SPIS 4.0
SPIS-Num upgrade overview

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return on innovation

Outline

- Introduction
- Overview of new SPIS v4.0 features
- Circuit solver

SPIS context and project overview

- SPINE *(Spacecraft Plasma Interaction Network in Europe)* community setup around year 2000 (A. Hilgers, J. Forest...):
  - An idea was born: gather European efforts for SC-plasma interactions
  - Exchange: knowledge, data, codes, results...
  - Boost the development of a common simulation toolkit: ESA ITT in 2002 => SPIS

- SPIS Development *(Spacecraft Plasma Interaction Software) :*
  - Initial development: 2002 – 2005
    - ONERA-Artenum consortium
    - ESA/ESTEC contract
  - Solver enhancement: 2006 – 2009
    - Mostly ONERA
    - ESTEC contract, French funding
  - Others:
    - Some community developments
    - Some CNES-funded modules (EP, ESD)
    - ESD triggering modelling in progress (ESA TRP)
    - Probably soon: EP integration, SPIS-GEO...

Overall status of SPIS code

- SPIS-UI:
  - Real framework: task monitor, data management, script console (jython)…
  - Interfacing with modeler/mesh-generator, postprocessing tools…
- SPIS-Num:
  - Plasma:
    - Matter models: PIC (leapfrog/exact (potential P1)), Boltzmann distribution, multi physics
    - E field solver: Poisson, non linear Poisson, singularities (wires, plates)
    - Volume interaction: CEX (MCC)
  - Spacecraft:
    - Material properties: secondary emission (under electron/proton/UV), conductivities (surface/volume, intrinsic/RIC), field effect, sputtering (recession rate, products generation and transport)
    - Equivalent circuit: coatings (RLC) + user-defined discrete components (RCV), implicit solver
    - Sources: Maxwellian, Axisymmetric, two axes
  - Specific features:
    - Time integration: control at each level (population, plasma, simulation)
    - Numerical times: integrate fast processes over a smaller duration (electrons/ions, plasma/SC…)
    - Multiscale capabilities: cell = box / 100,000 (cf. examples below)
    - Modularity: OO (Java), “plug-in” classes (Java introspection)

Recent developments => SPIS v4.0

- Objective: extension of SPIS to overcome some limitations of the current version of SPIS, mostly including :
  - Improved time-dependent solvers
  - Multi physics (dense / low density regions, multi space scale)

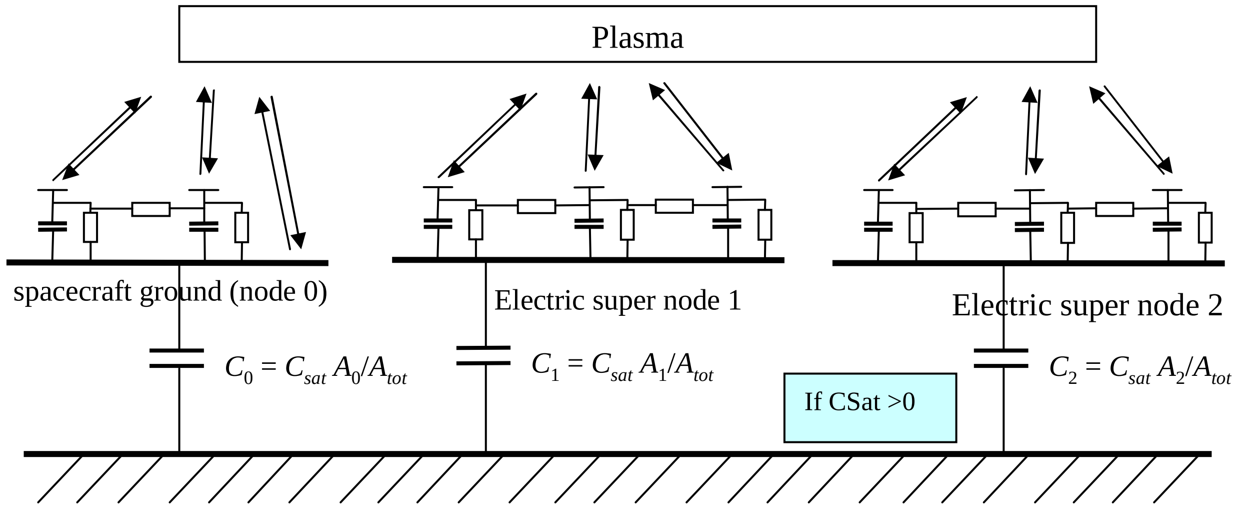
- Context:
  - ESA ARTES contract, French funding (optional)
  - Project:
    - 2006 through 2009
    - Code improvement
    - Then testing/validation and possible improvement
  - Collaboration with CNES (funding, validation data...)

- Released in July 2009 (v4.0RC)

Major improvements in SPIS v4.0 (1/3)

- Surface potentials / SC circuit:

Cf. the end of this presentation



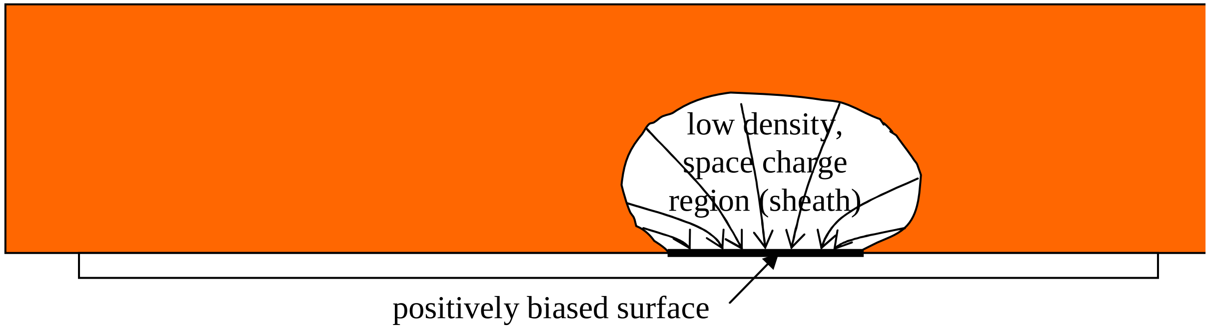
- Circuit:
  - Inductances
  - Exact Csat (through Gauss theorem) instead of user defined

- Circuit solver:
  - Implicit
  - Variable, automatic time step

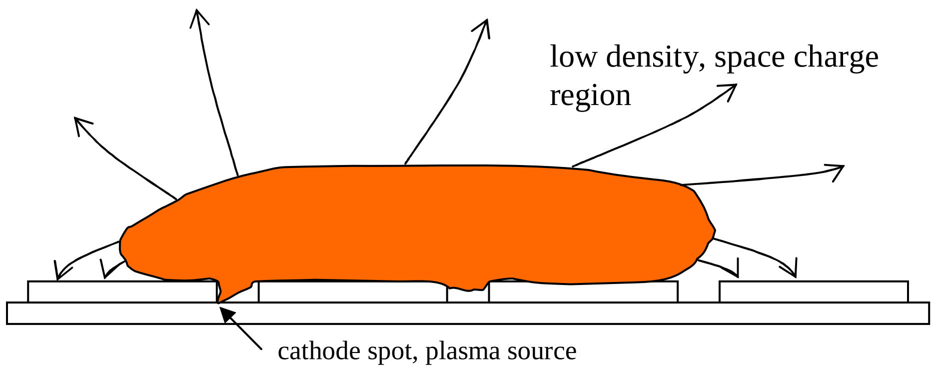
Constraints:
- multi time scale 10E-11 to 10E4 s !
- steep function (FN emission)

Major improvements in SPIS v4.0 (2/3)

- Plasma dynamics (1/2):
  - Multi-physics
    - Typically simulate in a single simulation:
      - Dense quasi-neutral regions
      - Low density, space charge regions
    - Examples:
      - Ambient plasma at rest / sheath:



      - Expanding plasma / fast electrons ahead of the plasma front (ESD):



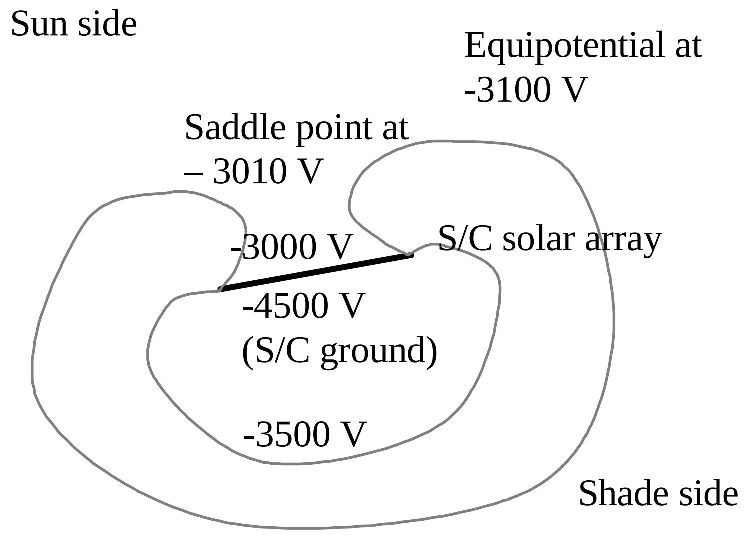
    - Method: multi-zone, interface handling

Cf. other presentation later today

Major improvements in SPIS v4.0 (3/3)

Test case => cf. B. Andersson presentation

- Plasma dynamics (2/2):
  - Potential barrier / GEO charging:
    - Blocking of photo/secondary emission by the barrier (small barrier height compared to potentials involved)
    - Accuracy of (collected) currents: small object in a large computation box (noisy) => backtracking needed (can be useful for detector also e.g.)
  - Multi-time scale modelling
    - Implicit SC circuit solver



Specific "small" improvements

- SPIS v4.0:
  - Particle pusher, local switch between
    - constant E (in tetrahedron): exact integration (parabolic)
    - varying E or presence of B: Runge-Kutta Cash-Karp method (RK 4th order with adaptive time step to control accuracy
  - "Exact Csat":
    - Indeed do not use a (user-defined) Csat
    - But uses Gauss theorem (integral form of Poisson eq.) to determine Vsat (ensuring charge conservation)
  - Cathode spot model

- Coming soon (SPIS v4.1?):
  - Completion of symmetry conditions (particle specular reflection)
  - Completion of particle trajectory plotting
  - Improve neutral particle handling
  - Improve material handling (from external DB through UI)
  - Other UI improvements

The circuit solver

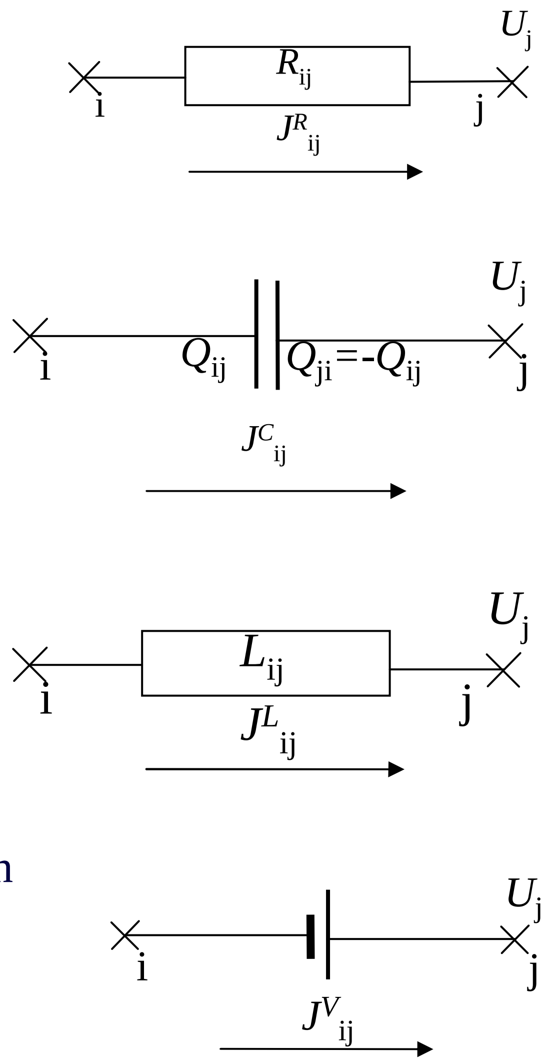
- Circuit equations:

$$-\underline{\underline{C}}.\dot{\underline{U}} + \underline{\underline{G}}.\underline{U} + \underline{\underline{P}}\,\underline{J}^{L} + \underline{I}^{I} = 0$$

$$\underline{\dot{J}^{L}} = \underline{\underline{H}}.\underline{U}$$

or

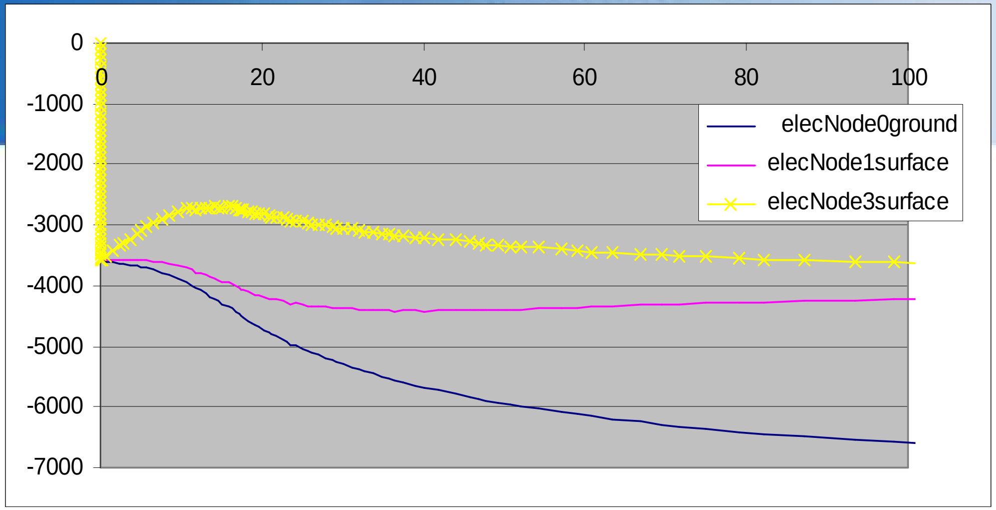
$$\begin{bmatrix} \dot{\underline{U}} \\ \underline{\dot{J}^{L}} \end{bmatrix} = \begin{bmatrix} \underline{\underline{C}}^{-1}.\underline{\underline{G}} & \underline{\underline{C}}^{-1}.\underline{\underline{P}} \\ \underline{\underline{H}} & 0 \end{bmatrix} . \begin{bmatrix} \underline{U} \\ \underline{J}^{L} \end{bmatrix} + \begin{bmatrix} \underline{\underline{C}}^{-1}.\underline{I}^{I} \\ 0 \end{bmatrix}$$

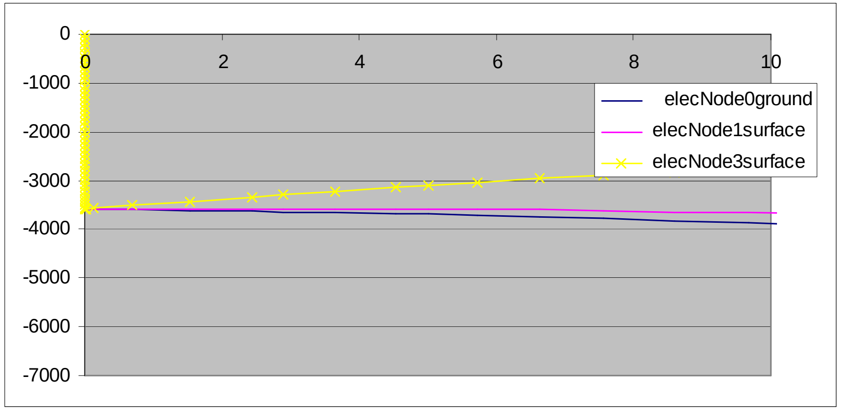


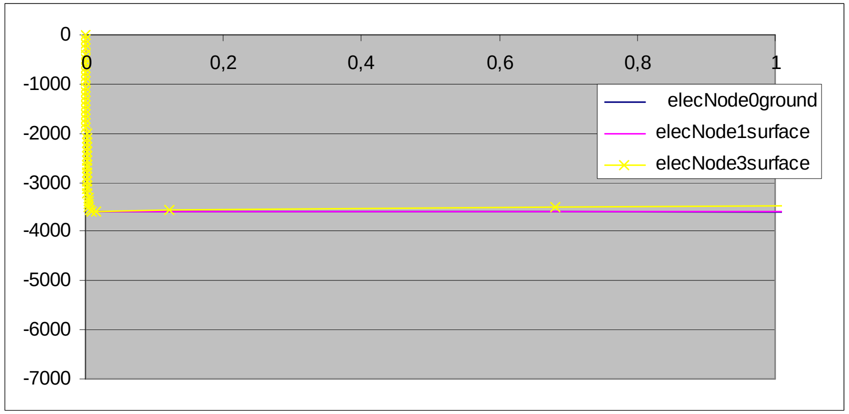
- Implicit solver:
  - Need to anticipate on I variation with V
    - Linear (in the matrix equation)
    - Or non linear on the source term $I^{I}(V)$: plasma collection
  - => each physical process to supply dI/dV and validity
  - Time step maximised to saturate validity

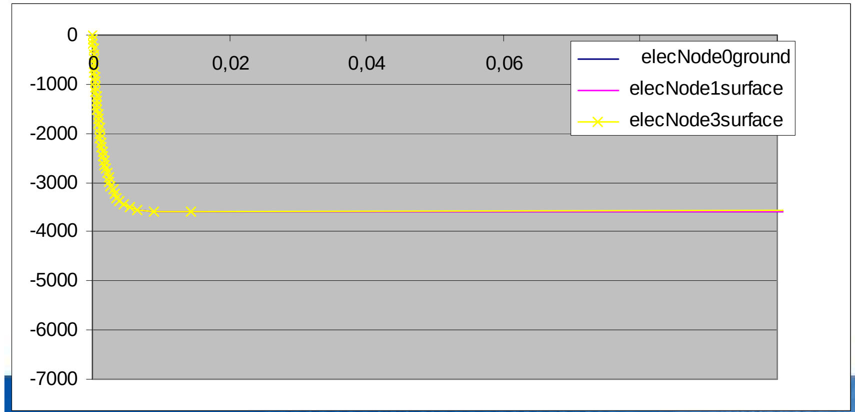
The circuit solver

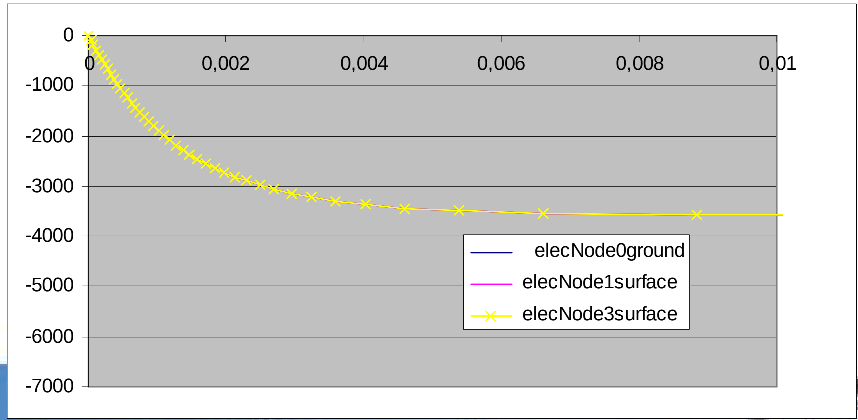
- Automatic time step:
  - An example (GEO charging)
  - Quite large range of time scales











Conclusion and perspectives

- Major development done
- Code released (v4.0RC in July, v4.0 ~ next month)
- Testing done by contractor and ESA
- Further testing by the community welcome