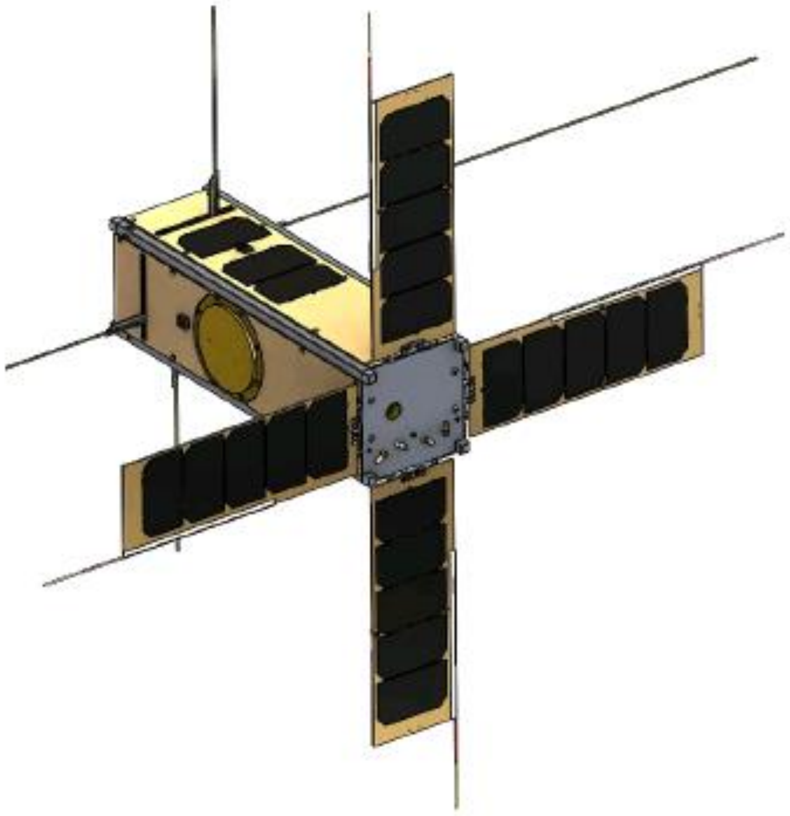

PICASSO spacecraft plasma interactions

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SPINE M24, 23/10/2017

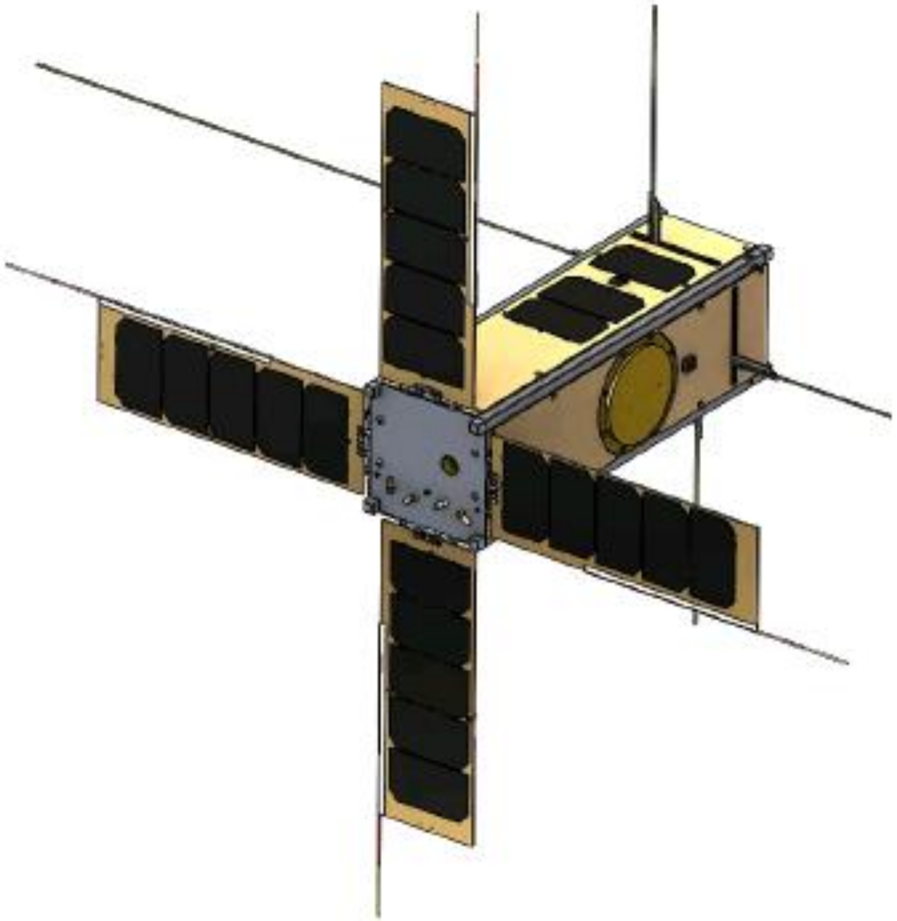
Outline

- What is PICASSO?
- Surface charging in LEO
- SPIS simulation setup
- Simulation results:
  - Langmuir probe sweep test
  - PICASSO geometry vs cuboid geometry model sensitivity
  - S/C orientation parametric study
  - Background density parametric study
- Difficulties encountered & lessons learned

PICASSO spacecraft

- **PIC**osatellite for **A**tmospheric and **S**pace **S**cience **O**bservations (BIRA, VTT, Clyde Space, CSL)
  - Distribution of ozone in stratosphere
  - Profile of stratosphere temperature
  - Measure ionospheric electron density (Multi-needle Langmuir probe)

- Orbit
  - LEO: 500 (current baseline) - 700 km
  - High inclination: 98º→ Polar orbit crossing the auroral region



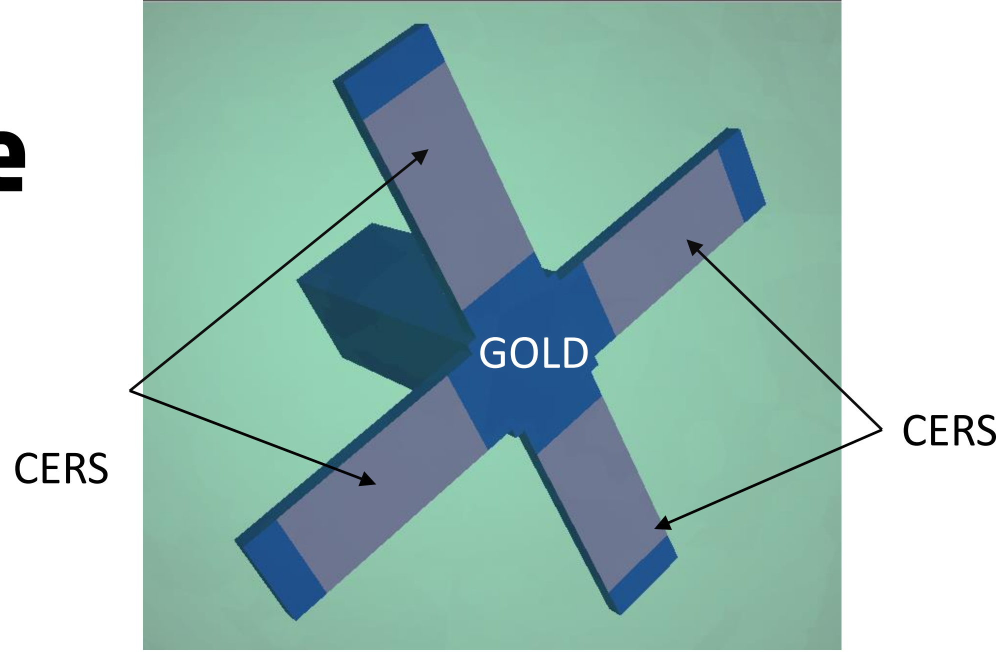
Objectives: simulate PICASSO surface charging in SPIS

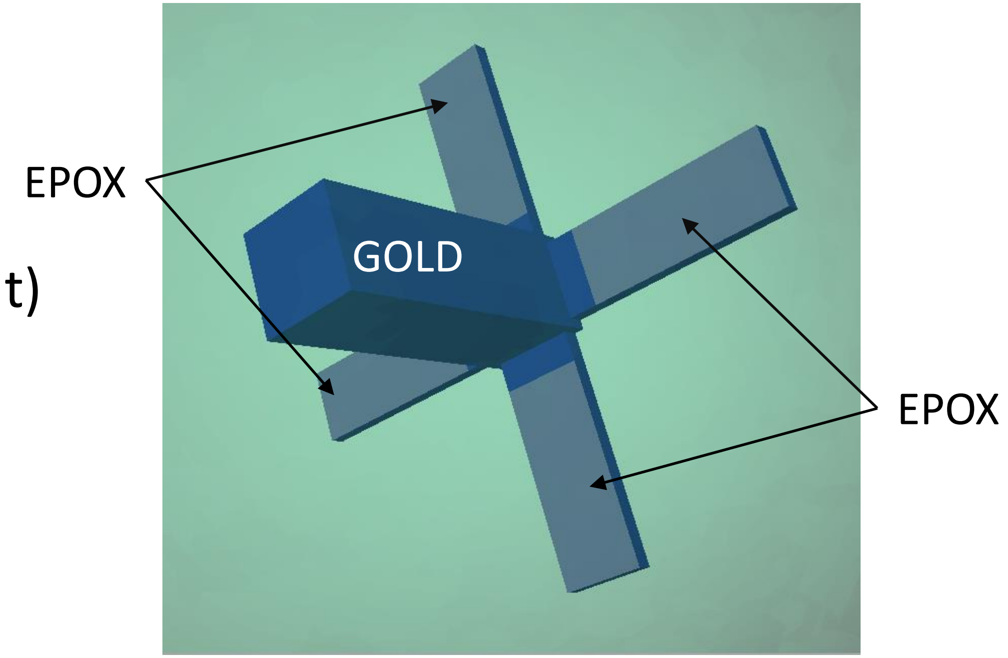
- PICASSO mission contraints:
  - Mesothermal regime ($v_e \gg v_{S/C} \gg v_i$) for a spacecraft with $v_{S/C} \approx 7000$ km/s (ram-wake effect)
  - Surface materials on spacecraft: Gold, cover glass, epoxy, …

- 1) In the **LEO** ionospheric environment
  - Cold (0.2 eV) and dense ($1x10^{10}$ m^{-3}) plasma
- 2) In an **auroral worst case** environment
  - Flux of precipitating high-energy electrons (isotropic in our simulations)

Geometry & (SPIS) surface materials

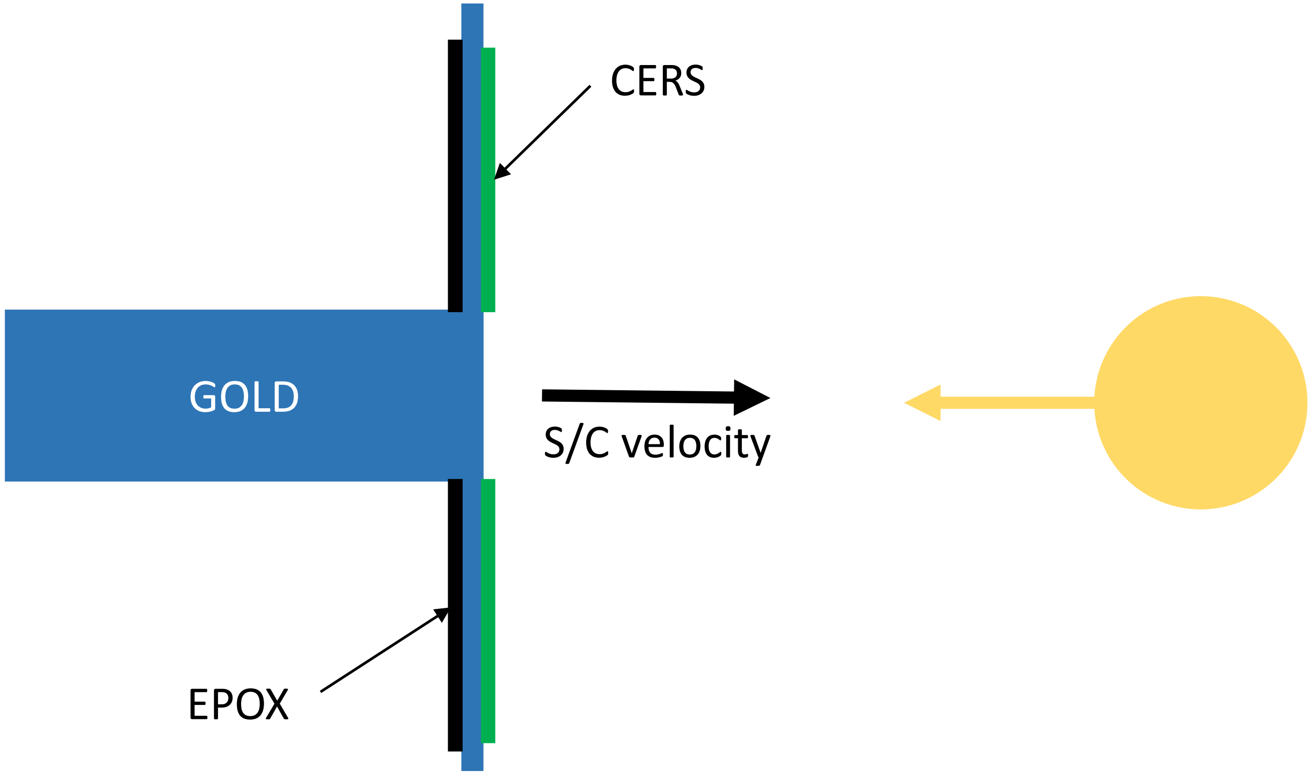
- 3U Cubesat
  - 0.3m x 0.1m x 0.1m
  - Material: GOLD
- 4 solar arrays (deployed)
  - 0.23m x 0.08m x 0.002m
  - Base material: GOLD
  - Solar cells material: coverglass (CERS)
  - Back of solar array material: EPOX (50µm default)
- Use of a simple electric circuit
- Spacecraft orientation fixed in simulations:
  - CERS in ram surface
  - EPOX in wake surface





Geometry & surface materials

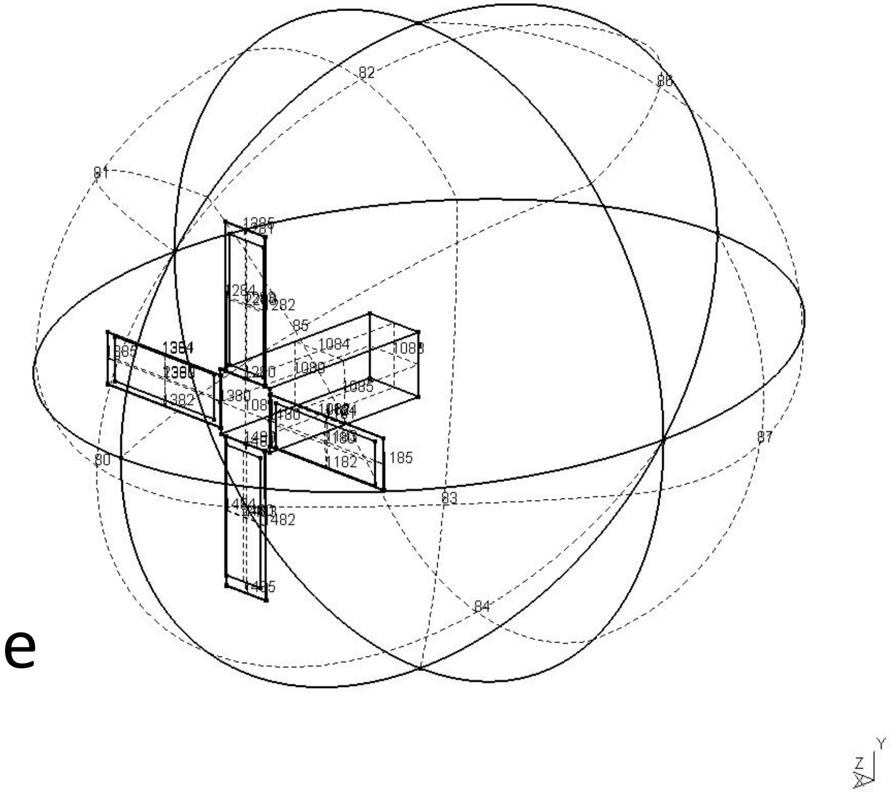
- Spacecraft orientation fixed in simulations:
  - CERS in ram surface
  - EPOX in wake surface



PICASSO simulations in LEO environment

- LEO ionospheric plasma

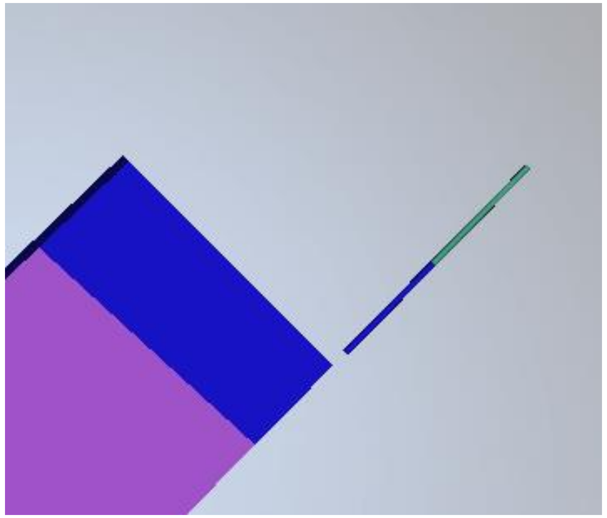
	electrons	ions (O^+)
Density (m^{-3})	$1x10^{10}$	$1x10^{10}$
Temperature (eV)	0.2	0.2
Drift velocity	0 km/s	-7500 km/s
Simulation method	Maxwell-Boltzmann/ Particle In Cell	Particle In Cell



- Short Debye length: 0.06m, thin/intermediate sheath around spacecraft
- Simulations performed in eclipse

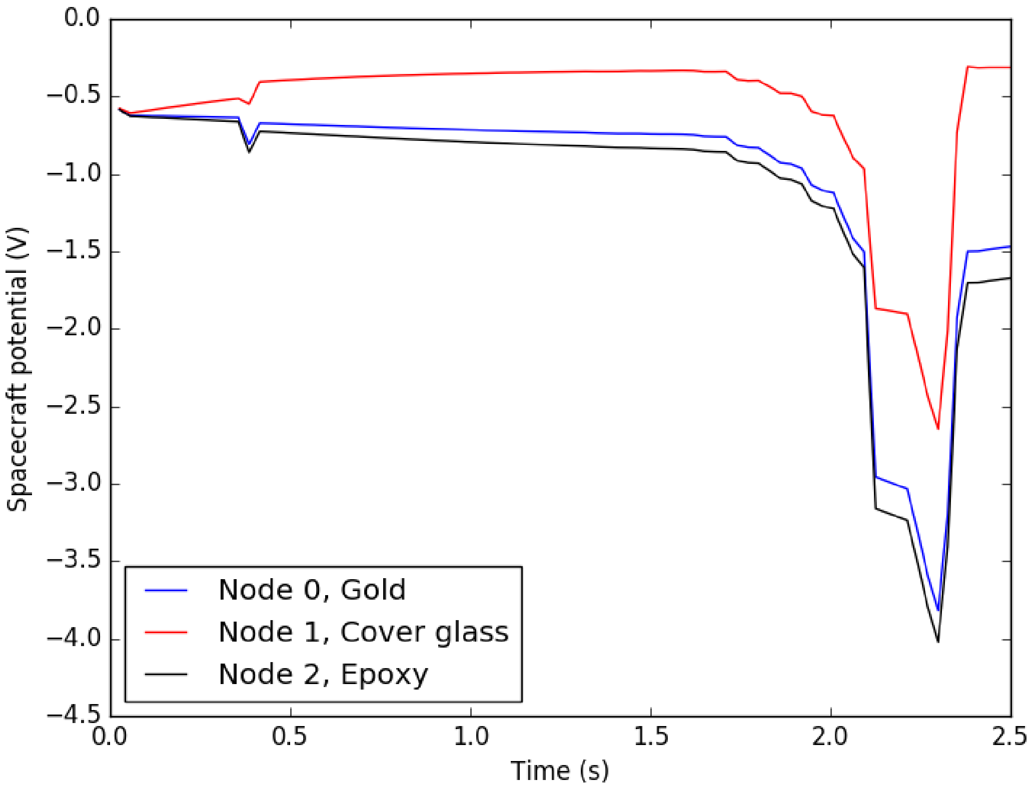
PICASSO Langmuir Probe simulation in LEO

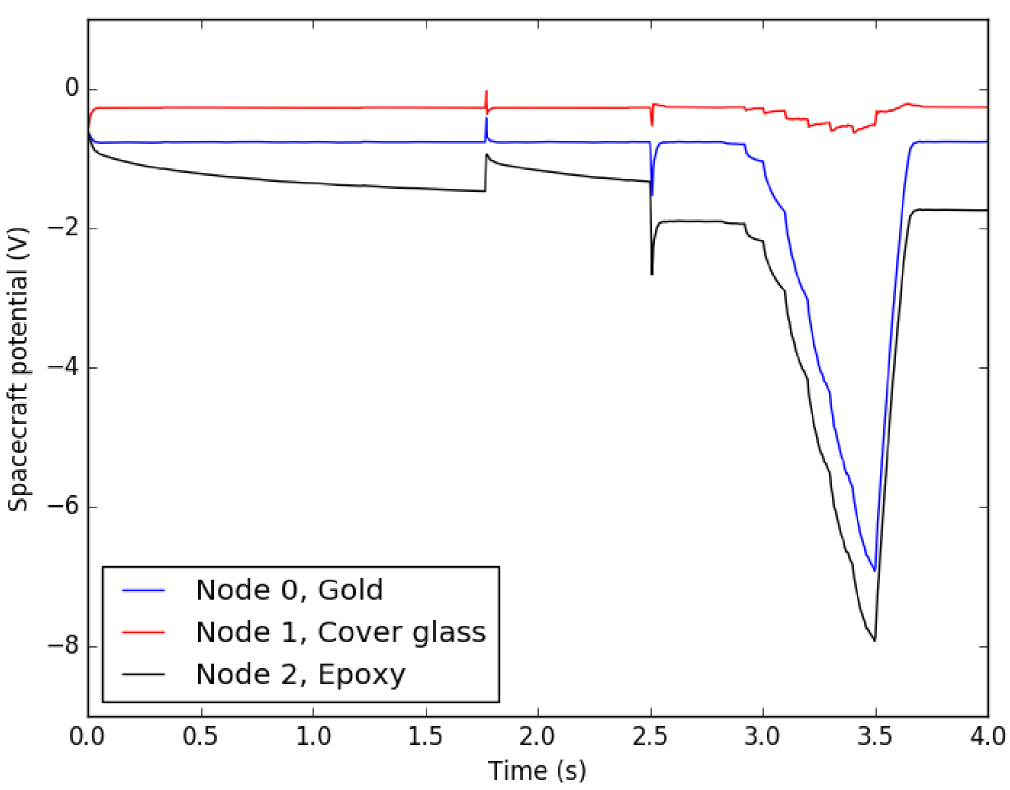
- Sweeping Langmuir Probe (SLP):
  - 4 Langmuir probes mounted on extremity of solar panels
  - Cylindrical: 1mm radius, 40mm length, 40mm boom
  - Always at least one probe out of the wake
  - Operated between -5 and 13 V w.r.t. to s/c ground



PICASSO Langmuir Probe simulation in LEO

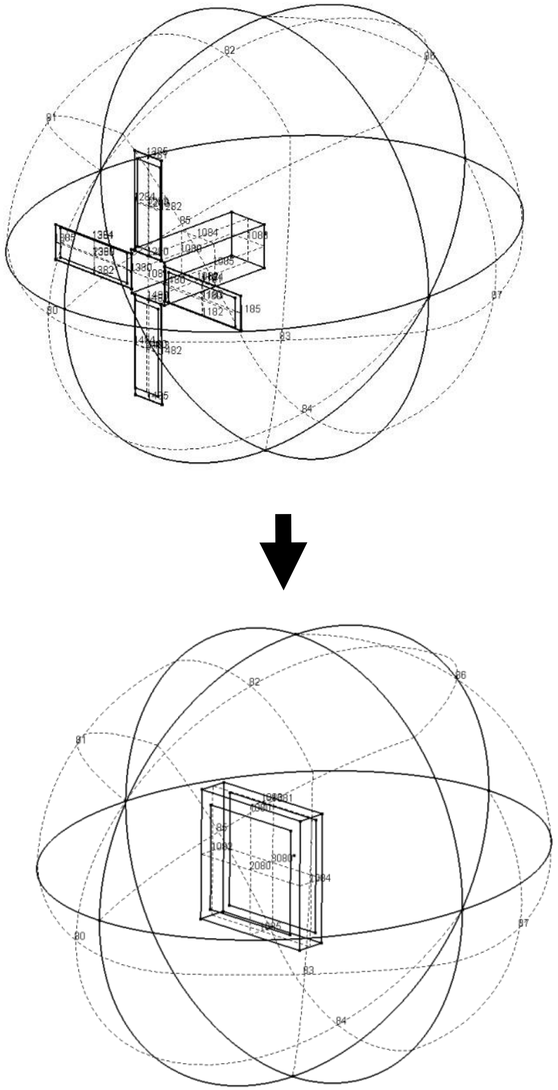
- Sweeping Langmuir Probe (SLP):
  - Output of SPIS simulations in $N_e = N_i = 1E8\ m^{-3}$ and $N_e = N_i = 1E10\ m^{-3}$





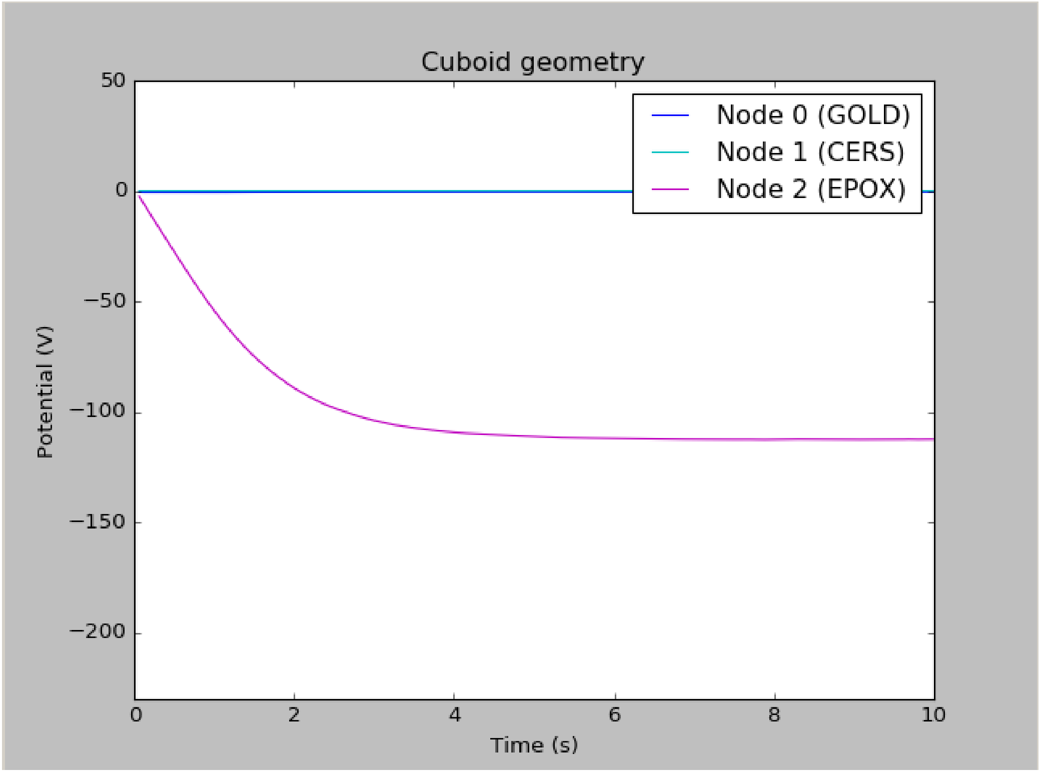
PICASSO simulations in LEO environment

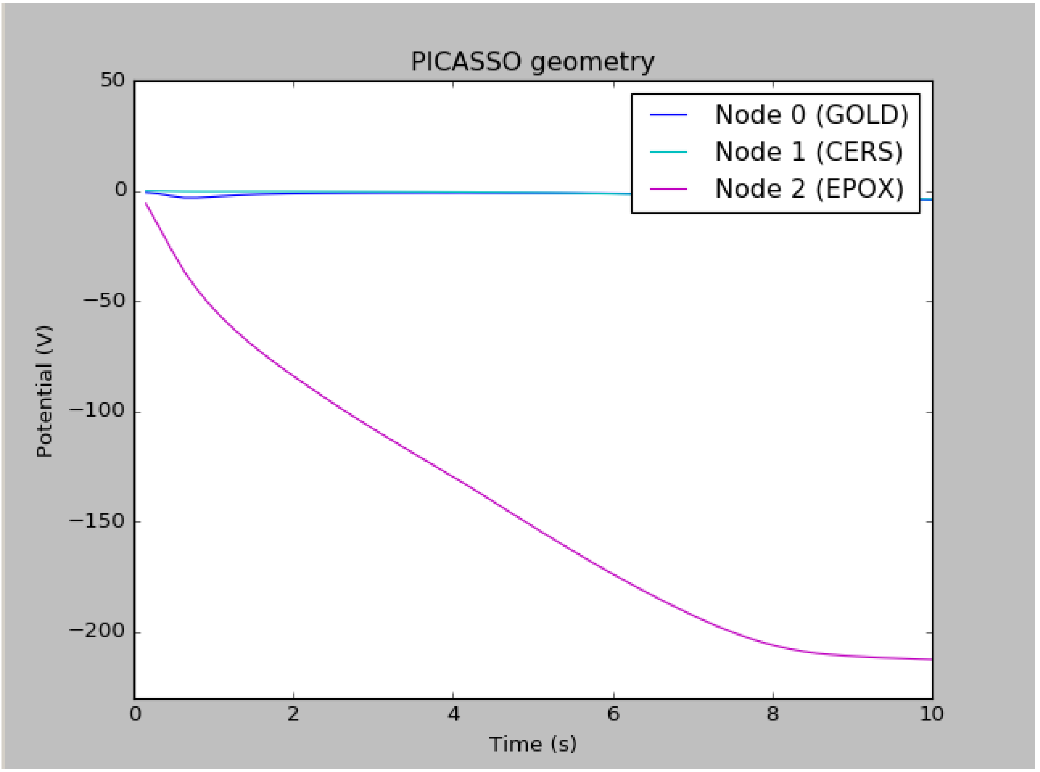
- Simulations using actual PICASSO dimensions produce potential divergences during simulations
- Simplify geometry to cuboid
  - Preserving total surface area
  - Preserving surface area of each material on all sides
  - No Langmuir probe
- Result: excluding small mesh elements (S/A edges, Langmuir probe)



PICASSO simulations in LEO environment

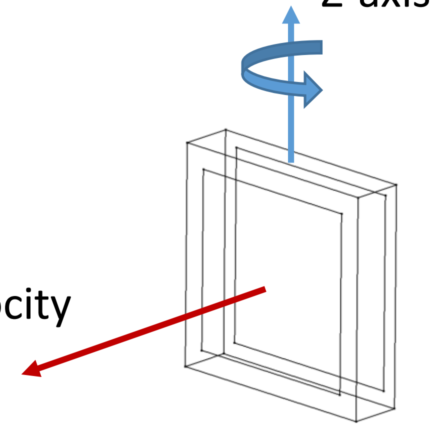
- Potentials at equilibrium in $N_e = N_i = 1E10\ m^{-3}$ + auroral population environment: **difference of ~ 100 V**



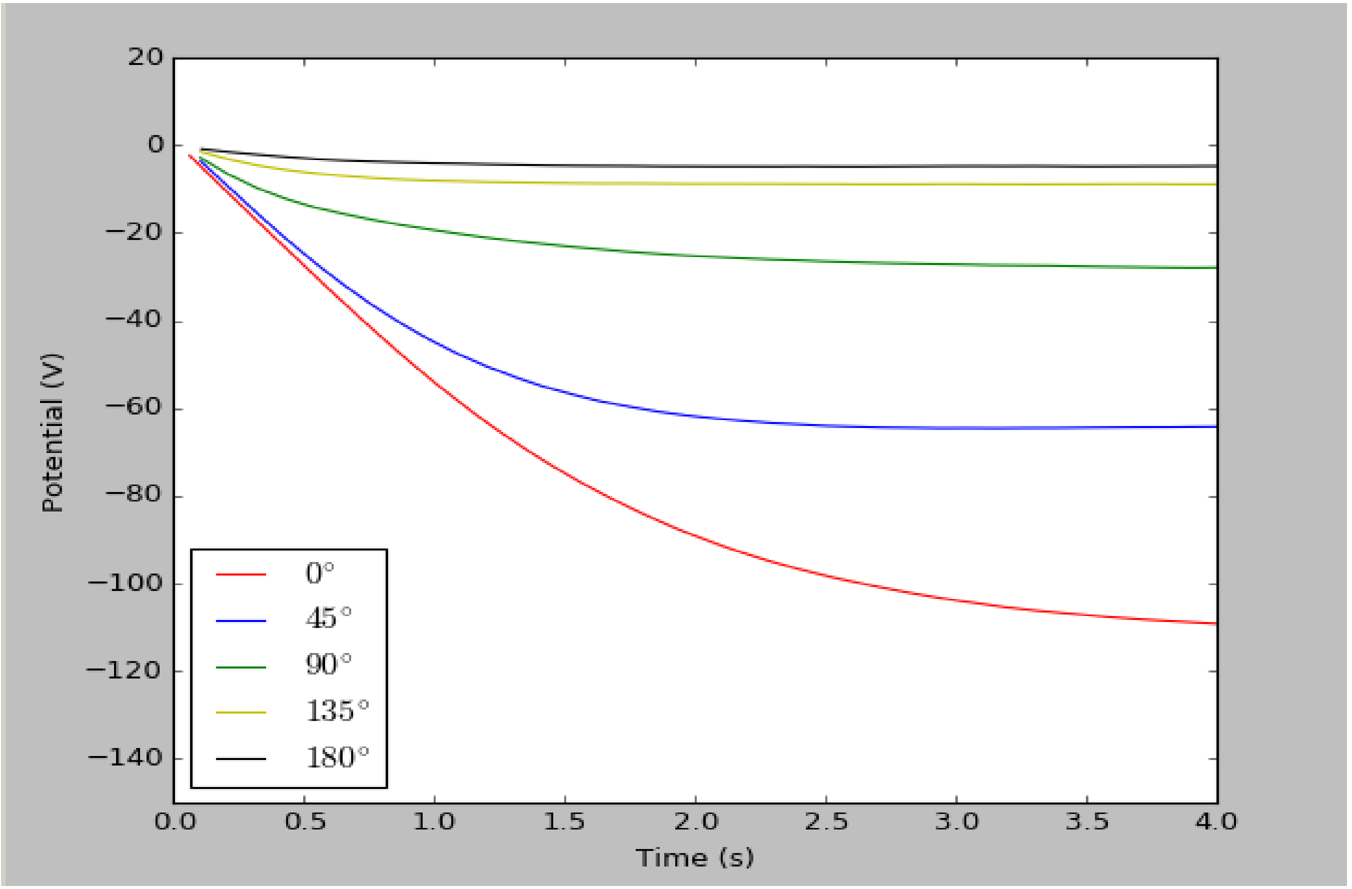


PICASSO simulations in LEO environment

- $N_e = N_i = 1E10\ m^{-3}$ + auroral population
- Orientation of geometry w.r.t spacecraft movement
- I.e. rotation around Z-axis
  - **0°**: CERS on ram surface, EPOX on wake surface
  - **180°**: EPOX on ram surface, CERS on wake surface



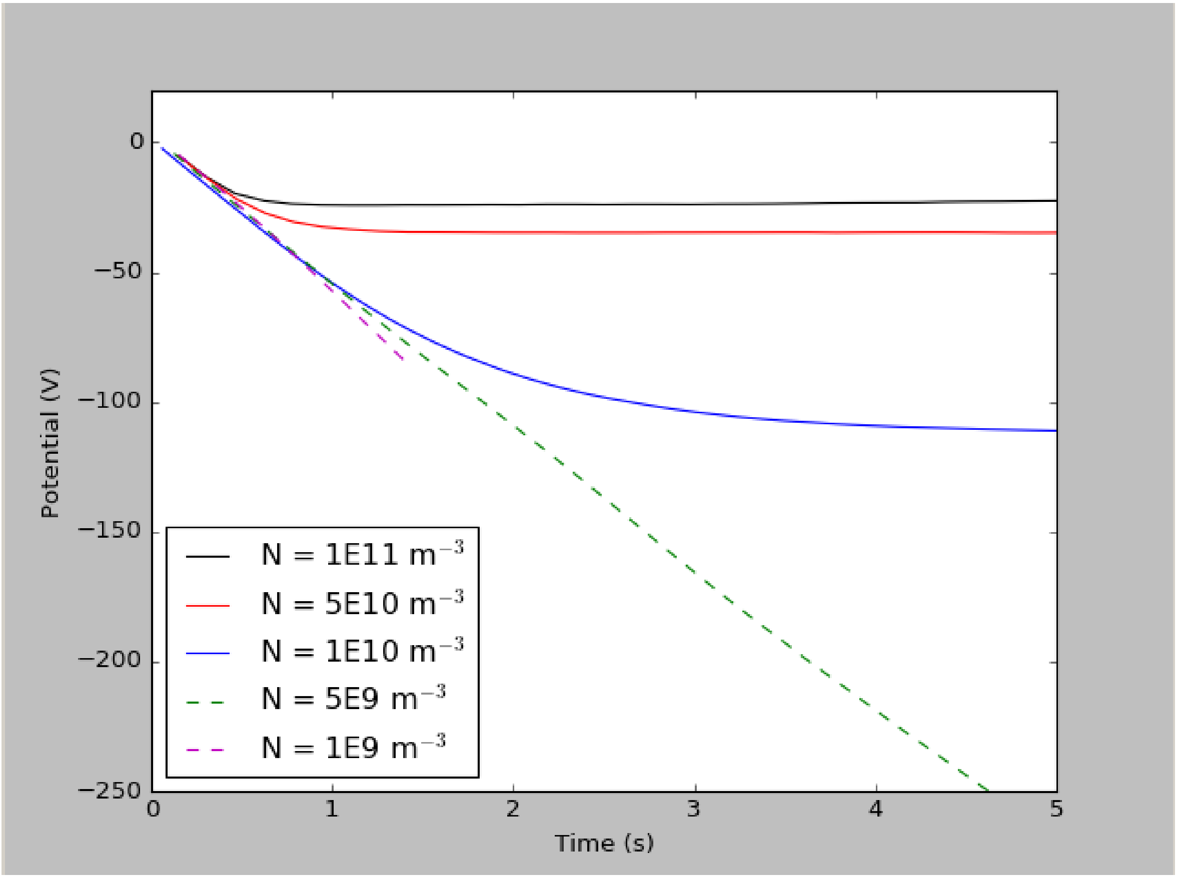
Node 2 (EPOX) potential



PICASSO simulations in LEO environment

- Auroral population with different background densities
- Background density range: **1E9 – 1E11** m^{-3}
- Unstable simulations indicated by dashed lines

Node 2 (EPOX) potential



Difficulties encountered performing LEO simulations in SPIS

- High density plasma → short Debye length + small spacecraft
  → High resolution mesh needed, heavy simulation

- Mesothermal S/C velocity → collected current noise
  → Instabilities in circuit solver
  → Not resolved when using GlobalMaxwellBoltzmann, Backtracking,…
  → Divergences in potential evolution when approaching equilibrium at random times

2017/10/19-10:18:03	Time: 7.068639, Dt = 0.01 s
2017/10/19-10:19:00	dt = 0.0
2017/10/19-10:19:00	changed into 9.999999E-4 s

- Success ratio below 15% (22/150)

Conclusions

- Simulations of Cubesat in LEO using SPIS is difficult
  - Simulation instabilities, specific tuning of parameters is needed.
  - Effects and results of Langmuir probe instrument unclear

- On Simulations in auroral ECSS worst case environment
  - Effect of different S/C orientation gives expected results
  - Effects of background plasma density (when stable) as expected

- Main issues encountered with SPIS and open questions

Difficulties encountered performing LEO simulations in SPIS: Lessons learned

- Simplifying geometry reduces simulation time and improves stability, however can yield very different results.
- To reduces noise the *AvPartNbPerCell* and *electronSecondaryDensification* parameters need to be set to high values (5-8 and 10-14 resp.).
- *SimulationDt* is best kept limited (max 0.01s).
- *Csat* set to realistic value (~1E-9 F)
- *ValidityRenormalisation* must be set to very low values (0.5).