LEO Polar Charging

Dependence of the overall behaviour on the relative SA area

DEFENCE AND SPACE

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Motivation & Effect under Investigation

- Focus on new ECSS definition for the LEO polar worst case plasma proposed for the update of the ECSS-10-04 standard
- All recent and some heritage projects have been analysed using the updated plasma definition
  - In this frame a strong variation of the simulated absolute potentials has been identified while the differential charging remained comparable
- Strong difference especially between satellites with body mounted solar array and satellites with a external solar array wing
  - body mounted solar array satellites have shown strong differential charging but moderate absolute charging (IPGs up to 1 kV with absolute potentials between -1 kV and -2kV)
  - Winged solar array models have shown very high absolute charging with also high differential charging (IPGs of about 1 kV with absolute potentials around -10 kV to -13 kV)

- Goal of the activity is to identify the physical reason behind these strongly differing results for different satellites geometries

Motivation & Effect under Investigation

- The effect which is considered as the main influence for this phenomenon is the relative area of solar cells with respect to the total satellite area
  - This is one of the major differences between satellites with a SA wing and body mounted SA design
    - Body mounted satellites with relative areas of about > 30 %
    - Satellites with SA wing with relative areas around 15 % - 25 %
  - Solar cells are one of the major elements producing SEE on the structure and therefore have a big influence on the current balance on the satellite

Hypothesis under investigation

- Hypothesis for the explanation of the observed major differences between the models with changed relative SA area

- ➢ The larger the SA cell area the more emitted electrons are produced so that the net electron current which is the driver for negative charging is reduced
- ➢ There is a crossover point in the overall current collection on the satellite where the net current changes the sign
  - For large cell areas over the complete surface of the satellite more electrons are emitted than collected
    - In such a scenario a strong negative charging of the cell surface is impossible since already the emitted current from this surface alone is strong enough to compensate for the complete collected electrons current
    - Due to the limited conductivity of the cover glasses the satellite structure and other dielectrics are still charging negative, however, on a timescale driven by the high capacitances of the dielectric layers
  - For small cell areas the electron collections dominates
    - Total electron current to the satellite leads then to a fast charging which is driven by the small capacitance of the satellite towards the plasma
    - The stronger electron emission on the cover glasses then drives the IPG built up on the SA

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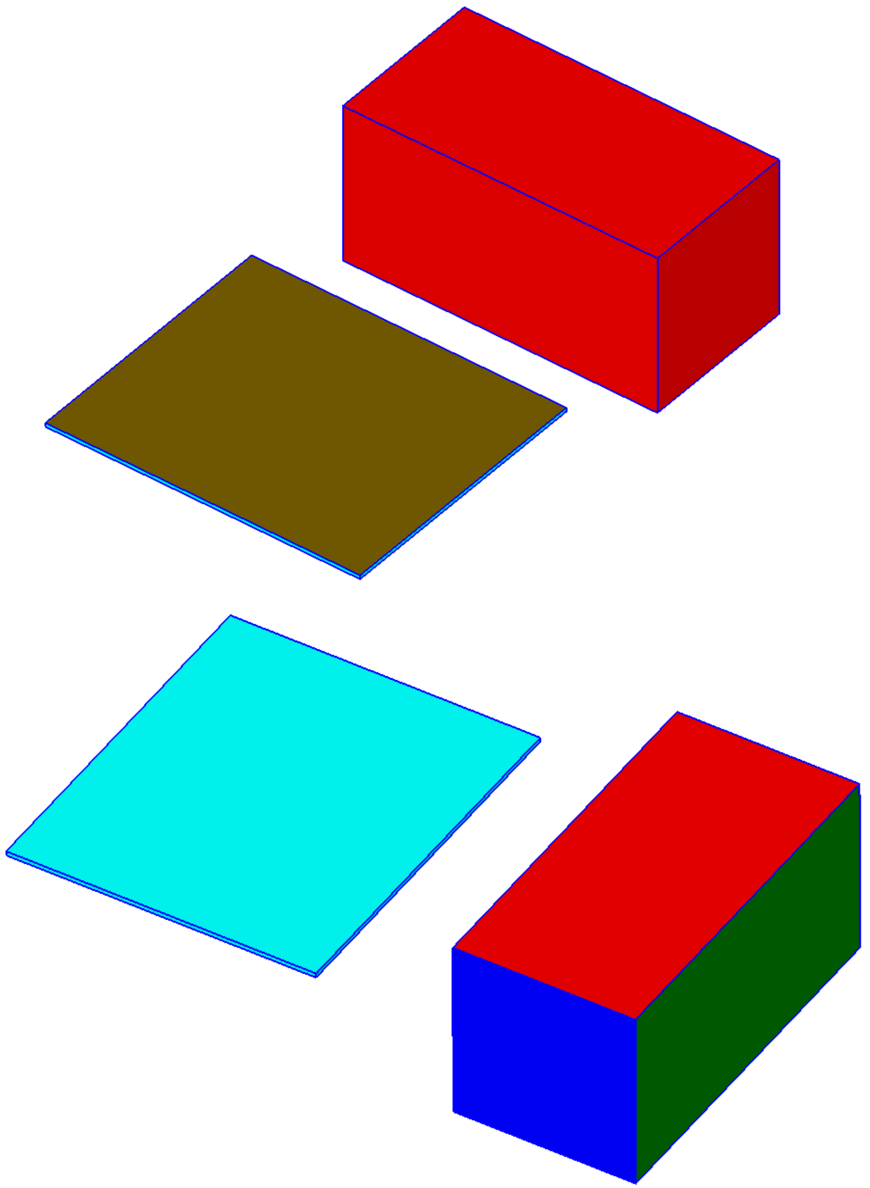
Satellite model & Plasma definition

- Simple cubiod satellite shape is used with a SA wing
  - The SA width is chosen to be the same length as the satellite body
  - The SA length is calculated based on the desired ratio of SA cell area
    - Please note, that there is a theoretical maximum of < 50 % for the percentage in the model
    - Ratios under investigation are between 15 % and 30 %

Color	Material	SPIS Material
Blue	Black Kapton MLI	Black Kapton
Green	Radiators	Teflon
Red	Kapton MLI	Kapton
Cyan	Bare CFRP	Epoxy
Brown	Cover Glass	CERS



- Plasma Environment Defninition according to updated ECSS recommendation applied over 10 s

Population	Density in cm^{-3}	Energy in eV
Auroral Electrons	10.78	11000
Background Electrons	125	0.2
Background Ions	125	0.2

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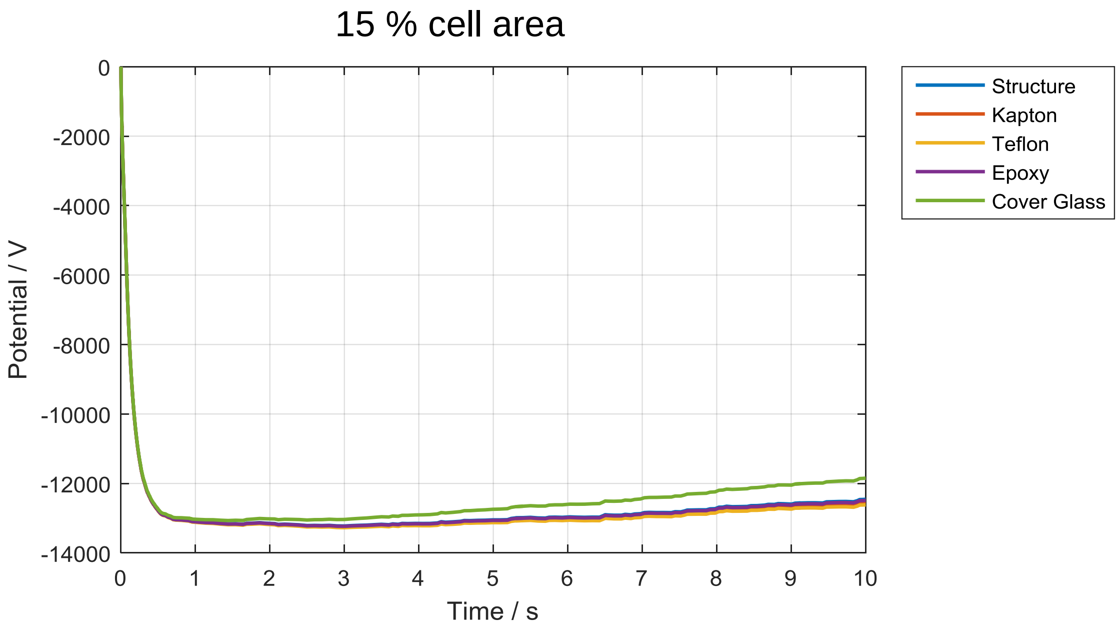
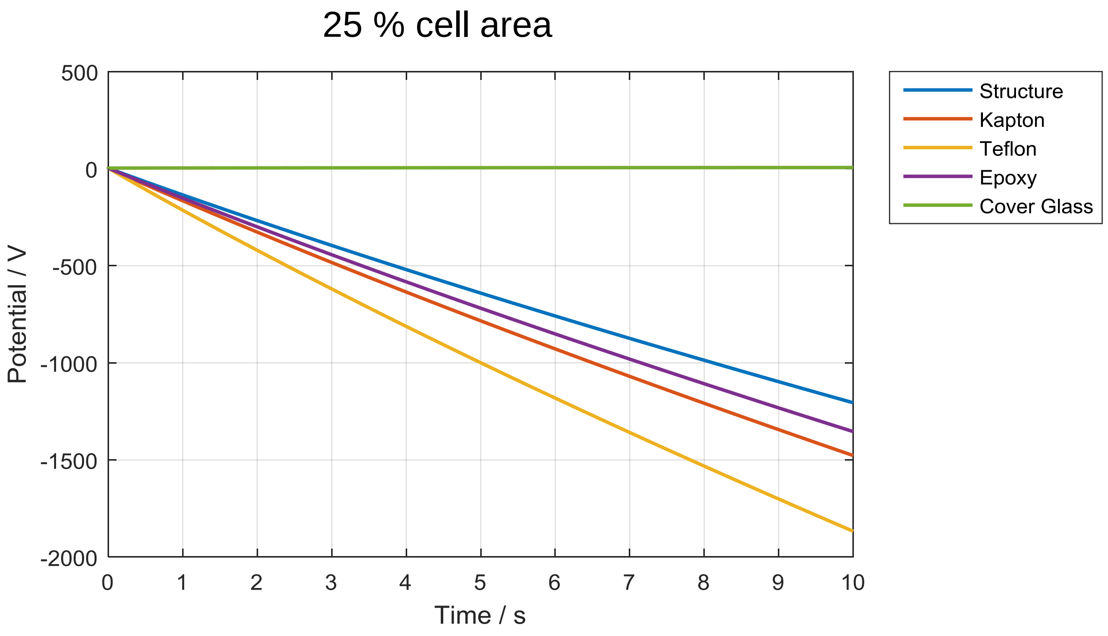
Simulation Settings

- Satellite capacitance of 1 nF
- Simulation time of 10 s
- Eclipse conditions -> no photoemission
- Satellite velocity is taken into account -> Ram / Wake effect is modelled
- SEE is modelled
  - No secondary dynamics are modelled

Simulation Results

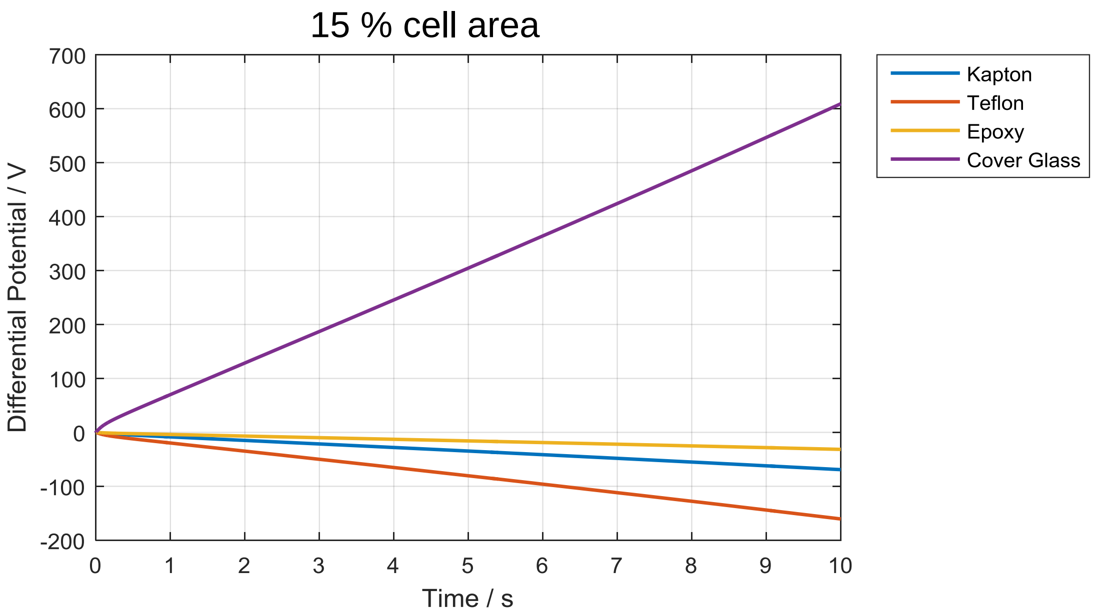
- Comparison of the surface potential evolution between the 15 % model and the 25 % model
  - Already in these simulations the effect of the different behaviour of the absolute charging can be observed
  - For the 15 % cell area model all surfaces charge to high negative potentials before after about 2 s the differential charging starts
  - For the 25 % cell area model the cover glasses remain at potentials close to 0 V and all other surfaces are charging negative

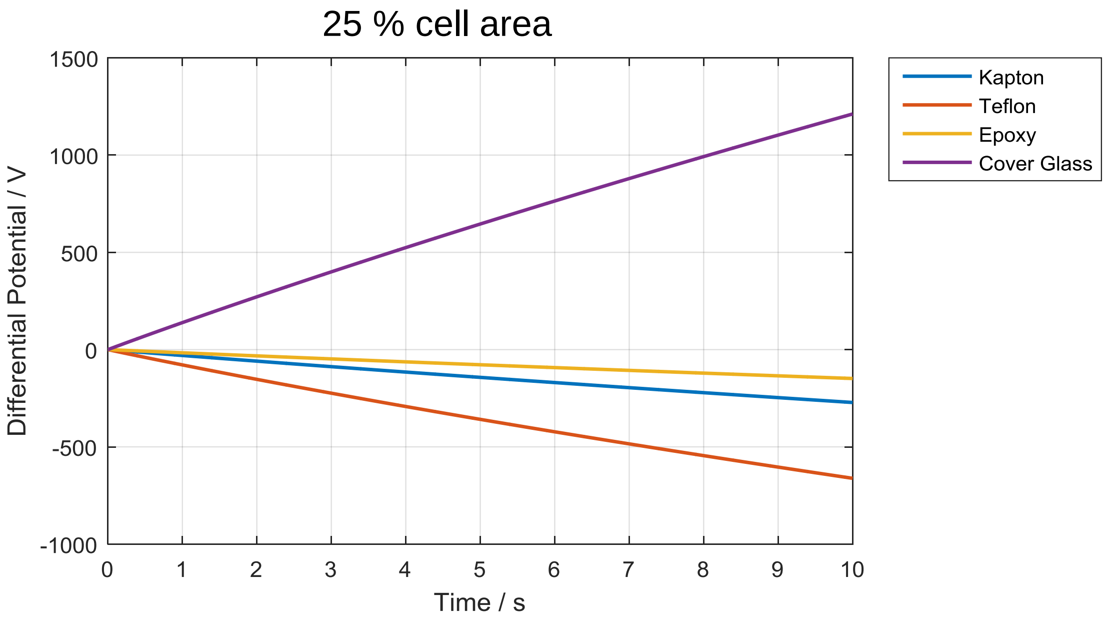




Simulation Results

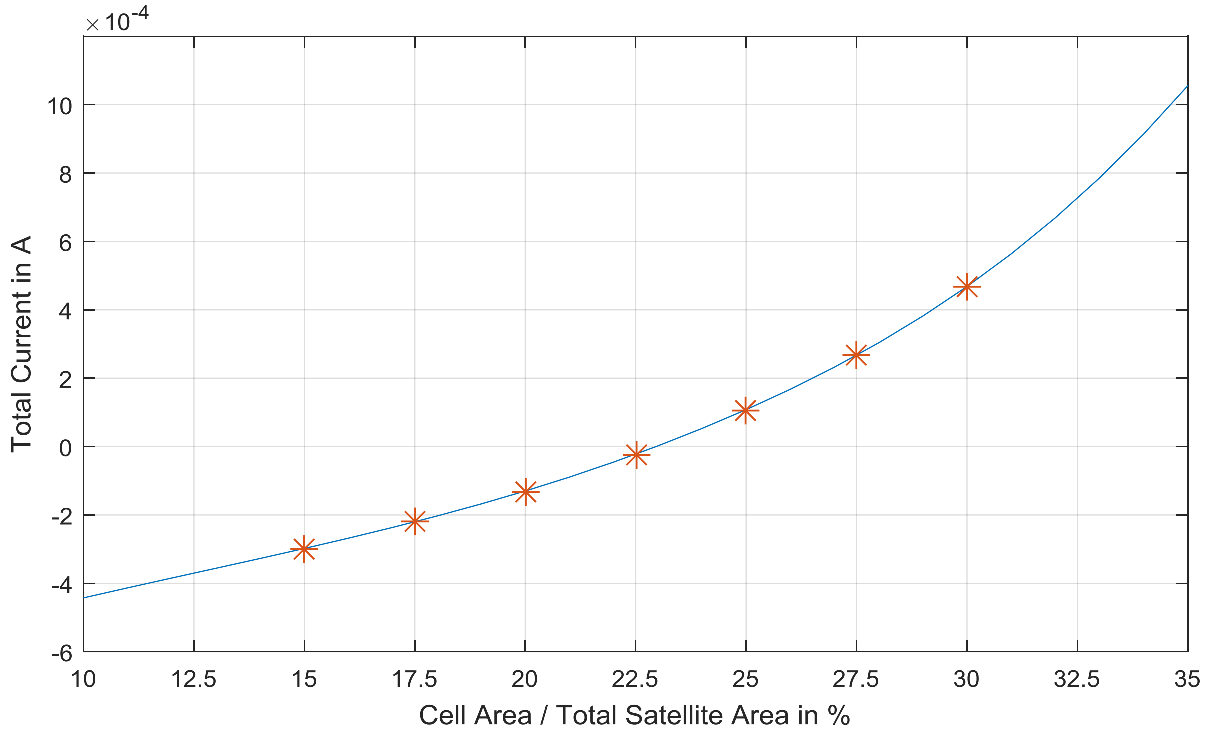
- Differential Potentials are smaller for the case with the higher absolute charging
  - Expected result since the overall current collection on the satellite is reduced in this case due to the large negative potential
  - Also the difference in the emitted current is then smaller in this case leading to a slower progression of the IPG on the cover glasses
- In both cases the IPG is critical with a violation of the ECSS threshold
- DPGs are in both cases below the critical levels specified in the ECSS





Simulation Results

- Additional simulations are performed with a fixed satellite potential of 0 V
  - The initial current towards the satellite is then calculated
  - The fixed 0 V potential is needed so that the changing surface potentials are not influencing the current calculation
- The resulting current collection curve clearly reveals the "sign change" in the current collection at about 23 % relative cell area
  - The markers represent the simulated cases and the curve is generated by a spline interpolation between these measurement points



Simulation Results

Itot > 0

- Total system tends to charge positively due to SEE on the cover glass
  - Cover glasses can never go negative since the SEE on these parts is higher than the combined electron collection on the rest of the satellite
- Re-collection of emitted electrons limits the positive charging
  - Cover glasses are then in a “local” steady state since the re-collection of the emitted electrons compensates the emission
- other surfaces on the satellite are collecting negative current and are thus charging negative
- Charging of the structure potential is a charging of the capacitance between structure and the cover glasses
  - High capacitance → slow effect

Itot < 0

- Total system tends to charge negative due to high electron collection and reduced SEE due to smaller SA area
  - Cover glasses will go negative although the local current is positive
- “Direct” charging of the satellite capacitance versus the undisturbed plasma
  - Small capacitance → fast effect
- The slower differential charging becomes only visible after the absolute charging is close to equilibrium
- Cover glasses are then charging positively with respect to the satellite structure

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Conclusions

- The simulations with the models with varying relative area of the solar array cover glass clearly revealed that this parameter is the main driver for the different behaviour with respect to the absolute charging of the satellite in the LEO polar plasma
- Current collection investigations show that the sign change in the current collection appears at about 23 %
  - Please note that this value is also dependent on the satellite geometry since the ion collection is also contained in the shown curves
    - Cross section size of the satellite has an influence (RAM surface)

- The result is important especially in cases where some measurements and findings from literature shall be transferred to an actual project
  - Both the relative amount of cell area of the heritage / reference satellite and the actual one need to be known
  - Care has to be taken on the individual case the satellite falls into (large amount of cell area or small amount of cell area)
- Practical implications for the useage of SPIS
  - observed differences in the overall global evolution of the potentials are influencing the convergence and stability of the simulations
  - Depending on the case a different set of global parameter especially for the time step control are needed

Thank you