End-to-end validation of the SPIS-ASPOC module through simulations of the Cluster spacecraft and comparison with Cluster data

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Goals of the project

ESA Expro+ project in collaboration with ONERA and Artenum to validate key features of the new SPIS-ASPOC module :

- Improvements in thin wires and their physical connection with bulk surfaces.
- Introduction of a static and uniform electric field.
- Creation of an ASPOC device representative of an actual space mission : Cluster.
- Introduction of an external magnetic field together with an ASPOC device.
- Test of the new PIC-Perturbative model used to compute population evolution.

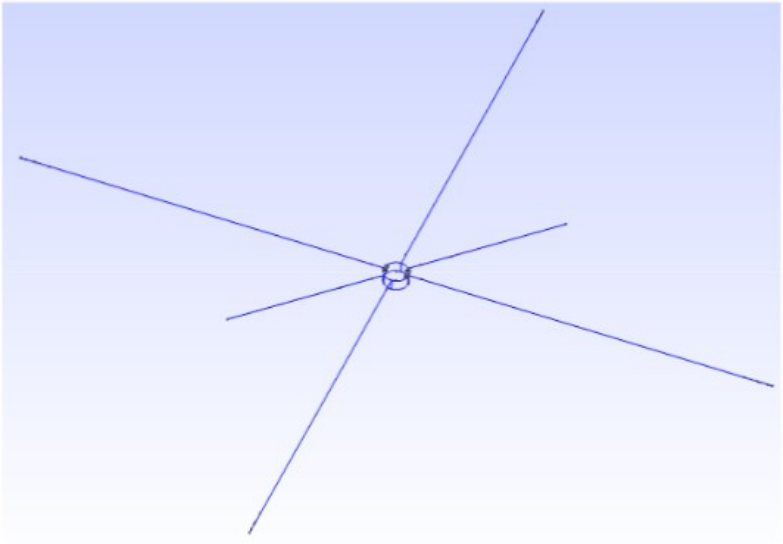
A study between simulation and data

Such an important improvement needs end to end validation with actual data !

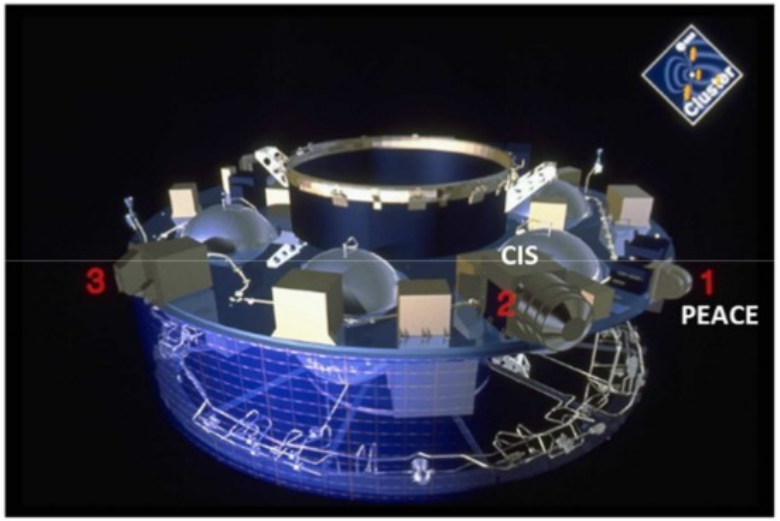
- Simulations are representative of Earth's magnetosphere investigated during Cluster mission.
- Three typical environments are considered :
  - Dayside magnetosheath
  - Pristine solar wind
  - Plasma sheet
- Simulation inputs are fixed using instruments data (PEACE, CIS, FGM, EFW, ASPOC).
- Simulation outputs are compared with instrument data.

SPIS model

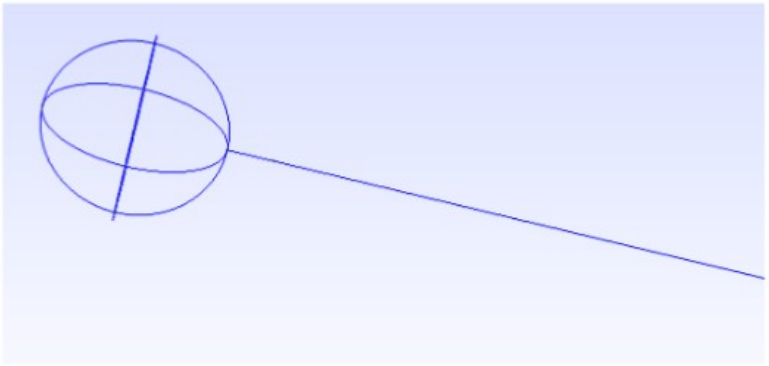
- Four thin wires
- Four spherical probes
- Two wire booms
- Instruments PEACE, CIS, ASPOC, FGW, EFW



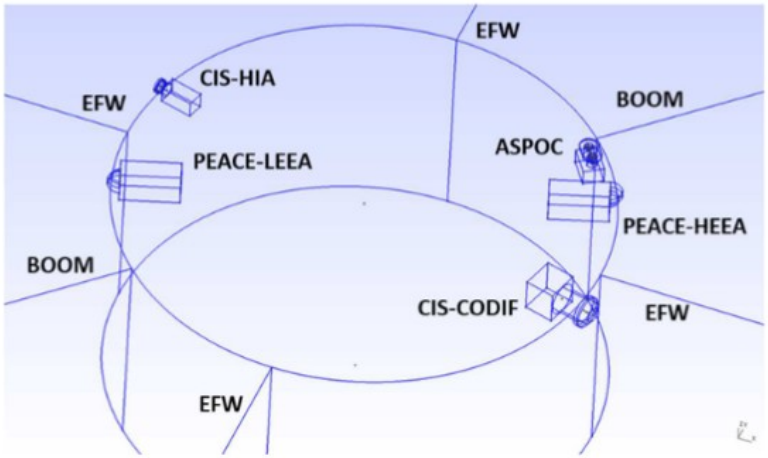
GMSH model of the Cluster spacecraft



Cutaway of Cluster spacecraft with its payload



GMSH model of the EFW instrument probe



GMSH model of the Cluster spacecraft with some of its instruments

Thin wires validation

Are there artifacts in the vicinity of the thin wires or around the wire-probe connection ?

Mesh size around the wire : 3 cm to 30 cm

Wire radius : From 0.3 mm to 1.1 mm

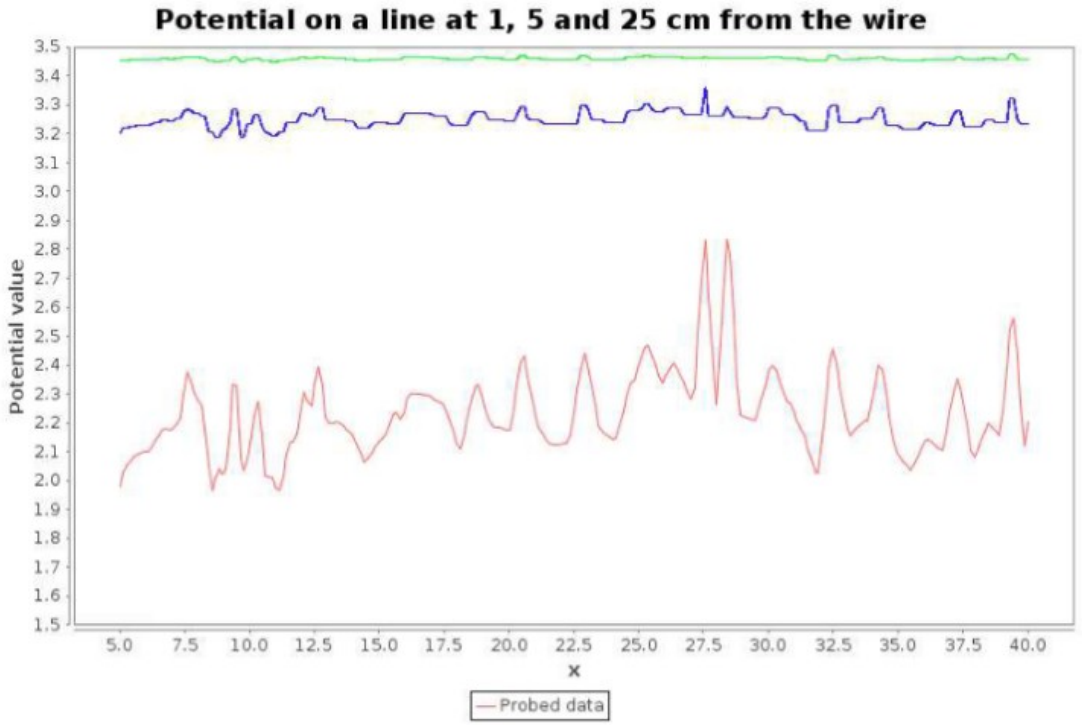
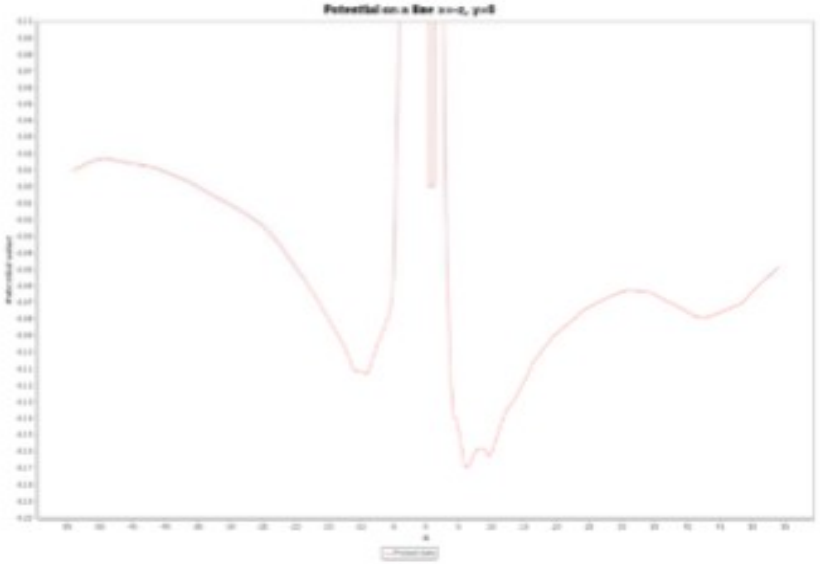
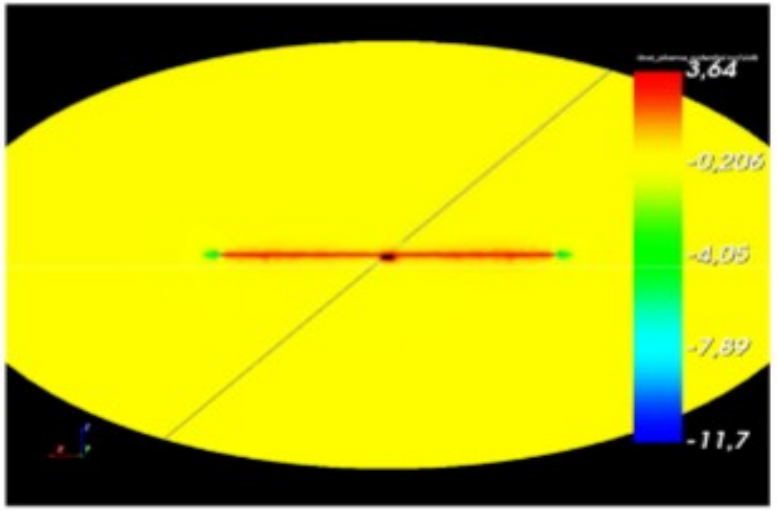


Figure 10 Potential measured at 1 (green), 5 (blue) and 25 cm (red) from EFW wire. The mesh size is constant equal to 30 cm.

Electric field validation (1)

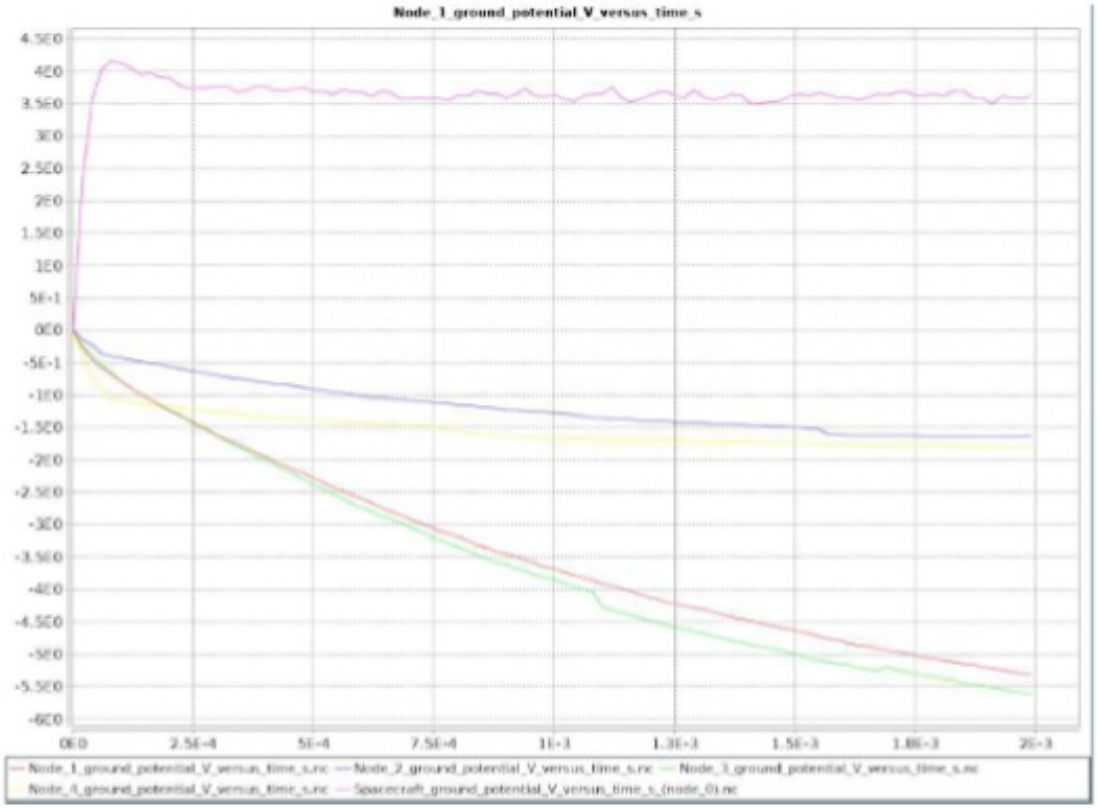
- Introduction of a static electric field of 1.4 mV/m
- A bias current of 140 nA is set on the probes wrt the spacecraft.
- Robin boundary conditions are used.
- The simulation in magnetosheath environment is used.





Electric field validation (2)

Potential evolution on spacecraft and probes



A difference between duskward and sunward Probe potentials is observed.

- Potential difference bewteen boundaries :

Expected : -210 mV
Observed : -70 mV

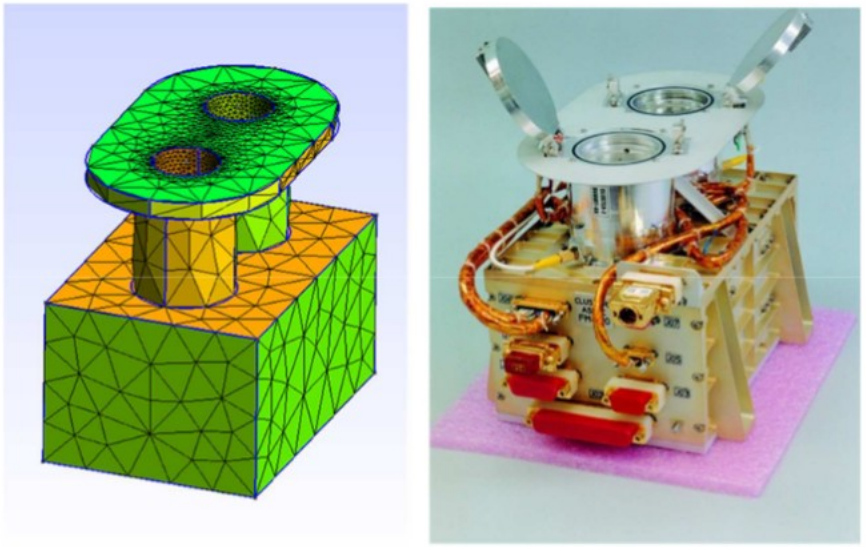
Robin boundary conditions do not allow to Impose the electric field on boundaries.

- A potential difference of 200 mV is found between probes 1 and 3, compared to an expected potential difference from the imposed electric field of 80 mV

This discrepancy could be due to spacecraft wake effect, which is removed from calibrated Cluster data but could be still present in the SPIS simulation.

ASPOC device validation (1)

ASPOC geometry

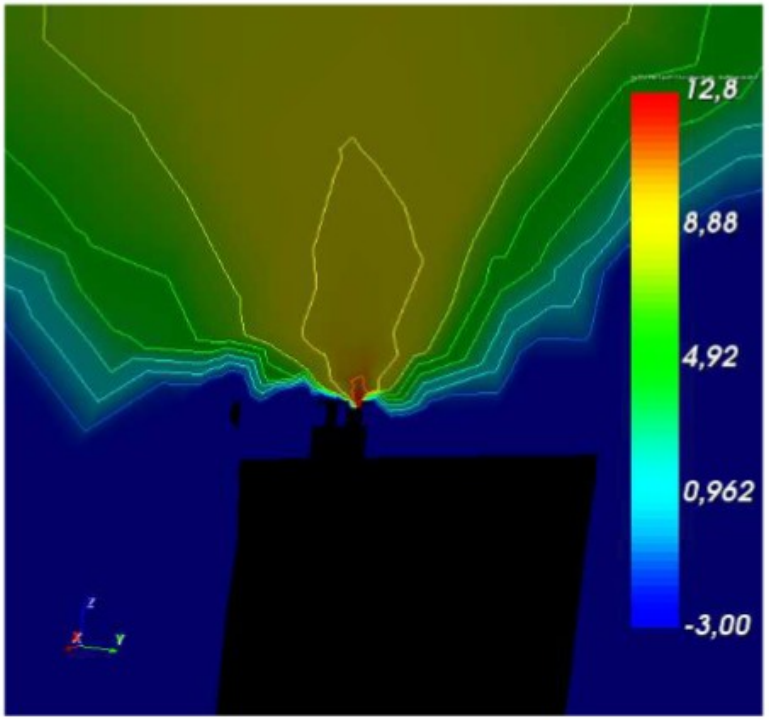


Cluster ASPOC instrument: (left) GMSH meshing (right) actual instrument

Features validated :

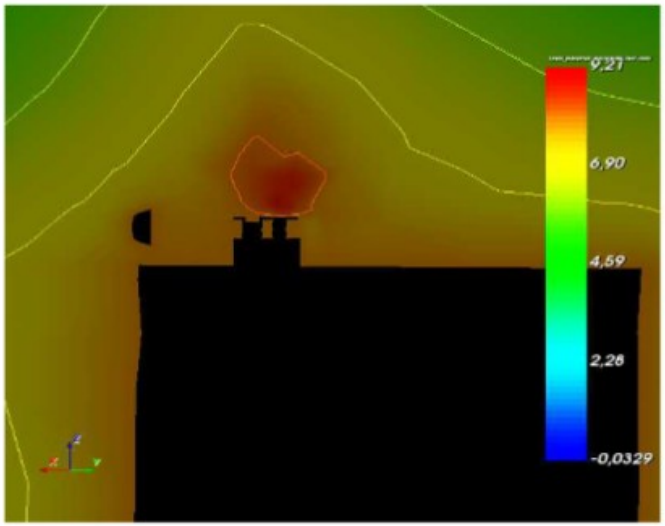
- Switching ON/OFF by hand during the simulation
- Pre-program the switch ON/OFF at a specific time in the simulation

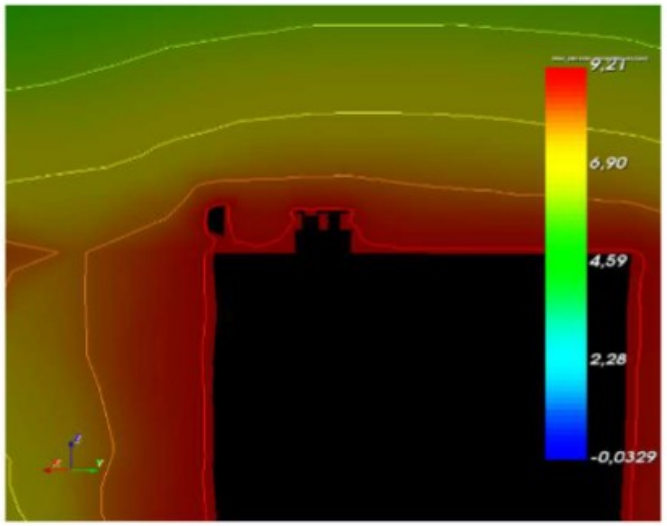
Density map isocontour around ASPOC

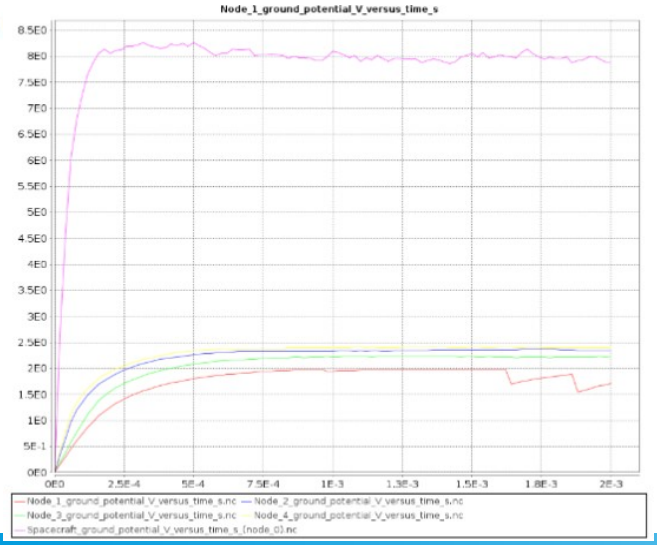


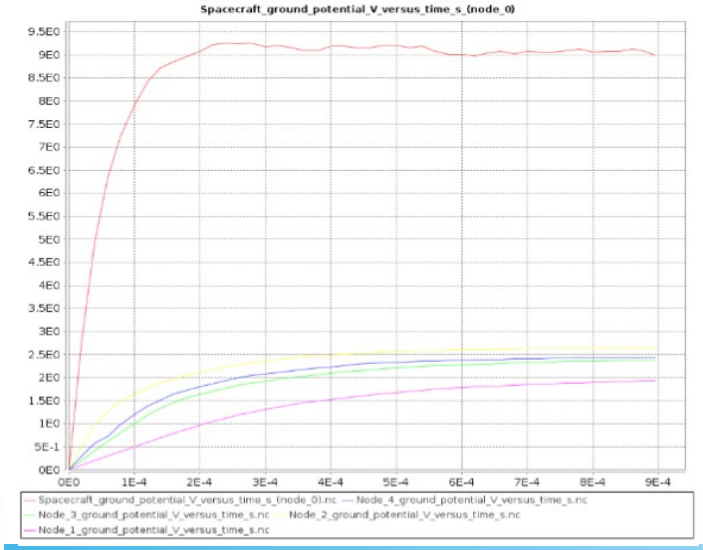
ASPOC device validation (2)

Potentials when ASPOC ON (left) and OFF (right)









Probe to spacecraft potential

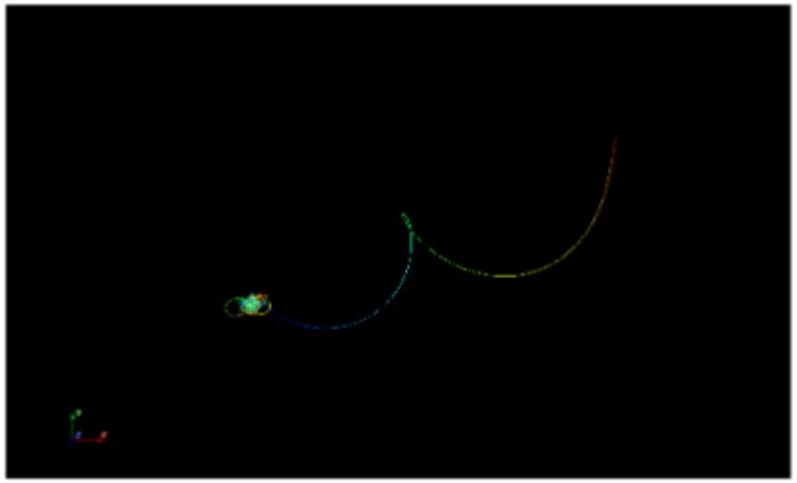
	Data (EFW)	Result (SPIS)
ASPOC ON	3.4 V	6 V
ASPOC OFF	5.4 V	6.5 V

Difference wrt data:
20 % of electron temperature when ASPOC ON
10 % when ASPOC OFF

The decrease of potential due to ASPOC is underestimated in simulations.

Magnetic field validation

Bfield : 13 nT
Environment : Plasma sheet

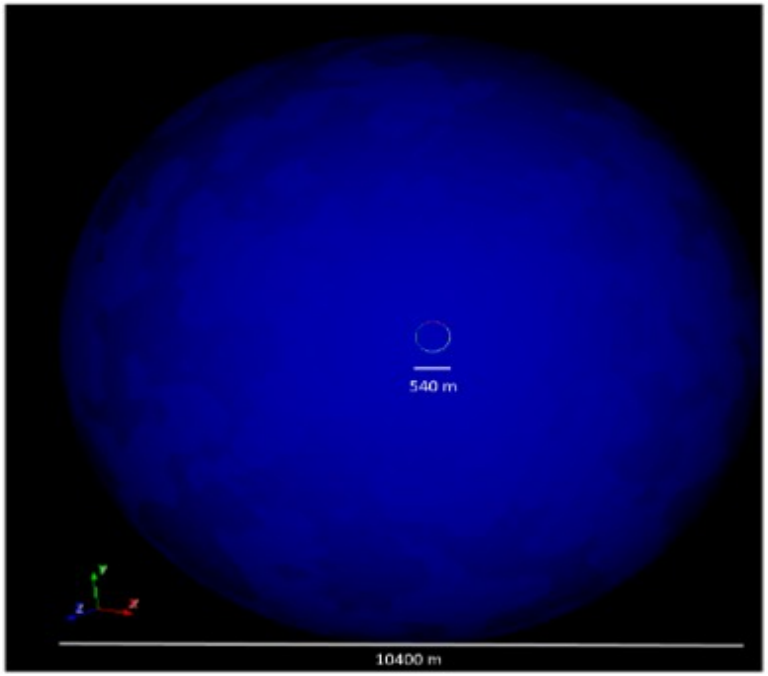


Spacracraft potential : 18 V

3 % of the 2 eV photoelectron distribution should have higher energies. Not all of them can escape.

Over 100 trajectories, one is escaping the spacecraft Potential in the simulation.

Larmor radius for this photoelectron : 270 m corresponding To an energy of ~19 eV at emission



Conclusion

- Thin wires showed no issues.
- Electric field needs caution when chosing boundary conditions.
- ASPOC devices are functional. Not representative photoelectron distributions could explain the observed discrepancy with respect to the Cluster data.
- Introduction of a magnetic field when ASPOC is ON leads to consistent trajectories on photoelectrons.
- Some functionalities are still to be validated : Spacecraft dipolar moment, antennas generating low frequency waves, particle detectors accuracy...