

Technical Note (TN)

# **SPIS Validation Tests**

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

	Name and Function	Date	Signature
Prepared by	Julien Forest	20/10/2010	
Verified by			
Approved by			

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

PAGE 2 /14

#### **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<sup>3</sup> 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

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



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

PAGE 3 /14

# Table of contents

1.	Generalities	5	
	Reference and applicable documents	5	
	Glossary	5	
2.	Introduction	6	
3.	Presentation of the input system	7	
	Geometrical system, meshing and group settings	7	
	Environment parameters	8	
	Numerical model	8	
	Internal circuitry and model	8	
	Global parameters summary	8	
4.	Reference results of the simulation	9	
	Time evolution	9	
	Final state	10	
5.	Conclusion	11	
An	Annexe 1: List of the global parameters 13		

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1	
Status: Approved	Date : 2010/10/30		
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TN 2010/10-001: Floating Simple Sphere Low Resolution

PAGE 4 /14

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Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



# 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

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1	
Status: Approved	Date : 2010/10/30		



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

PAGE 6 /14

# 2. Introduction

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Status: Approved Data : 2010/10/20	Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved Date : 2010/10/30	Status: Approved	Date : 2010/10/30	



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

# 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.

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



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<sup>3</sup> 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<sup>-11</sup>F, a simulation duration time of 4.10<sup>-4</sup>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.

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



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

PAGE 9 /14

## 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<sup>-11</sup>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.

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



PAGE 10/14

#### 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).

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



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

PAGE 11/14

# 5. Conclusion

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Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	<b>Date</b> : 2010/10/30	



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

PAGE 12/14

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Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1	
Status: Approved	Date : 2010/10/30		



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

PAGE 13/14

# A. Annexe 1: List of the global parameters

D	T	Description	<b>T</b>		M-1
Parameter	Index	Description	туре	Unit	value
		one of ions1, ions2, elec1, elec2, source1, source4, photoElec.			
inPop2VolInteract	Volume Interactions	secondElec	string	None	fractionOfFirstPopSource
		time step for spacecraft ground potential monitoring (0 => none, -n			
scPotMonitorStep	Outputs	=> n times)	float	[s]	-100.0
electronDistrih?	Placma	Name of the VolDistrib class to be used for the 2nd electron	string	None	PICVolDistrib
initPot	Spacecraft	initial potential	float	rv1	0.0
inici oc	opucceruit	Flag for defining artificial source No 3 on the spacecraft: 0 => none, 1	nout	[•]	0.0
sourceFlag3	Spacecraft	=> 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]	100000.0
-la -ma Cara di la		Numerical times speed-up factor for plasma (plasma dynamics is only	61 h	r 1	1.0
plasmaSpeedUp	Simulation control	Integrated over a fraction 1/plasmaSpeedup of actual physical time ) Elag for defining artificial source No 1 on the spacecraft: $0 = >$ none 1	float	[-]	1.0
sourceFlag1	Spacecraft	=> yes, x => number of super-particles densified by x	float	[-]	0.0
		Name of the SurfDistrib class to be used on the spacecraft as source			
sourceType1	Spacecraft	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
tolGradiontNI	Poisson equation	Tolerance for conjugate gradient Poisson Solver when non-linear	float	r_1	0.0001
ionTypo2	Poisson equation	Solving	ctring	L-J Nono	0.0001
ionType2	Placma	Eirst ion population	ctring	None	11 <del>1</del>
юптуре	FidSilld	Cross section for volume interaction, either a float (its value [m2]) or	sung	None	11+
crossSectionVolInteract	Volume Interactions	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
		Maximum integration time step for electron 2nd population (automatic			
electronDt2	Plasma	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
outDop2DtV/olTetorpet	Volume Interactions	Maximum integration time step for first population produced in volume interaction (automatic if pagativo)	fleat	[a]	1.0
outPop2DtVoiinteract	volume interactions	Time step for global simulation dynamics (semi-automatic if 0:	noat	[5]	-1.0
simulationDt	Simulation control	determined by lower level time step = plasmaDt)	float	[s]	0.0
		Maximum integration time step for ion 2nd population (automatic if			
ionDt2	Plasma	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
		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 2 bits			
		are for ambient population 1, ambient population 2, source 1, source			
electronSecondaryEmissio	Surface Interactions	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
outPart2\/olInteract	Volume Interactions	Type of particles for second population produced in volume interaction	string	None	Yo
oucl artz voimteract	Volume interactions	time step for spacecraft local potential monitoring ( $0 =>$ none, $-n =>$	Scring	None	AC
scPotMapMonitorStep	Outputs	n times)	float	[s]	-10.0
sourceParticleType1	Spacecraft	Type of particles emitted by source 1	string	None	Xe+
		Flag to turn on volume interaction: $0 \Rightarrow off$ , $1 \Rightarrow on$ , $x \ge 0 \Rightarrow on$ ,			
volInteract	Volume Interactions	superparticles densified by x	float	None	0.0
outPop1Dt\/olIntoract	Volumo Interactions	Maximum integration time step for first population produced in volume interaction (automatic if negative)	float	[c]	-1.0
parameter2\/olInteract	Volume Interactions	3rd parameter of volume interactor	float	[5]	-1.0
parametersvonnteraet	Volume interactions	Maximum integration time step for particles from 4th source	noac	[variable]	0.0
sourceDt4	Spacecraft	(automatic if negative)	float	[s]	-1.0
		cumulate currents and densities at the end of simulation ? 0=no,			
finalCumulation	Outputs	10r2=yes	int	None	2
exportAllDataFields	Outputs	ASCII=ASCII multi-files)	string	None	None
		Name of the SurfDistrib class to be used on the spacecraft as source	et		
sourceType2	Spacecraft	No 2	string	None	MaxwellianThruster
		Flag for defining artificial source No 4 on the spacecraft: $0 =>$ none, 1			
sourceFlag4	Spacecraft	=> yes, x => number of super-particles densified by x Maximum integration time stop for all types of cocondary electrons	float	[-]	0.0
secondaryDt	Surface Interactions	(automatic if negative)	float	[s]	-1.0
ionSpeedUp	Plasma	Numerical times speed-up factor for ion 1st population	float	[-]	1.0
		Select the export mode for density data fields (None=no export,			
exportDensity	Outputs	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
		Numerical times speed-up factor for first population produced in			
outPop1SpeedUpVolInter	Volume Interactions	volume interaction	float	[-]	1.0
electricCircuitIntegrate	Spacecraft	SC electric circuit integration: 0=no change, 1=floating	int	None	1
environmentType	riasma	Name or the Environment class to be used	string	None	bimaxwellianEnvironment
surfaceConductivity	Surface Interactions	II O NO SUNACE CONDUCTIVITY, IF 1 SUFFACE CONDUCTIVITY TURNED ON	int	None	0
iterGradient	Poisson equation	Flastern density (1st negulation)	int	INONE	100
electronDensity	riasma	Electron density (1st population)	rioat	[m-3]	10000000
secondary remperature	Surrace Interactions	Secondary electron temperature (from electron impact)	rioat	[ev]	2.0
ionTomporature	Placma	Ion temperature (1ct population)	float	[#/m3]	1.0
ionTemperature	ridSMa	Flag for defining artificial source No 2 on the spacecraft: 0 => popo_1	noat	[ev]	1.0
sourceFlag2	Spacecraft	=> yes, x $=>$ number of super-particles densified by x	float	[-]	0.0

Reference : SPIS-TN-2010-10-001	Version : 1	Revision : 1
Status: Approved	Date : 2010/10/30	



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

PAGE 14/14

		No second states and second seco			
outPon2SneedLInVolInter	Volume Interactions	Numerical times speed-up factor for first population produced in volume interaction	float	r-1	1.0
electronTemperature2	Plasma	Electron temperature(2nd population)	float	[eV]	1000.0
sunX	Surface Interactions	x-component of sun direction	float	[-]	0.0
buint		x-component of the magnetic field (uniform over the computation	nouc		0.0
Bx	B Field	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
		Defines first interacting population (e.g. ions for CEX), must be one of			
inPop1VolInteract	Volume Interactions	ions1, ions2, elec1, elec2, source1 source4, photoElec, secondElec	string	None	source1
		Number of particle sources: not to be modified in UI, but only in defaultGlobalParam by if the number of sources is modified in			
sourceNb	Spacecraft	defaultGlobalParam.py if the number of sources is mounted in	int	None	4
ionVv2	Plasma	Ion drift velocity along v axis (2nd population)	float	[m/s]	0.0
ionVy	Plasma	Ion drift velocity along x axis (1st population)	float	[m/s]	0.0
ION IX	Tidoffid	Maximum integration time step for electron 1st population (automatic	nout	[, 5]	0.0
electronDt	Plasma	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
		Time step for global plasma dynamics (semi-automatic if 0:			
plasmaDt	Simulation control	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
		Maximum iteration number for Newton algorithm in non-linear Poisson			
iterNewton	Poisson equation	solving	int	None	50
		finalCumulation=2 fraction of the simulation at which cumulation			
finalCumulationStartTime	Outputs	starts	float	[s] or [-]	0.5
ionDistrib2	Plasma	Name of the VolDistrib class to be used for ions 2nd population	string	None	PICVolDistrib
		Maximum integration time step for particles from 2nd source			
sourceDt2	Spacecraft	(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
	_	Maximum integration time step for particles from 3rd source			
sourceDt3	Spacecraft	(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
ccCurrontManMonitorStor	Outpute	time step for spacecraft local currents monitoring (0 => none, -n =>	float	[c]	-10.0
sccurrentriaphonitorstep	Volume Interactions	Interior of volume interactor	float	[5]	-10.0
parameter 1 vonnter act	Poisson equation	Deservations that each be used by some BC types (a.g. 1/m synametry)	floot	[variable]	0.05
poissondCParameter 1		a component of our direction	float	[varies]	1.0
SURZ	Surrace Interactions		noat	L-J	1.0
InPart1voiInteract	volume interactions	An average of particles for first interacting population	string	None	Xe+
sourceDt1	Spacecraft	(automatic if negative)	float	[s]	-1.0
		time step for numerical behaviour monitoring (0.0 => none, -n => n		[-]	
numericsMonitorStep	Outputs	times)	float	[s]	-100.0
		Name of the SurfDistrib class to be used on the spacecraft as source			
sourceType4	Spacecraft	No 4	string	None	LocalMaxwellSurfDistrib
sourceType4 protonSecondaryEmission	Spacecraft Surface Interactions	No 4 if 0, no secondary emission, if 1, secondary emission turned on	string	None None	LocalMaxwellSurfDistrib
sourceType4 protonSecondaryEmission tolNewton	Spacecraft Surface Interactions Poisson equation	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving	string int float	None None [-]	LocalMaxwellSurfDistrib 0 0.02
sourceType4 protonSecondaryEmission tolNewton ionTemperature2	Spacecraft Surface Interactions Poisson equation Plasma	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population)	string int float float	None None [-] [eV]	LocalMaxwellSurfDistrib 0 0.02 1000.0
sourceType4 protonSecondaryEmission tolNewton ionTemperature2	Spacecraft Surface Interactions Poisson equation Plasma	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 2	string int float float	None None [-] [eV]	LocalMaxwellSurfDistrib 0 0.02 1000.0
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft	No 4 If 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 recorders clockers temperature (from proton import)	string int float float string	None [-] [eV] None	LocalMaxwellSurfDistrib 0 0.02 1000.0 LocalMaxwellSurfDistrib
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTem	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) mathefing in second in a late	string int float float string float	None           [-]           [eV]           None           [eV]	LocalMaxwellSurfDistrib 0.02 1000.0 LocalMaxwellSurfDistrib 2.0
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTen currentLogPlotCutoff	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions Outputs	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) cutoff for current log plots Wenerical Lines a pood up fortage for log 2nd approximate	string int float float string float float	None [-] [eV] None [eV] [A/m2]	LocalMaxwellSurfDistrib 0 0.02 1000.0 LocalMaxwellSurfDistrib 2.0 1,00E-12
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTen currentLogPiotCutoff ionSpeedUp2	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions Outputs Plasma	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) cutoff for current log plots Numerical times speed-up factor for ion 2nd population Maximum intervation (and constrained in the comparison)	string int float float string float float float	None [-] [eV] None [eV] [A/m2] [-]	LocalMaxwellSurfDistrib 0.02 1000.0 LocalMaxwellSurfDistrib 2.0 1,00E-12
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTen currentLogPlotCutoff ionSpeedUp2 ionPt	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions Outputs Plasma Plasma	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) cutoff for current log plots Numerical times speed-up factor for ion 2nd population Maximum integration time step for ion 1st population (automatic if negative)	string int float float string float float float float	None [-] [eV] None [eV] [A/m2] [-] [s]	LocalMaxwellSurfDistrib 0 0.02 1000.0 LocalMaxwellSurfDistrib 2.0 1.00E-12 1.0
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTen currentLogPlotCutoff ionSpeedUp2 ionDt	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions Outputs Plasma Plasma	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) cutoff for current log plots Numerical times speed-up factor for ion 2nd population Maximum integration time step for ion 1st population (automatic if negative) Select the export mode for potential data fields (None=no export,	string int float float string float float float	None [-] [eV] None [eV] [A/m2] [-] [s]	LocalMaxwellSurfDistrib 0 0.02 1000.0 LocalMaxwellSurfDistrib 2.0 1.0 -1.0
sourceType4 protonSecondaryEmission tolNewton ionTemperature2 sourceType3 secondaryFromProtonTen currentLogPlotCutoff ionSpeedUp2 ionDt exportPotential	Spacecraft Surface Interactions Poisson equation Plasma Spacecraft Surface Interactions Outputs Plasma Plasma Outputs	No 4 if 0, no secondary emission, if 1, secondary emission turned on Tolerance for Newton algorithm loop in non-linear Poisson solving Ion temperature (2nd population) Name of the SurfDistrib class to be used on the spacecraft as source No 3 secondary electron temperature (from proton impact) cutoff for current log plots Numerical times speed-up factor for ion 2nd population Maximum integration time step for ion 1st population (automatic if negative) Select the export mode for potential data fields (None=no export, ACCII=ASCII multi-files)	string int float float string float float float float string	None [-] [eV] None [eV] [A/m2] [-] [s] None	LocalMaxwellSurfDistrib 0 0.02 1000.0 LocalMaxwellSurfDistrib 2.0 1.0 -1.0 None
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