Advanced CAD tool and experimental integration of GRAS/GEANT-4 for internal charging analysis in SPIS

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Introduction: multi-physics modelling in space environment, an open issue

Future scientific and commercial missions present new needs and challenges in terms of modelling space environment effects. ESA's Juice Jovian mission is expected to cross intense radiating and plasma environments, potentially leading to severe radiation and internal charging effects. The new generation of commercial missions in MEO is marked by a massive use of non-hardened components or ions thrusters. Cumulated doses and charges may lead to strong internal electric fields and risks of discharges, potentially dangerous for embedded equipment. Design and shielding must be carefully computed and more accurate numerical models needed.

To cover self-consistently all involving physics, a multi-physics/multi-models approach is needed, chaining different numerical models. But the global modelling process should be also considered as a whole. Such chaining requires numerous operations hard to perform manually, making the simulations difficult to drive by non-experts. A unified user interface, helping the user to follow the whole modelling process in a coherent way, is needed. This is the purpose of **I**ntegrated **M**odelling **E**nvironments or IMEs that aim to integrate the various numerical kernels as well as all needed pre/post-processing tools, like CAD editors, in a common and simplified frame.

Coupled radiations / internal charging analysis

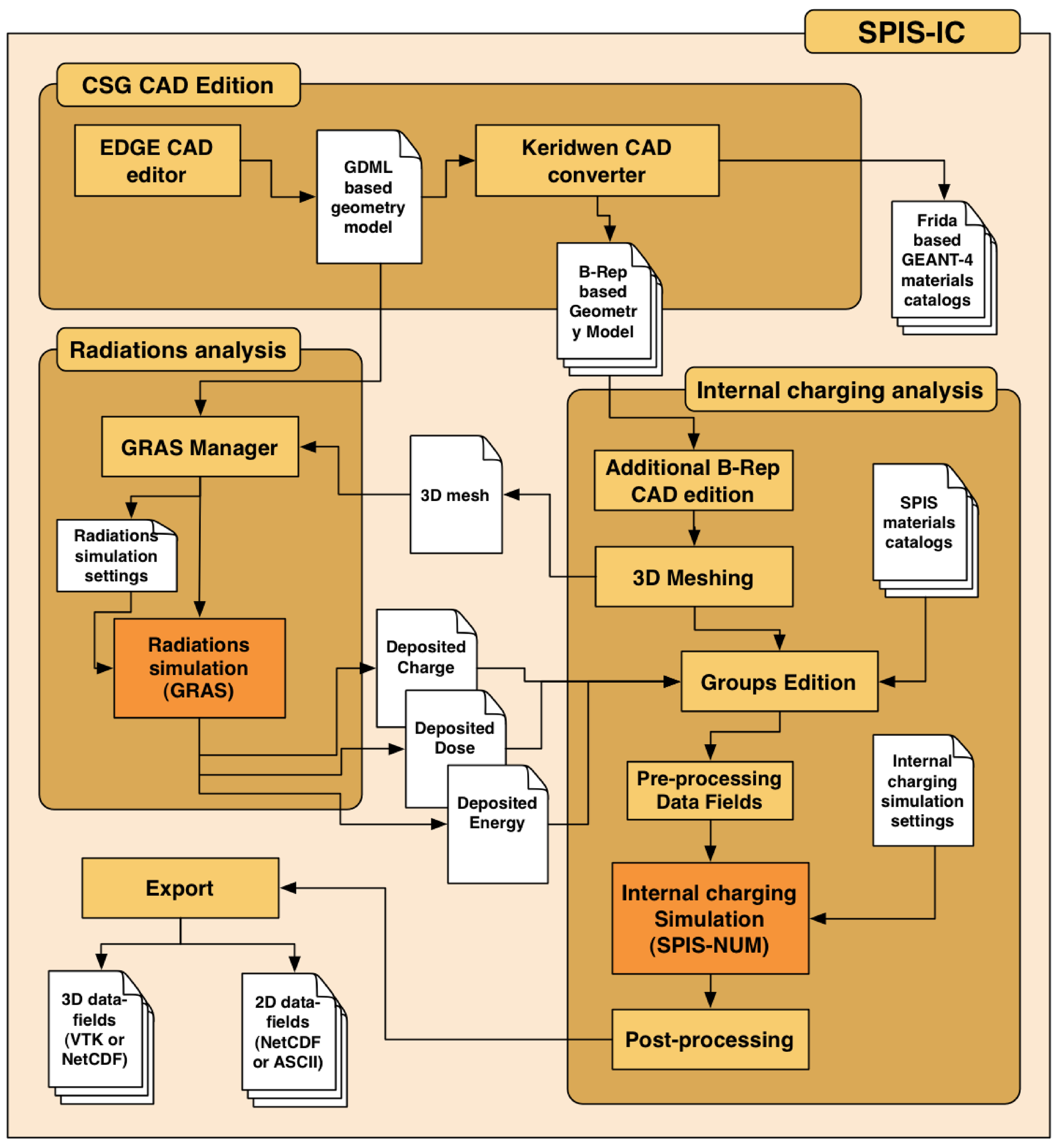
A coupled 3D radiations/internal charging analysis implies tree main steps:

1- Construction of realistic geometrical model(s);
2- Computation of the deposited energy, charge and dose, using a Monte-Carlo model;
3- Computation of the evolutions of the inner charges and electric fields with a charging code.

Based on GEANT-4, ESA/GRAS [1] is a simulation core especially designed for the modelling of the radiations effects of the space environment.

Open-source, based on electro-static 3D PIC models, SPIS [2] is a reference tool in surface charging analysis. Through several projects, ESA has encouraged the development of new numerical models to compute internal charging effects as well. Added to ONERA's internal R&D, this has recently led to a new branch, SPIS-IC, for internal charging effects, detailed in P.Sarrailh presentation [3].

The possibilities to interface both kernels has been explored in the frame of previous ESA initiatives (e.g. Elshield, CIRSOS and 3DMICS projects). However the global simulation remained still difficult to drive in an industrial context.



SPIS includes its own modular IME, SPIS-UI, based on Artenum's Keridwen solution [4].

On this basis and to simplify the collaboration process, a first integration of GRAS into SPIS-UI has been done through a dedicated module.

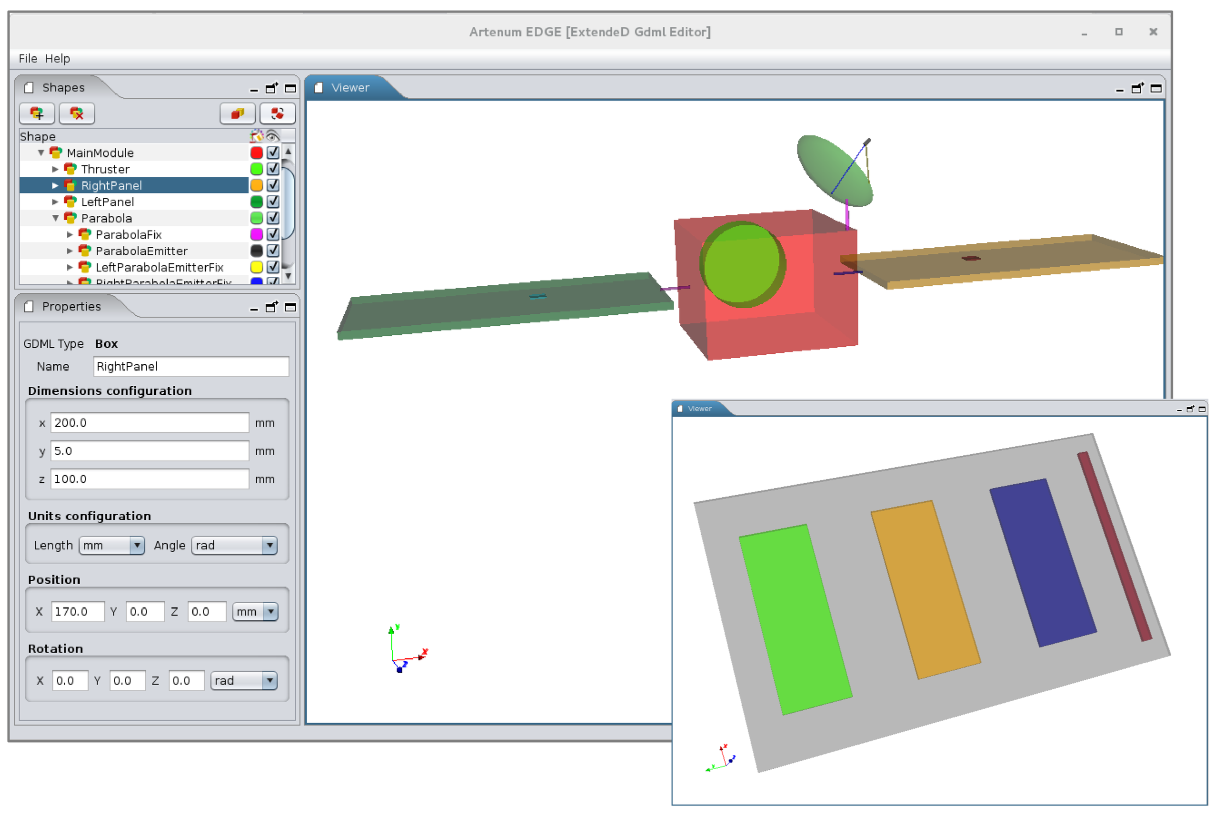
To help the user to model the geometry of the studied system, a new WYSIWYG 3D CAD tool has been developed ab initio on the basis of an internal Artenum R&D effort and integrated into SPIS.

EDGE, the **E**xtende**D** **G**dml **E**ditor:

- GDML geometries (CSG) creation and edition
- Geometrical operations
- Real-time 3D visualization
- GDML files loading/saving
- Import existing Gmsh mesh files

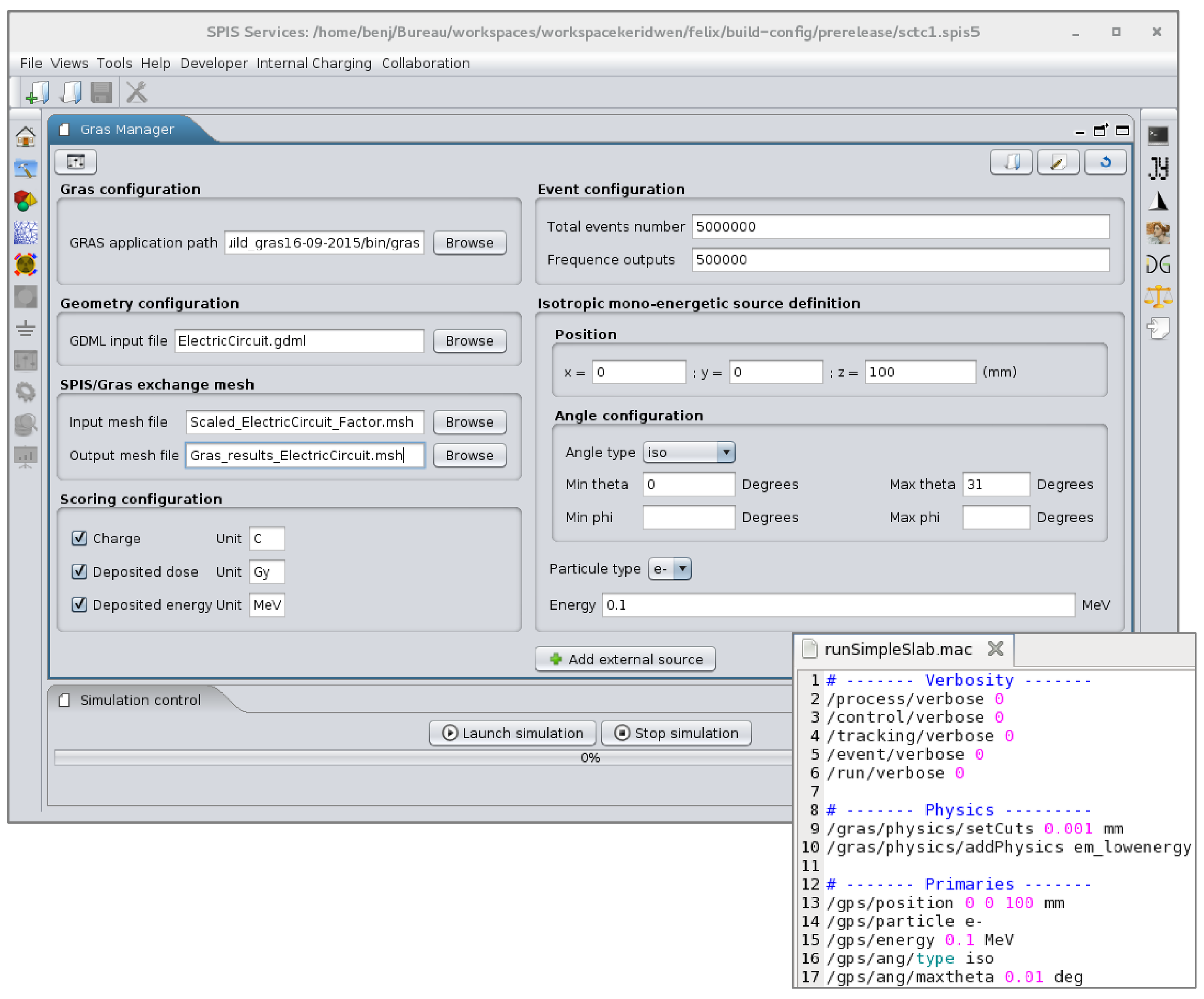
A CSG-to-B-Rep bridge:

- Export to Gmsh geometry files (CSG-to-Brep)
- Full compliance with SPIS's Geometry Editor
- Additional simplification tools: automatically duplicated elements suppression



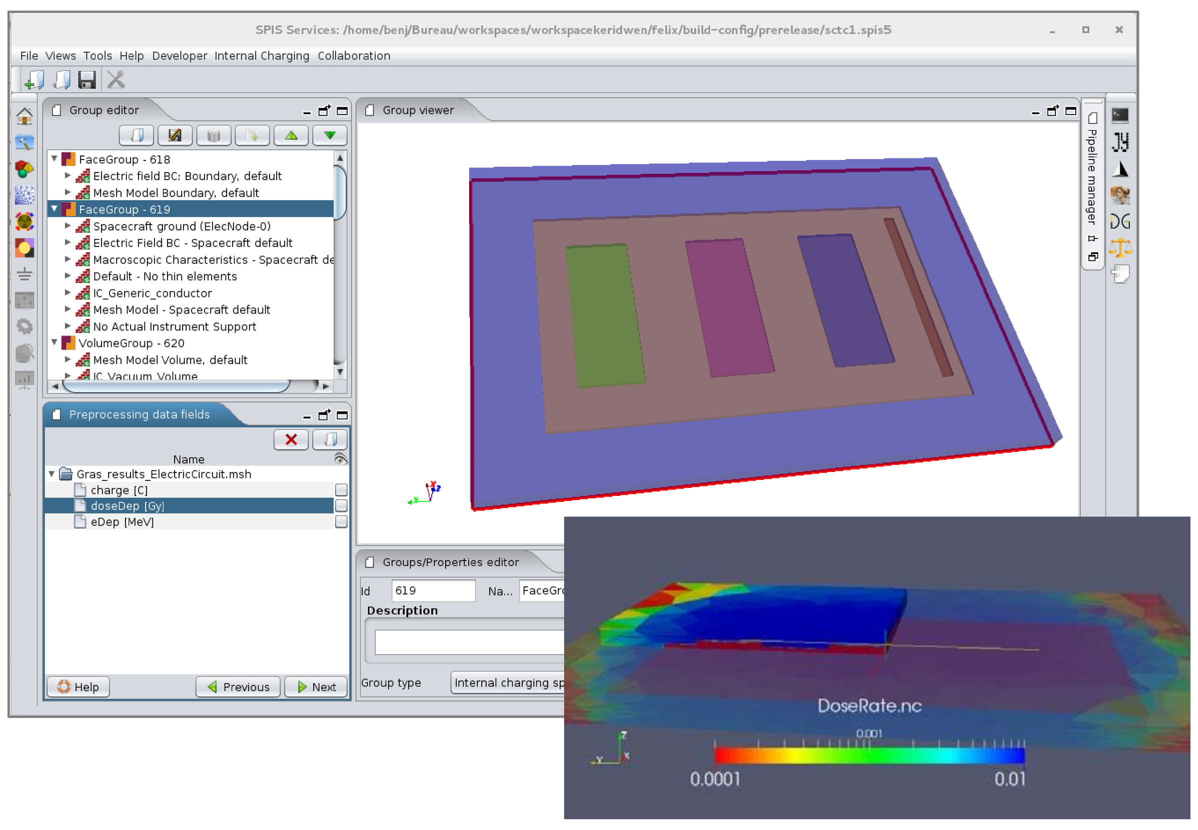
SPIS IC – GRAS Manager

- Integration of Geant4 Radiation Analysis for Space (GRAS), a radiation modelling software
- Dedicated GRAS GUI allowing to set all radiation models parameters :
  - Environment settings
  - Selection of input geometry GDML file
  - Selection of input mesh file for scoring
  - Events configuration
  - Isotropic mono-energetic source
- Generation of full self-consistent .mac files
- Import and edition of existing .mac files
- Real-time progress of GRAS simulation



Inter models data exchanges

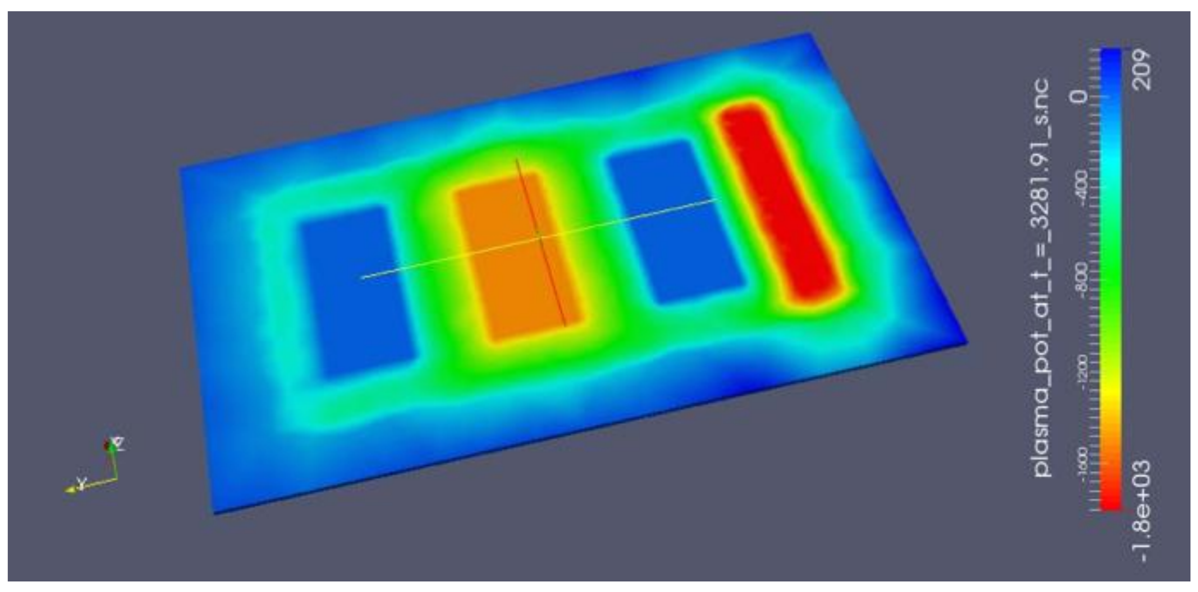
- Conversion of GRAS outputs into data fields: Deposited doses, charges and energy automatically
- Preloading into SPIS's Properties and Groups editor and conversion
- Used as initial boundaries for charging analysis

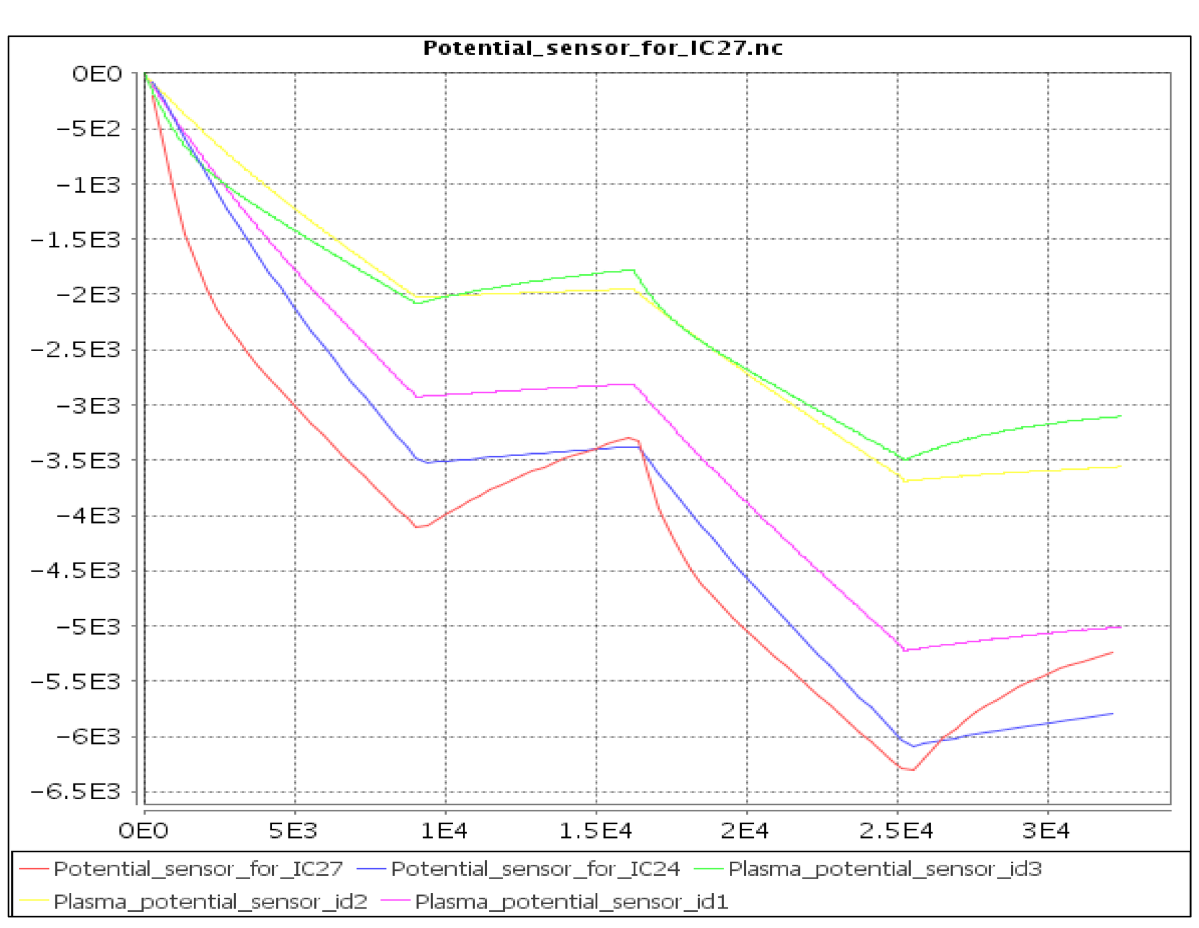


Example of simple application case

Charging of floating surface patches on flat dielectric samples:

- Epoxy sample metallized on its back-face and a few millimeters thick.
- Several metallic flanges on its front sides
- Resulting charging can reach -6000 V
- Depending on deposited energy, high risk of electrical breakdown in spite simple design





Conclusion and Perspective: A first experimental integration of radiation analysis tools, **ESA/GRAS**, and the internal charging simulation core, **SPIS-IC**, into a unified **IME** has been presented. The relevance of an integrated approach for a multi-physics modelling in radiations / internal charging analysis is confirmed. The newly GDML CAD editor, **EDGE**, deeply simplify of the geometrical modelling for **GEANT-4** based simulations and the interfacing with internal charging models.

Most of these new tools are expected to be available as advanced functionalities in the frame of the ONERA/Artenum offer SPIS-Services (see www.spis-services.eu).

[1] space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html, [2] www.spis.org, [3] Sarrailh P. et. al, 14th SCTC, Development and validation of a 3D time dependent model used for the simulation of internal charging at spacecraft level, [4] www.keridwen.org

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