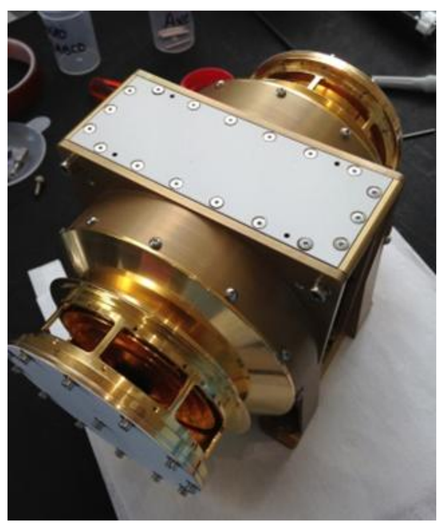
Internal charging analysis of a realistic experiment with a dedicated modelling chain

B. Jeanty-Ruard[(1)], P. Sarrailh[(2)], D. Payan[(3)], A. Trouche[(1)], A. Champlain[(1)], J. Forest[(4)]

(1) Artenum Toulouse, (2) ONERA, (3) CNES, (4) Artenum Paris

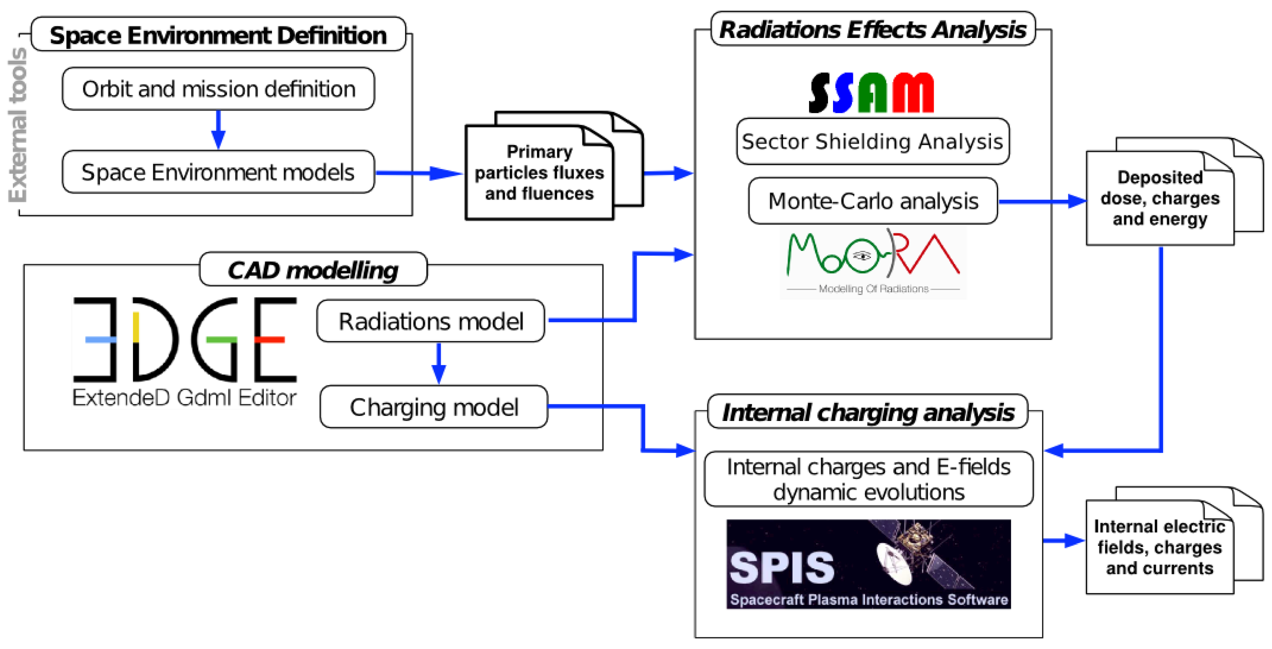


Introduction: Due to the technological evolutions and the new mission profiles, the study of **internal charging** effects is an increasing issue for space systems. It may potentially impact all thick dielectric or floating metallic parts inside the spacecraft. All equipment could be affected, especially **scientific instruments** outside the spacecraft, particularly exposed to the space environment. Moreover, the role of the shielding is preponderant and the **global geometry** system must be taken into account precisely.

The **AMBER** instrument, for **A**ctive **M**easurement **B**ox of **E**lectrostatic **R**isk, developed at CNES, aims to measure the spacecraft potential and auroral particle precipitations for electrons and ions in the energy range of 10 eV-28 keV. AMBER is currently on-board the ocean topography mapper Jason-3 [1] and is used in this study for a detailed internal charging analysis, with the new **EDGE**, **MoORa/GRAS** and **SPIS-IC** simulation chain as a realistic application case.

Global approach

The electrons coming from the external environmental fluxes have high energies (~MeV) which make a direct computation of the electrostatic effects neither reachable nor relevant. When these primary particles are slow-down enough, the deposited charges and dose can be considered as initial conditions for the internal charging analysis. Moreover, the deposited dose impacts the conductivity of materials which influences the dynamic of charges evolution and finally the probability of electrostatic discharges occurring inside the dielectrics.
After a radiation analysis, performed by the open Monte-Carlo code **ESA/GRAS** based on **Geant4** and set through the **MoORa** IME [2], the internal charging must be realised with the **SPIS-IC** open source charging models[3].

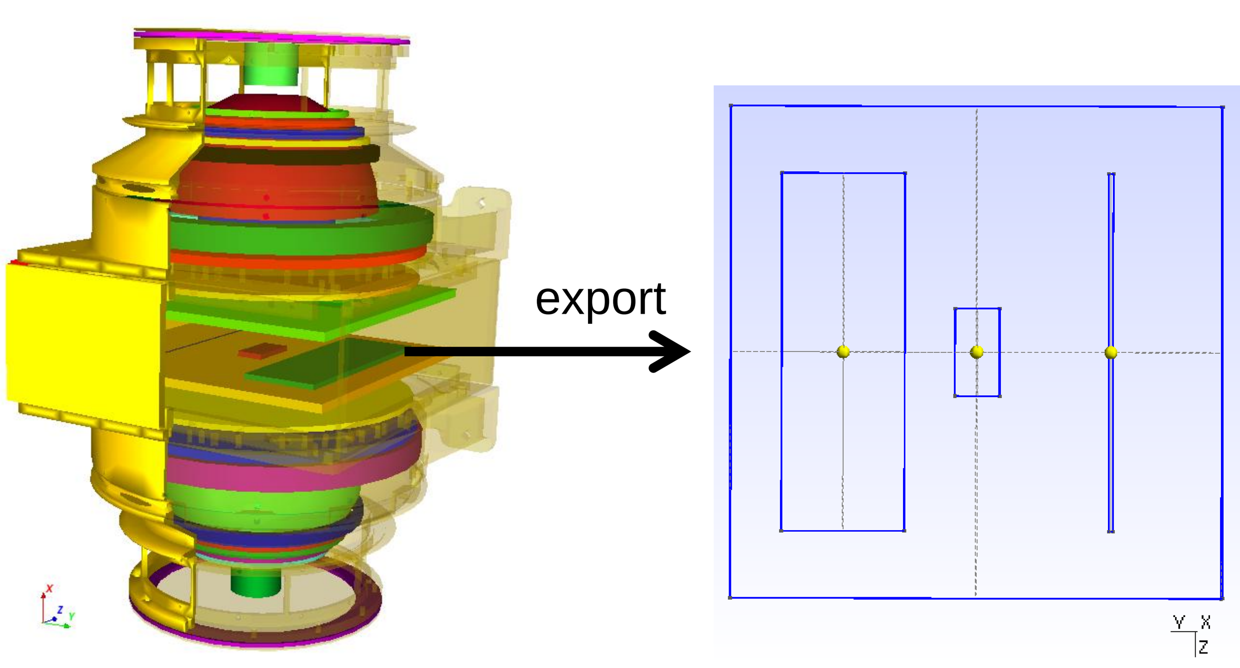


Simulations settings

3D geometry

The initial geometrical description is provided in a **STEP-AP 203/214** design file. This industrial file format cannot be used as it is for the internal charging modelling chain.

This model has been simplified, to remove non relevant parts for radiations and charging analysis and converted into a **GDML** file to be consistent with the **GRAS/Geant4/MoORa** tools, using the WYSIWYG CAD GDML editor **EDGE**.



Radiation GDML CAD model — Internal charging CAD model

Sensitive component choice

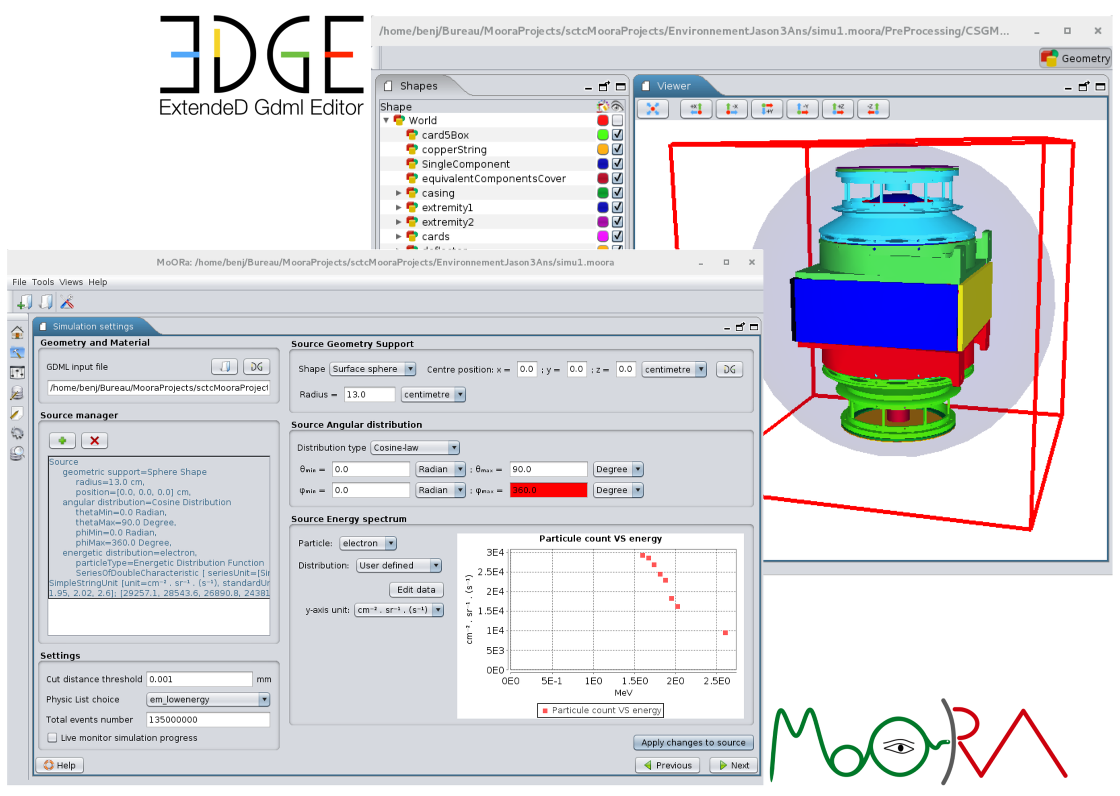
The internal charging analysis is focused on a specific part and different components may be considered as sensitive for such a study, like the connectors, the cables or the cards. The current application case has been focused on the high-tension card inside AMBER.

Space environment definition

The space environment considered in this study corresponds to the Jason-2 orbit during 3 years. Even if it is not exactly the same than Jason-3, from an engineering point of view, these results will be representative for AMBER, considering the retained fluencies corresponding to a worst case.

Radiation simulation settings

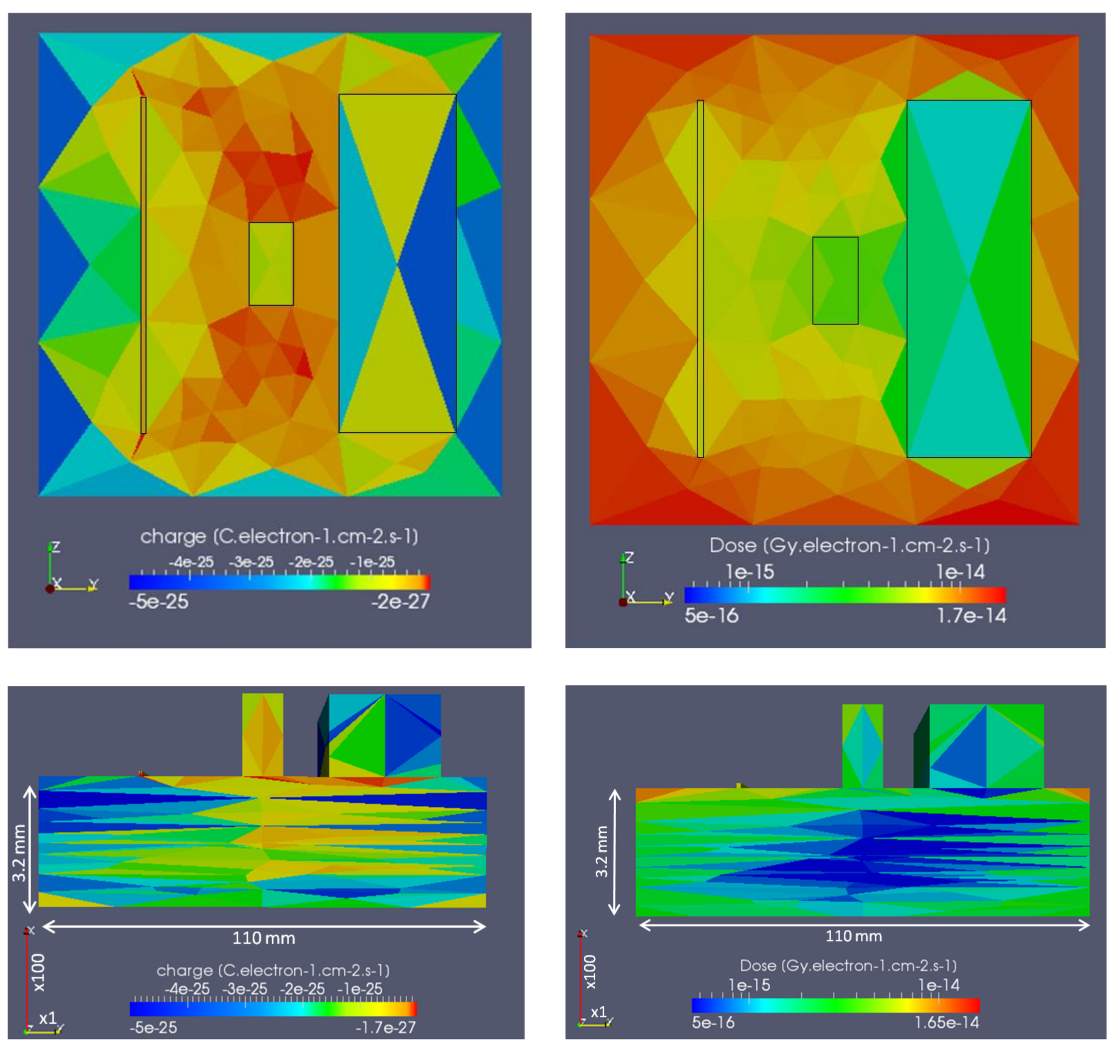
Input parameters for the radiation analysis, i.e. energy spectrum, geometry of space environment sources, angular distribution, output format are fully defined through the **MoORa** application.



Radiation analysis

The dose is mainly deposited in the first micrometres of the card and corners, where the influence of self-shielding is less evident. No major anisotropy is observed as well. This is consistent with the fact that primary sources have been defined as isotropic and also with the shielding relative isotropic thickness analysed with **SSAM**, the EDGE sector shielding analysis tool.

As for the dose, the charge is mainly concentrated in the first micrometres of the card. As well, no major anisotropy is observed. There is a statistical noise for the charge results because of the nature of its computation but it is smoothed back by the charge interpolation scheme of the plasma code and is not an issue for the charging analysis.

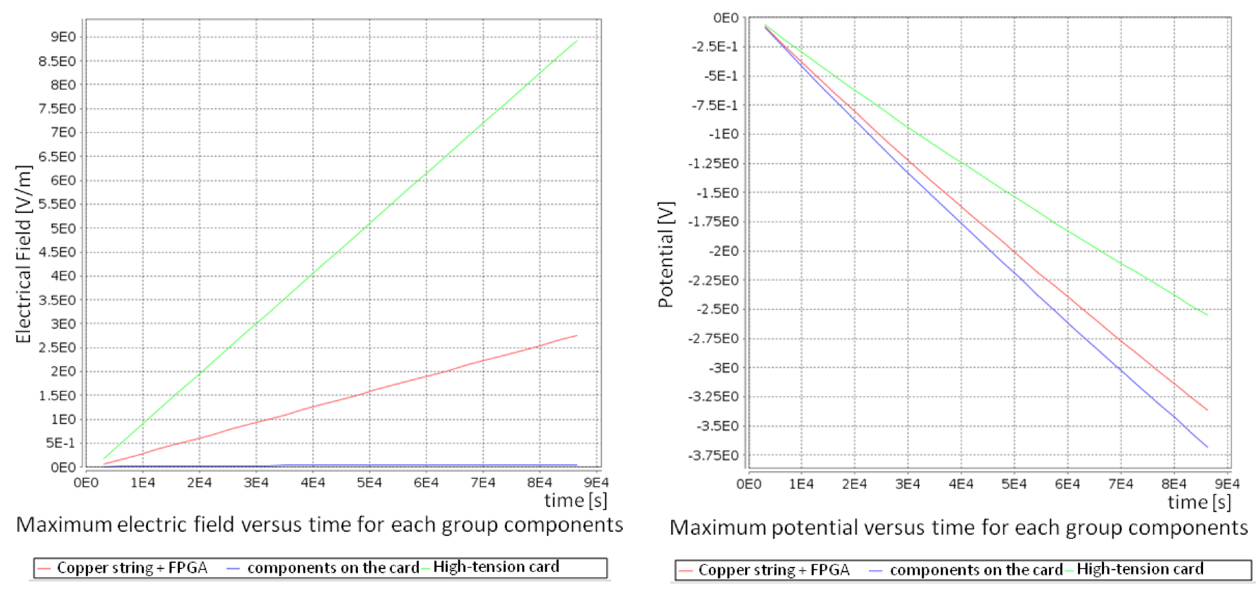


Internal charging analysis

The main part of the fluence received on an orbit of 3 years depends usually on a short time period chosen equal to one day in this analysis

The exact threshold in terms, of electric field above which one arcing and discharge appear depends on numerous factors and can be difficultly evaluated without precise (and often destructive) experimental measurements. However, a threshold value of 10^7 V/m is commonly considered as a reference. The high-tension card body, with electric fields below 8.5 V/m, which is about six orders of magnitude below the reference threshold value, should not present any internal charging problem.

On the other hand, the threshold usually considered for the tension where no internal charging issue may appear is 1000 V. The final potential of modelled components on the card remains in a maximal potential range of -4 V. This shows, again, that the components should not present any internal charging problem.



Results discussion

The spacecraft hub has not been considered in the present work. By neglecting the corresponding relative screening, this clearly minimize the situation regarding the total deposited doses and charges, but softens eventual anisotropies, potential sources of inner electric fields, in the charge deposition. A more detailed analysis regarding the influence of the relative disposition of the instrument with respect to the spacecraft structure is a subject of investigation.

The primary induced dose and charge deeply depend on the orbit profile and on the variations of the space environment. On other orbits, strong auroral electrons rainfall or trapped particles may punctually induce strong deposited doses and charges in a short time and in an anisotropic way. It seems relevant and careful to perform deeper internal charging analysis for each new mission profile and/or space event.

Last, the present work outlines the importance of the shielding in order to screen and to homogenize the primary particles fluxes, reducing, in the present case, the risk of internal charging for component inside the shielding. But the question reminds open for dielectrics outside the shielding like cable, connectors or glue.

Conclusion: A detailed 3D internal charging analysis of AMBER onboard Jason-3 has been performed and confirms the validity of **EDGE**, **MoORa** and **SPIS-IC** to model realistic systems. The comparison of key results against previous works and other codes also confirm the confidence into the implemented numerical models. Thanks to the adaptability of this chain, new AMBER geometry designs, orbit profiles or components and materials could be easily modelled to prevent these internal charging effects.

[1] D. Payan "AMBER, the French plasma monitor on-board Jason 3", 15th Spacecraft Charging Technology Conference, Proceedings, Kobe, Japan, 25-29 JUNE 2018, [2] http://space-suite.com/moora/, [3] www.spis.org, [4] http://space-suite.com/edge/