OHB System AG: Jens Laube, Henning Wulf
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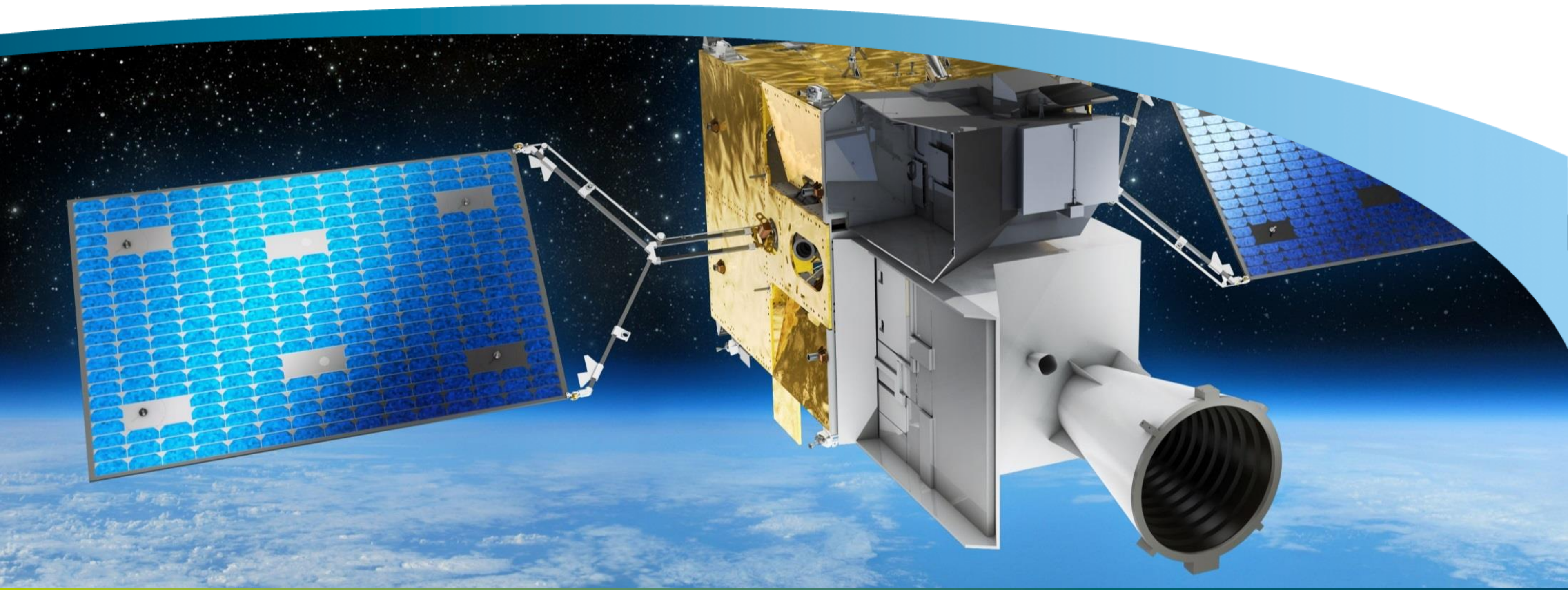

SPACE SYSTEMS

Charging and ESD risks during in-orbit rendezvous manoeuvres

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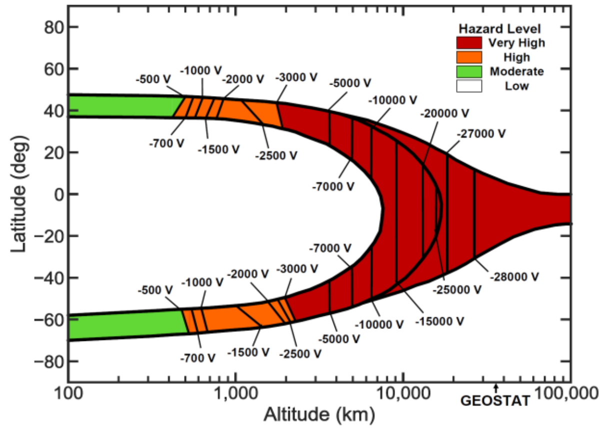
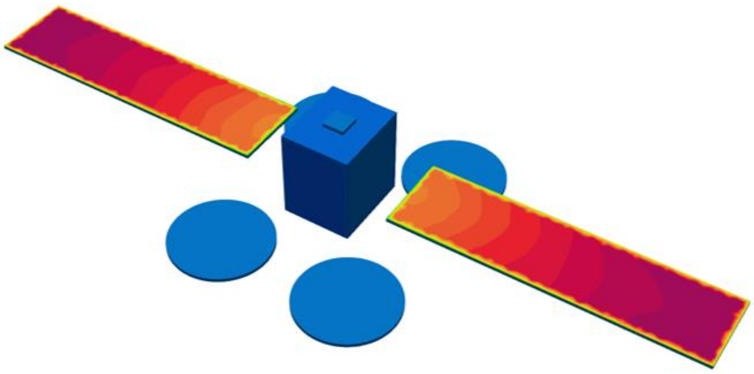
Electrostatic challenges for in-orbit servicing

- Electrostatic discharges are among the most severe threads for spacecraft electronics
- Spacecraft surfaces are generally designed to have a common electrostatic ground
- Safety of design can be verified from charging simulations
- **But**: During servicing separate S/C-circuits are brought into contact
- Uncontrolled arcing through the contact interface can have severe effects on both client and servicer S/C.



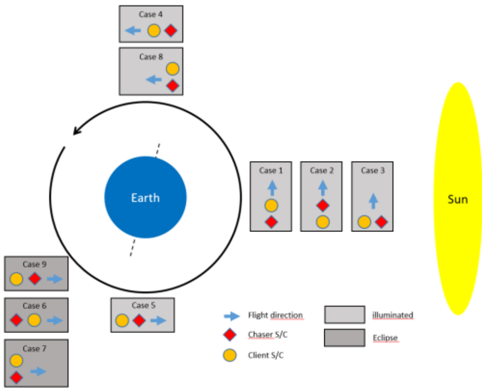


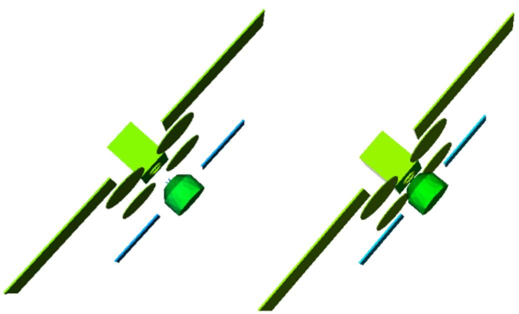
The In-orbit servicing ESD (IOSESD) project

- ESA-project: Activity No. 1000029621
- Title: “Characterising the Potential for Electrostatic Discharge (ESD) for In-Orbit Servicing Missions”
- Questions to answer:
  - What is the differential charging between 2 S/C under different In-Orbit Servicing (IOS) conditions?
  - What are the end-effects as a result of discharging
  - What are the solutions/technologies that could mitigate the end-effects.

The In-orbit servicing ESD (IOSESD) project

- Approach:
  - Task 1: Analyse the differential charging between 2 S/C before the contact:
    - Orbits: LEO-ISS, LEO-SSO, GEO
    - Orientations: sun-shadow and wake
    - Configurations: Different potential S/C candidates
  - Task 2: Analyse the arcing during contact:
    - Final approach phase
    - Charge flow during contact
    - Resulting ESD-effect
  - Task 3: Evaluate the possible mitigation techniques
    - Operational mitigations
    - Design mitigations





Task 1 methods

- S/C charging simulations with SPIS
- Static distance between S/C: 1 m
- GEO environment: ECSS worst Case
- LEO ISS environment: Ionospheric plasma conditions
- LEO SSO environment: auroral plasma depletion event (ECSS worst case)

GEO:

Parameter	Electron-1	Ion-1 (H+)	Electron-2	Ion-2 (H+)
Density (m^{-3})	7E5	6E5	1.2E6	1.3E6
Temperature (eV)	400	200	27500	28000
Drift velocity	0 m/s	0 m/s	0 m/s	0 m/s
Simulation Method	Maxwell-Boltzmann	PIC	Maxwell-Boltzmann	PIC

LEO ISS:

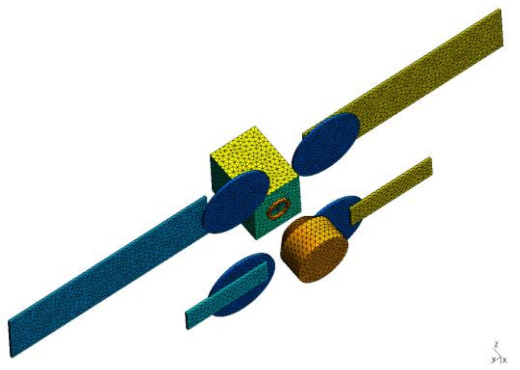
Parameter	Electron-1	Ion-1 (O+)
Density (m^{-3})	$1x10^{10}$	$1x10^{10}$
Temperature (eV)	0.2	0.2
Drift velocity	0 m/s	-7500 m/s
Simulation Method	KineticMB	DriftingMB

LEO SSO:

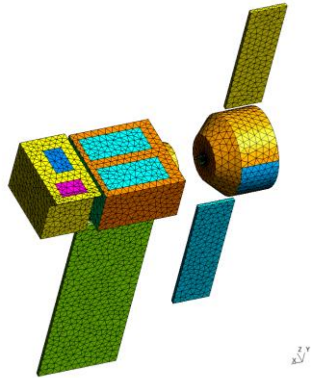
Parameter	Electron-1	Ion-1 (H+)	Electron-2	Ion-2 (O+)
Density (m^{-3})	1.1422E8	6.25E7	1.078E7	6.25E7
Temperature (eV)	0.2	0.2	11000.0	0.2
Drift velocity	0 m/s	-7500 m/s	0 m/s	-7500 m/s
Simulation Method	KineticMB	PIC	KineticMB	PIC

Task 1 methods

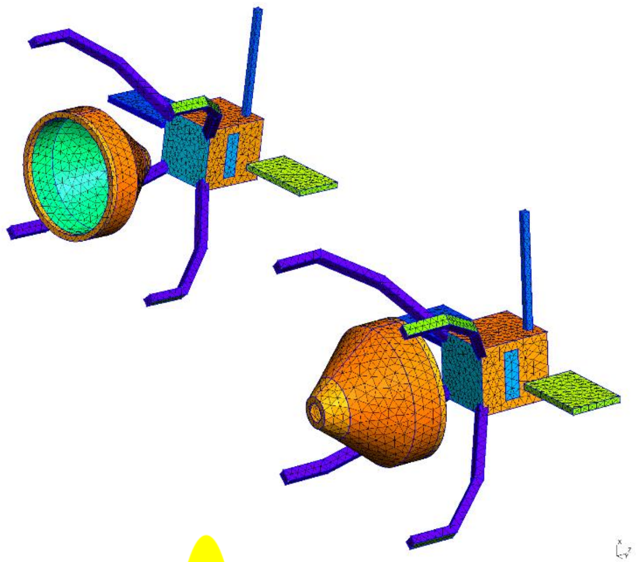
GEO: Servicing of ELECTRA S/C:



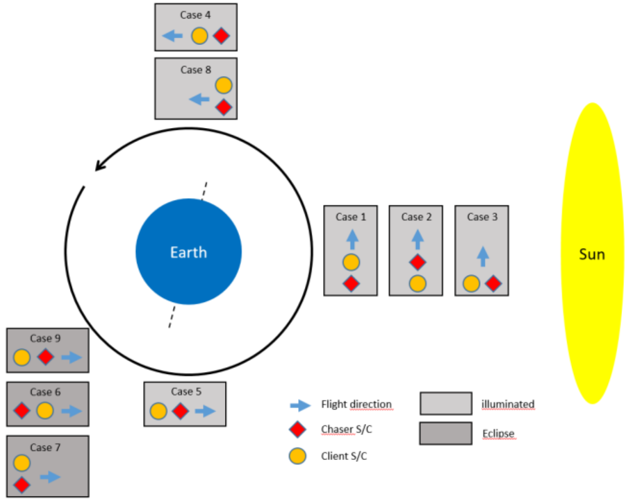
LEO: Servicing of CO2M S/C:



LEO: Removal of VESPA Module:

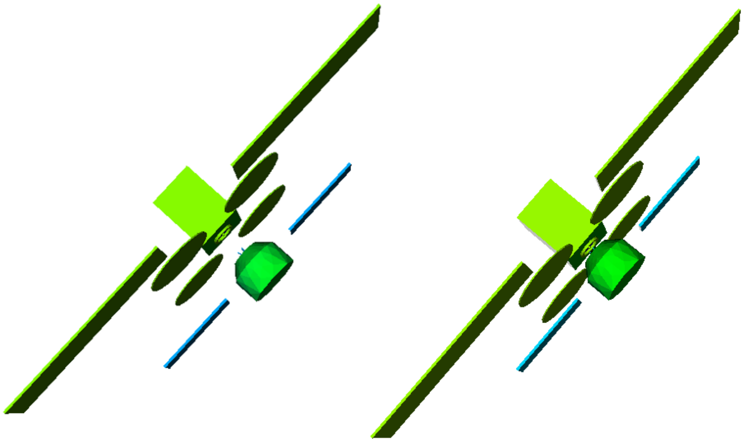


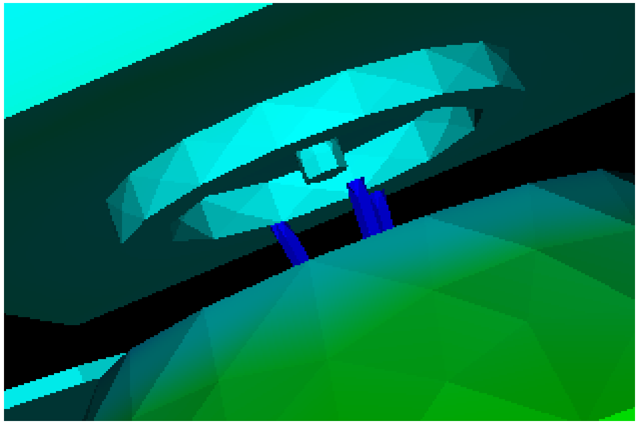
Simulation Case	Orbit Scenario
GEO-1	Equinox 00:00
GEO-2	Equinox 06:00
GEO-3	Winter Solstice 06:00
GEO-4	Eclipse
GEO-5	Equinox 12:00



Task 2 Methods

- Spacecraft Close-up:
  - 90 cm → 5 cm
  - velocity: 0,85 cm/s
- Self-consistent capacitance:
  - Computed dynamically and used in circuit
- Short-circuit at « contact »
  - 10 Ω resistor after contact → discharge ~ns
- Simulation in 4 steps (GEO timings)
  - Time = 0s → 2500s, initial charging
  - Time = 2500s → 2600s, close up
  - Time = 2600s discharge
  - Time = 2600s → 3000s, relaxation

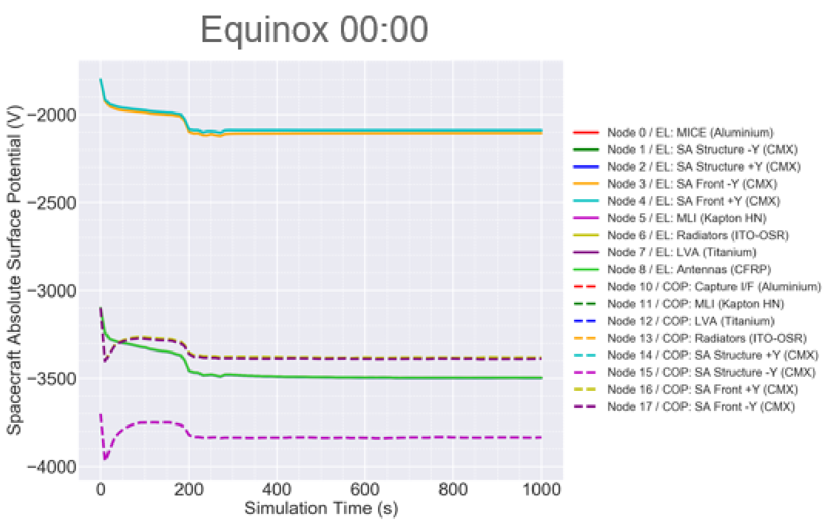


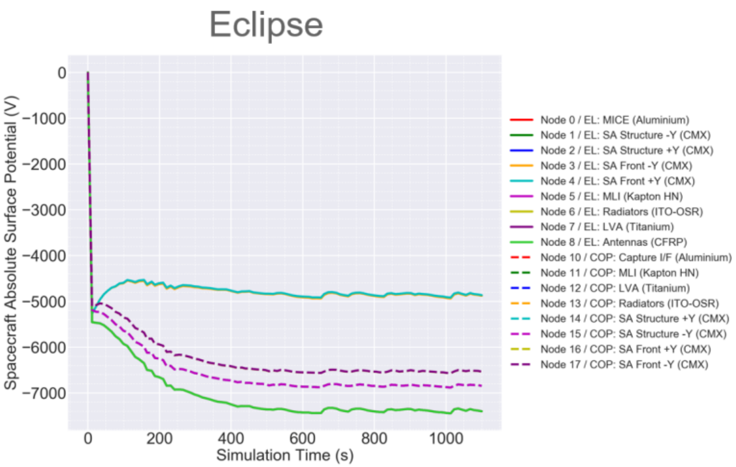


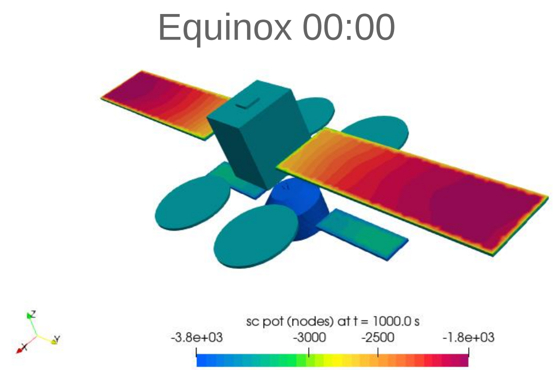
Task 1 Results

GEO: Servicing of ELECTRA S/C:

Case	S/C ground Servicer [V]	S/C ground client [V]	ΔV S/C grounds [V]
Equinox 00:00	-3836 V	-3496 V	340 V
Equinox 06:00	-3564 V	-3727 V	163 V
Winter Solstice 06:00	-3569 V	-3745 V	176 V
Eclipse	-6833 V	-7385 V	552 V
Equinox 12:00	-3313 V	-3435 V	122 V



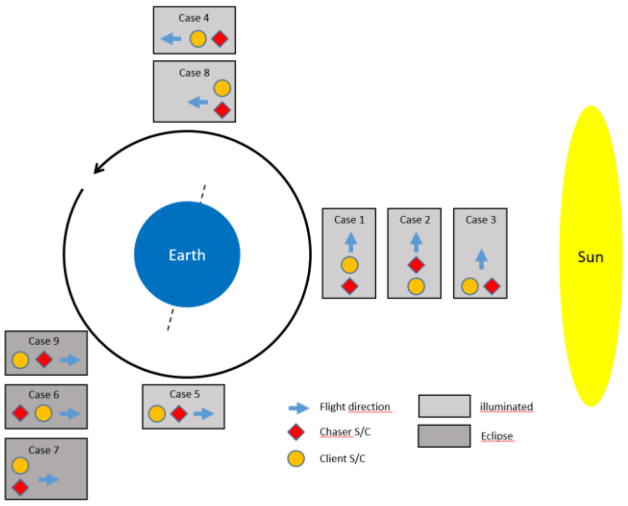


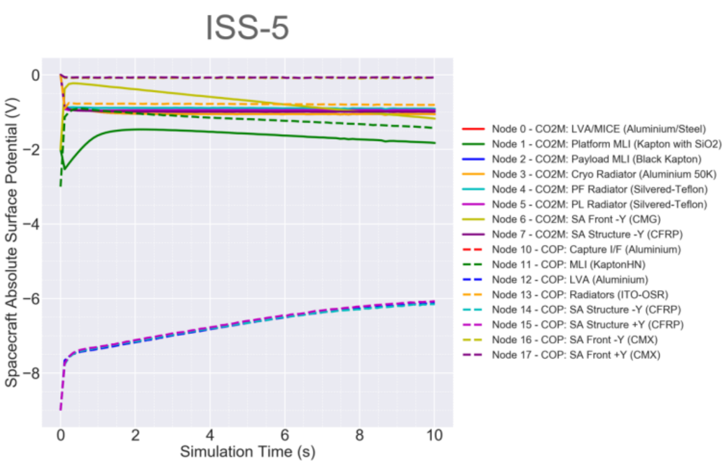


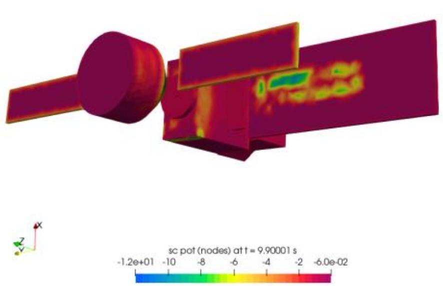
Task 1 Results

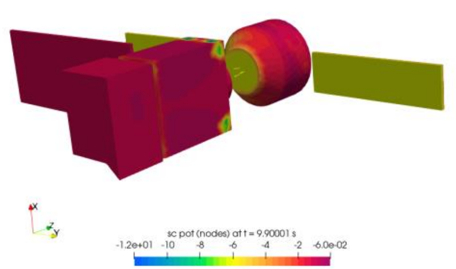
LEO ISS: Servicing of CO2M S/C:

Case	S/C ground servicer [V]	S/C ground client [V]	ΔV S/C grounds [V]
ISS-1	-0.92	-0.71	-0.21
ISS-2	-0.9	-0.86	-0.04
ISS-3	-1.35	-0.8	-0.55
ISS-4	-0.86	-0.73	-0.13
ISS-5	-6.13	-1.06	-5.07
ISS-6	-0.89	-0.77	-0.12
ISS-7	-1.21	-0.82	-0.39
ISS-8	-0.65	-0.73	0.08





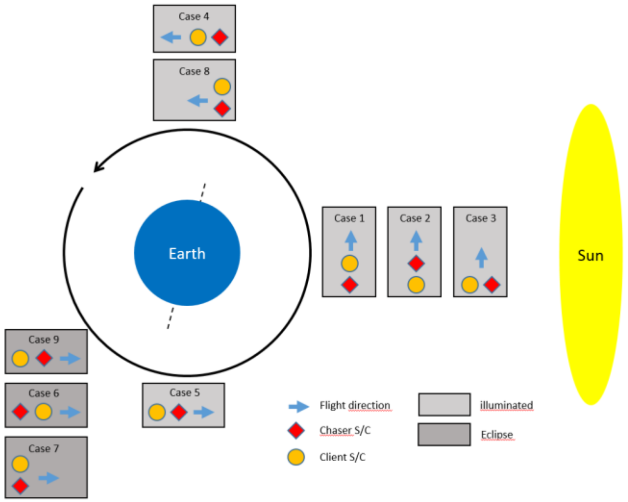


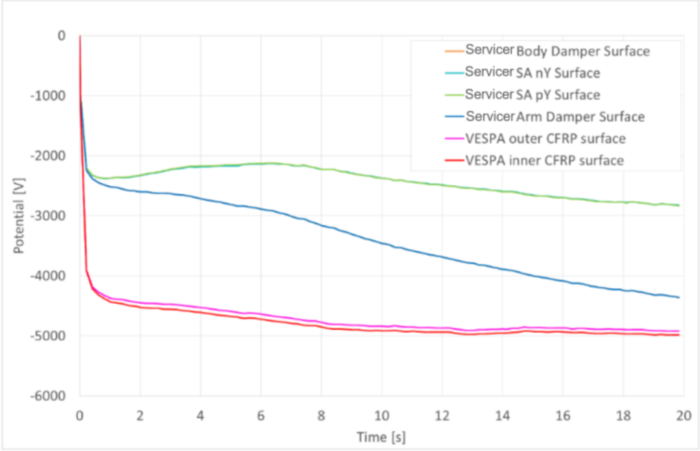


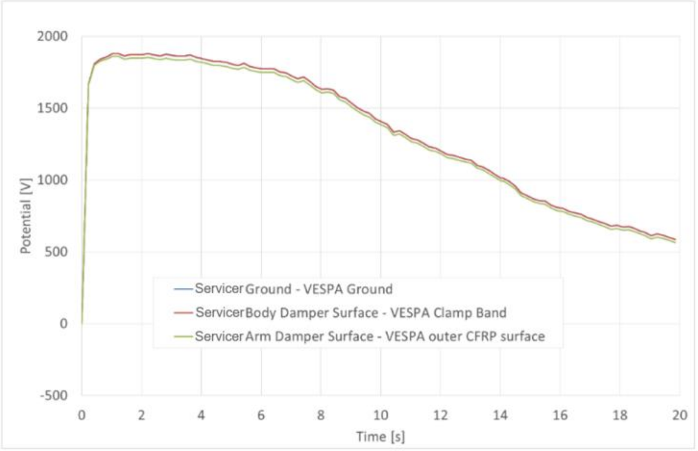
Task 1 Results

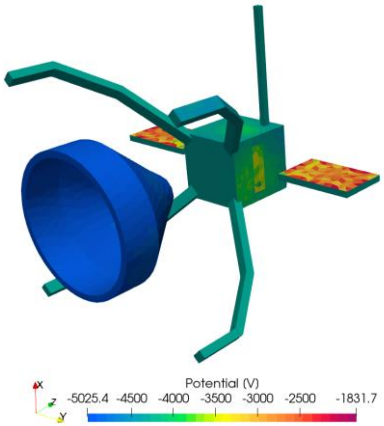
LEO SSO: Removal of VESPA Module:

Case	S/C ground servicer [V]	S/C ground client [V]	ΔV S/C grounds [V]
A-V-C1-SSO-E-6	-4356	-4940	1879
A-V-C1-SSO-E-7	-4686	-5461	1443
A-V-C1-SSO-E-9	-5034	-3924	-1110
A-V-C2-SSO-E-6	-4681	-5733	1804
A-V-C2-SSO-E-7	-4946	-5283	974
A-V-C2-SSO-E-9	-5446	-3649	-1823



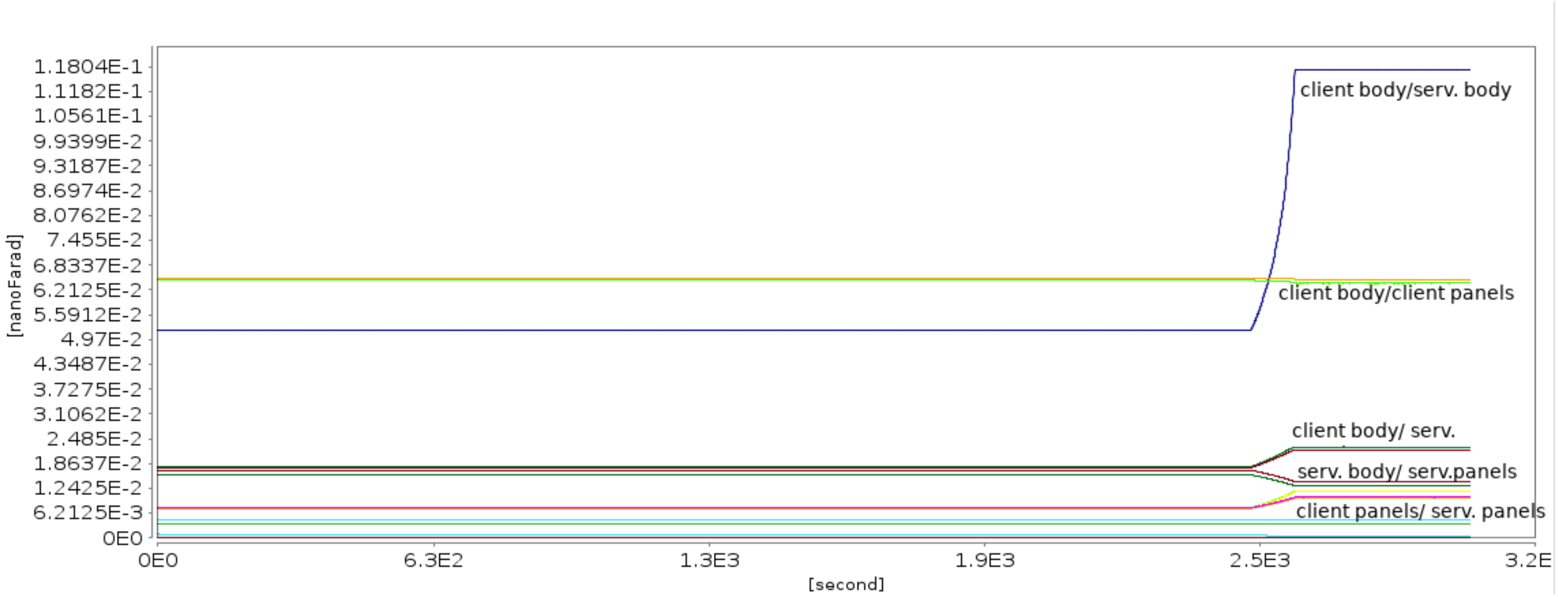






Task 2 Results

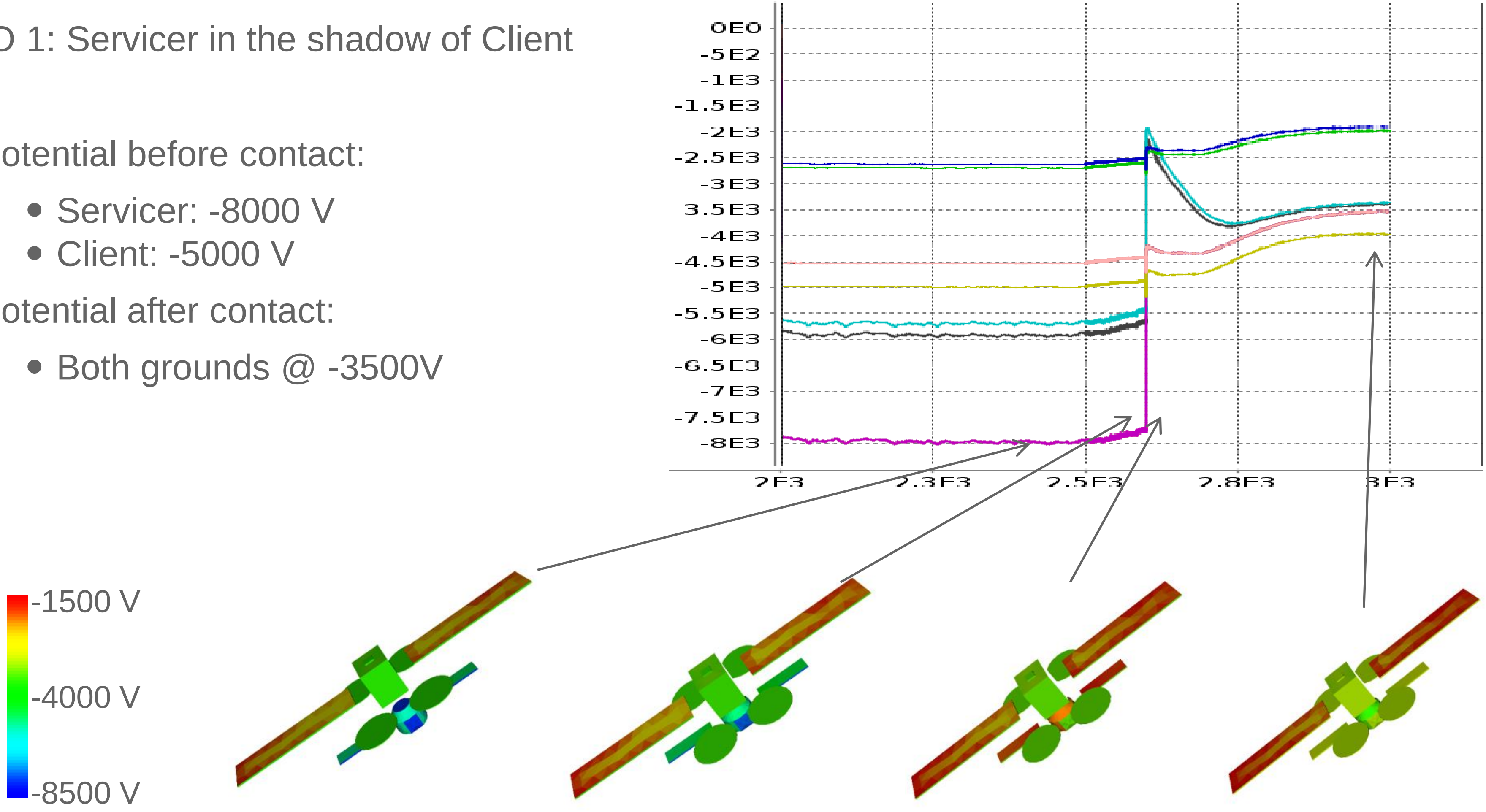
- Large Debye sheath: Capacitance evolves as 1/d:



Task 2 Results

GEO 1: Servicer in the shadow of Client

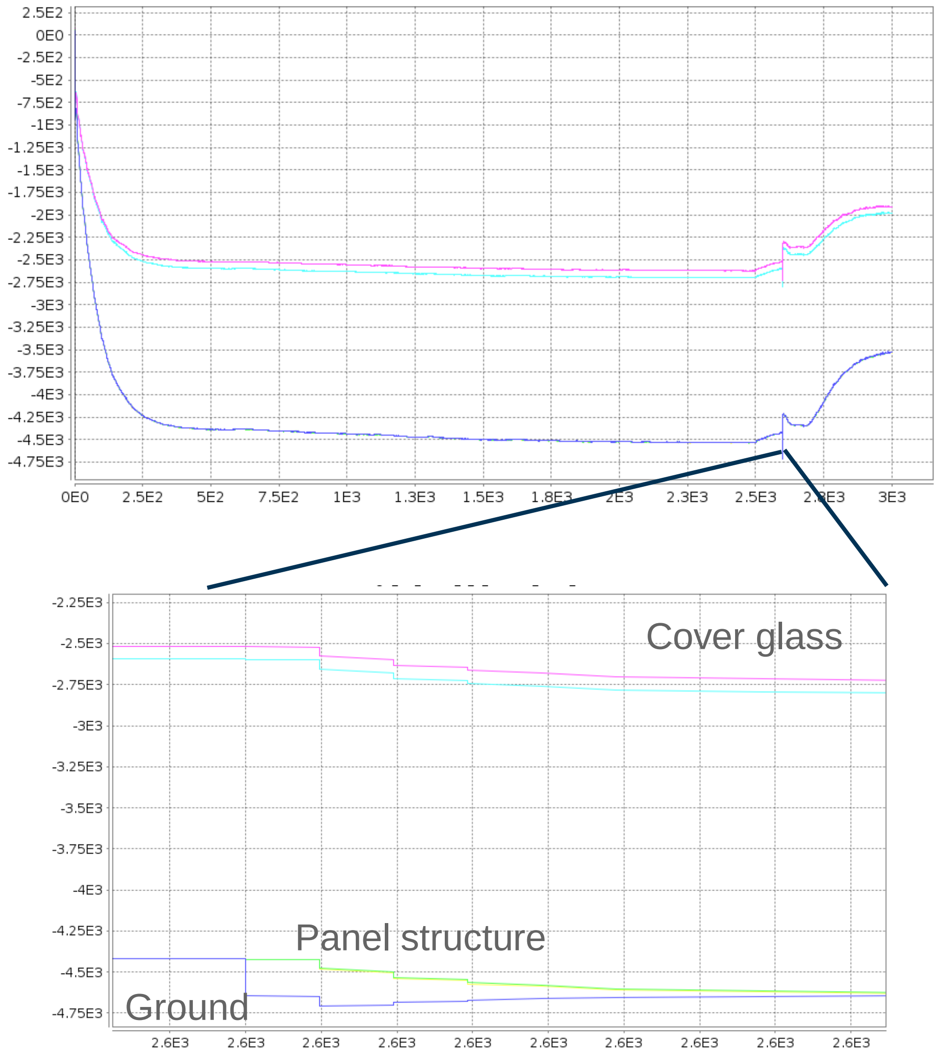
- Potential before contact:
  - Servicer: -8000 V
  - Client: -5000 V
- Potential after contact:
  - Both grounds @ -3500V



Task 2 Results

GEO 1: Servicer in the shadow of Client

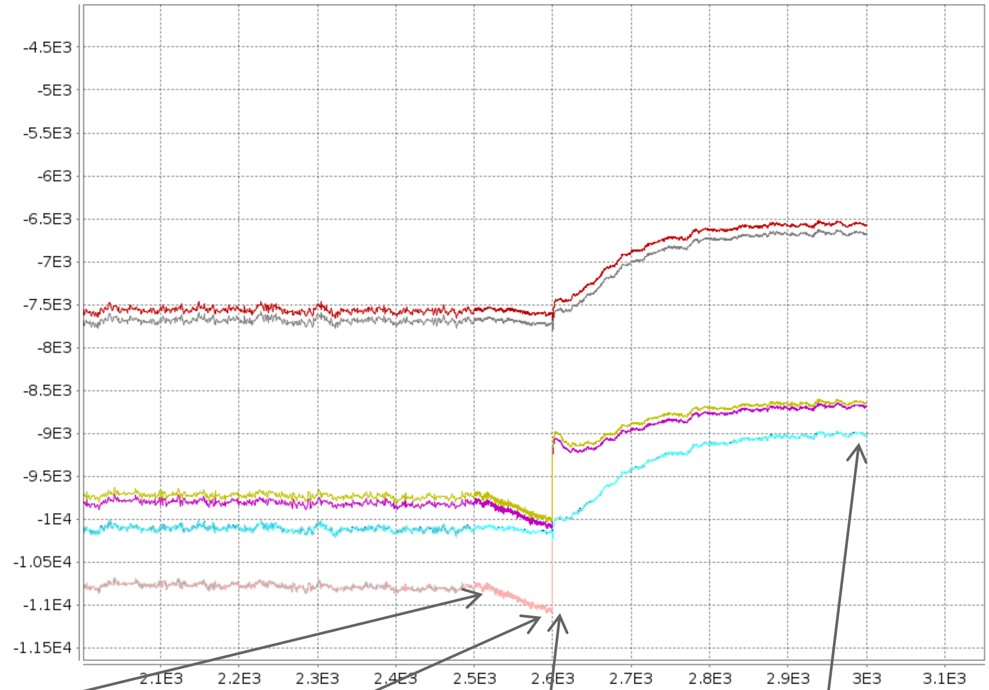
- Potential evolution transient
  - Rear side of panels changes slower due to bleed resistance

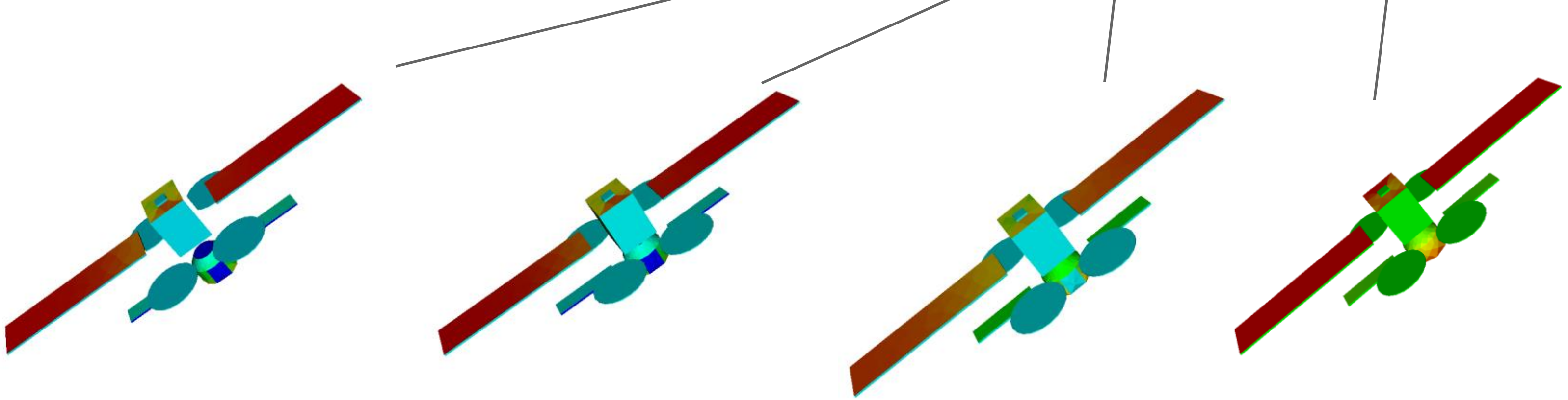


Task 2 Results

GEO 4: Eclipse

- Potential before contact:
  - Servicer: -11000 V
  - Client: -10000 V
- Potential after contact:
  - Both grounds @ -9000V





Conclusion

- Charging simulations of 2 S/C provide operational suggestions for docking
  - Which configurations are beneficial
  - Which configurations are dangerous
- Dynamic docking simulations enable the simulation of the ESD-event.
- No ESD risk identified in LEO ISS environment
- In LEO SSO the auroral plasma depletion events can lead to severe potential differences between the S/C
  - Do not dock in eclipse in the auroral region
- In GEO, shadowing of one of the S/C or eclipse can lead to severe potential differences between the S/C
  - Do not dock, when 1 S/C is in shadow

Way Forward

- Evaluation of discharge in LEO configurations in Task 2
- Evaluation of the ESD-effects in Task 2
- Assessment of ESD mitigation techniques in Task 3
- Flow-down of results into our projects.

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Thank you!

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