ONERA-CNES Ongoing & Upcoming activities around SPIS

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Summary

Worst case spectrum

SPIS

- **Simulation & Improvement &**
- **Available development**

New approch for Space Project

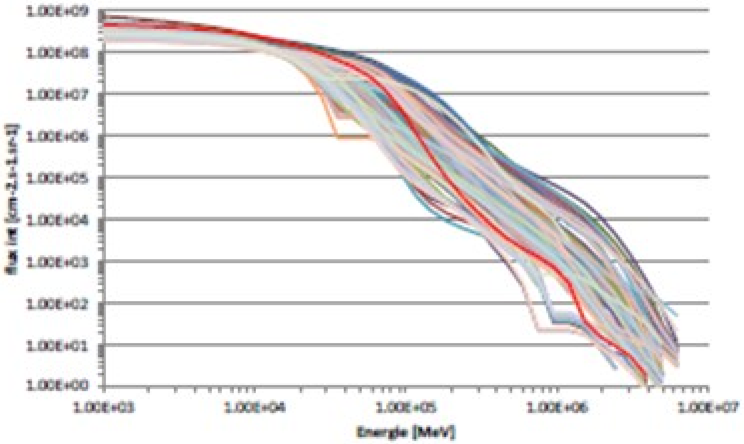
Testing for SPIS and facilities available

Flight Measurement AMBRE

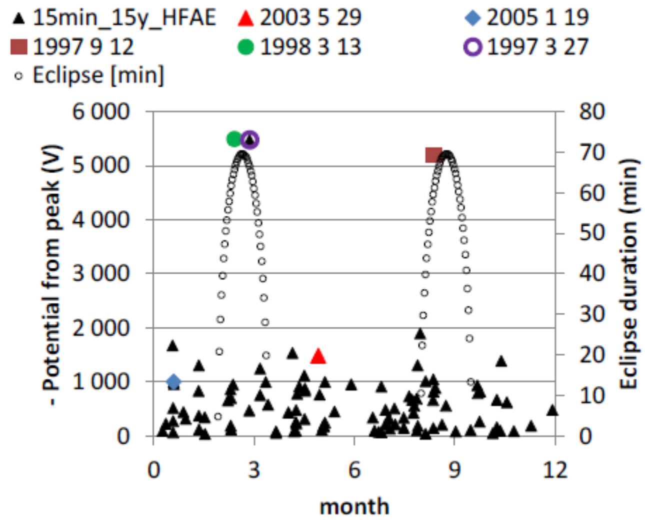
Comments and Needs

Worst Cases Spectra

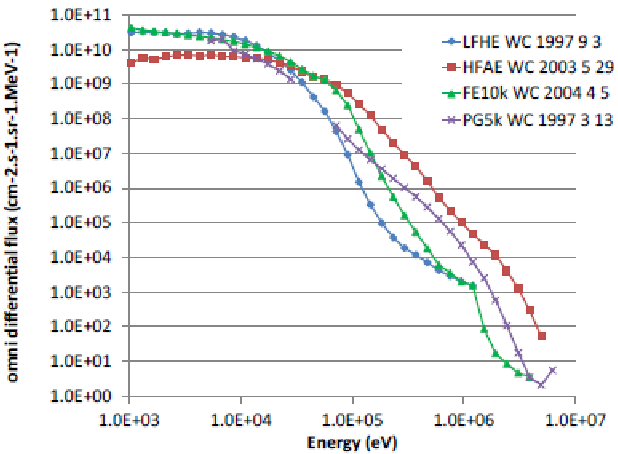
Worst Cases Spectra for SIRENE and SPIS (ECSS-E-HB-20-06)



Integrated flux in energy [cm-2.s-1.sr-1] for the 100 first 15min worst cases FE10k.
First Worst case plotted in red.



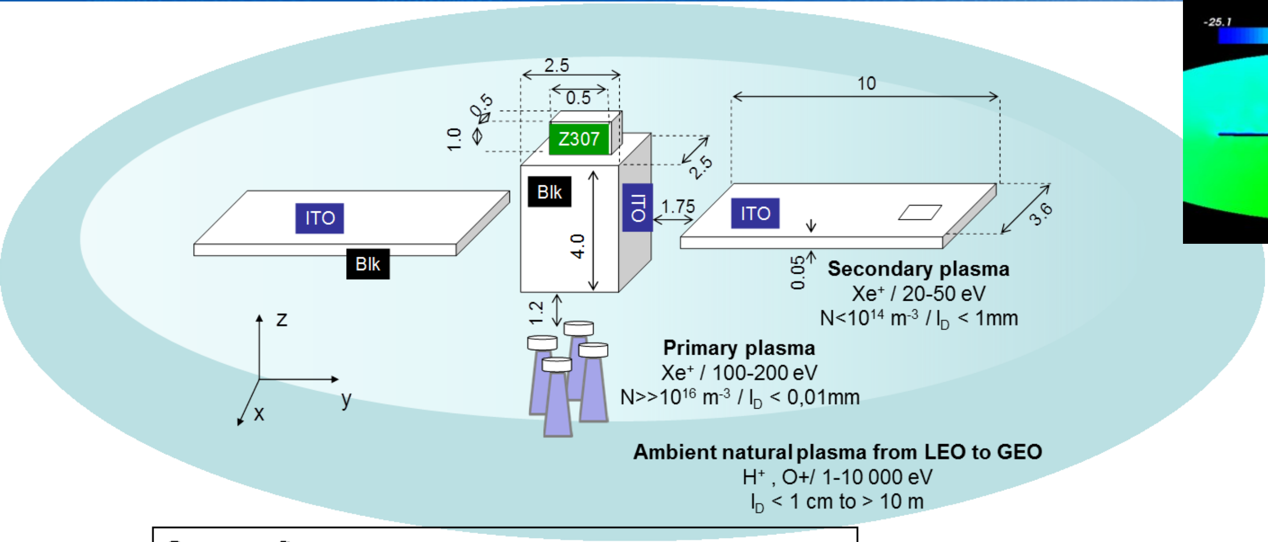
Absolute Potential for HFAE events vs. Eclipse Season satellite
more photo-emission and Dielectrics materials colder

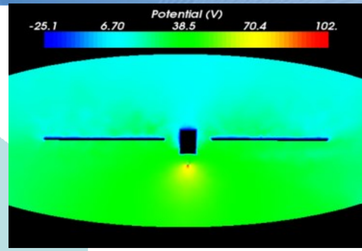


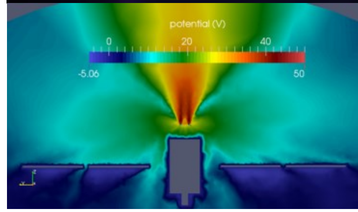
Example of a flux deducted for SIRENE facility and SPIS
(Omnidirectional Differential Flux in LANL Worst cases

Spis Simulation

Electrical Propulsion and High Voltage Solar Array

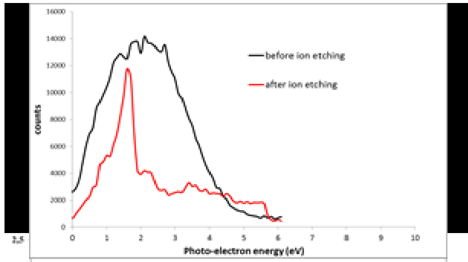


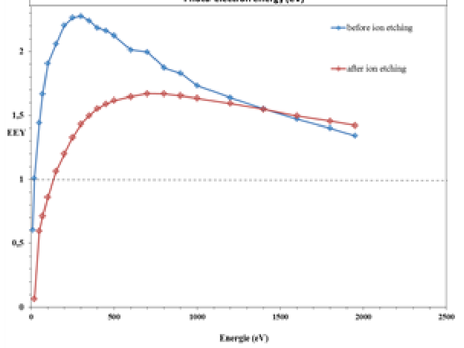




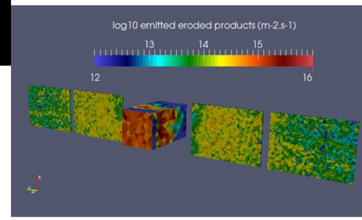
Spacecraft
- Solar arrays constant orientation towards the Sun (+Z)
- Body and thrusters rotation around (Y)

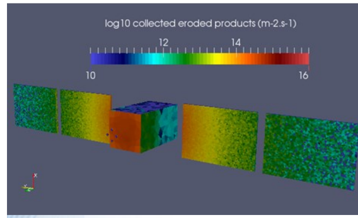
Thrusters
- Option A : 4 small electric thrusters (type SPT 100)
- Option B : 1 larger electric thruster (type SPT 140)
- Fast ions: Ti = 0.1 eV, drift energy = 150 eV, 20 A
- Electrons: Te = 3.0 eV
- Charge exchange reaction assuming 5 % neutrals

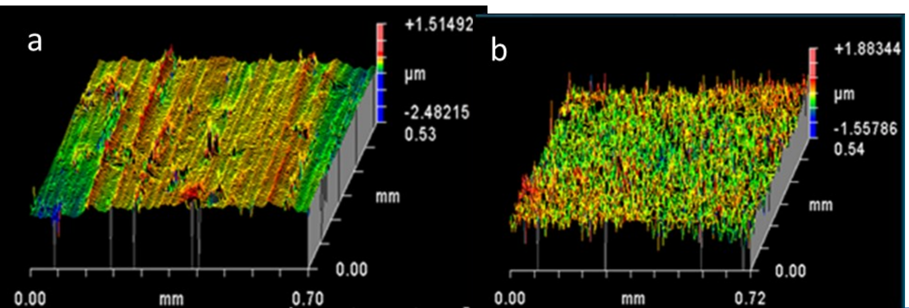




SC Voltage
-25 V
Plume potential
+50 V
CEX energy
75 eV at impact







Electrical propulsion cover a large band of phenomenon

Plume Modelling

Plasma recollection modelling

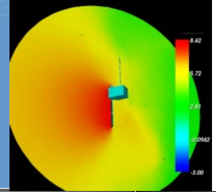
- **Sputtering**
- **Contamination**
- **Charging and Electrical Consumption**

Need to model thin wires at High Voltages

new thematic on material ageing (contamination and sputtering)

TARANIS Spacecraft (CNES)

700km Heliosynchrone Orbit



Mission

Detection and study electrical discharge in the upper atmosphere

TLE Signal

Some mV, lower than the PIC simulation noise ≈ 90mV

*Considering an ionospheric plasma with T = 0.2 eV

IME-BF probes

Measurements around ≈ 1mV

Need 10^{12} particles in a pic simulation

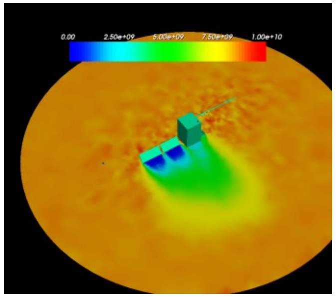
Simulation

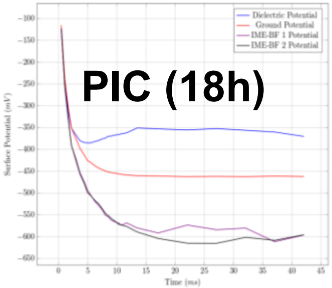
A PhD on coupled method: Multi Physics Multi Scales → SPIS LEO Module

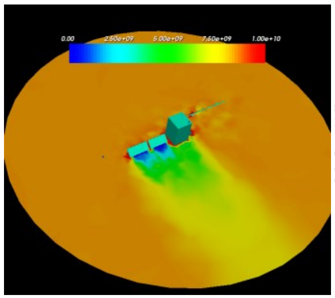
Initials Moments computed thanks a PIC simulation

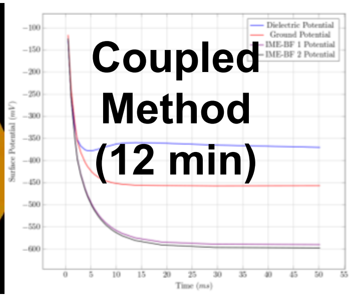
Equation normalization on Analytical model

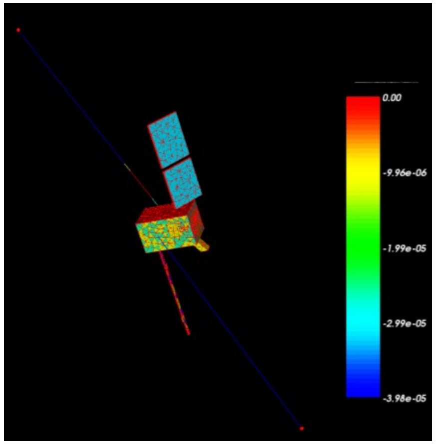
Resolution Poisson-Boltzmann equations

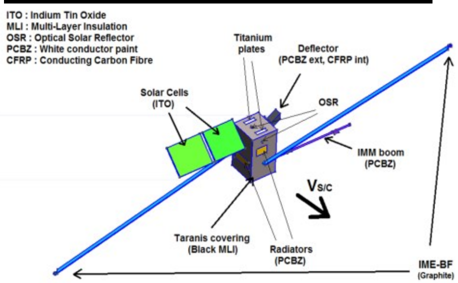












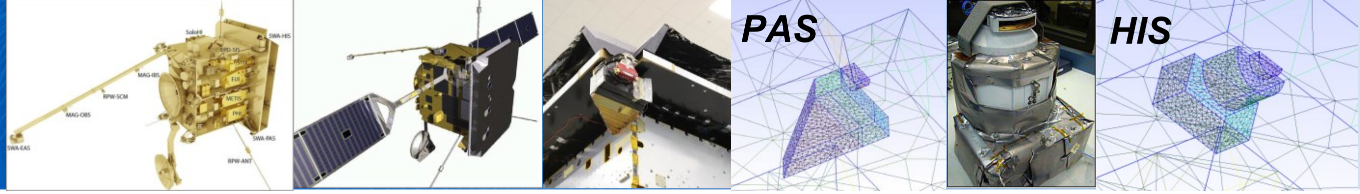
Kapton tape influence

To remain <1mV/m, a maximum of 15% of the total MLI covered by tape (initially it was 30%)

- PIC Simulation:
  - Ions O+ : PIC
  - Electrons & H+ Ions : Fluide
  - 190.000 meshes
  - 95 M numerical particles
  - Statistical Noise ≈ $10\ mV$
- Fluid Simulation :
  - All fluid populations
  - 23.000 meshes

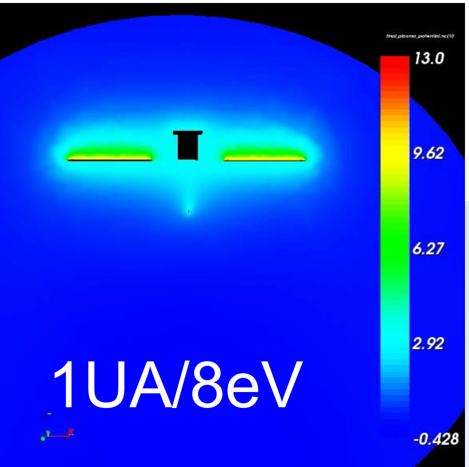
Temperature : 0.2 eV, Density : $10^{10}\ m^{-3}$, Populations: Electrons & Ions (85% O+,15% H+)

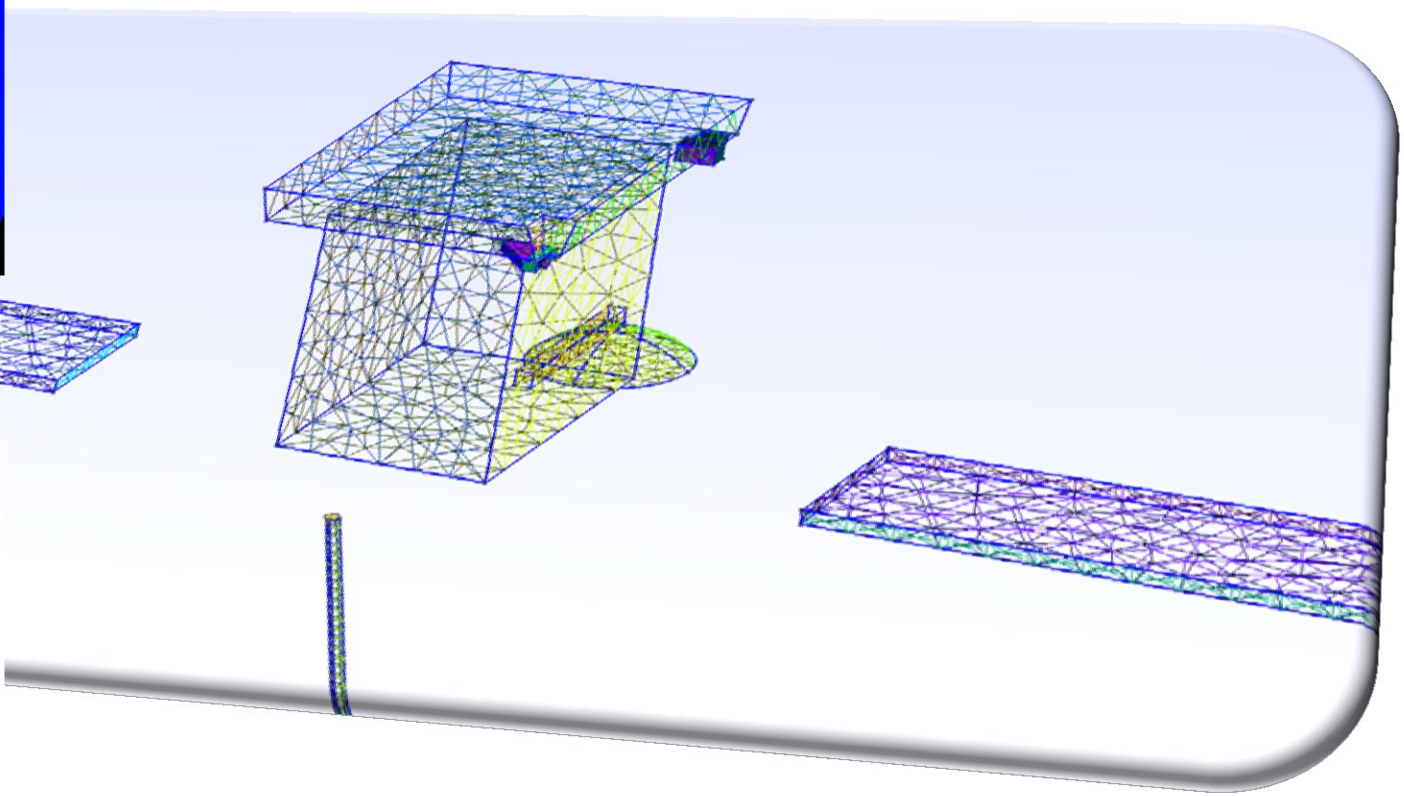
SOLO

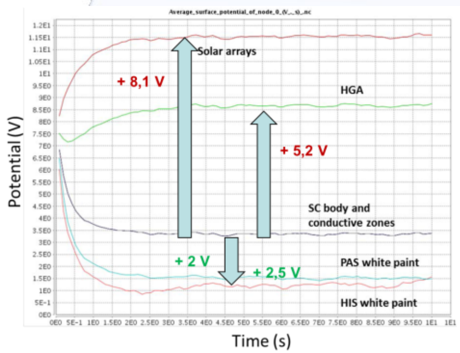


SOLO GEOMETRY (ESA) with PAS and HIS (CNES)

Same Cad than the one used by ESA







SPIS Non linear patch method

Objective

Faster simulation with SPIS ultra meshing refinement over GMSH refinement capabilities

Example

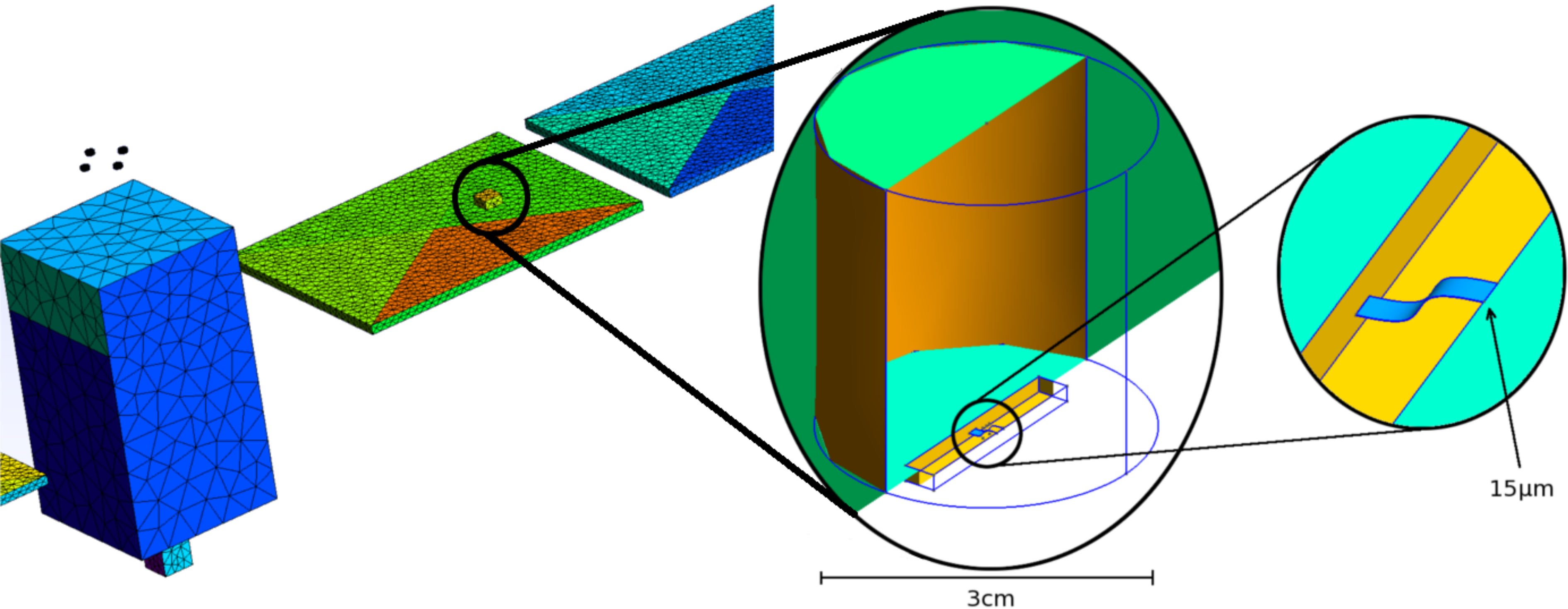
Patch method on a 3D 15µm-thick interconnect on a telecom spacecraft

Method

local refinement of the mesh around small-scale geometries

Results

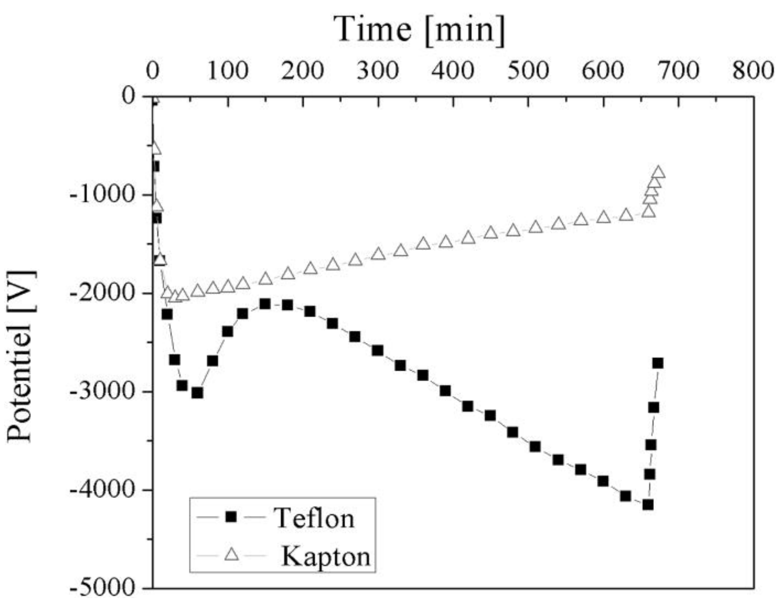
A 30 min simulation instead of a full Day one



Référence: ECCOMAS Congress 2016
Non linear patch method and application, A. Brunet, P. Sarrailh, F. Rogier, J.-F. Roussel, and D. Payan,

Study of the physico-chemical and electrical behavior of spatial polymers under high energy irradiation (PhD)

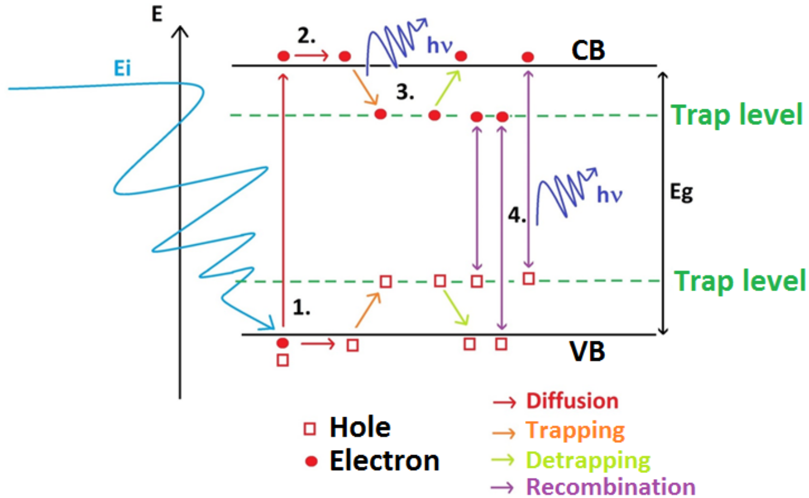
<u>Objective :</u> Understand the physical mechanisms behind this behavior (RIC)



Temporal evolution of surface charging potential on space used polymers under geostationary like electron irradiation: [20 keV, 250 pA.cm^{-2}] + [0–400 keV, 50 pA.cm^{-2}], during irradiation and after beam shut-down (relaxation phase).

Understand the phenomena of trapping and transporting charges in polymers for space applications

Describe the charge and ionization effects of space materials



Energy transfer : Electron beam ➔ Material

Non radiative transfer : Phonon (Detrapping)

Radiative transfer : <u>Luminescence</u> (Relaxation of energy)

⬇

Information on the nature of chemical species or on the interactions between electrical charges and groups acting as trapping centers

Test & Facilities

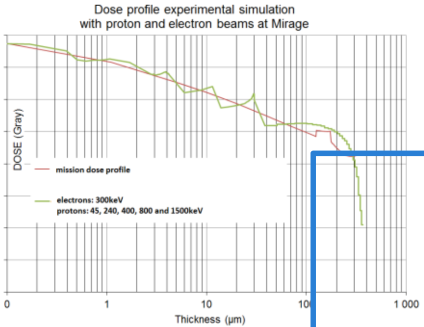
ONERA Facilities dedicated to Spacecreaft Charging Studies

Specificity	Electrons	Protons	Others
Global approach (overall environment) Multidisciplinarity Irradiation tests	VdG: 400keV and 2.5MeV Electron gun : 1eV to 100keV Range: 1eV to 2.5 MeV	VdG accelerator : 2 MeV Range: from 25eV to 2MeV Proton gun : 25 eV to 5 keV	Heating, UV, Dose, Under Vacuum Transfert

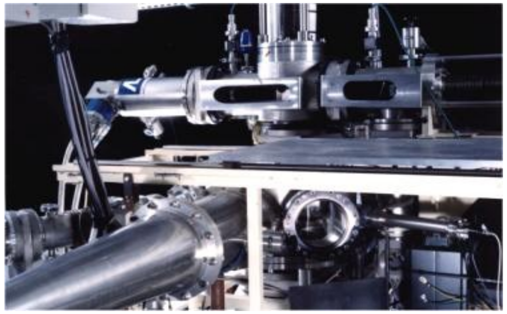
Capabilities

- **Potential (during irradiation), Charge in Depth (PEA), Conductivity (flight configuration)**
- **Surface Charging Only**
- **Deep Dielectric Charging (RIC, DRIC)**
- **Internal Charging (realistic configuration)**
- **Temperature –170° C, Room, Temp, >400° C**
- **Dose effect (Ageing BOL MOL EOL)**
- **Combined effect (UV+Proton+Electrons)**
- **SEE (new, cleaned, contaminated material)**

In situ testing of materials (Sample transfer and interconnectivity between testing units)

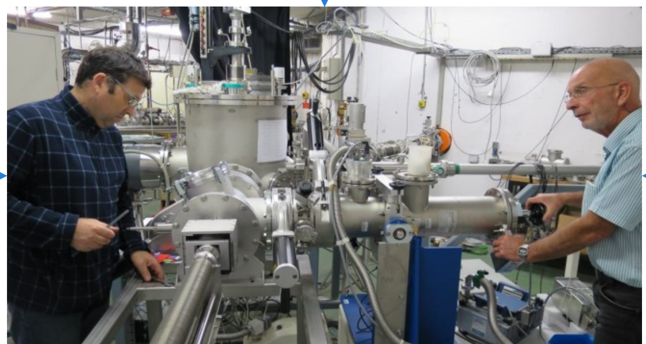


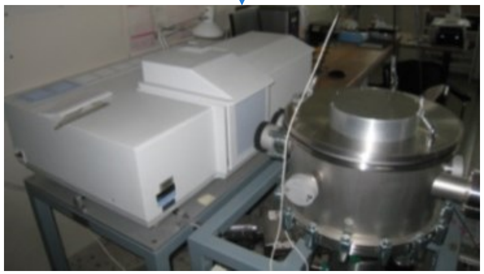
MIRAGE
Ageing
(combined env.)



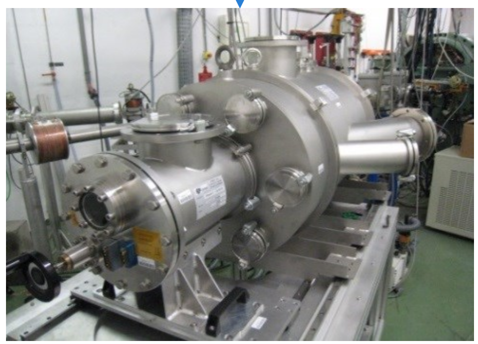
SEMIRAMIS
Ageing (combined env.)
Reflectance

TRANSFER STRASS

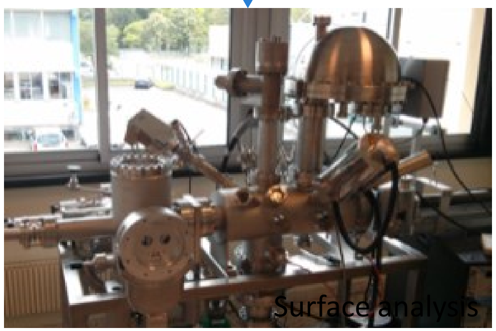




SPECTRO lab
Thermo-optical properties



GEODUR
Ageing
Bulk/Surface/RIC conductivity



Surface analysis

DEESSE
(SEE, potential during irradiation …)

SIRENE
Bulk/Surface/RIC conductivity

SPIDER
Long-term charges relaxation monitoring

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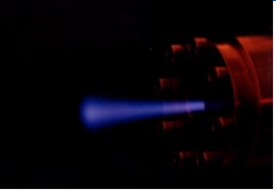
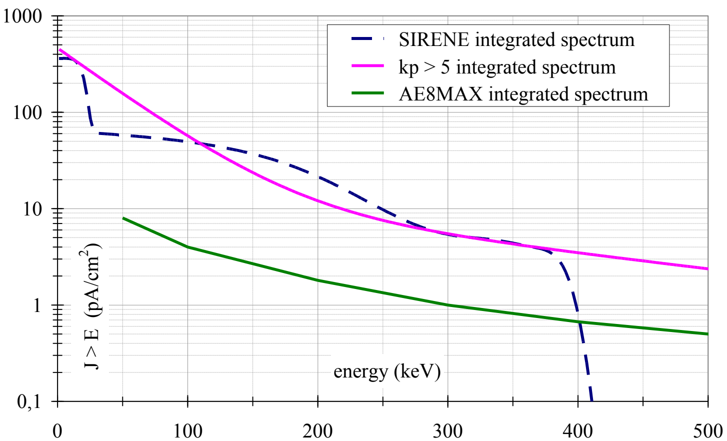
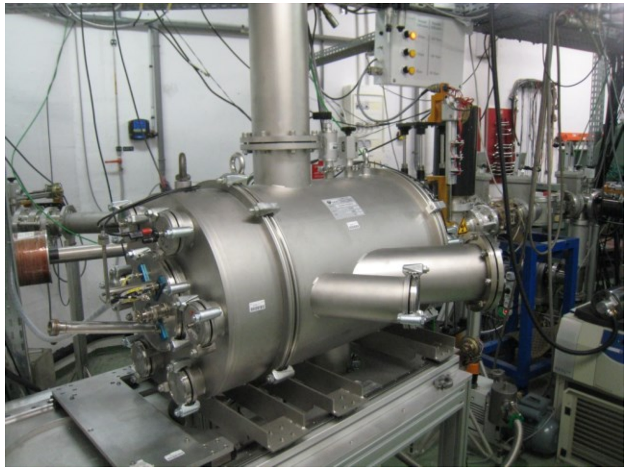
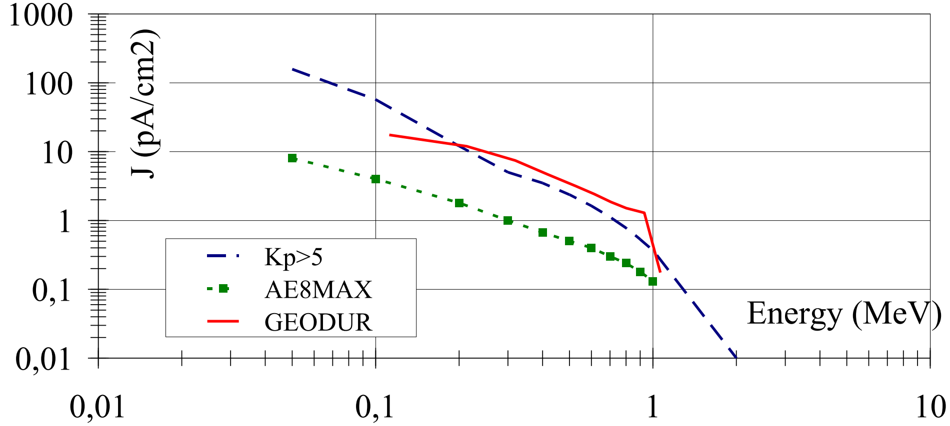


For surface charging
SIRENE



For internal charging
GEODUR





Future Development

Needs

Make specific (and confidential) development easier and compatible with release

→ out of the core of SPIS

Drive the availability of physical model for material

→ restricted distribution (France, Europe, TBD)

Make possible a participation without any funding

Possible external validation

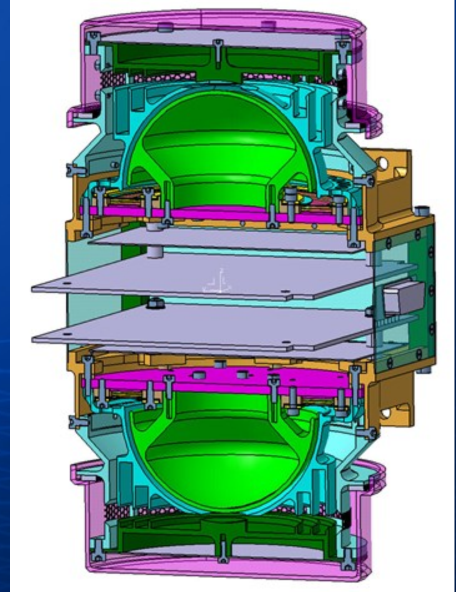
Specific recognizable model

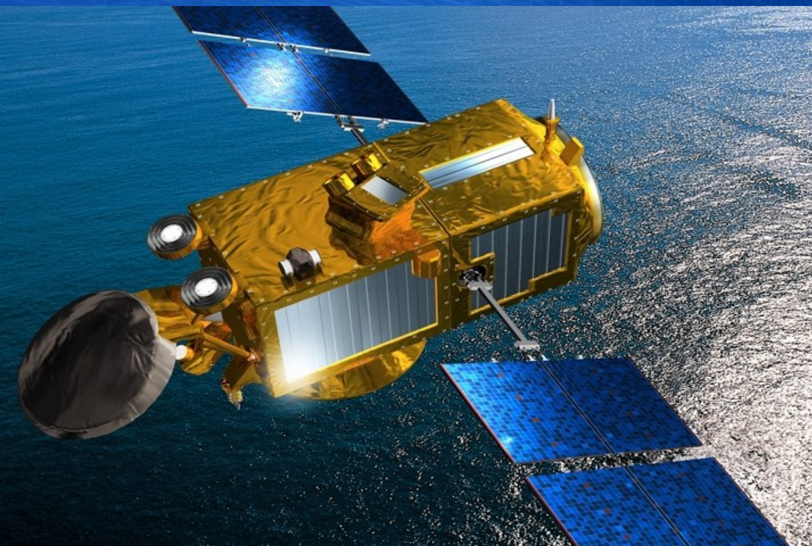
Link with material reference in Database

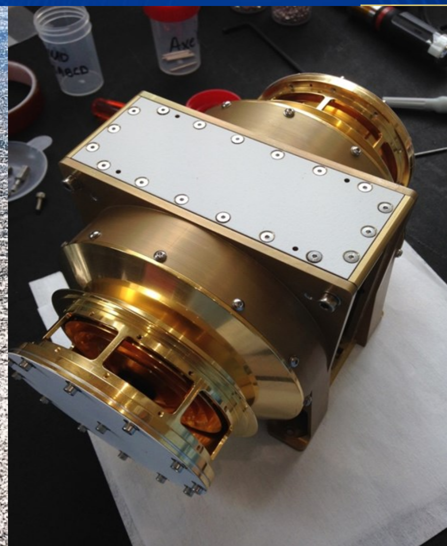
Sharing the funding of a needed model

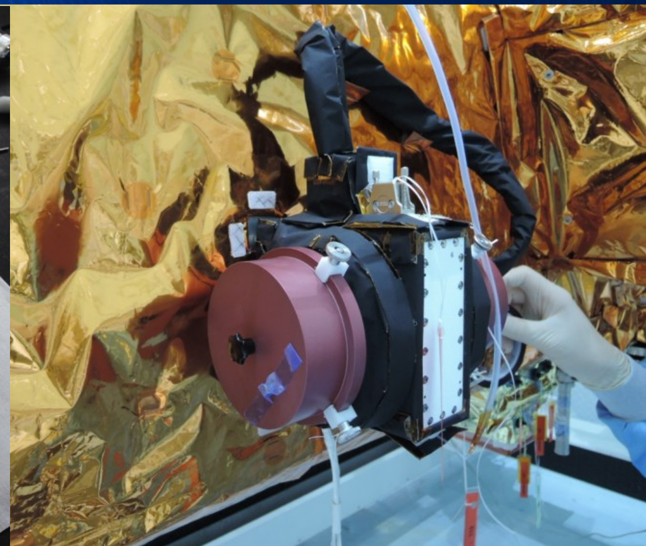
Towards SPIS Plugin and SPIS market

Flight measurements









Conclusion

- Simulation has a strong dependence on physical model used (this is the key point)
- Need to define a measurement test set
- The development of physical model of SEE or conductivity is a long and expensive process
- SPIS is mature enough to be used by project at PDR (DJD) level as for structure or thermal aspects.
- Define funding for the Website maintenance
- New business development model to be found
- Effective Participation of the community

Thank You