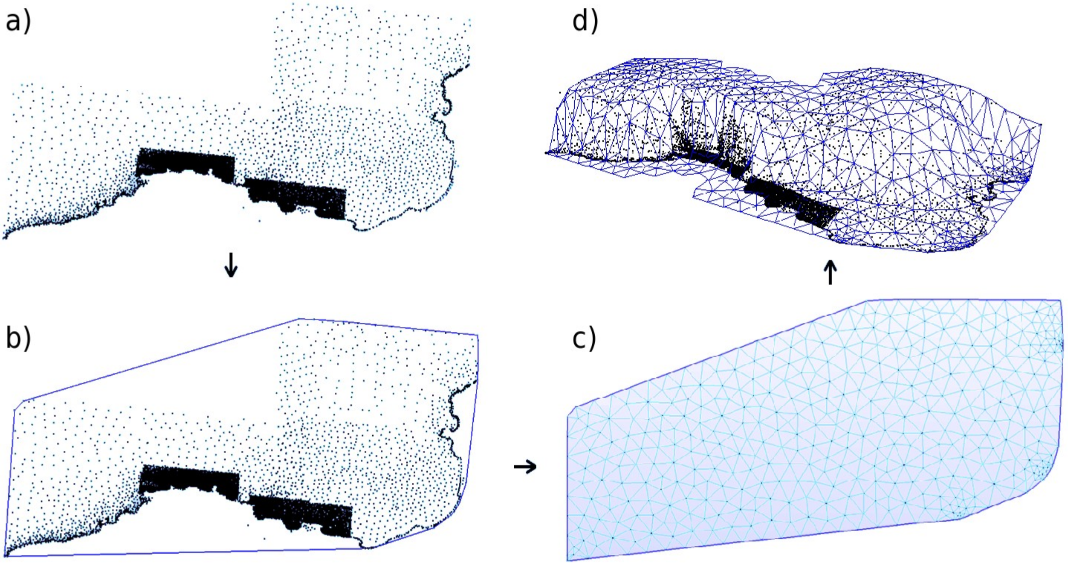


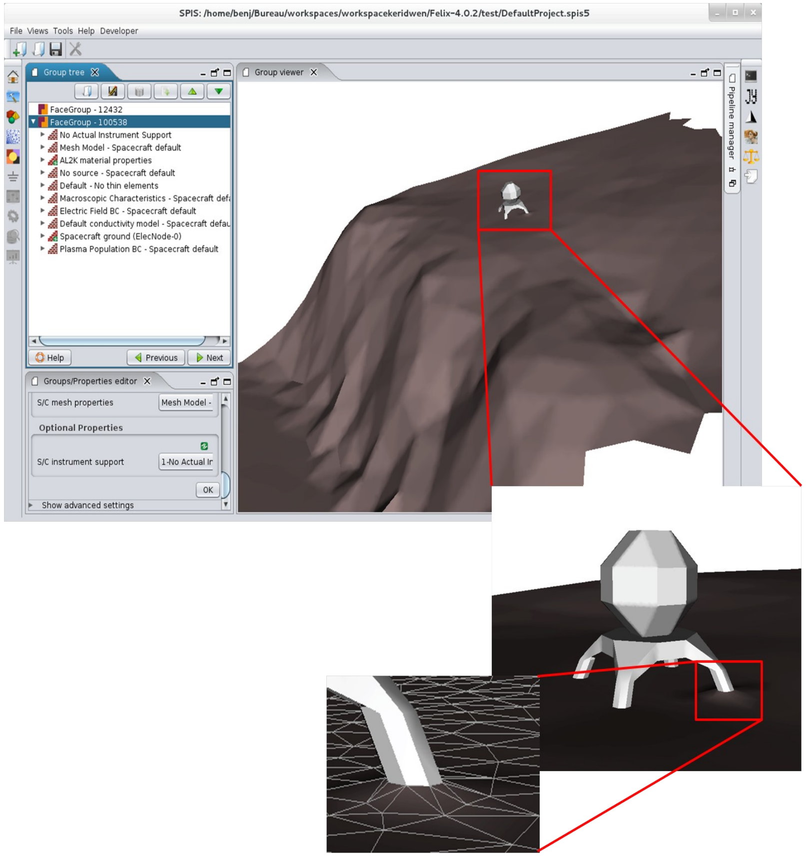


Gains depends on the type of simulation: for the ECSS worst case scenario at GEO, the overall gain was about 60% on the computation time (simulation 2 to 3 times faster), for a similar accuracy.

This gain is due to a better computation of the validity of the current scaling.

SPIS-Dust capabilities

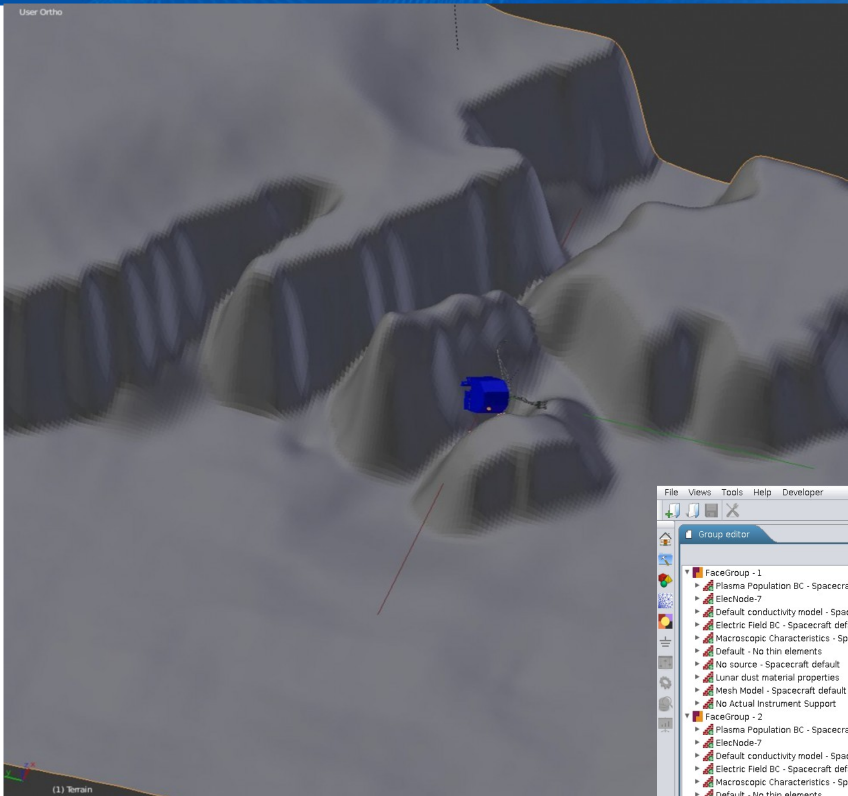




SPIS-Dust UI now allows one to load a DTM, to generate a surface geometry from it, to insert a spacecraft or any another geometry element, to translate and rotate it, and to merge it with the surface geometry.

Then, it is possible to automatically generate the simulation volume and to mesh it.

SPIS-Dust capabilities

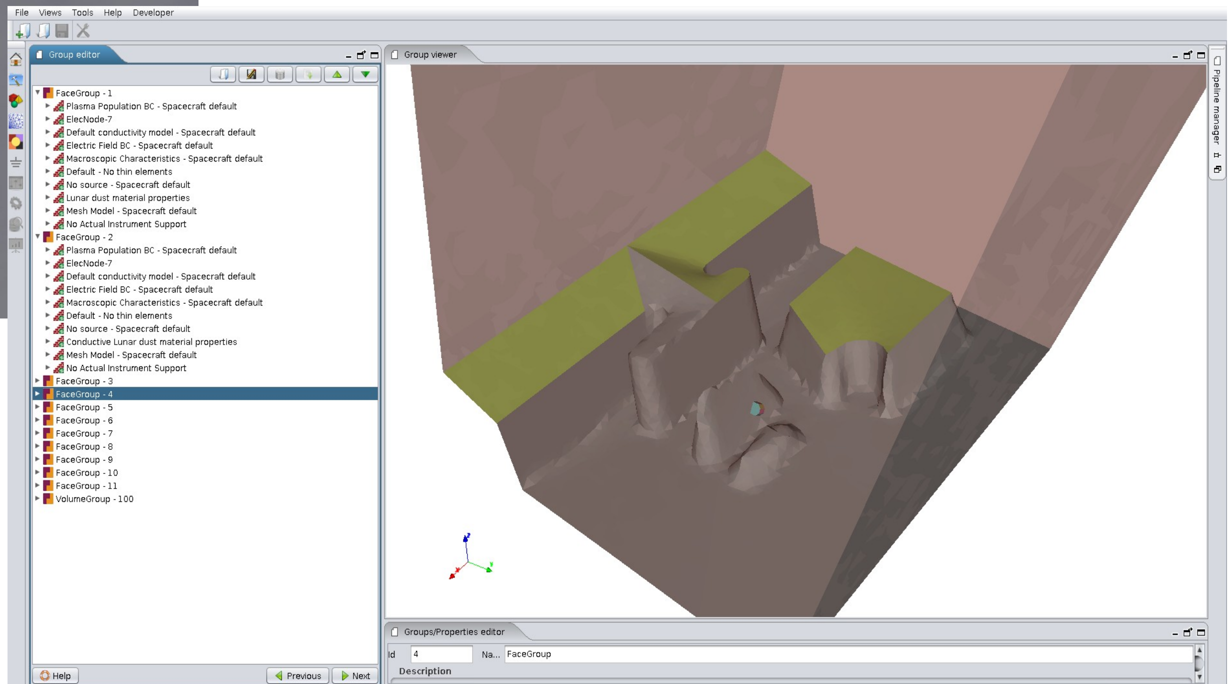


Exemple of Philae on Churyumov-Gerasimenko

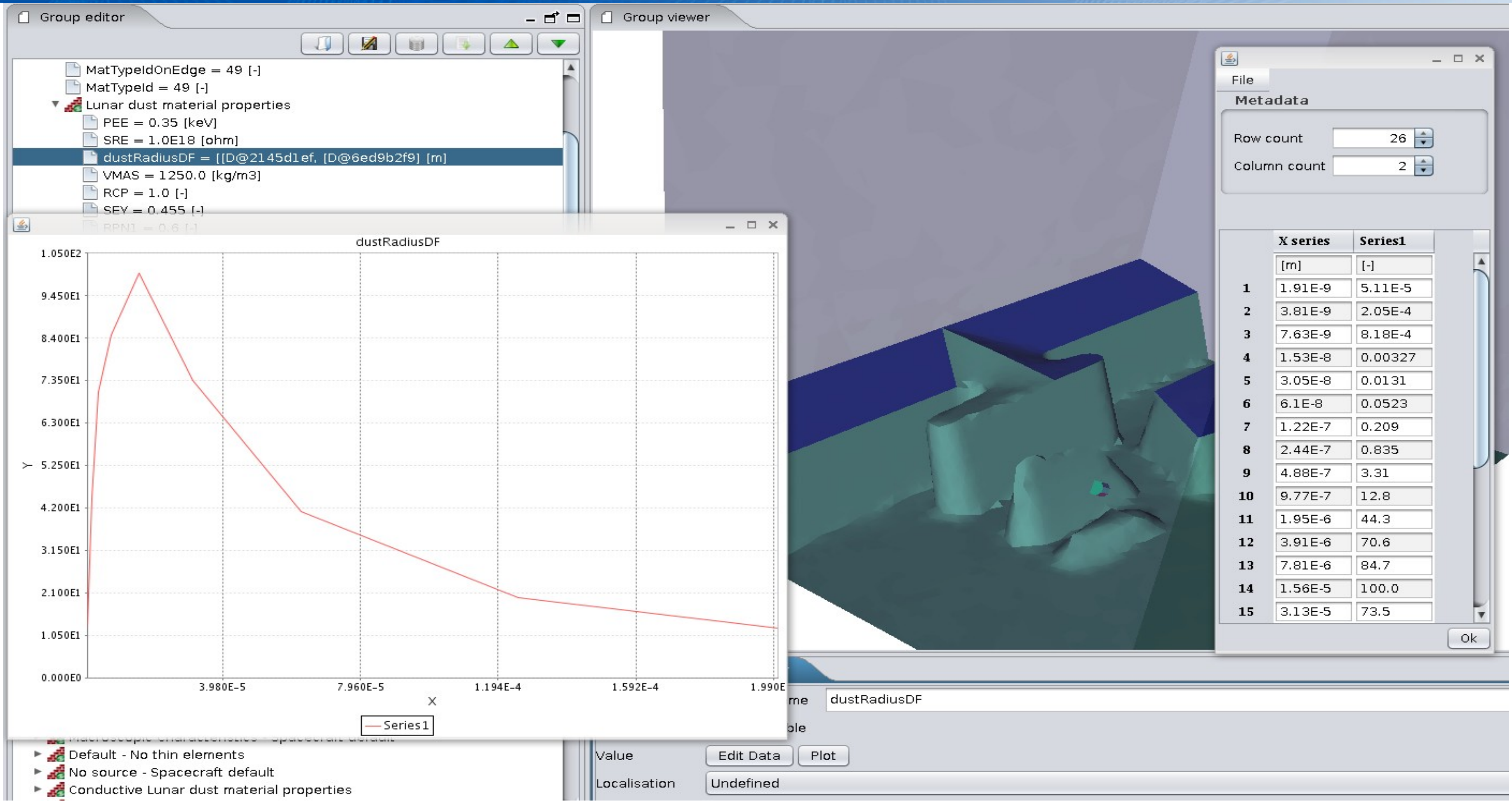
DTM exists at CNES

Reproduced “by hand” for this simulation

50 m x 50 m x 130 m



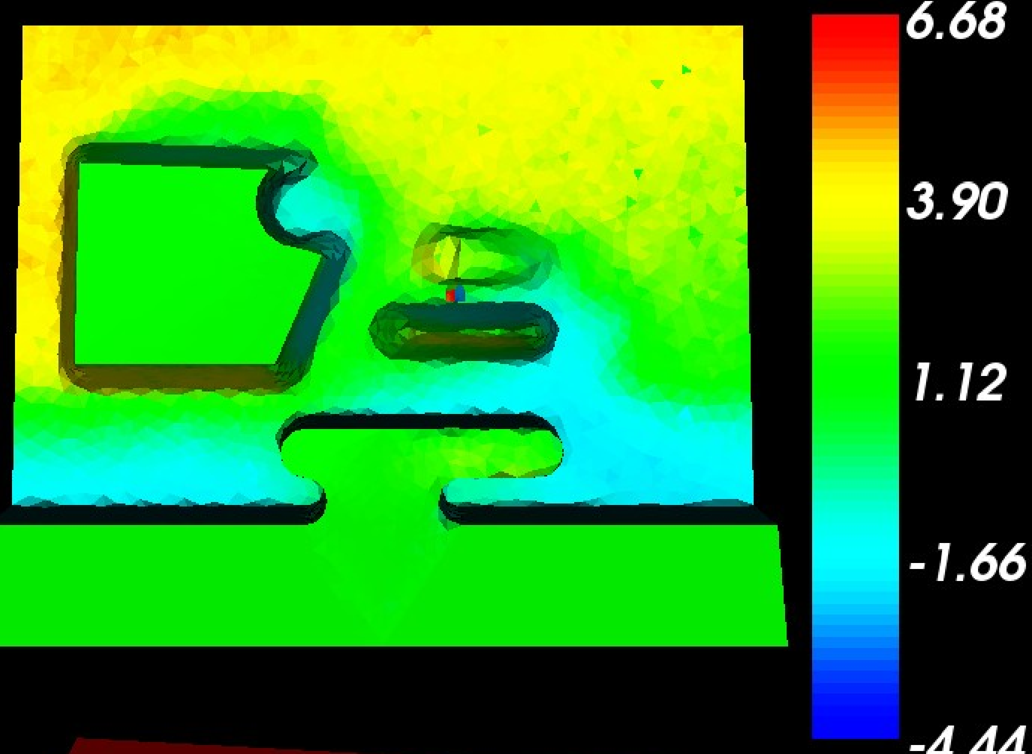
SPIS-Dust capabilities

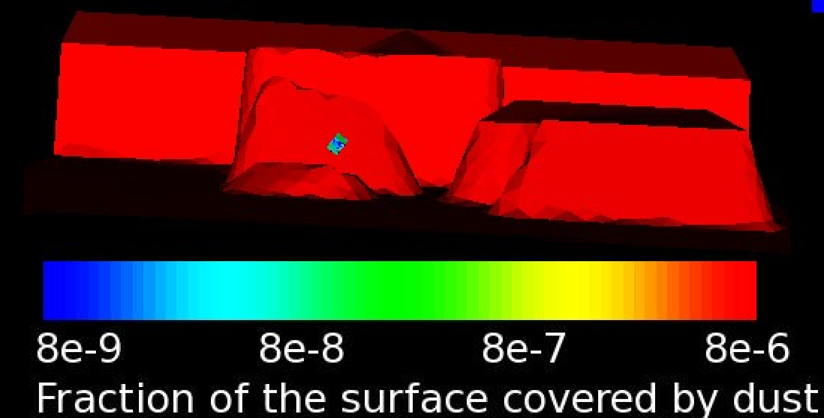


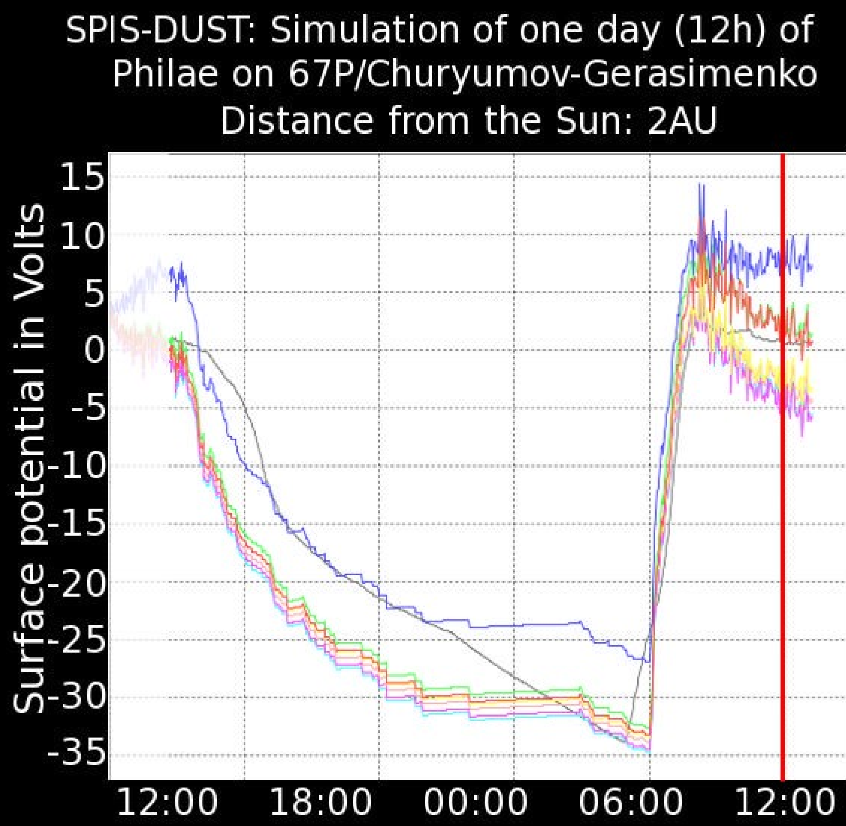
The comet is given the same properties than the lunar soil.

In particular the same dust size distribution, defined thanks to the new table parameters in SPIS.

SPIS-Dust capabilities

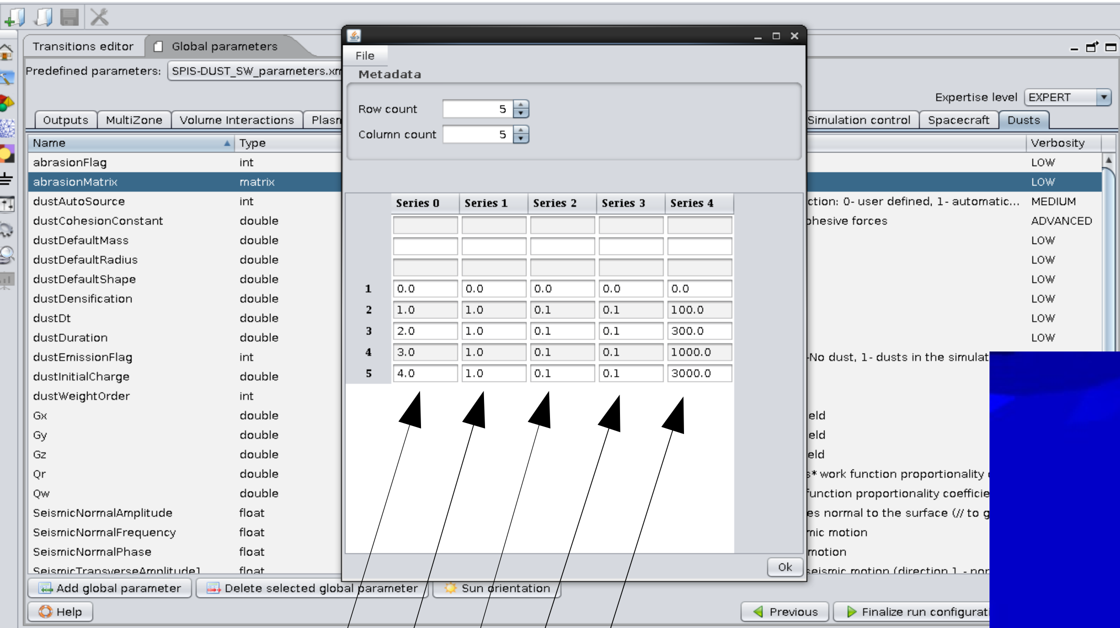






SPIS-Dust capabilities

Risk matrix:



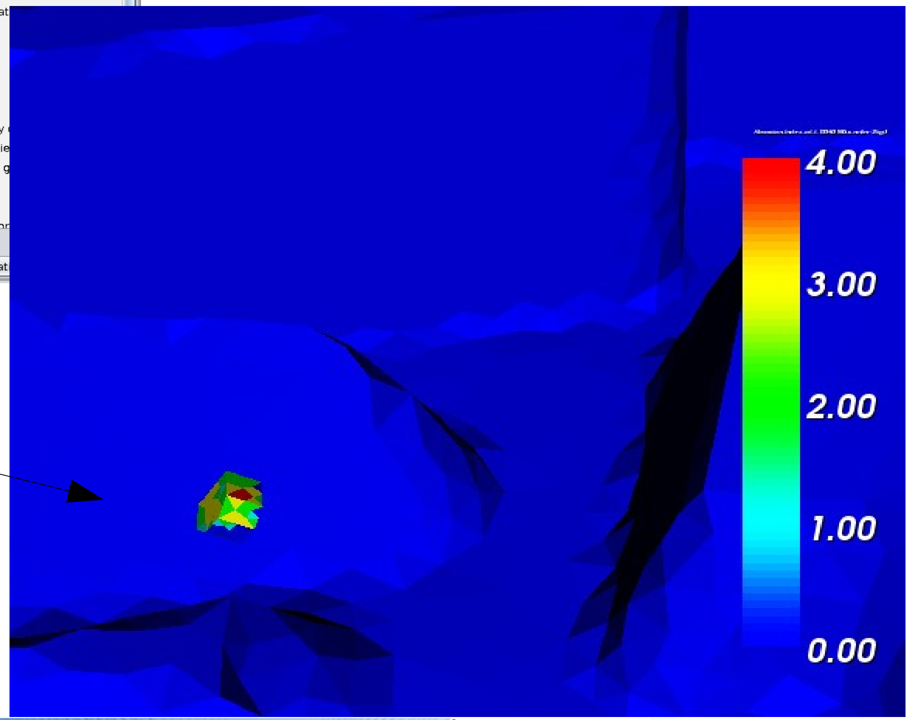
Risk level

Maximum hardness

Minimum severity

Minimum risk for mission

Minimum impact rate



ARTENUM, PARIS Science & Groupware

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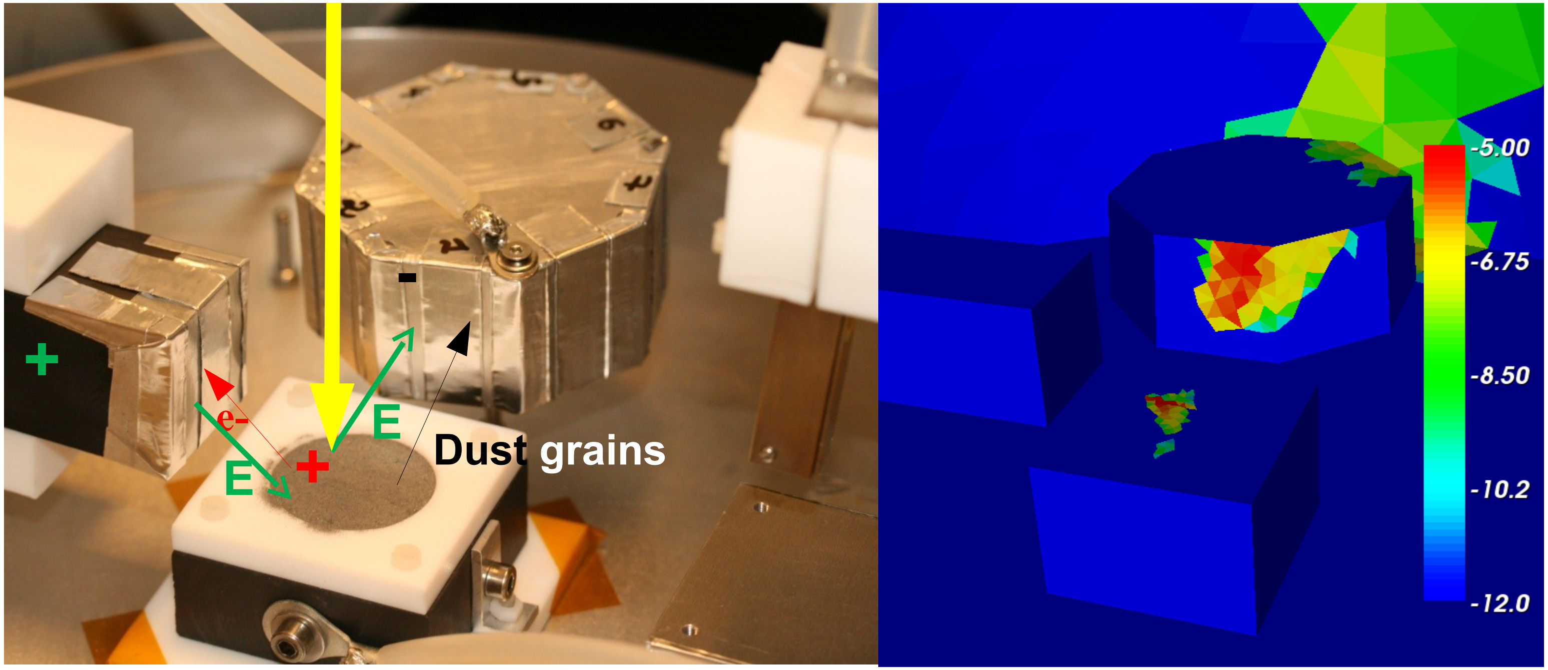
SPIS-Dust capabilities

SPIS-Dust has been used to model actual experiments. It permitted to avoid cross-contamination of different samples. Model/experiments results are being compared.

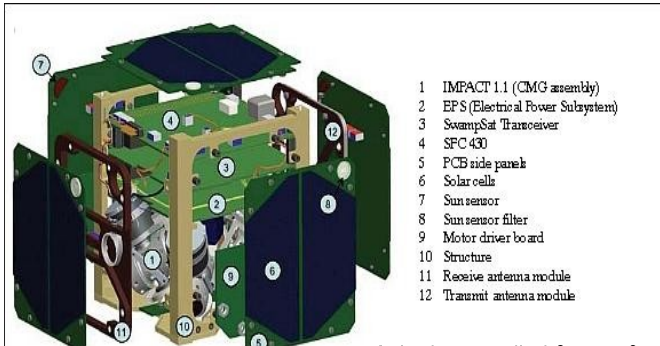
UV



New capabilities interesting out of the dust context

Magnetic dipole:

-> modelling of attitude control actuators, electric propulsion,...
Can be quite interesting for cubesats, ...



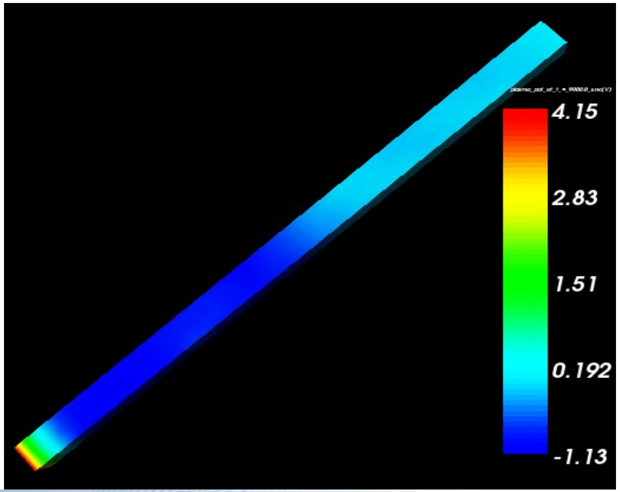
Attitude controlled SwampSat

LocalTimeTransition:

Allows for the evolution of the solar flux and ambient species direction, fluxes and moments (n,v,T) versus time and zenith angle.
-> modelling of spacecraft attitude changes, of evolving conditions,...

Quasi-1D sheath model:

Allows to compute the boundary condition to apply to the ambient electron density above a 1D photo-electron sheath to ensure quasi-neutrality at the boundary.
-> quasi-1D modelling above a spacecraft element without computing the global interaction of the spacecraft



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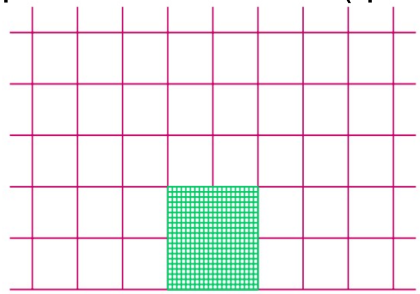
On-going work at ONERA

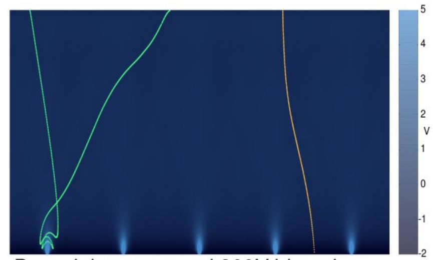
PhD thesis are on-going or are scheduled for 2015 on the development of SPIS under CNES grants:
advanced numerical schemes allowing to solve more complex problems in realistic times.

_ Patch method (A. Brunet – started 2014):
Advanced multi-domain method allowing to refine the mesh on particular locations (“patch”).



Solve linear and nonlinear Poisson problems on combined coarse and refined meshes

Small-scale systems simulation: SC interconnectors, sensors
Large-scale simulations: thruster plume, wake. . .



Potential map around 200V biased interconnects, and electron (green) and ion (orange) trajectories. Interconnect distance: 50cm, Interconnect width: 0.5mm

_ Hybrid method (O. Jorba-Ferro – scheduled 2015):
Coupled fluid and perturbative-PIC method allowing the simulation of dense plasma flows
First targets are the MYRIADE spacecraft (TARANIS).

Future developments foreseen at ONERA

.

Electric propulsion dedicated developments:

Better plume modelling in particular concerning its structure
Addition of collisional effects, “chemistry”,...
Recollection by the spacecraft, erosion,...

Dust/micro-meteorites impacts:

Develop models of the plasma generated by impact and of its interaction with the spacecraft from engineering and scientific point-of-view. Problem related to ESD flash-over.
Implementation in SPIS.

Dust consolidation:

In order to be fully operational, SPIS-Dust should include other important dust sources: meteorite impacts and ice sublimation (modelling of outgassing could be of wider interest).
Need for some consolidation work on the UI (in particular geometry editor) and non-regression cases.
Coupling with larger environment modelling code and environmentaltal data (implementation of VO inputs/outputs)

Future developments foreseen at ONERA

Internal charging maintenance and merging:

For maintenance purposes, the numerical core of IC must be merged by the surface charging version (+ESD).
Interest of a Internal+Surface charging version to better investigate the ESD risk due to IC, e.g. for electric boards.
Needed to correctly model secondaries.
Some important work needed to have a robust consistent model.

Better, Faster, Stronger, Friendlier:

Continuation of the GEO work: make SPIS easier to use and to control.
Live monitoring and control of the interactors and transitions (similar to instruments)
Use of the current scaler predictions to accelerate the computation (semi-analytic computation)
Ease the use of the multi-domain or hybrid methods.
Stabilize and optimize the most advanced capabilities of SPIS (grids, wires, panels,...)
Better management of the materials, coupling with material databases