LEO auroral Charging Simulations with SPIS

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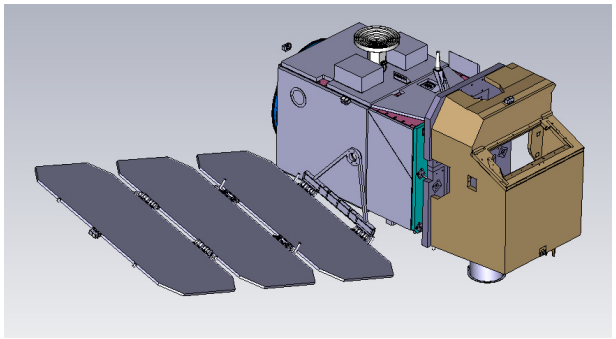
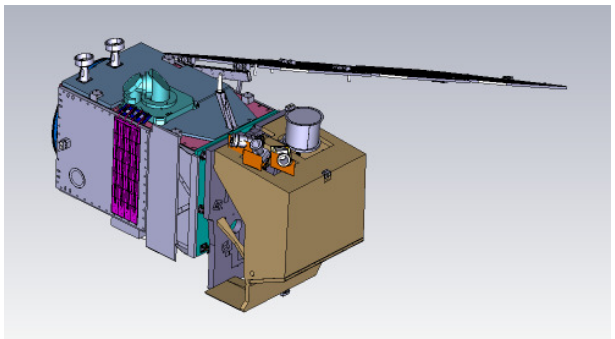
Outline

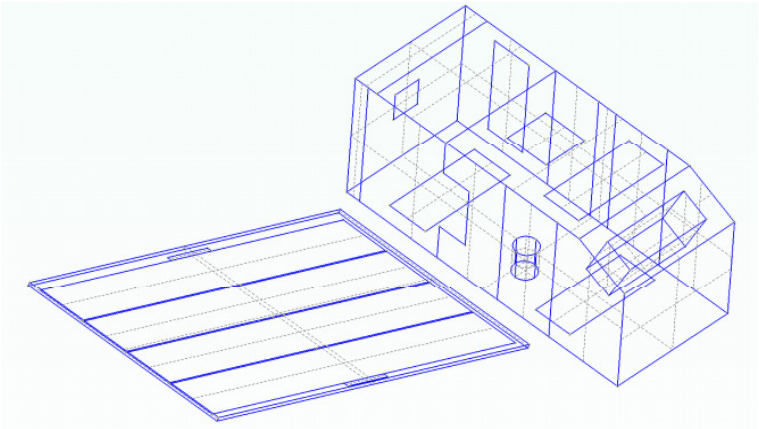
- Modelling of the Satellite
- Simulation Settings
- Simulation Results
- Conclusions

Modelling of the Satellite

Trade off between detailed modelling and tolerable values for the computation time and memory demands.







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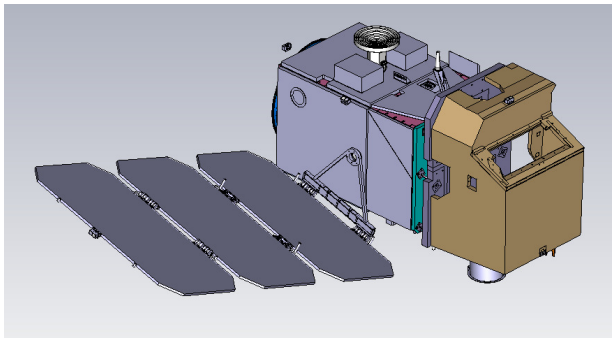
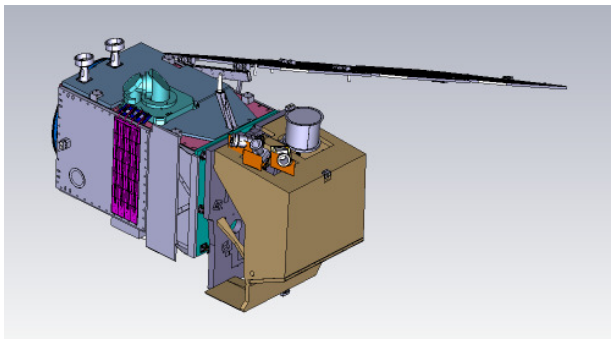
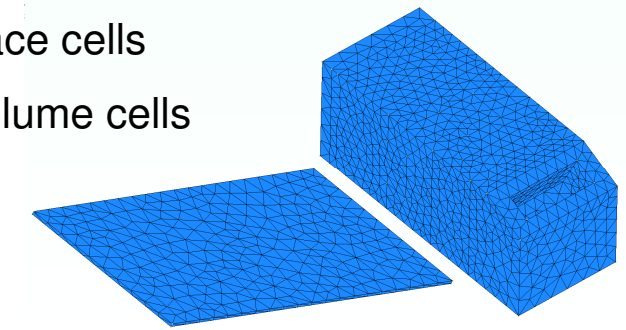
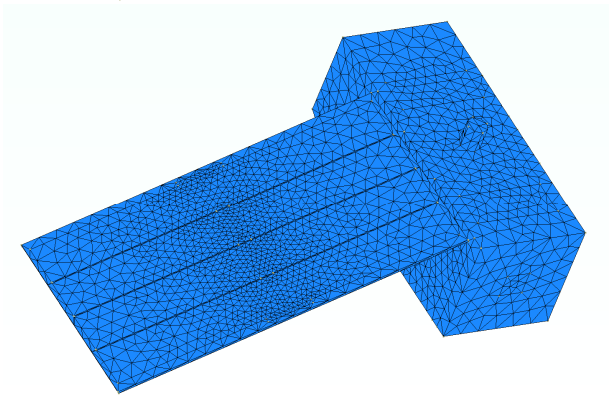




≈ 9000 surface cells

≈ 215000 volume cells



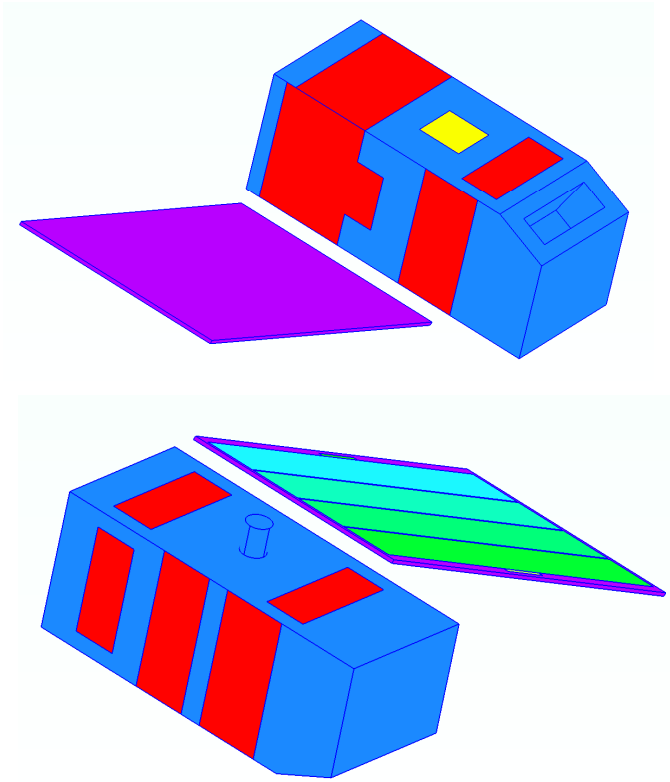


Modelling of the Satellite

Material Distribution

Colour	Description	SPIS Material	Node #
Blue	Spacecraft Body; MLI	Kapton	0
Red	Radiators	ITO	0
Yellow	XBA, Thrusters	Steel	0
Purple	Solar Array Structure	Epoxy	5
Light Blue to Green	Solar Cell Coverglasses	CERS	1 - 4
Light Yellow to Green	Solar Cell Interconnects	Silver	0 - 4

SA Structure is connected to ground by a 10 kΩ bleeder resistor



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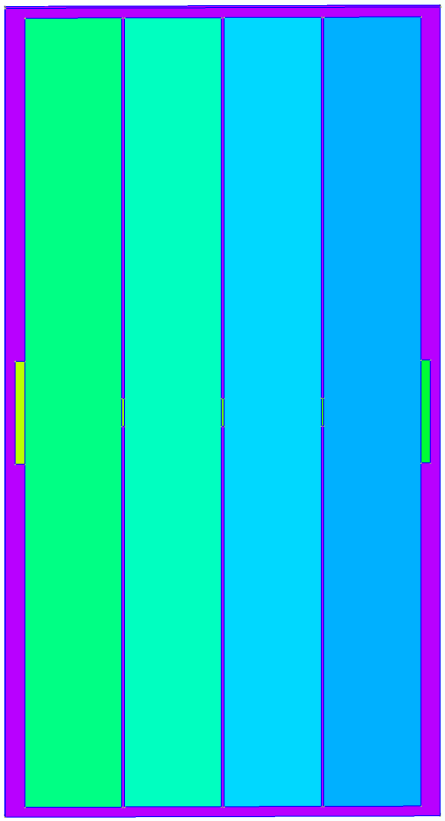


Simulation Setup

Undisturbed LEO Conditions

- Charging behaviour in this plasma is well understood
- Consistency checks of the simulation model and parameters are possible

Plasma Parameters

Population	Density in cm^{-3}	Energy in eV
Electrons	10^5	0,2
Ions	10^5	0,1

Expected Results

- Floating potential of up to 80% of the solar generator maximum voltage (90 V) for negative grounding scheme
- Slightly negative floating potential for eclipse conditions
- No critical differential potentials on the structure to be expected

Simulation Setup

Auroral plasma environment

- Passing of the auroral zone is considered the worst case scenario

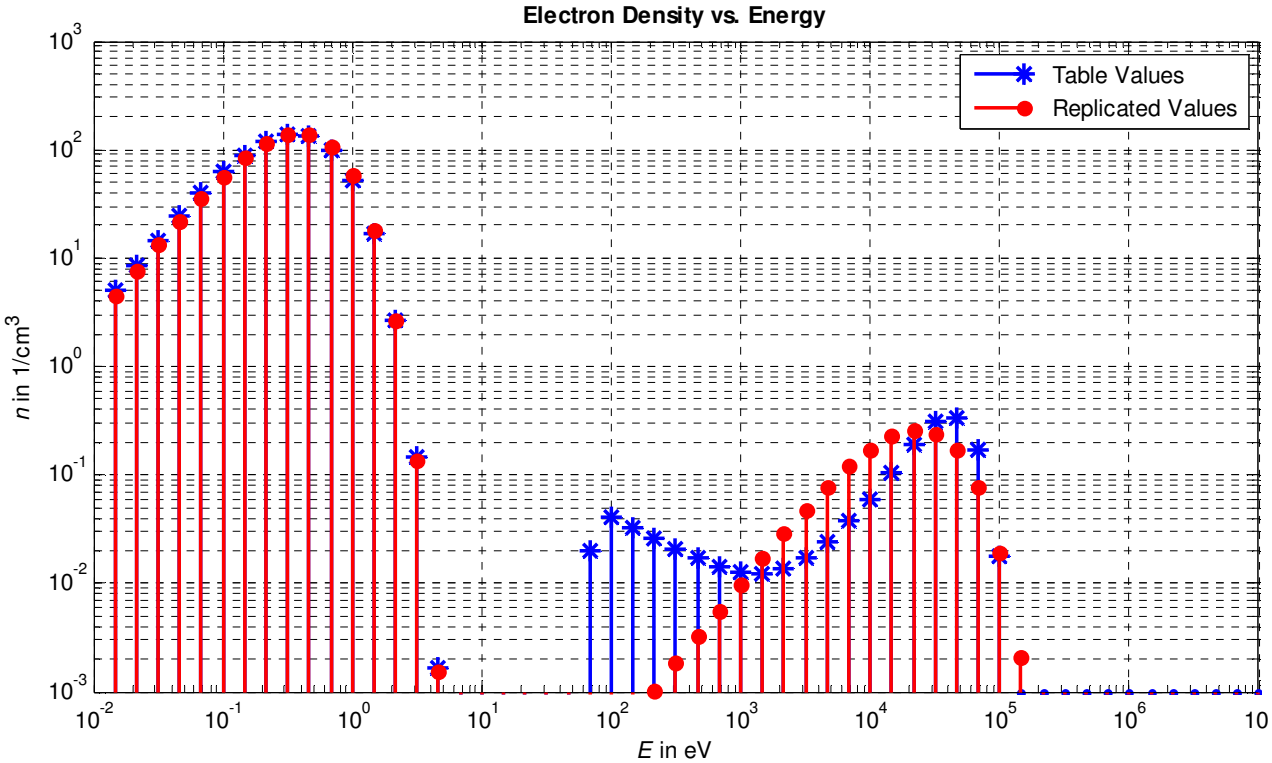
Auroral Plasma Properties

- Characterized by additional high energy electrons and a lowered density of the cold populations
- Parameters of the population are specified according to the SPENVIS population „Cold single Maxwellian and Fontheim electrons“

Chosen Maxwellian Parameters

Population	Density in cm^{-3}	Energy in eV
Electrons 1	809,9	0,2156
Electrons 2	1,482	12940
Ions 1	811,3	0,2156

Simulation Setup



Simulation Setup

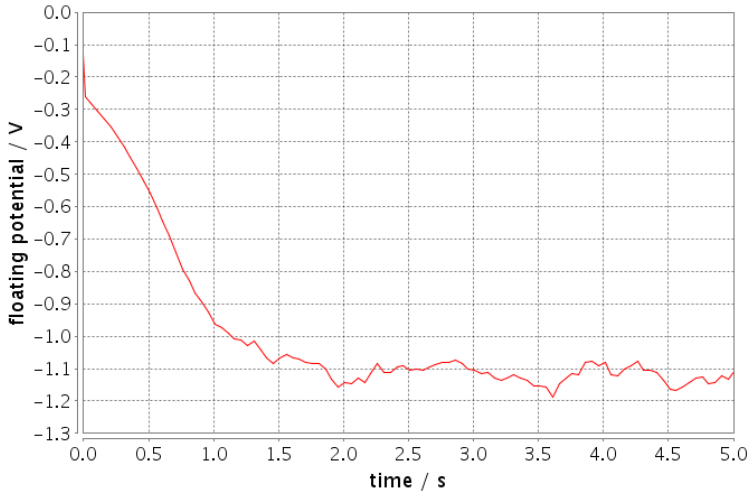
Global Settings of the simulation

- Electrons modelled with Global Maxwell-Boltzmann Model
- Ions are modelled using the PIC model
- Non linear poisson solver
- all occuring secondary effects are considered
- Velocity of the satellite is adressed in order to simulate ram / wake effects
- secondary particle dynamics and external magnetic field are not considered
- maximum time step of 100 ms is chosen
  - due to the automatic time step algorithm the average time step was on the order of 30 – 60 ms
- satellite capacitance is set to 1 nF

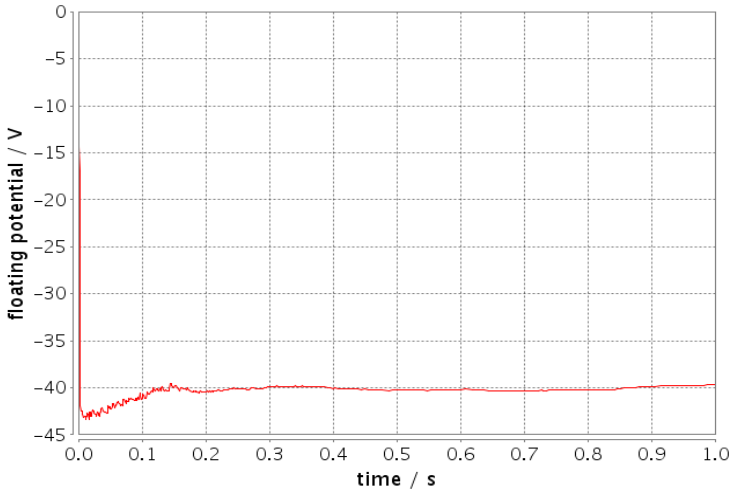
Simulation Results

Undisturbed LEO conditions

eclipse; no voltage on the SA



sunlight; max. 90 V SA voltage



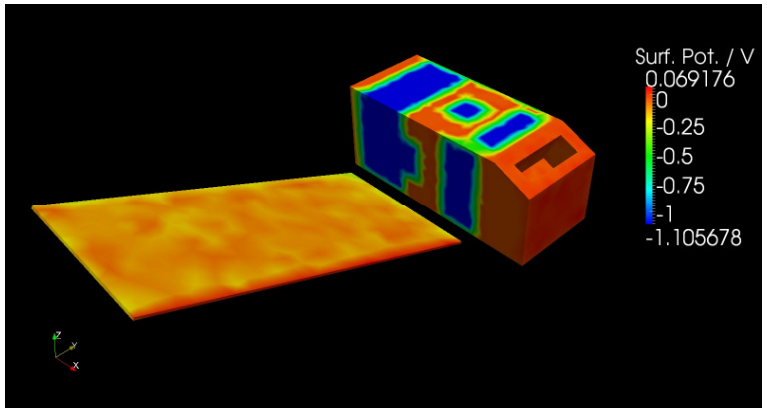
➔ results are consistent with theory

Simulation Results

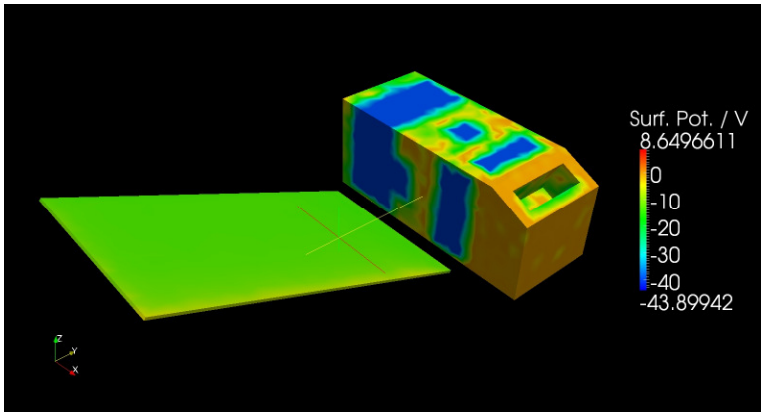
Undisturbed LEO conditions

surface potential

eclipse



sun

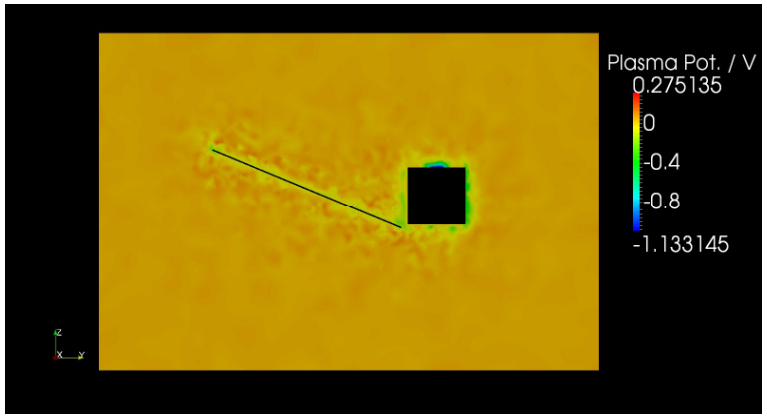


Simulation Results

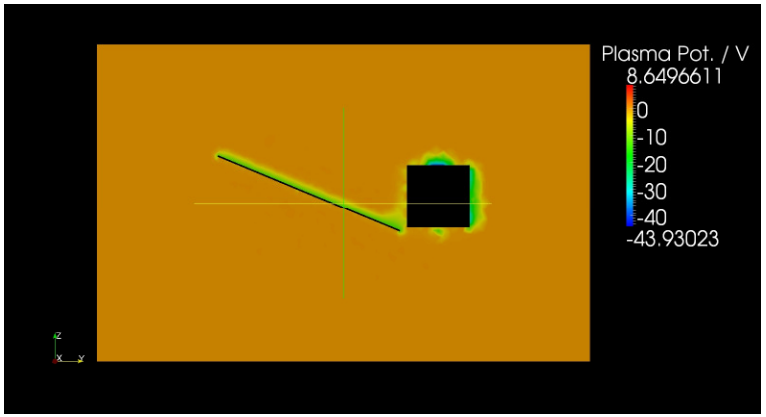
Undisturbed LEO conditions

plasma potential

eclipse



sun

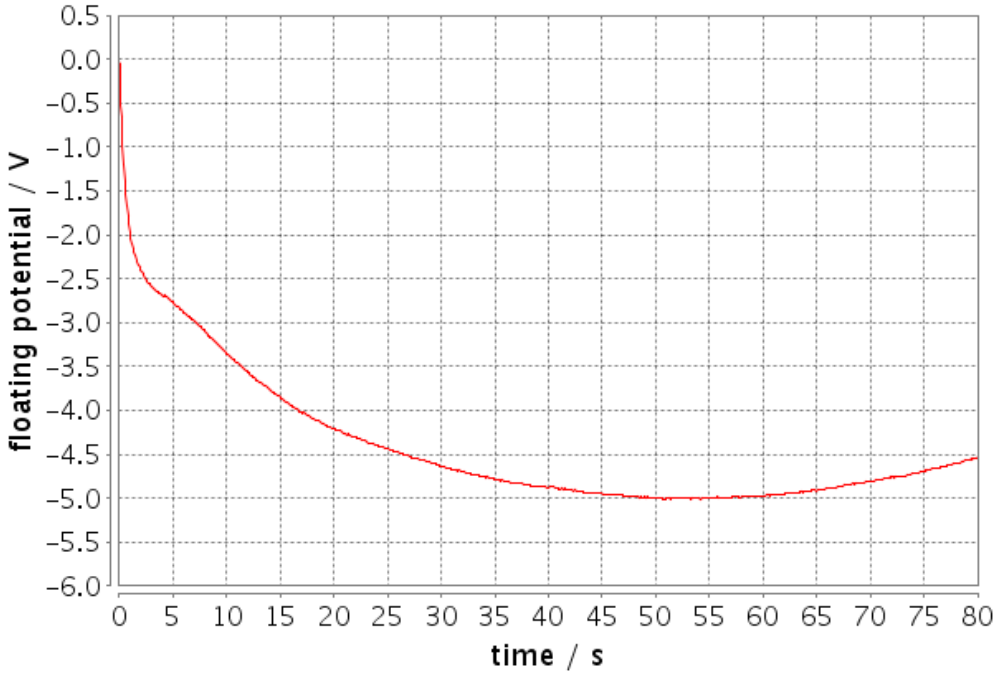


➔ plasma potential is another proof of consistency

Simulation Results

Fontheim Plasma and sun

Floating Potential



Simulation Results

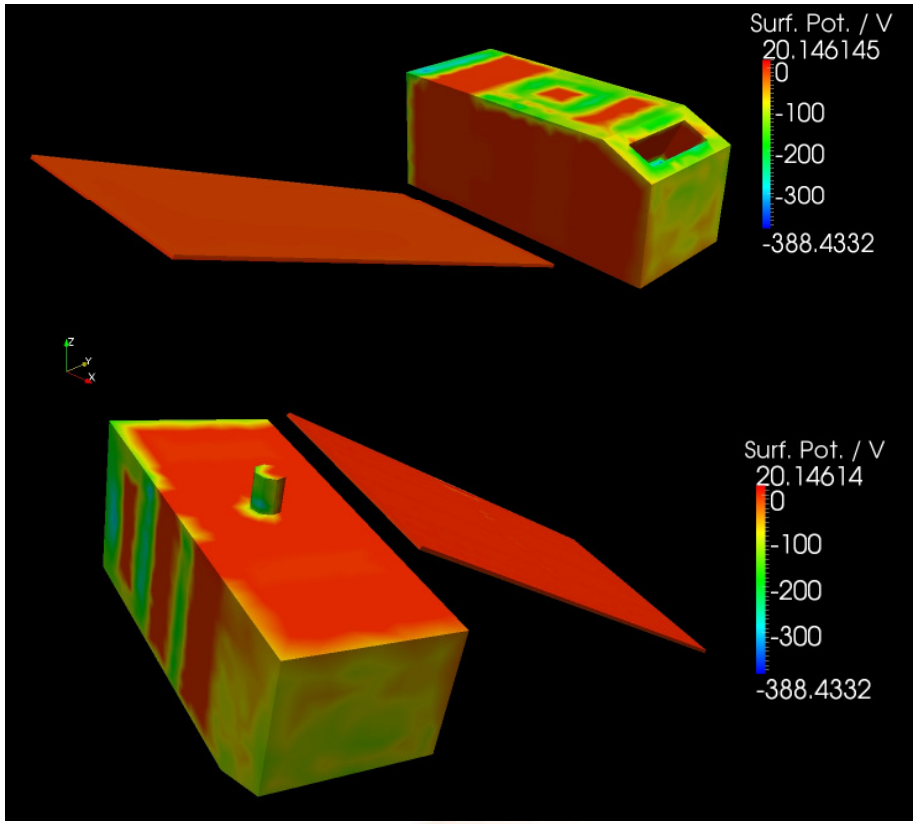
Fontheim plasma and sun

Potentials for t = 80 s

- All surfaces in the sun take on potentials close to 0 V
- Max. negative potential of -388 V in the aperture of the MSI
- Max. differential potential of 200 V
- No critical IPG on the solar array

Simulation time > 4 days

Memory costs ≈ 7 GB



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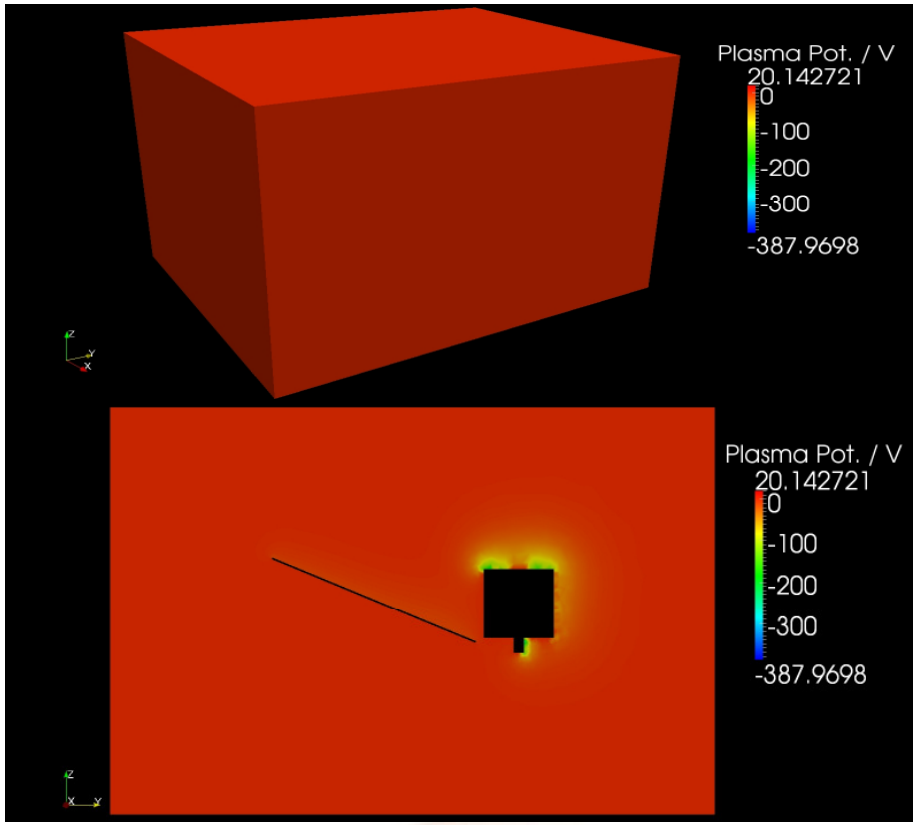
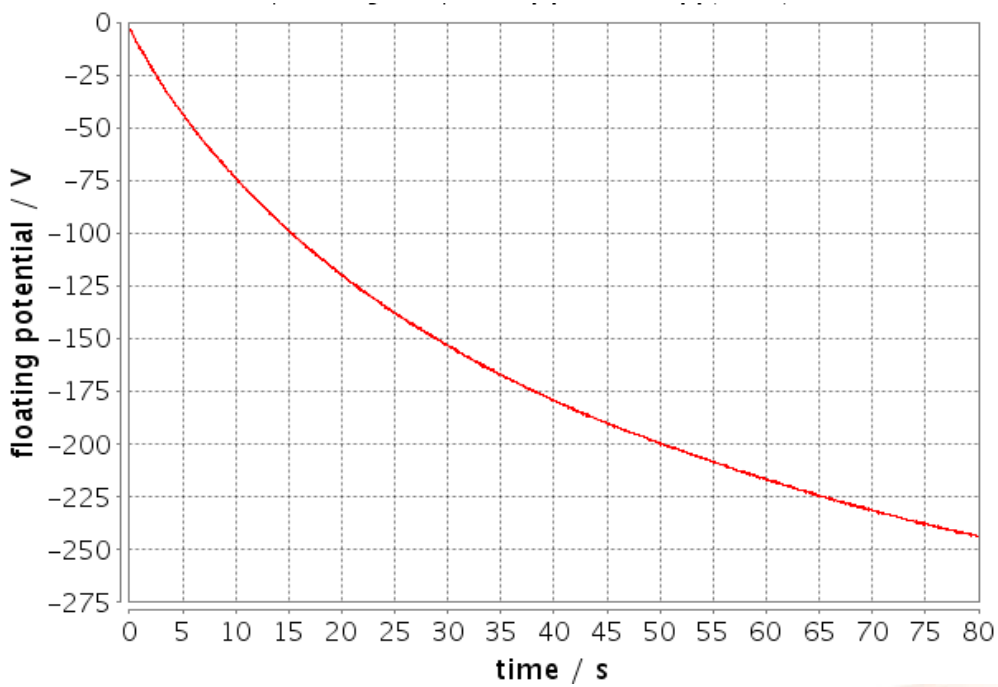


Simulation Results

Fontheim Plasma and eclipse

Floating Potential



Simulation Results

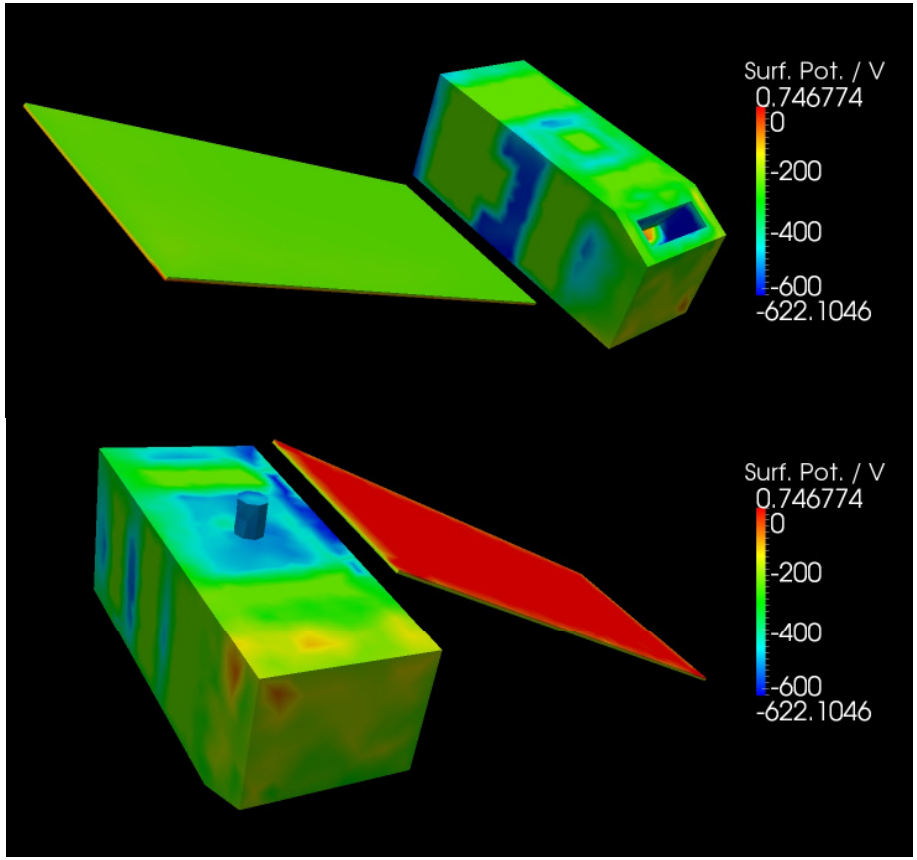
Fontheim plasma and eclipse

Potentials for t = 80 s

- Max. negative potential of -622 V in the aperture of the MSI
- Solar array cover glasses still at a potential around **0 V** due to high secondary emission
  ➔ IPG on the SA of -245 V
- Max. differential potential of 380 V

Simulation time > 3 days

Memory costs ≈ 6 GB



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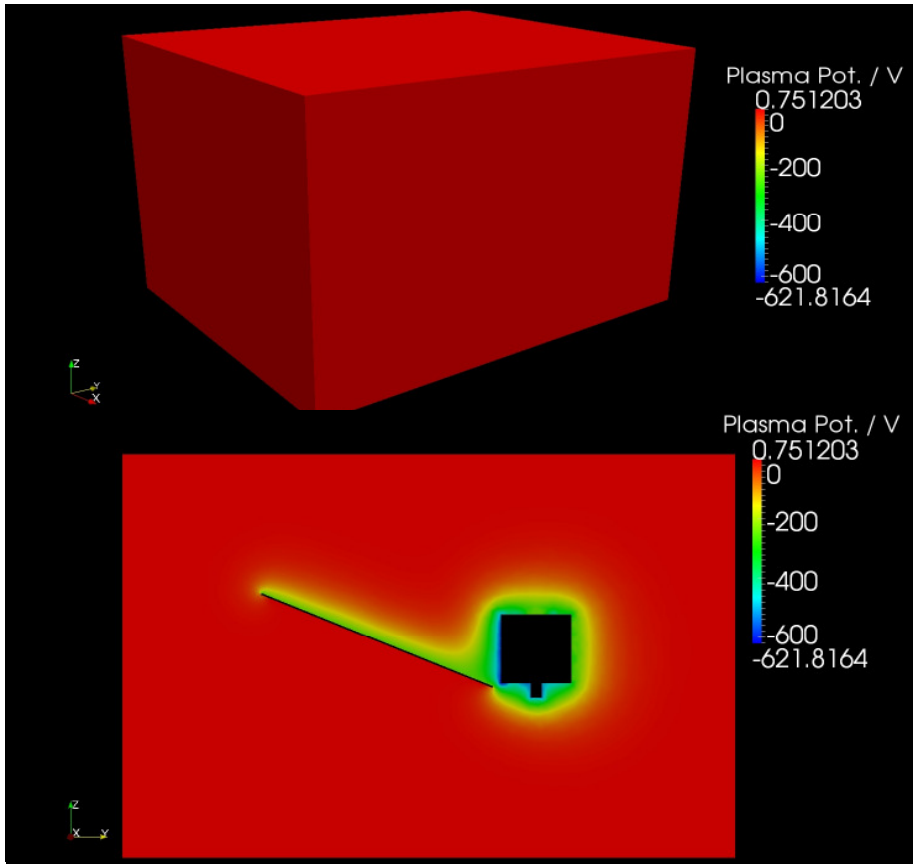


Simulation Results

Influence of material distribution

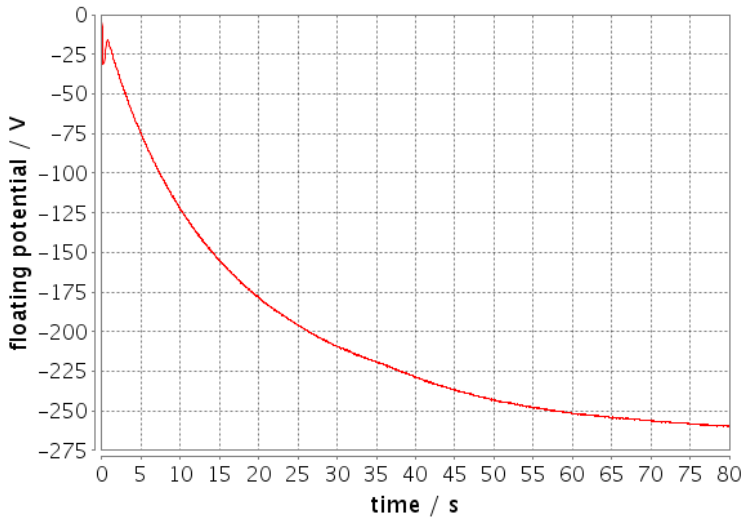
Under investigation:

- ITO coated radiators vs. blank Teflon radiators
- performed on model with shorter SA for simulation time reasons

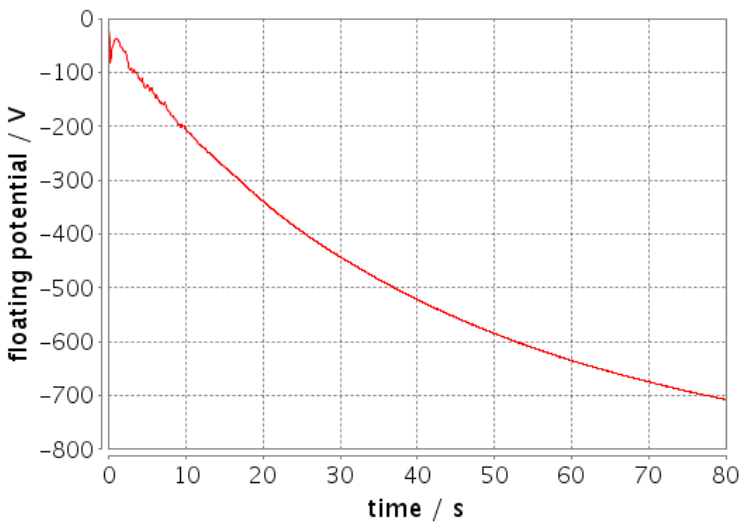
Simulation Results

Fontheim Plasma and shade

ITO coated radiators



Teflon radiators

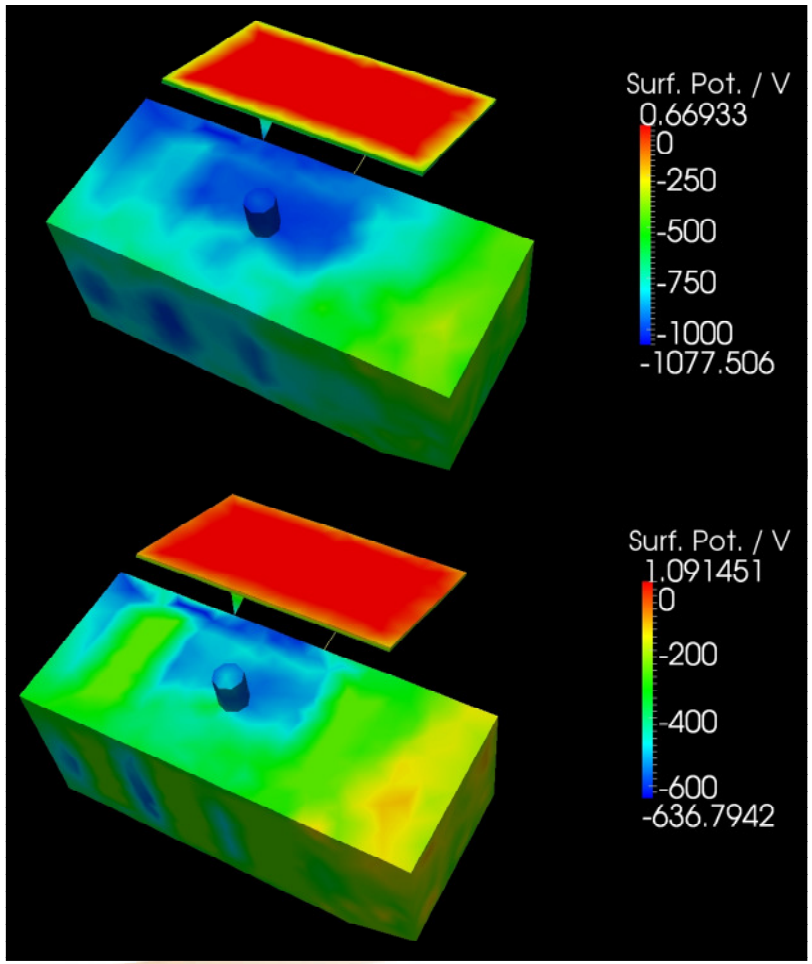


Simulation Results

Fontheim plasma and eclipse

Potentials for t = 80 s

- max. potentials on the satellite with uncoated radiators are nearly doubled compared to the version with coated radiators
- IPG on the solar array rises to 700 V
  ➔ high threat of ESD / arcing



Conclusions

Simulation Results

- Simulations reveal potentially dangerous potentials on the satellite
- Calculated potentials can be used as input for ESD analysis

SPIS Tool

- Possibility to assess the risks to the satellite due to surface charging
- Chance to gain a better understanding of the charging phenomena
- Impact of different materials on the charging process can be assessed
- Software has to be handled with extreme care to avoid crashes and inconsistent resuts
- Further improvement on the numerical algorithms and on the usability are desirable