Geometry, biasing and measurement of particle distribution functions

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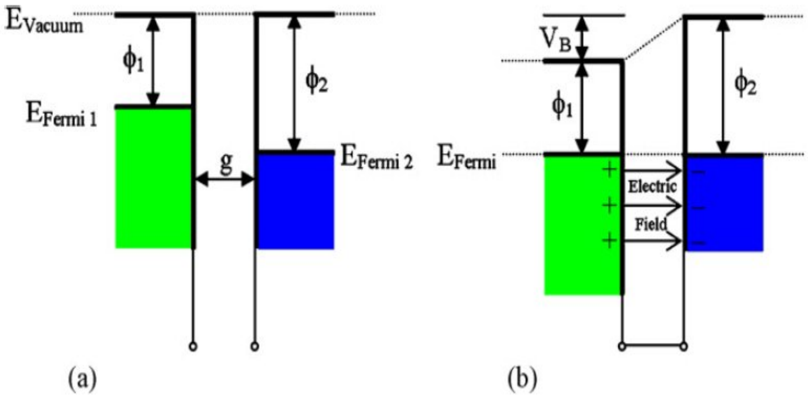
Outline

- Capacitances
- Photoionisation from solar UV
- Contact potentials from different surface materials
- Active biasing and current balance
- Distribution functions at SC boundary
- Distribution functions in space
- Summary and requirements

Active biasing and current balance

- Certain parts of DEMETER are negatively biased (balls at the end of the four booms).
- While the net current on the satellite is zero, certain components are net collectors/emitters.

Contact potentials



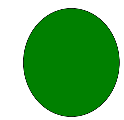
Kuehne, Sensors and Actuators A, 2008

- When electrically connected, different materials will develop contact potentials given by the difference between their work functions.
- This is in addition to any active biasing.

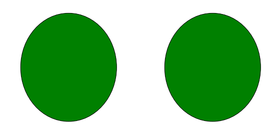
Self and mutual capacitances

$$q_i = \sum_{j=1}^{N} C_{ij} V_j \qquad V_i = \sum_{j=1}^{N} C^{-1}{}_{ij} q_j$$

- Capacitances can be computed from solving Laplace's equation, when object surfaces are completely exposed.
- Ex. 1: Using gmsh with nv=7052 and nt=31359 for a 2cm sphere in a 20cm hollow conducting sphere.
- Similarly, for two spheres of the same radius separated by 2 cm
- For partly exposed surfaces, calculations are not straightforward and C(i,j) should be measured.



$$C_{11} = 2.70 \times 10^{-12}\, SI$$
$$(2.47 \times 10^{-12})$$

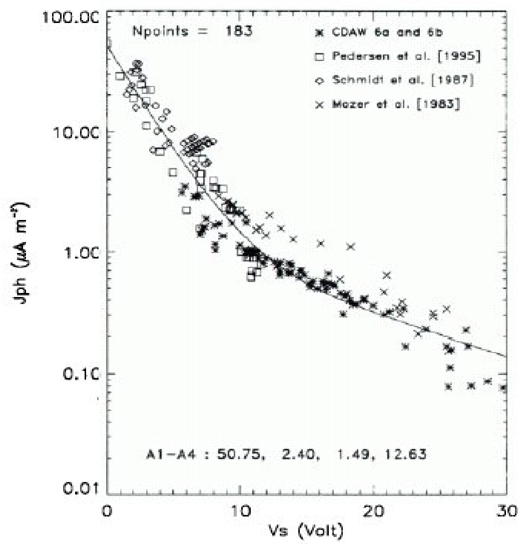


$$C_{11} = C_{22} = 2.14 \times 10^{-12}\, SI$$
$$C_{12} = C_{21} = -0.58 \times 10^{-12}\, SI$$

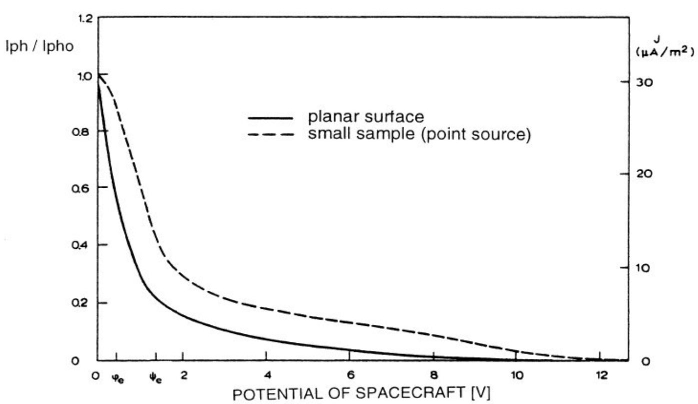
Photoelectrons from solar UV

$$I_e - (I_{ph} + I_i + I_{se} + I_{bse}) = 0.$$

- Photoelectron current densities can be dominant in current balance.
- They depend on materials, SC potential, angle of illumination, solar activity.
- Currents between different components of the satellite would help validate models.



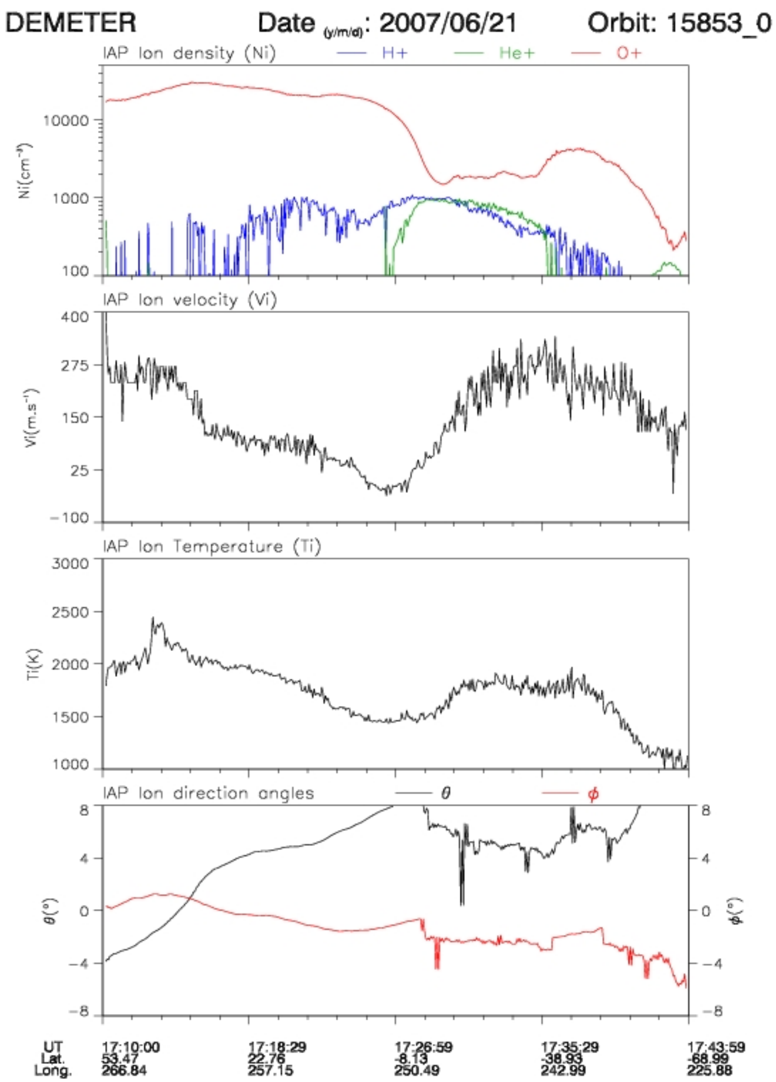
Escoubet, et al., JGR 1997



Nakagawa, Earth Planets Space 2000

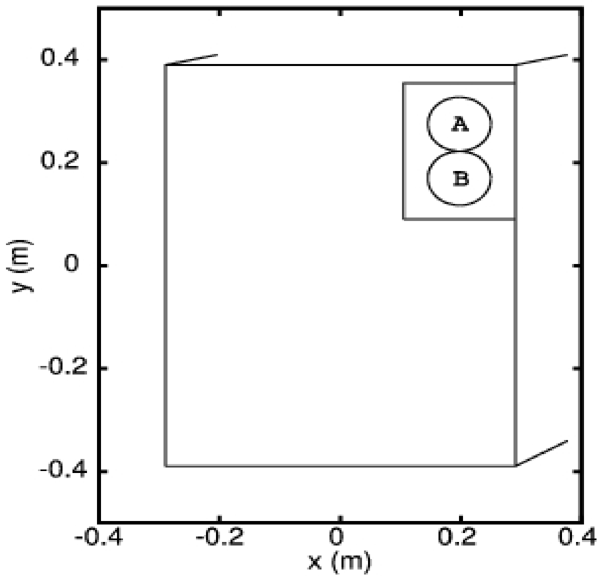
Distribution functions on SC boundary

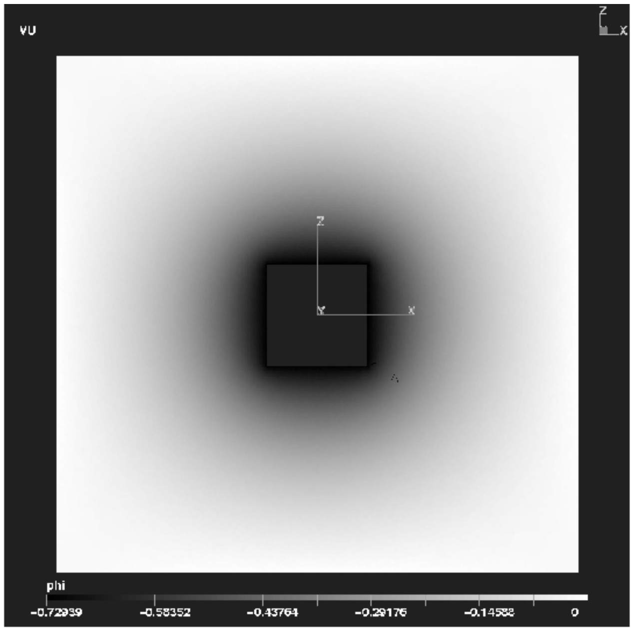
- On DEMETER, the IAP instrument measures deviations in direction of incoming ions that cannot be explained from natural ionospheric plasma flows.
- Other causes, such as electrostatic sheath effects must be considered.

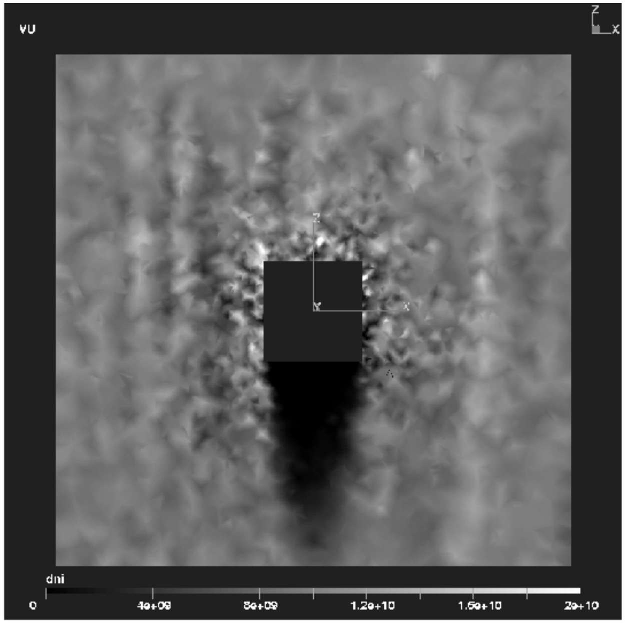


Modelling f(v) at IAP

- IAP is in the upper corner of the ram face of DEMETER.
- The satellite is treated as a single electrically floating rectangular prism – booms and their relative biasing are neglected.
- The domain is delimited by an outer boundary at least 1m away from the satellite.

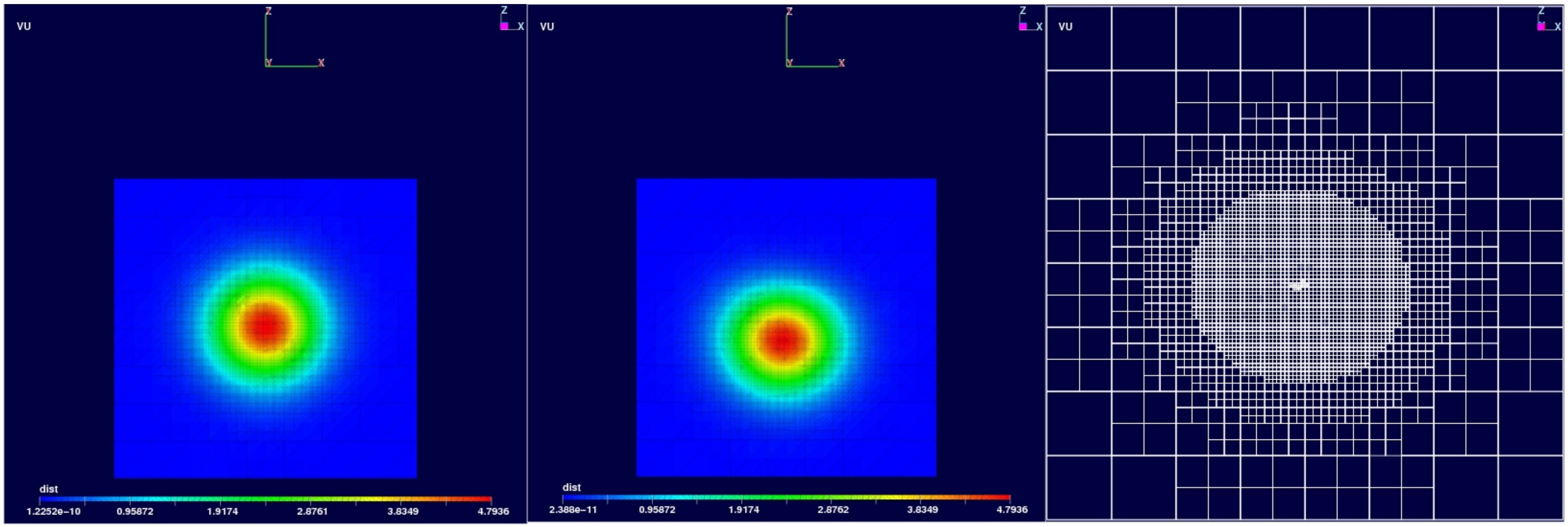






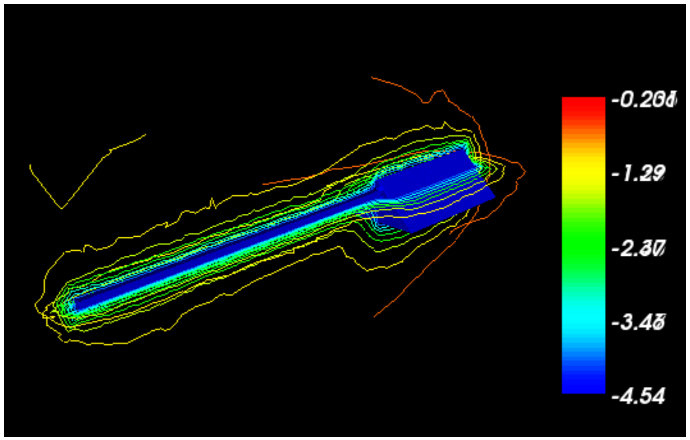
Electrostatic potential and density profiles in a cut plane parallel to the rammed plasma flow

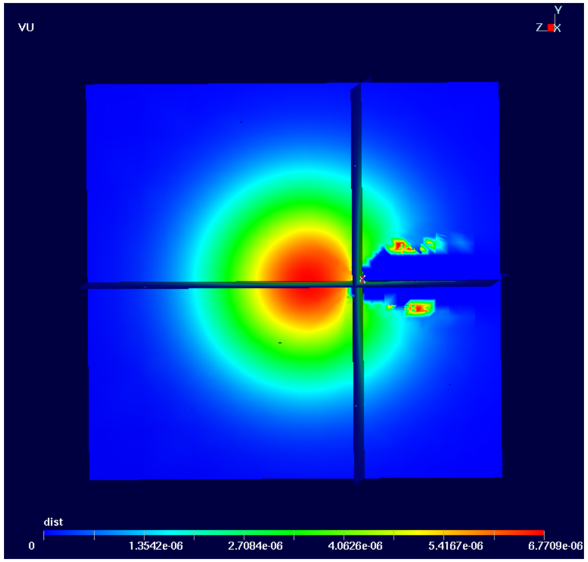
Distribution function at IAP

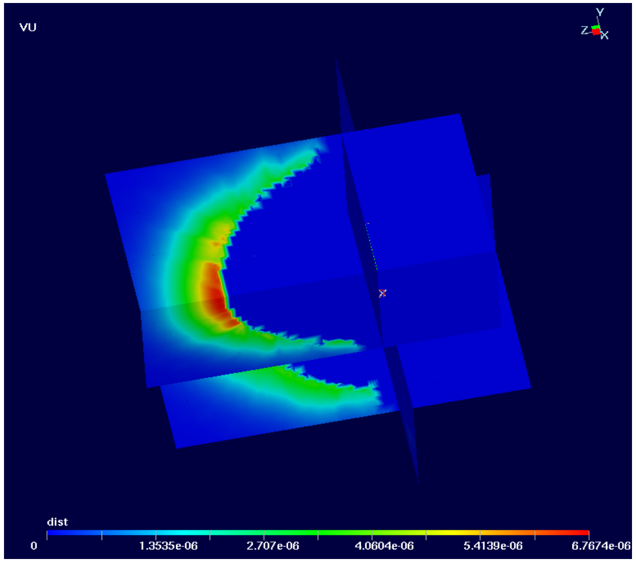


- Illustration of the distribution function in the $v_y = 0$ cut plane upstream (left), at point A on IAP (centre).
- The mesh used in velocity space is also shown (right).
- The distortion in the ion distribution function correspond to $\phi = 7.1^0, \theta = 7.6^0$
- At point B, in IAP, these angles are $\phi = 7.3^0, \theta = 0.4^0$

Distribution function around SWARM





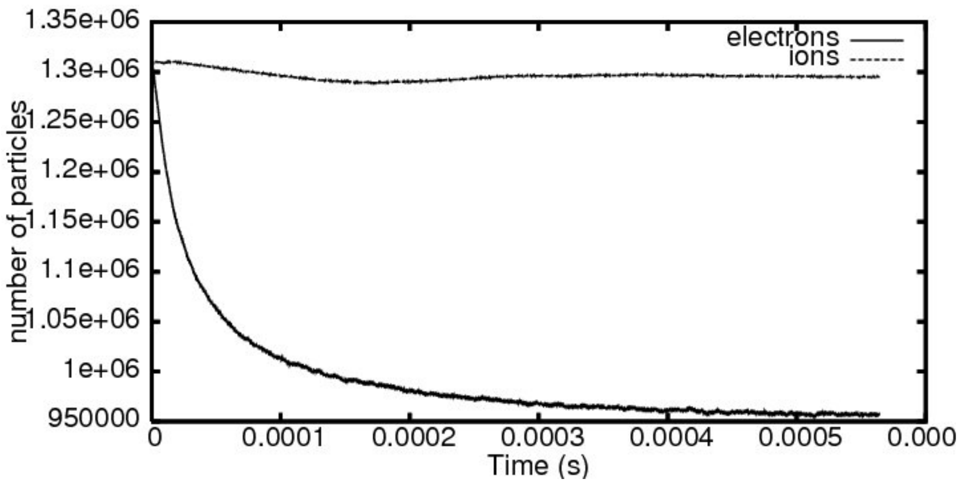


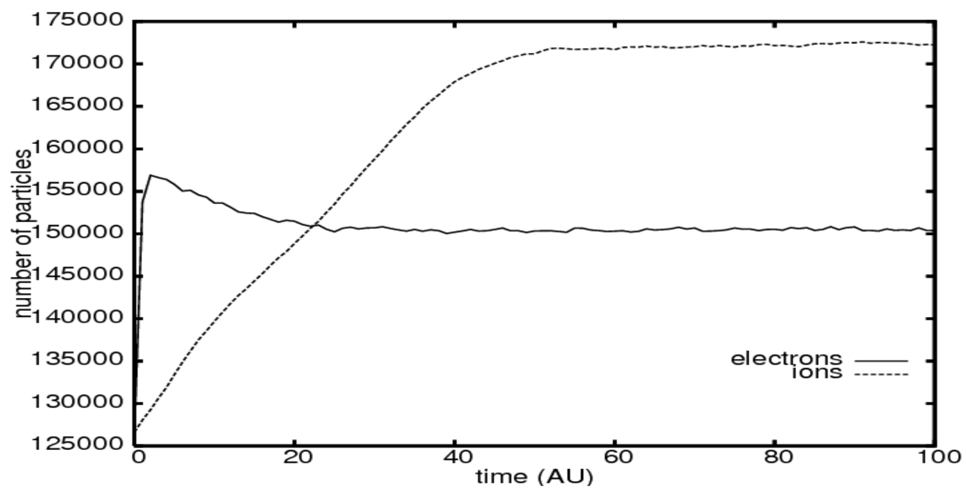
- Schematic SWARM satellite (left).
- Proton distribution function 3m upstream, on the satellite axis (middle).
- Proton distribution function on the upstream face (right).

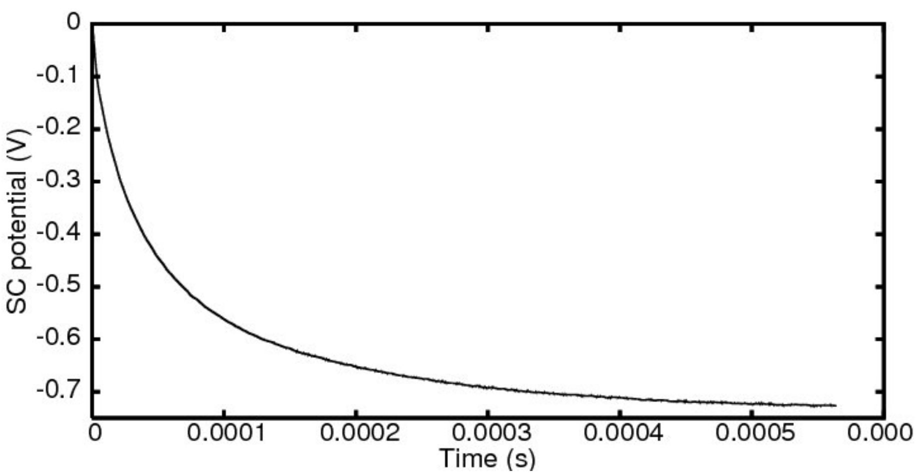
Some comparisons with SPIS

PIC 3D

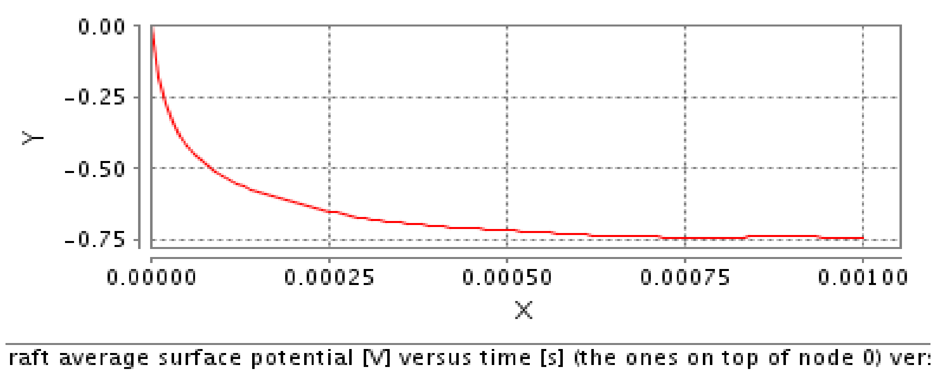
SPIS





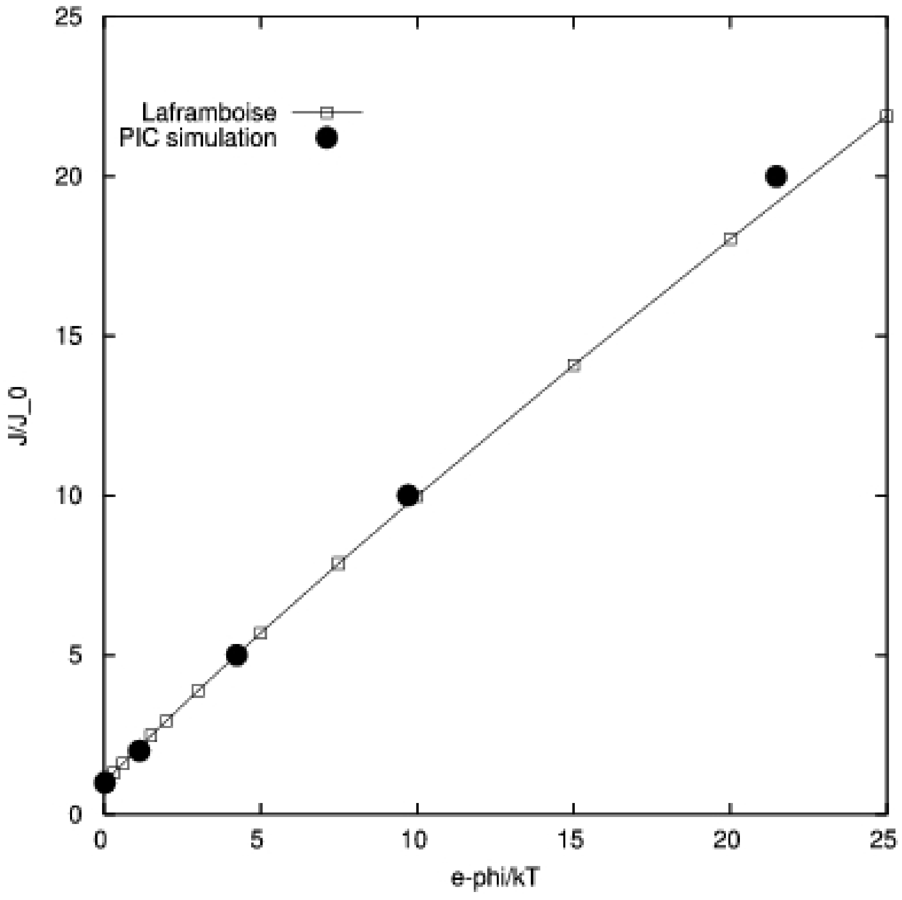


Plot of Spacecraft average surface potential [V] versus time [s] (the ones on top of node 0)



Code validation

- Visual comparisons were made with SPIS solutions
- Floating spacecraft potentials agree within a few percent
- Quantitative comparisons are made between spherical probe characteristics obtained from the code and computed by Laframboise (1966).



Summary

- Measurements to characterise the satellite:
  - Self and mutual capacitances.
  - Material properties (work functions).
  - Photoelectric currents.
- In situ
  - Currents between the different components.
  - Surrounding plasma parameters.
  - Electron and ion distribution functions at various. locations, or moments thereof.
  - Orientation, solar illumination.
  - ...