Technical Note (TN)

SPIS Validation Tests

TN 2010/10-001: Floating Simple Sphere Low Resolution

	Name and Function	Date	Signature
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Verified by			
Approved by			

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Executive summary

This Technical Note (TN) presents the reference results of a simulation run performed the test3_sphere_low_resol.spis project, as updated for SPIS 4.3 (i.e modification of the spacecraft capacitance for a better dynamic). This test should compute the equilibrium potential of a simple sphere immersed in a Maxwellian plasma at rest with a density of Ne= 10^6 p/m^3 and an electronic temperature of Te = 1eV, without photo-emission and any secondary emissions.

The final equilibrium potential of the sphere is about -2.23V.

The corresponding project is available as input at the following place :

$SPIS_ROOT/Data/ValidationTest/test3_sphere_low_resol.spis

This TN gathers all needed inputs for the simulation and the key reference outputs.

The outputs are conform to the expected theoretical values. The present simulations have been successfully performed with with SPIS 4.3 on Apple Mac OSX 10.6.4, with the Apple JVM 1.6.

This reference project constitutes the main and first regression test case of SPIS. These results can be used as reference results for earlier tests and validation. All versions of SPIE higher than 43. should pass it successfully and provides the same results than listed in the present TN.

Diffusion

Nom	Organisation
Not classified	All

Modifications

Version	Révision	Date	Auteur / Observations
1	1	30/10/2010	Julien Forest

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1. Generalities

1.1. Reference and applicable documents

1.1.1. Reference documents

[DR1] TN 1.0 SPIS User Manual

1.1.2. Applicable document

N/A

1.2. Glossary

- **N/A**

2. Introduction

This Technical Note (TN) given the standards results of a simulation run performed the test3_sphere_low_resol.spis project, as updated for SPIS 4.3 (i.e modification of the spacecraft capacitance for a better dynamic). This test should compute the equilibrium potential of a simple sphere immersed in a Maxwellian plasma at rest with a density of Ne= 10^6 p/m^3 and an electronic temperature of Te = 1eV, without photo-emission and any secondary emissions.

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3. Presentation of the input system

3.1. Geometrical system, meshing and group settings

The system is reduced to a simple sphere of 1m of radius inside of a cubic computational box of 20m length as illustrated here after. Only one property group is defined one the spacecraft (i.e the sphere).

The mesh counts about 14795 cells, for a meshing performed with Gmsh on Mac OSX.

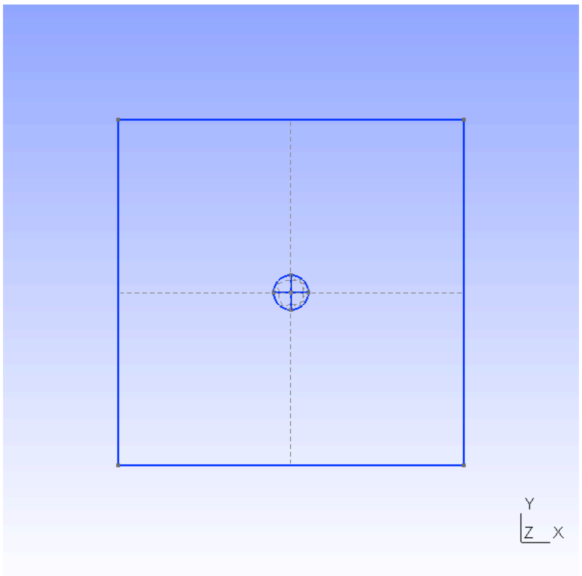


fig. 1: View of the modelled system.

The figures 2 and 3 here after show the Rho quality factor for this test case with a low mesh resolution. The mesh quality is here poor due to the limited number of cells, but relatively homogenous. We do not recommend to go lower in term of mesh quality.

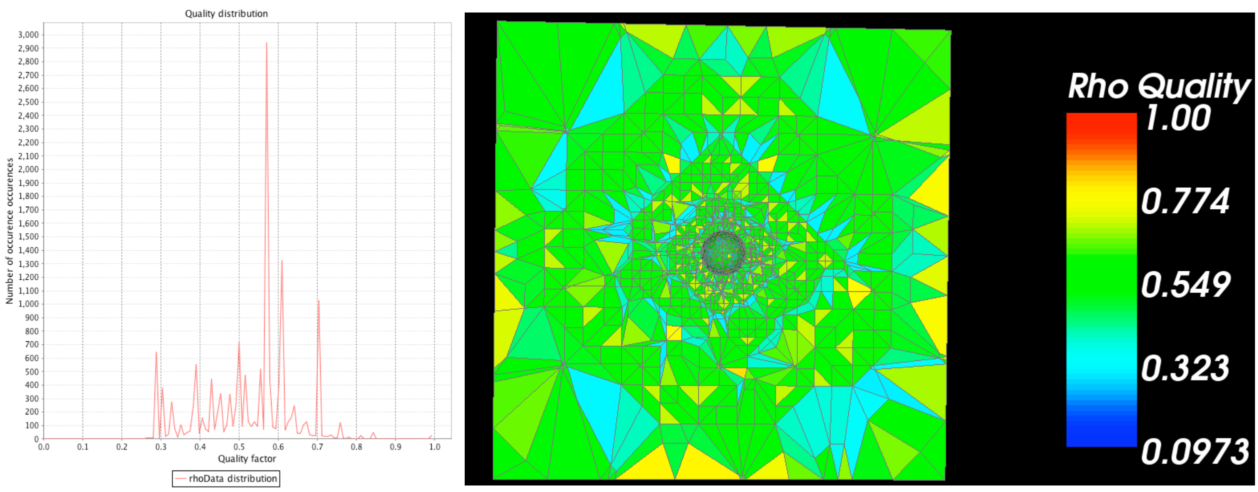
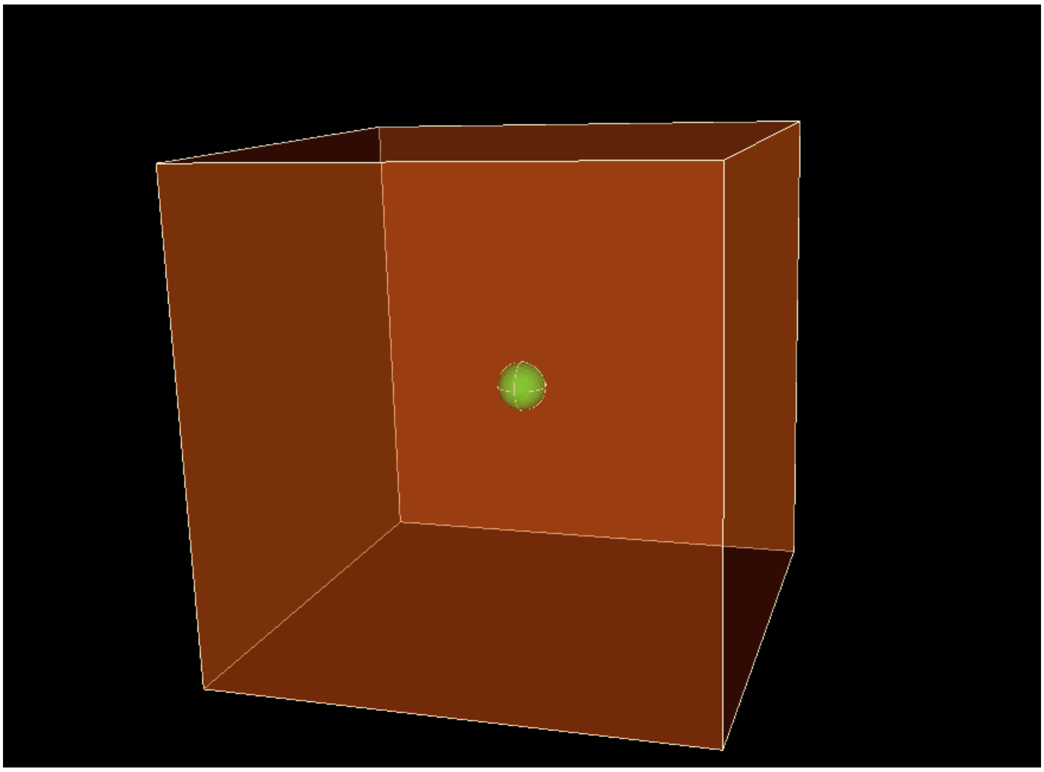


Figure 2 and 3: Evaluation of the mesh quality done with the JFreeMesh Inspector.



View to the properties groups. The spacecraft (group 56) is in green. The external boundary group (group 57) is in brown and transparent. The group of volume (group 58) is not represented for a bette visibility

3.2. Environment parameters

The space environment is modelled by a Maxwellian plasma at rest with a density of Ne= 10^6 p/m^3 and an electronic temperature of Te = 1eV.

3.3. Numerical model

Because, it is expected the spacecraft become negative, the plasma is modelled using an hybrid approach, with electrons modelled using a thermalised approach and the ions by a PIC model. Please see the SPIS-NUM documentation for further information regarding numerical model selection.

For an arbitrary spacecraft capacitance of 10^{-11}F, a simulation duration time of 4.10^{-4}s at least is needed.

3.4. Internal circuitry and model

There is no internal circuit defined for this model. The spacecraft (i.e sphere) is defined by only electrical macro-node (i.e node 0 - spacecraft ground).

3.5. Global parameters summary

All inputs of global parameters are summarised in ANNEXE 1.

4. Reference results of the simulation

4.1. Time evolution

Figures 4 and 5, here after, show the time evolution respectively for the spacecraft potential (node 0 - spacecraft ground) and the total net collected current. The plot of net collected current confirms that the equilibrium is reached, the net current converging toward zero. The equilibrium potential is about -2.34V with respect to the undisturbed plasma.

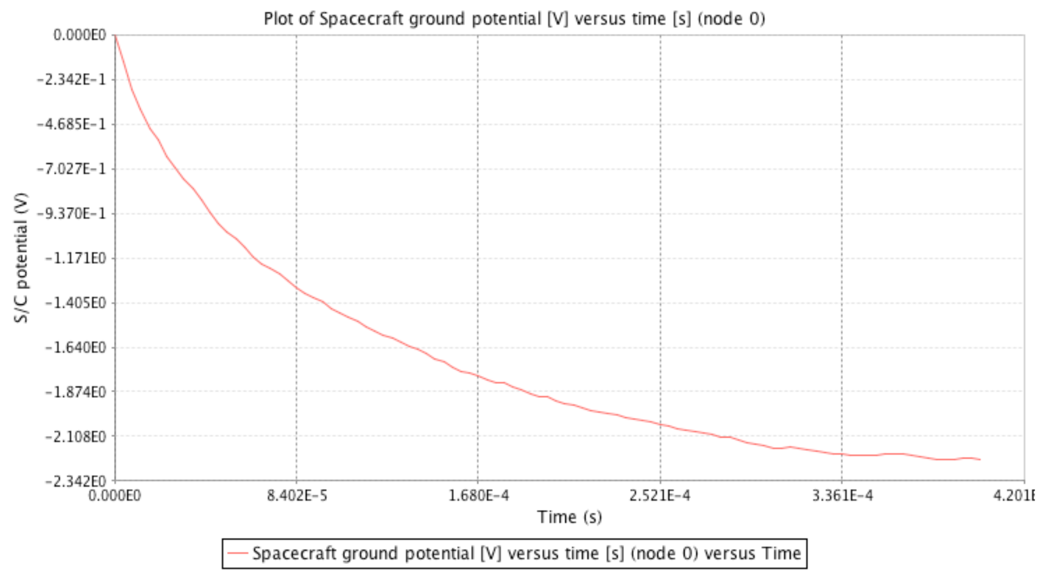


Figure 4: Time evolution of the spacecraft potential. The relaxation time is here indicative, the spacecraft to plasma capacitance being arbitrary set to 10^{-11}F.

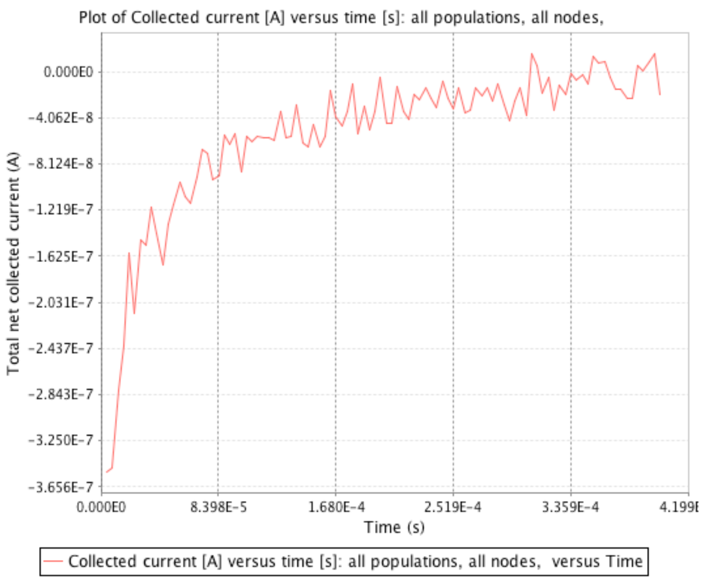


Figure 5: Time evolution of the total net collected current. The fact that the curent tends to zero confirmes that the equilibrium is reached.

4.2. Final state

4.2.1. Final plasma potential

Figure 6 and 7 heres after show the final plasma potential around the spacecraft. Figure 6 corresponds to a cutting plan in the x-y plan. Figure 7 corresponds to the potential along radial axis form the centre of the spacecraft. The zero value is due to the fact for a radius lower that 1 m where are inside the spacecraft and de facto outside the computational domaine.

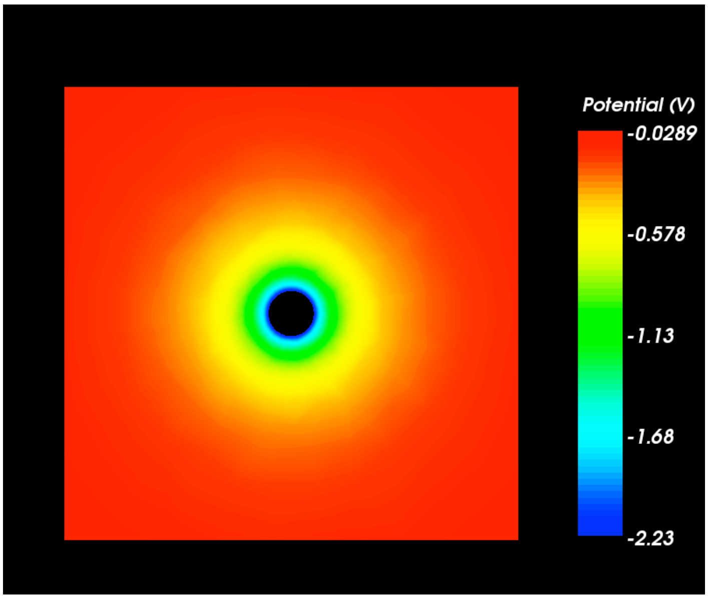


Figure 6: Cut of the final plasma potential.

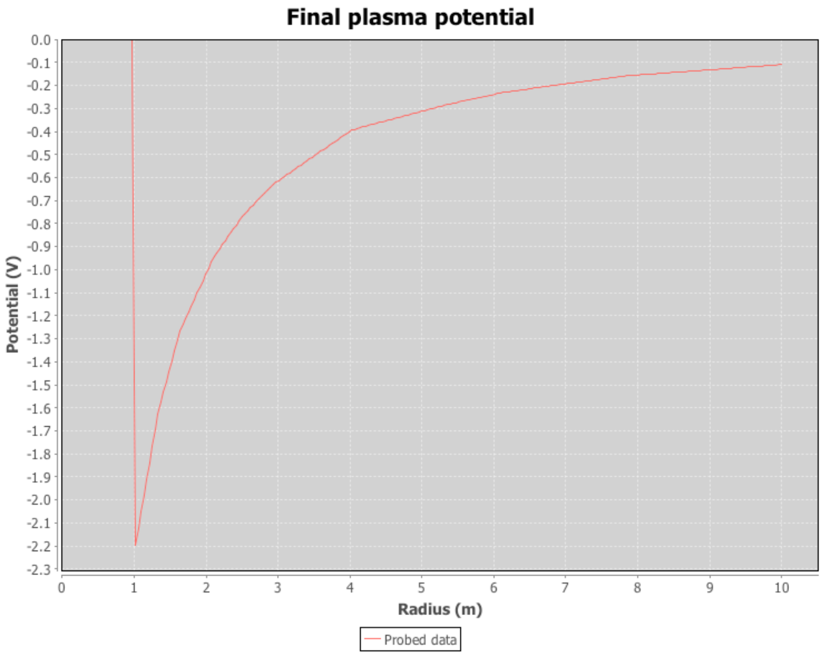


Figure 7: Value of the final plasma potential versus the distance to the center (radius).

5. Conclusion

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A. Annexe 1: List of the global parameters

Parameter	Index	Description	Type	Unit	Value
inPop2VolInteract	Volume Interactions	Defines second interacting population (e.g. neutrals for CEX), must be one of ions1, ions2, elec1, elec2, source1... source4, photoElec, secondElec	string	None	fractionOfFirstPopSource
scPotMonitorStep	Outputs	time step for spacecraft ground potential monitoring (0 => none, -n => n times)	float	[s]	-100.0
electronDistrib2	Plasma	Name of the VolDistrib class to be used for the 2nd electron population	string	None	PICVolDistrib
initPot	Spacecraft	initial potential	float	[V]	0.0
sourceFlag3	Spacecraft	Flag for defining artificial source No 3 on the spacecraft: 0 => none, 1 => yes, x => number of super-particles densified by x	float	[-]	0.0
poissonBCParameter2	Poisson equation	2nd parameter that can be used by some BC types	float	[varies]	0.0
ionVx2	Plasma	Ion drift velocity along x axis (2nd population)	float	[m/s]	0.0
ionDensity	Plasma	Ion density (1st population)	float	[m-3]	1000000.0
plasmaSpeedUp	Simulation control	Numerical times speed-up factor for plasma (plasma dynamics is only integrated over a fraction 1/plasmaSpeedUp of actual physical time)	float	[-]	1.0
sourceFlag1	Spacecraft	Flag for defining artificial source No 1 on the spacecraft: 0 => none, 1 => yes, x => number of super-particles densified by x	float	[-]	0.0
sourceType1	Spacecraft	Name of the SurfDistrib class to be used on the spacecraft as source No 1	string	None	LocalMaxwellSurfDistrib
ionDistrib	Plasma	Name of the VolDistrib class to be used for ions	string	None	PICVolDistrib
volumeConductivity	Surface Interactions	if 0 no volume conductivity, if 1 volume conductivity turned on	int	None	0
tolGradientNl	Poisson equation	Tolerance for conjugate gradient Poisson Solver when non-linear solving	float	[-]	0.0001
ionType2	Plasma	Second ion population	string	None	H+
ionType	Plasma	First ion population	string	None	H+
crossSectionVolInteract	Volume Interactions	Cross section for volume interaction, either a float (its value [m2]) or the name of the file describing sigma(E)	string	[m2] or None	1.0e-18
ionVz	Plasma	Ion drift velocity along z axis (1st population)	float	[m/s]	0.0
electronDt2	Plasma	Maximum integration time step for electron 2nd population (automatic if negative)	float	[s]	-1.0
secondarySpeedUp	Surface Interactions	Numerical times speed-up factor for all types of secondary electrons	float	[-]	1.0
photoElectronTemperatur	Surface Interactions	photo-electron temperature	float	[eV]	2.0
CSat	Spacecraft	absolute spacecraft capacitance	float	[F]	1,00E-11
outPop2DtVolInteract	Volume Interactions	Maximum integration time step for first population produced in volume interaction (automatic if negative)	float	[s]	-1.0
simulationDt	Simulation control	Time step for global simulation dynamics (semi-automatic if 0: determined by lower level time step = plasmaDt)	float	[s]	0.0
ionDt2	Plasma	Maximum integration time step for ion 2nd population (automatic if negative)	float	[s]	-1.0
linearPoisson	Poisson equation	if 1 linear Poisson solver, if 0 non-linear	int	None	1
Bz	B Field	z-component of the magnetic field	float	[T]	0.0
densityLogPlotCutoff	Outputs	cutoff for density log plots	float	[ecu/m3]	0.001
avPartNbPerCell	Plasma	average number of super-particle per cell	float	None	5.0
electronSecondaryEmissio	Surface Interactions	bits go by groups of 3 (bit0=on/off, bit1=simulate_secondary_elec_dynamics/don t, bit2=allow_secondaries_of-secondaries/don t), while groups of 3 bits are for ambient population 1, ambient population 2, source 1, source 2, source 3 and source 4 resp.	int	None	0
plasmaPotMapMonitorSte	Outputs	time step for plasma potential monitoring (0 => none, -n => n times)	float	[s]	-10.0
electricCircuitFilename	Spacecraft	File name of extra electric devices (RLCV)	string	None	circuit.txt
poissonVerbose	Outputs	Same as verbose, but specific to Poisson solver	int	None	3
verbose	Outputs	Verbosity level (level of screen messages about code execution)	int	None	3
outPart2VolInteract	Volume Interactions	Type of particles for second population produced in volume interaction	string	None	Xe
scPotMapMonitorStep	Outputs	time step for spacecraft local potential monitoring (0 => none, -n => n times)	float	[s]	-10.0
sourceParticleType1	Spacecraft	Type of particles emitted by source 1	string	None	Xe+
volInteract	Volume Interactions	Flag to turn on volume interaction: 0 => off, 1 => on, x>0 => on, superparticles densified by x	float	None	0.0
outPop1DtVolInteract	Volume Interactions	Maximum integration time step for first population produced in volume interaction (automatic if negative)	float	[s]	-1.0
parameter3VolInteract	Volume Interactions	3rd parameter of volume interactor	float	[variable]	0.0
sourceDt4	Spacecraft	Maximum integration time step for particles from 4th source (automatic if negative)	float	[s]	-1.0
finalCumulation	Outputs	cumulate currents and densities at the end of simulation ? 0=no, 1or2=yes	int	None	2
exportAllDataFields	Outputs	Select the export mode for all data fields (None=no export, ASCII=ASCII multi-files)	string	None	None
sourceType2	Spacecraft	Name of the SurfDistrib class to be used on the spacecraft as source No 2	string	None	MaxwellianThruster
sourceFlag4	Spacecraft	Flag for defining artificial source No 4 on the spacecraft: 0 => none, 1 => yes, x => number of super-particles densified by x	float	[-]	0.0
secondaryDt	Surface Interactions	Maximum integration time step for all types of secondary electrons (automatic if negative)	float	[s]	-1.0
ionSpeedUp	Plasma	Numerical times speed-up factor for ion 1st population	float	[-]	1.0
exportDensity	Outputs	Select the export mode for density data fields (None=no export, ASCII=ASCII multi-files)	string	None	None
currentLogPlotFlag	Outputs	plot log10 of currents? 0=no, 1=yes(log only), 2=both	int	None	2
densitiesMapsMonitorStep	Outputs	time step for densities monitoring (0 => none, -n => n times)	float	[s]	-10.0
outPop1SpeedUpVolIntera	Volume Interactions	Numerical times speed-up factor for first population produced in volume interaction	float	[-]	1.0
electricCircuitIntegrate	Spacecraft	SC electric circuit integration: 0=no change, 1=floating	int	None	1
environmentType	Plasma	Name of the Environment class to be used	string	None	BiMaxwellianEnvironment
surfaceConductivity	Surface Interactions	if 0 no surface conductivity, if 1 surface conductivity turned on	int	None	0
iterGradient	Poisson equation	Maximum iteration number for conjugate gradient Poisson Solver	int	None	100
electronDensity	Plasma	Electron density (1st population)	float	[m-3]	1000000.0
secondaryTemperature	Surface Interactions	secondary electron temperature (from electron impact)	float	[eV]	2.0
ionDensity2	Plasma	Ion density (2nd population)	float	[#/m3]	0.0
ionTemperature	Plasma	Ion temperature (1st population)	float	[eV]	1.0
sourceFlag2	Spacecraft	Flag for defining artificial source No 2 on the spacecraft: 0 => none, 1 => yes, x => number of super-particles densified by x	float	[-]	0.0

outPop2SpeedUpVolIntera	Volume Interactions	Numerical times speed-up factor for first population produced in volume interaction	float	[-]	1.0
electronTemperature2	Plasma	Electron temperature(2nd population)	float	[eV]	1000.0
sunX	Surface Interactions	x-component of sun direction	float	[-]	0.0
Bx	B Field	x-component of the magnetic field (uniform over the computation box)	float	[T]	0.0
ionVy	Plasma	Ion drift velocity along y axis (1st population)	float	[m/s]	0.0
sourceParticleType2	Spacecraft	Type of particles emitted by source 2	string	None	electron
inPop1VolInteract	Volume Interactions	Defines first interacting population (e.g. ions for CEX), must be one of ions1, ions2, elec1, elec2, source1... source4, photoElec, secondElec	string	None	source1
sourceNb	Spacecraft	Number of particle sources: not to be modified in UI, but only in defaultGlobalParam.py if the number of sources is modified in defaultGlobalParam.py	int	None	4
ionVy2	Plasma	Ion drift velocity along y axis (2nd population)	float	[m/s]	0.0
ionVx	Plasma	Ion drift velocity along x axis (1st population)	float	[m/s]	0.0
electronDt	Plasma	Maximum integration time step for electron 1st population (automatic if negative)	float	[s]	-1.0
inPart2VolInteract	Volume Interactions	Type of particles for second interacting population	string	None	Xe
sourceSpeedUp4	Spacecraft	Numerical times speed-up factor for 4th source population	float	[-]	1.0
electronDensity2	Plasma	Electron density (2nd population)	float	[#/m3]	0.0
plasmaDt	Simulation control	Time step for global plasma dynamics (semi-automatic if 0: determined by lower level time step = smallest matter dt)	float	[s]	0.0
particleTrajectoriesNb	Outputs	number of particle trajectories per PIC population	int	None	0
parameter2VolInteract	Volume Interactions	2nd parameter of volume interactor	float	[variable]	0.1
iterNewton	Poisson equation	Maximum iteration number for Newton algorithm in non-linear Poisson solving	int	None	50
finalCumulationStartTime	Outputs	if finalCumulation=1 starting time for final dens-current cumulation, if finalCumulation=2 fraction of the simulation at which cumulation starts	float	[s] or [-]	0.5
ionDistrib2	Plasma	Name of the VolDistrib class to be used for ions 2nd population	string	None	PICVolDistrib
sourceDt2	Spacecraft	Maximum integration time step for particles from 2nd source (automatic if negative)	float	[s]	-1.0
duration	Simulation control	Duration of the simulation	float	[s]	0.0004
sourceSpeedUp2	Spacecraft	Numerical times speed-up factor for 2nd source population	float	[-]	1.0
sourceDt3	Spacecraft	Maximum integration time step for particles from 3rd source (automatic if negative)	float	[s]	-1.0
ionVz2	Plasma	Ion drift velocity along z axis (2nd population)	float	[m/s]	0.0
densityLogPlotFlag	Outputs	plot log10 of densities? 0=no, 1=yes(log only), 2=both	int	None	2
electronDistrib	Plasma	Name of the VolDistrib class to be used for electrons	string	None	PICVolDistrib
scCurrentMapMonitorStep	Outputs	time step for spacecraft local currents monitoring (0 => none, -n => n times)	float	[s]	-10.0
parameter1VolInteract	Volume Interactions	1st parameter of volume interactor	float	[variable]	0.05
poissonBCParameter1	Poisson equation	Parameter that can be used by some BC types (e.g. 1/rn exponent)	float	[varies]	0.0
sunZ	Surface Interactions	z-component of sun direction	float	[-]	1.0
inPart1VolInteract	Volume Interactions	Type of particles for first interacting population	string	None	Xe+
sourceDt1	Spacecraft	Maximum integration time step for particles from 1st source (automatic if negative)	float	[s]	-1.0
numericsMonitorStep	Outputs	time step for numerical behaviour monitoring (0.0 => none, -n => n times)	float	[s]	-100.0
sourceType4	Spacecraft	Name of the SurfDistrib class to be used on the spacecraft as source No 4	string	None	LocalMaxwellSurfDistrib
protonSecondaryEmission	Surface Interactions	if 0, no secondary emission, if 1, secondary emission turned on	int	None	0
tolNewton	Poisson equation	Tolerance for Newton algorithm loop in non-linear Poisson solving	float	[-]	0.02
ionTemperature2	Plasma	Ion temperature (2nd population)	float	[eV]	1000.0
sourceType3	Spacecraft	Name of the SurfDistrib class to be used on the spacecraft as source No 3	string	None	LocalMaxwellSurfDistrib
secondaryFromProtonTem	Surface Interactions	secondary electron temperature (from proton impact)	float	[eV]	2.0
currentLogPlotCutoff	Outputs	cutoff for current log plots	float	[A/m2]	1,00E-12
ionSpeedUp2	Plasma	Numerical times speed-up factor for ion 2nd population	float	[-]	1.0
ionDt	Plasma	Maximum integration time step for ion 1st population (automatic if negative)	float	[s]	-1.0
exportPotential	Outputs	Select the export mode for potential data fields (None=no export, ASCII=ASCII multi-files)	string	None	None
materialPropertyPlots	Outputs	flag for plotting material properties: 0=no, 1=yes	int	None	1
tolGradient	Poisson equation	Tolerance for conjugate gradient Poisson Solver	float	[-]	0.0001
outPart1VolInteract	Volume Interactions	Type of particles for first population produced in volume interaction	string	None	Xe+
photoEmission	Surface Interactions	if 0 no photo-emission, if 1 photo-emission turned on, if 3 turned on with photo-electron dynamics modelling, iF 4 more (hence 5 or 7) uses user-locally-defined sun flux instead of sun direction	int	None	0
cumulateBetweenSteps	Outputs	cumulate currents and densities between monitoring steps for improved statistics (0=no, 1=yes(improved only), 2=both)?	int	None	1
sourceParticleType4	Spacecraft	Type of particles emitted by source 4	string	None	In+
sourceParticleType3	Spacecraft	Type of particles emitted by source 3	string	None	Cs+
sunY	Surface Interactions	y-component of sun direction	float	[-]	0.0
initPotFlag	Spacecraft	flag to define initial pot: 0 => set to 0, 1 => set to global initPot, 2 => set to local potential defined as SC Dirichlet condition	int	None	1
electronTemperature	Plasma	Electron temperature(1st population)	float	[eV]	1.0
electronSpeedUp	Plasma	Numerical times speed-up factor for electron 1st population	float	[-]	1.0
sourceSpeedUp1	Spacecraft	Numerical times speed-up factor for 1st source population	float	[-]	1.0
sourceSpeedUp3	Spacecraft	Numerical times speed-up factor for 3rd source population	float	[-]	1.0
volInteractType	Volume Interactions	Type of volume interaction, UI-buildable class name derived from VolInteract	string	None	CEXInteractor
By	B Field	y-component of the magnetic field	float	[T]	0.0
inducedConductivity	Surface Interactions	if 0 no induced conductivity, if 1 induced conductivity turned on	int	None	0
plasmaUnderRelaxTimeCs	Simulation control	under-relaxation time constant for plasma (default=0 => no under-relaxation)	float	[s]	0.0
iterGradientNl	Poisson equation	Maximum iteration number for conjugate gradient non-linear Poisson Solver	int	None	100
poissonBCType	Poisson equation	Poisson boundary conditions type, see documentation	int	None	2
electronSpeedUp2	Plasma	Numerical times speed-up factor for electron 2nd population	float	[-]	1.0