SPIS code status (mostly numerical solvers)

ROUSSEL J.-F., DUFOUR G. , ROGIER F. ONERA
FOREST J. ARTENUM
... and many others ...

ONERA
THE FRENCH AEROSPACE LAB

return on innovation

Outline

- Current status of the code
- Forthcoming (large) developments
  - SPIS Time-Dependent (in progress)
- Extra needs
  - Continuous improvements
  - Governance

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 – 2008
    - Mostly ONERA
    - ESTEC contract, French funding
  - Others:
    - Some community developments
    - Some CNES-funded modules (EP, ESD)
    - Probably SPIS-GEO soon, CNES funding

SPIS code status

- 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
    - 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 solver: coatings (RC) + user-defined discrete components (RCV)
    - 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)

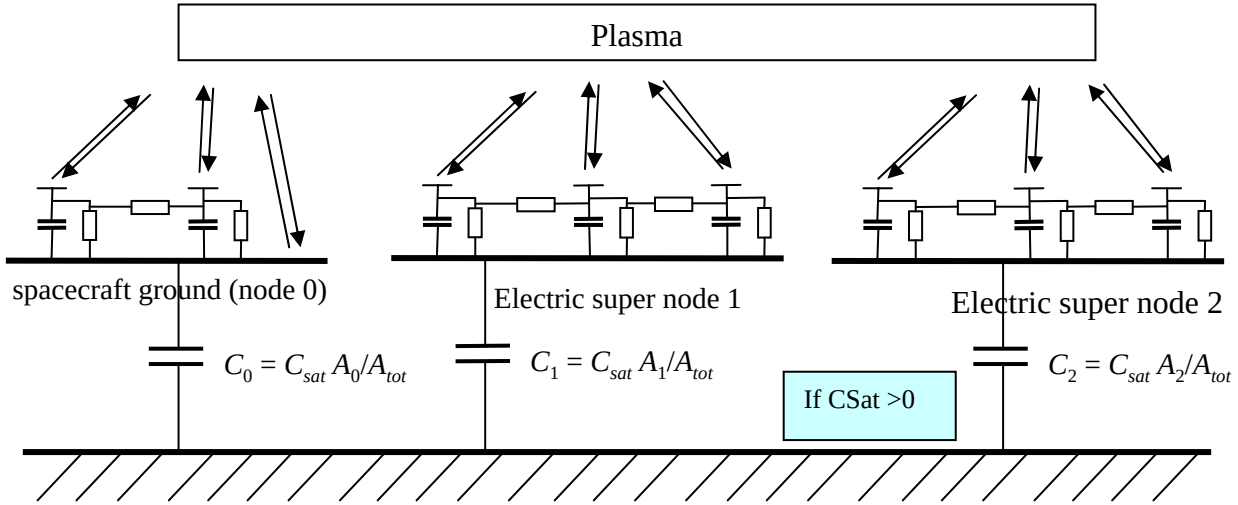
New development in progress

- 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 2008
    - Code improvement
    - Then testing/validation and possible improvement
  - Collaboration with CNES (funding, validation data...)

Major improvements in progress (1/3)

- Surface potentials / SC circuit:

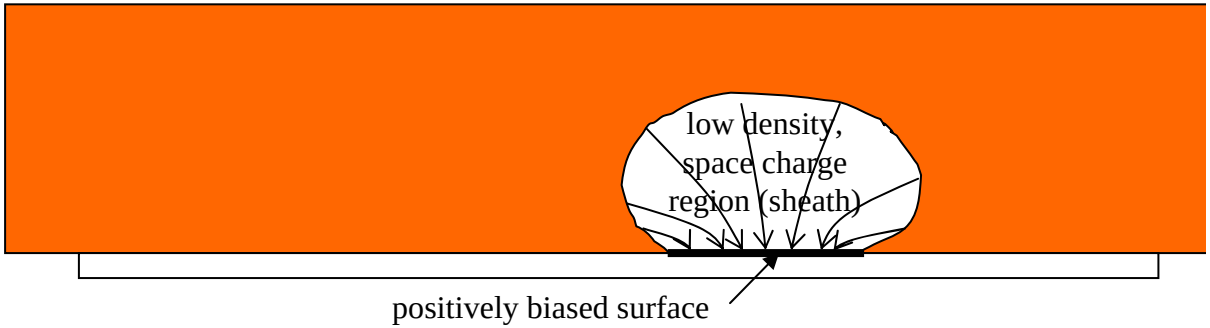


  - Circuit:
    - Inductances
    - Exact Csat (through Gauss theorem) instead of user defined
  - Circuit solver:
    - Implicit
    - Variable, automatic time step

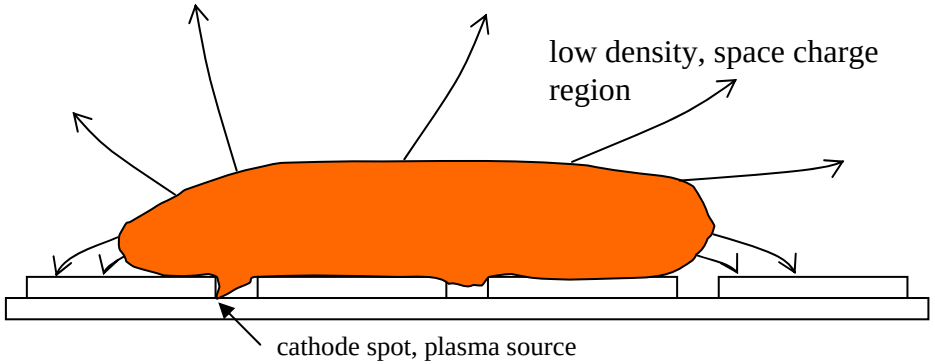
Constraints:
- multi time scale 10E-11 to 10E4 s !
- steep function (FN emission)

Major improvements in progress (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):

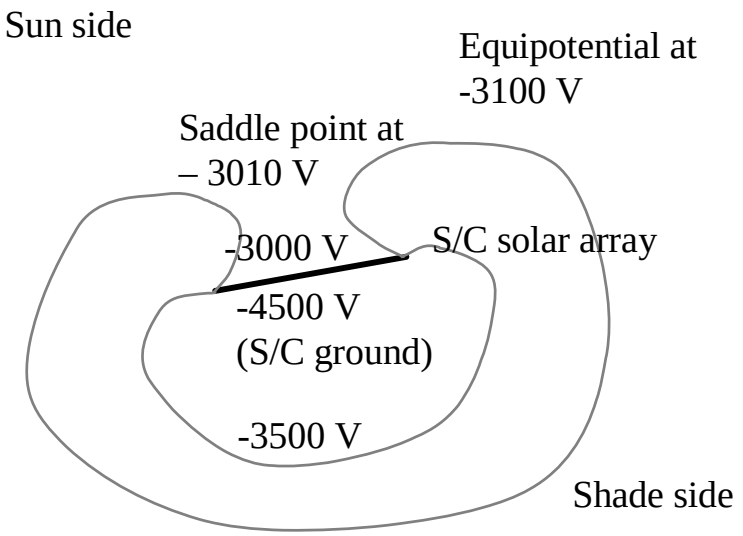


    - Method:

      multi-zone, interface handling

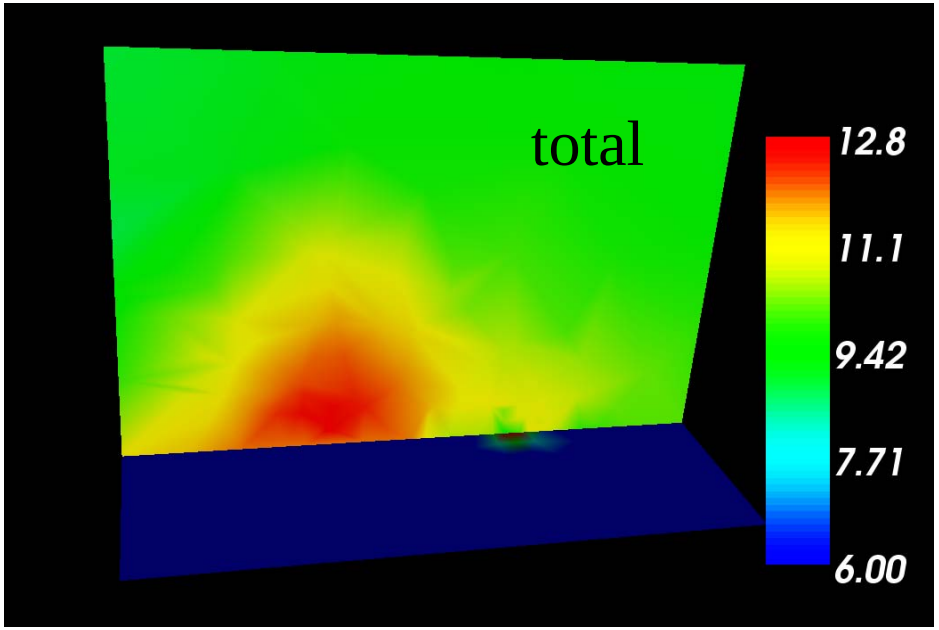
Major improvements in progress (3/3)

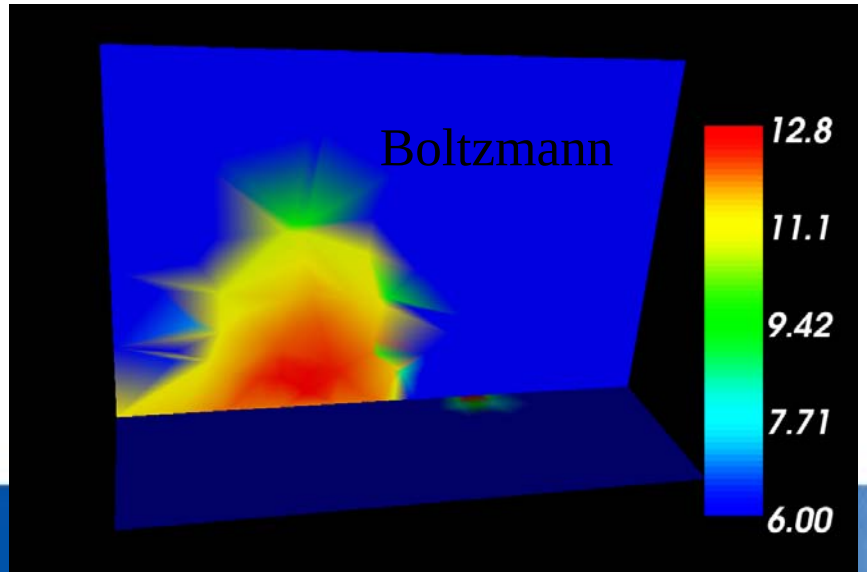
- Plasma dynamics (2/2):
  - Potential barrier / GEO charging:
    - Blocking of photo/secondary emission by the barrier (small barrier height compared to potentials involved)
    - Accuracy of (collected) currents: small object in a large computation box (noisy) => backtracking needed (can be useful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

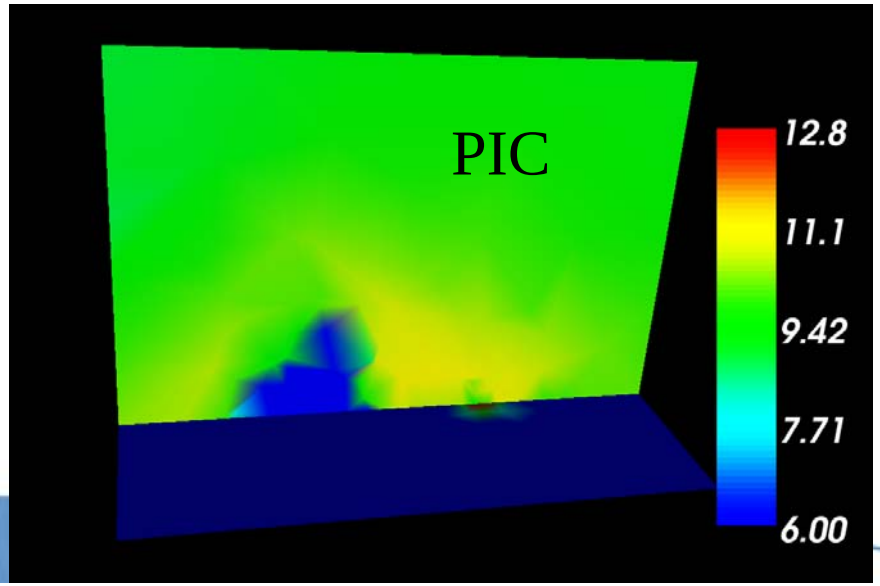


Multi physics / multi zone: first tests

- Test case: plasma bubble expansion
- Electron density:
  - composed of Boltzmann electrons in dense ion zone (quasi neutral)
  - and PIC electrons in low density zone (non neutral)





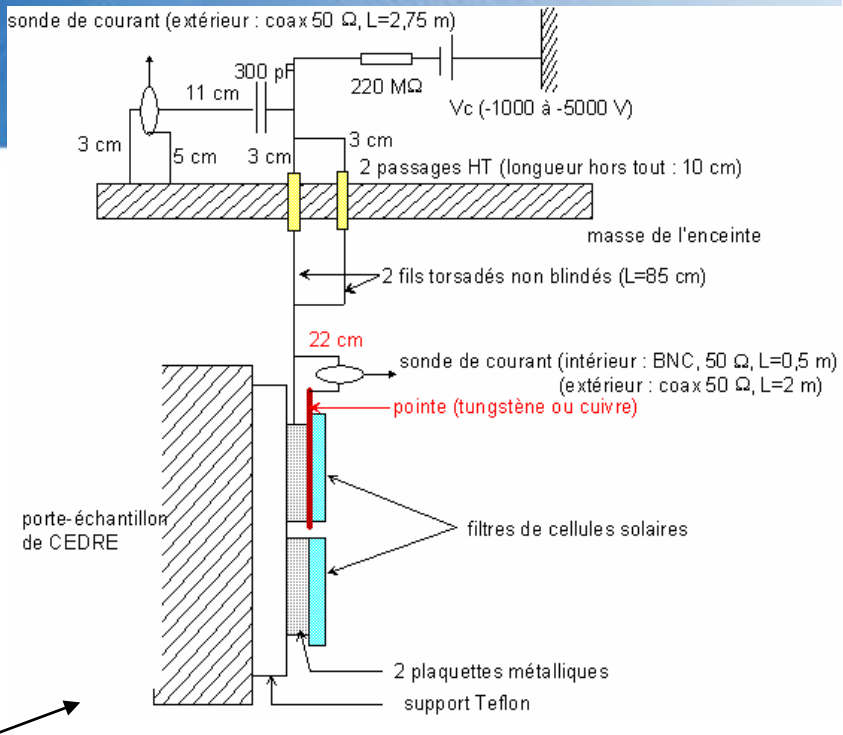


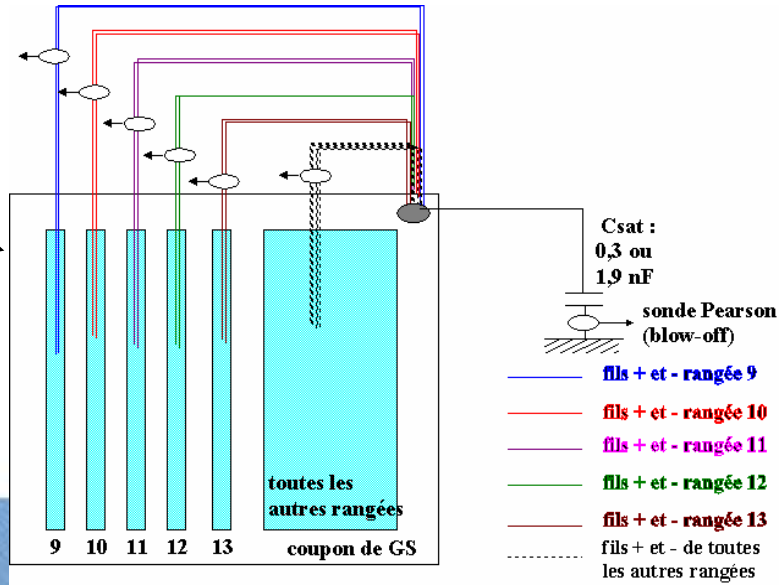
Specific "small" improvements

- Smaller improvements, developed for the above large objectives, or extra (CCN to the contract):
  - Particle pusher, local switch between
    - constant E (in tetrahedron),
    - constant E and B,
    - varying E and constant B: Runge-Kutta Cash-Karp method (RK 4th order with adaptive time step to control accuracy)
  - Completion of symmetry conditions (particle specular reflection)
  - Completion of particle trajectory plotting
  - Improve neutral particle handling
  - Some UI improvements

Tests / applications / validation

- GEO charging :
  - Comparison to published NASCAP simulation
- ESDs :
  - Comparison to ONERA/DESP ESD data (ground tests, CNES):
    - Artificial ESD triggering:
    - Flash over propagation:
- Cases extremely challenging to model!





Conclusion on SPIS enhancement in progress

- Work in progress
- Many improvements will be implemented in SPIS
- Capability to simulate:
  - Absolute/relative time-dependant charging (GEO and others): mostly done
  - ESDs, triggering, flashover / blow off expansion:
    - Extremely challenging
    - Starts working => good hope
    - Hope to do *most of it*...
      - Qualitative agreement: hopefully
      - Quantitative agreement: ??
      - Predictive modelling: certainly not (yet)
- Enhanced code will be released to the community when ready
- Some delay in the development...

Extra needs

- Wish list ~ maintained on SPIS web site, based on community requirements
  (http://dev.spis.org/projects/spine/home/spis/software/workshops/coreWS/wishesList)
- List update thanks to this meeting?
- Total not small => funding needed:
  - Incremental by small community funding (must first finance support)
  - Or small contracts, which already worked for
    - EP: sources, CEX, erosion/contamination
    - ESD (FN emission)
- Need for a governance
  - Development roadmap (priorities, overall consistency)
  - Funding
  - + support to users (not discussed here)