Simulation of the effects of the Active Spacecraft Potential Control system for the MMS and THOR missions

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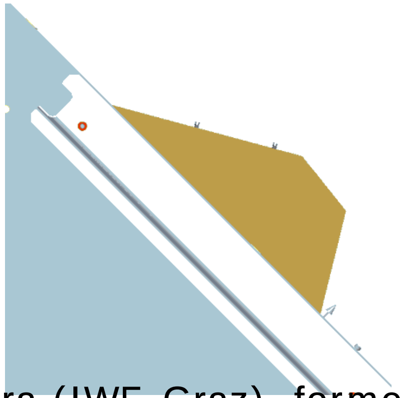
Active Spacecraft Potential Control and Floating Potential Stabilization

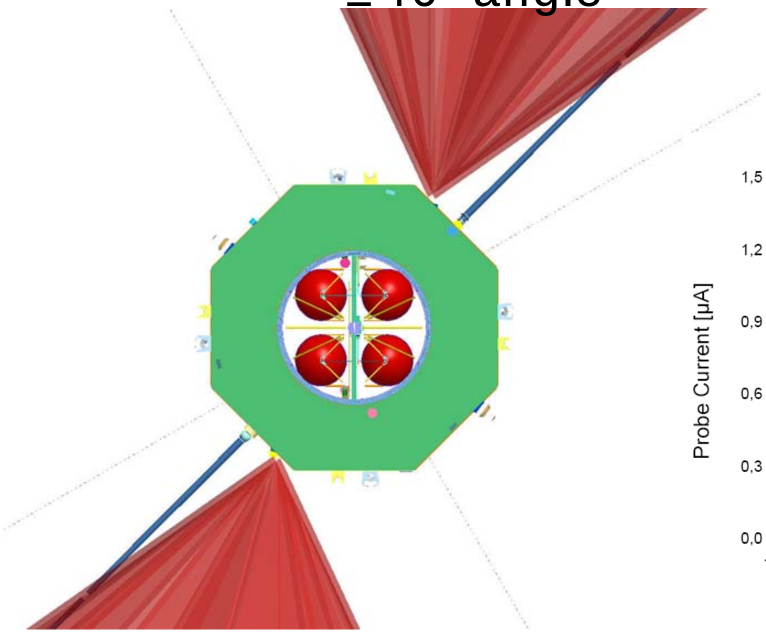
- floating potential results from balance between ambient electrons and photoelectric current
- Photoemission dominates, s/c potential in a range ~ 10V but can be significantly larger
- Balance achieved through escaping high energy photoelectrons
- Ion emission allows to drive the potential to lower positive values
- ASPOC system : field emission from liquid Indium, 10-20μA In^{+} beam ~5keV
- Successfully used on Cluster and Double Star, MMS (ongoing), possibly on THOR if selected



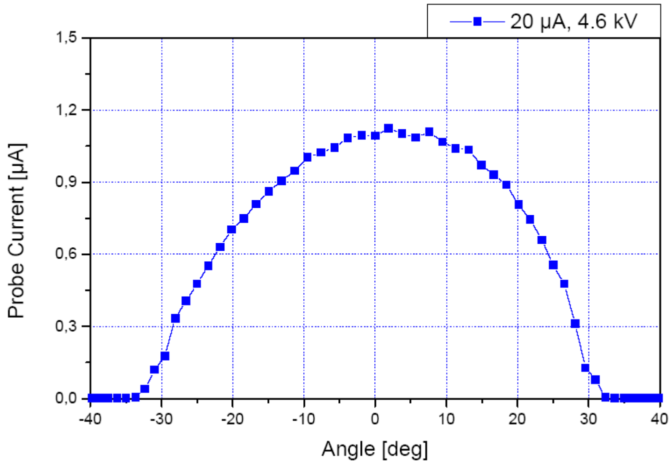
PI : R. Nakamura (IWF, Graz), formerly K. Torkar

ASPOC Beam on MMS

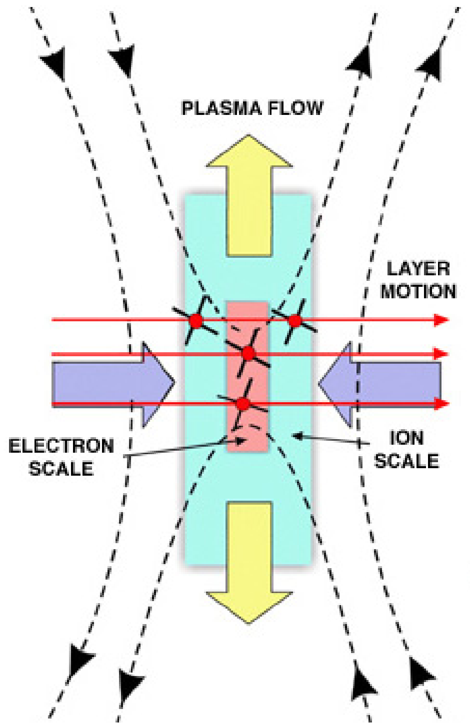
±40º angle



Typical beam profile at 20µA
Indium ions, 4.6keV



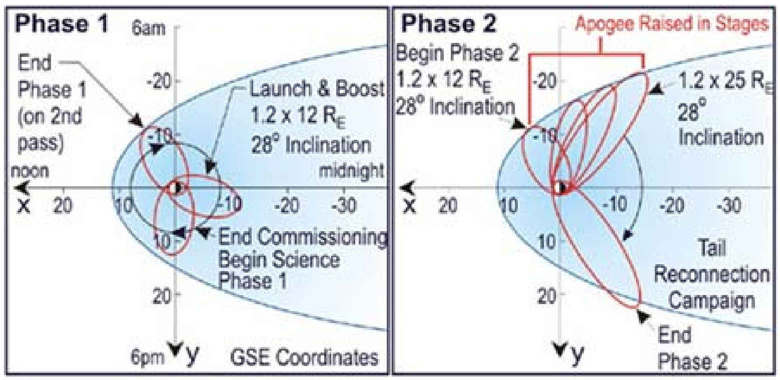
Magnetospheric Multiscale Spacecraft Mission



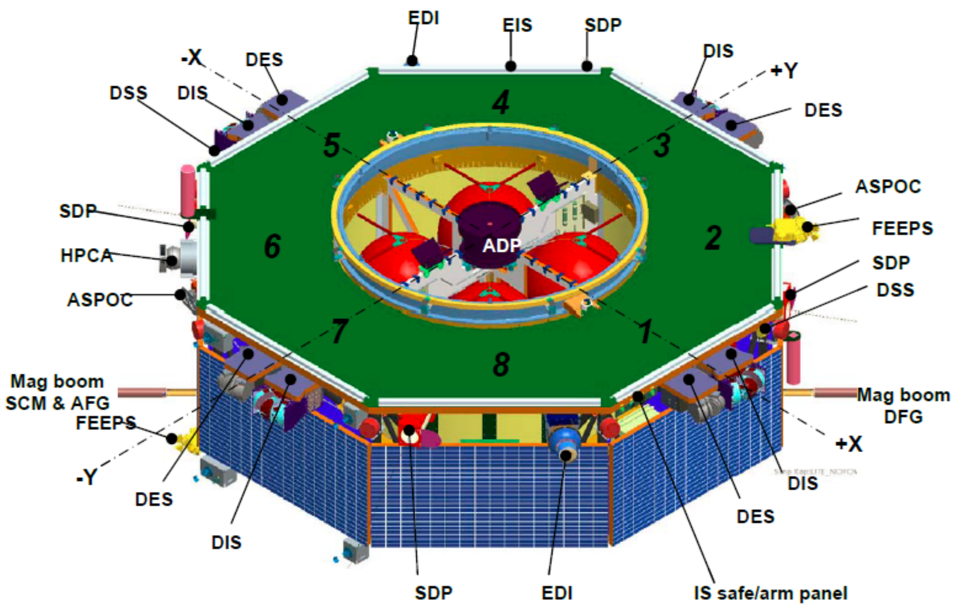
4 spacecraft in formation (tetrahedron) flying able to sample 3D structure of magnetospheric regions (reconnection, particle acceleration, turbulence)

Launched March 12th 2016 (Cap Canaveral, ATLAS)

Low-inclination (28 degree) elliptical orbit with a perigee of 1.2 Earth radii and an apogee during Phase 1 of 12 Earth radii. As the orbit evolves during Phase 1, the spacecraft will sample reconnection sites at different locations on the dayside magnetopause. During Phase 2, the tail reconnection campaign, perigee will remain at 1.2 Earth radii, but apogee will be increased in stages to a final distance of 25 Earth radii.



MMS Spacecraft

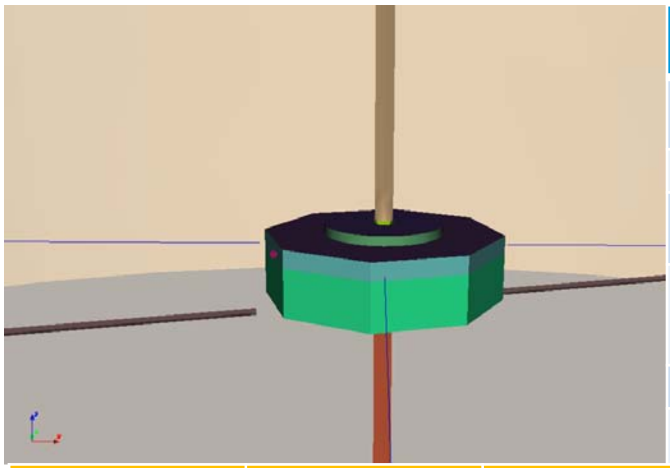


CIDP, IDPU, and CEB are mounted under the IS deck

SMART Components

- ADP - Axial Double Probe
- AFG - Analog Flux Gate Magnetometer (mounted on boom)
- ASPOC - Active Spacecraft Potential Control
- CEB - Central Electronics Box (Fields)
- CIDP - Central Instrument Data Processor
- DES - Dual Electron Spectrometer
- DFG - Digital Flux Gate Magnetometer (mounted on boom)
- DIS - Dual Ion Spectrometer
- EDI/GDU - Electron Drift Instrument/ Gun Detector Unit
- EIS - Energetic Ion Spectrometer
- FEEPS - Fly's Eye Energetic Particle Sensors
- HPCA - Hot Plasma Composition Analyzer
- IDPU - Instrument Data Processing Unit (FPI)
- SCM - Search-Coil Magnetometer (mounted on boom)
- SDP - Spin-Plane Double Probe

SPIS Model



S/C Part	Materials	SPIS Model material
Hub sides (except Solar Arrays)	Germanium Black Kapton	BK2K (Black Kapton – NASCAP)
Solar Arrays	ITOC	ITOC
Inner tube (external surface)	Gold	Gold
Top and bottom s/c faces	Germanium Black Kapton	BK2K
SDP booms	Silver plated braid	SILV
SDP preamp	DAG213 coated Aluminum	BLKC (conductive black paint – Electrodag 501)

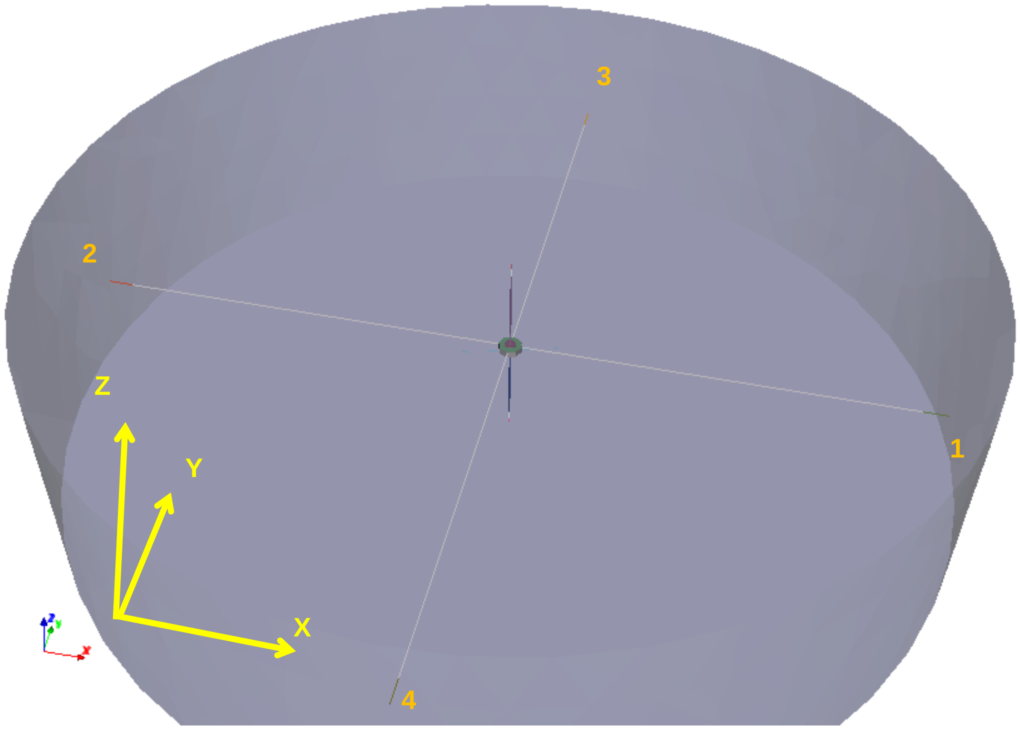
SDP wire	Titanium	AL2K
SDP probe	Titanium	AL2K
ADP boom	Stainless Steel	STEE
ADP outer guard	6061 Aluminum	AL2K
ADP antenna	Aluminum	AL2K
MAG booms	Germanium Black Kapton	BK2K
ASPOCS emitting surfaces	Aluminum	AL2K
ASPOCS blocks	Germanium Black Kapton	BK2K

Secondary (incl. backscattered) emission characteristics are default

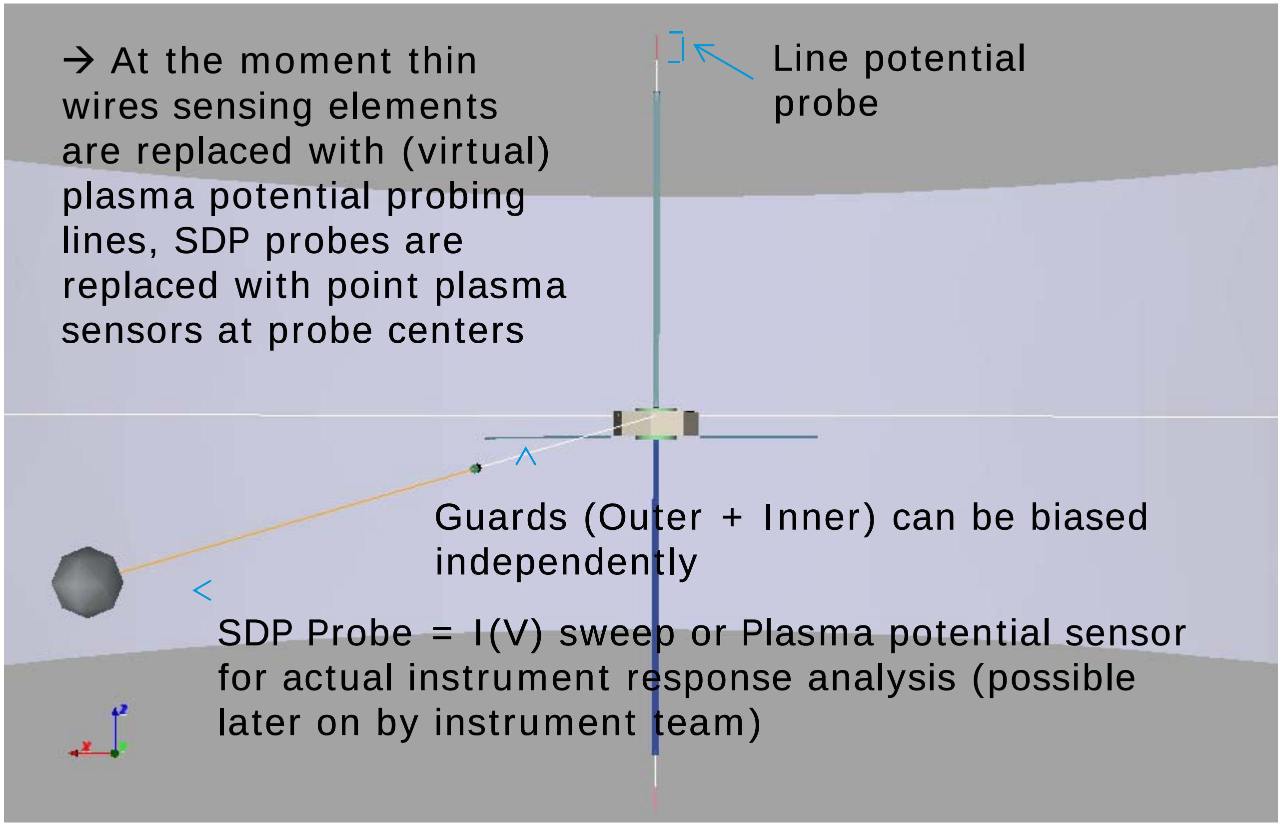
Photoemission characteristics are tuned

All surfaces grounded (except active)

Model Geometry



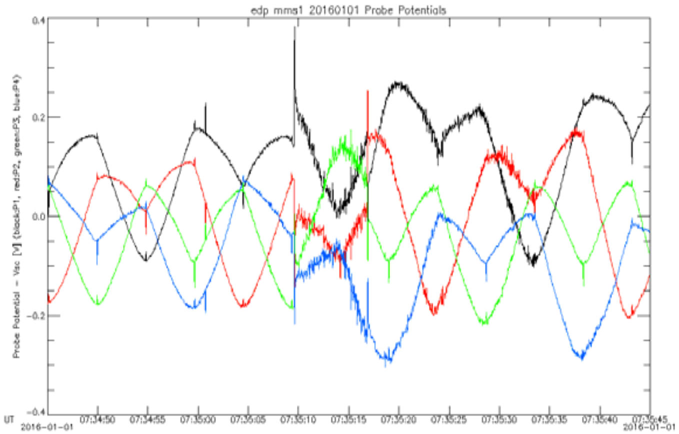
Model Geometry (extended but issues)

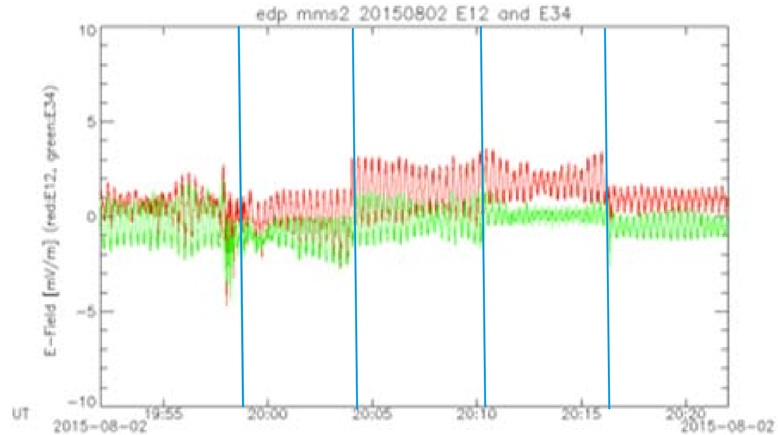


Simulation context - objectives

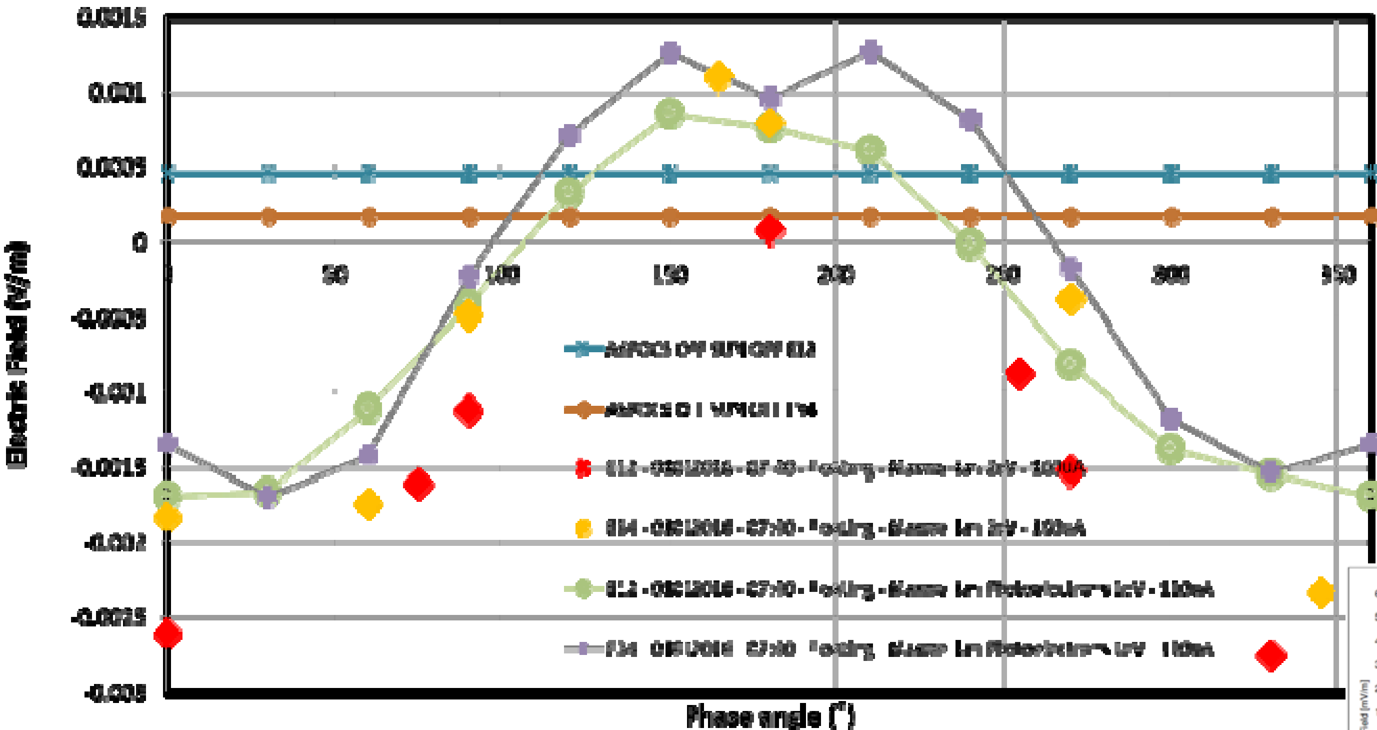
Perturbations in SDP and ADP potentials and electric fields measurements are expected during ASPOCS operations in low density regions. ASPOCS are firing directly in the spin plane.

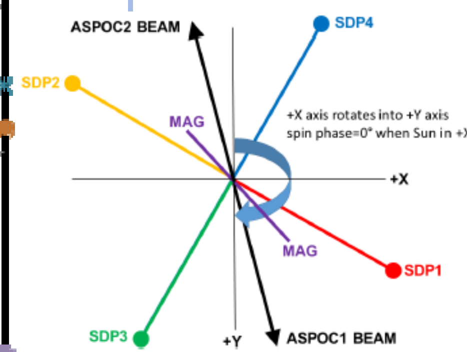
- Electric field offset (ASPOCS ON/OFF)
- Asymmetries during ASPOCS operations
- Noise perturbations (sensitivity ~0.1mV/m)

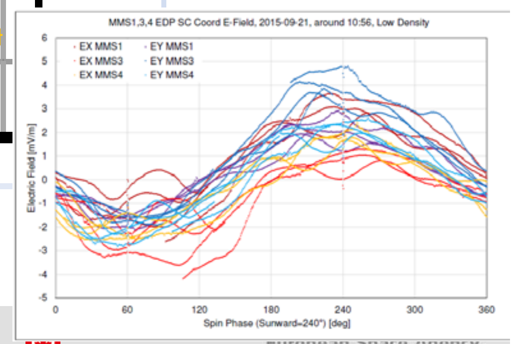




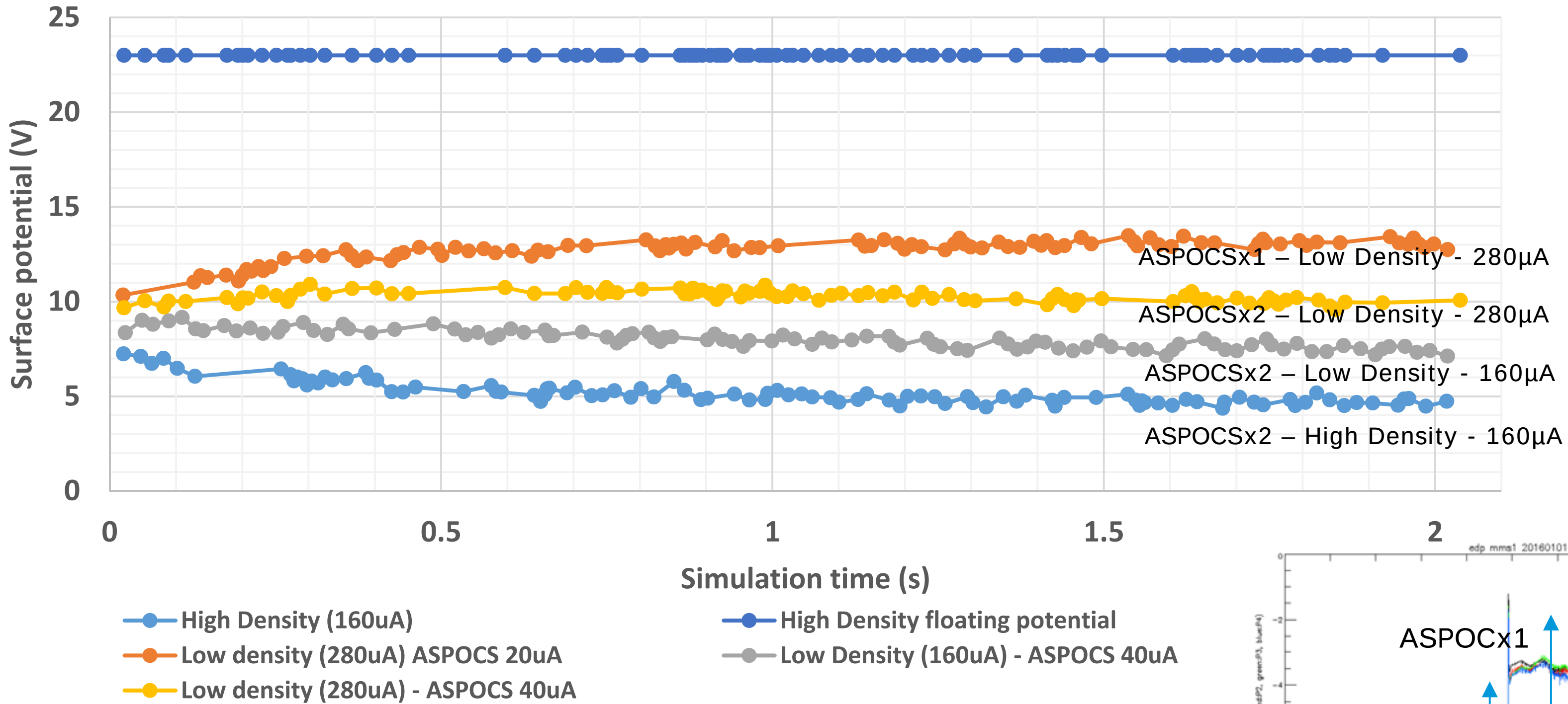
SDP Electric Field phase angle dependence

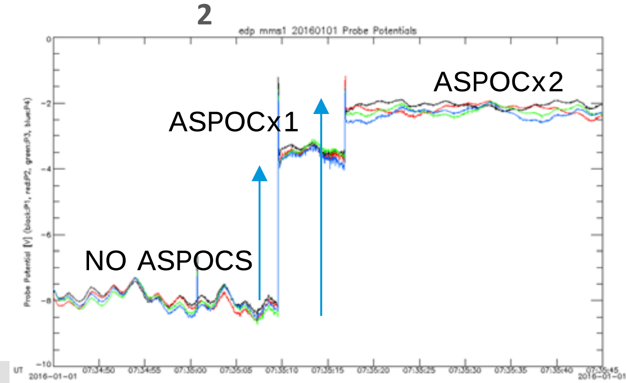






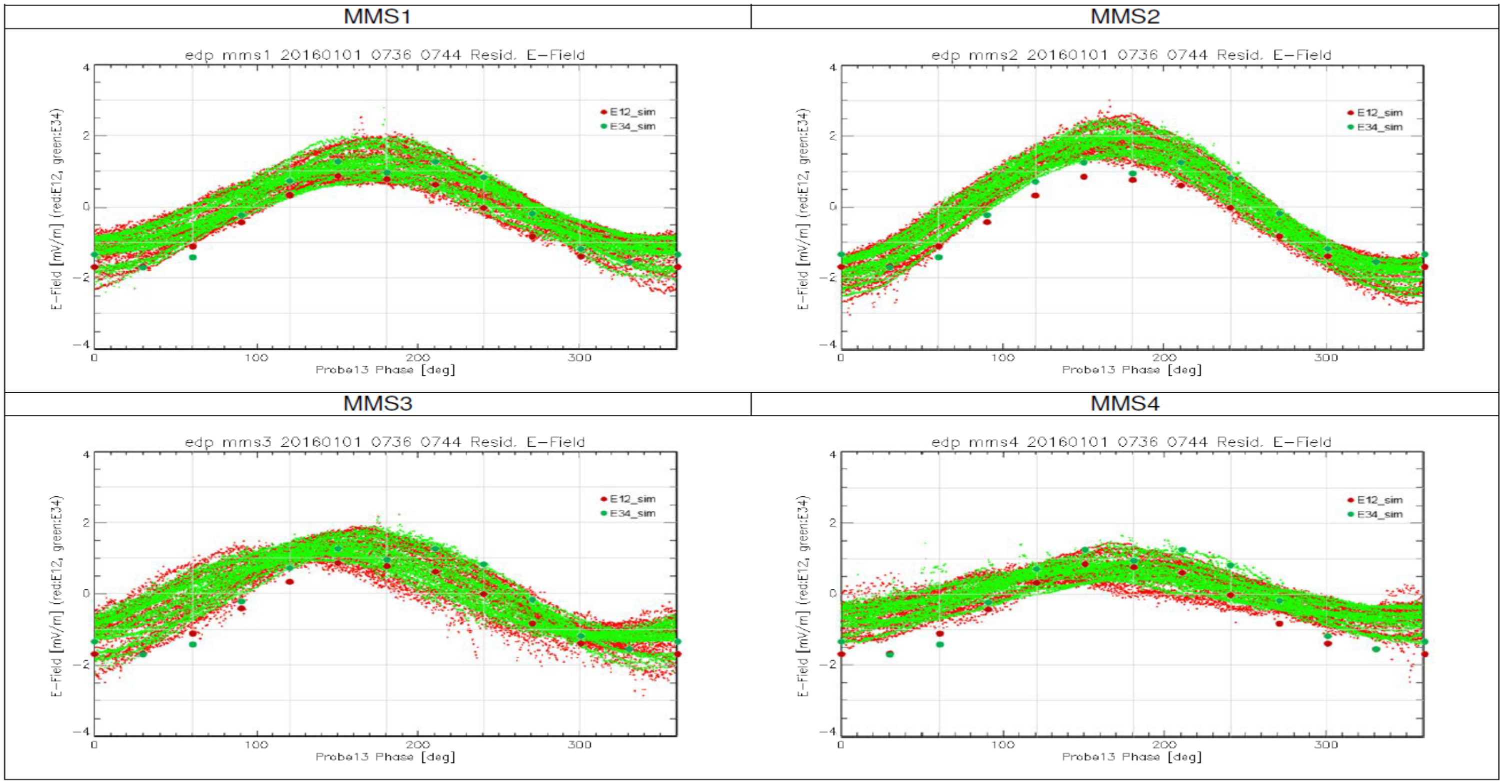
MMS body potential transitions 0 to 2x20uA





SDP data comparison

Spin frequency component only



Cipriani et al, IEEE TPS Special Issue SCTC 2016 (revision ongoing)

Next Steps 2017

- Fix possible geometry issues (Semi-Transparent Grids) on deployable booms
- Analysis of Axial Double Probes
- Sensitivity study towards photoelectrons distributions
- Consolidate comparison with MMS data in Magnetotail
- Include magnetic field
- Investigate possibilities for data correction for ASPOCS on case

THOR – Turbulence Heating Observer

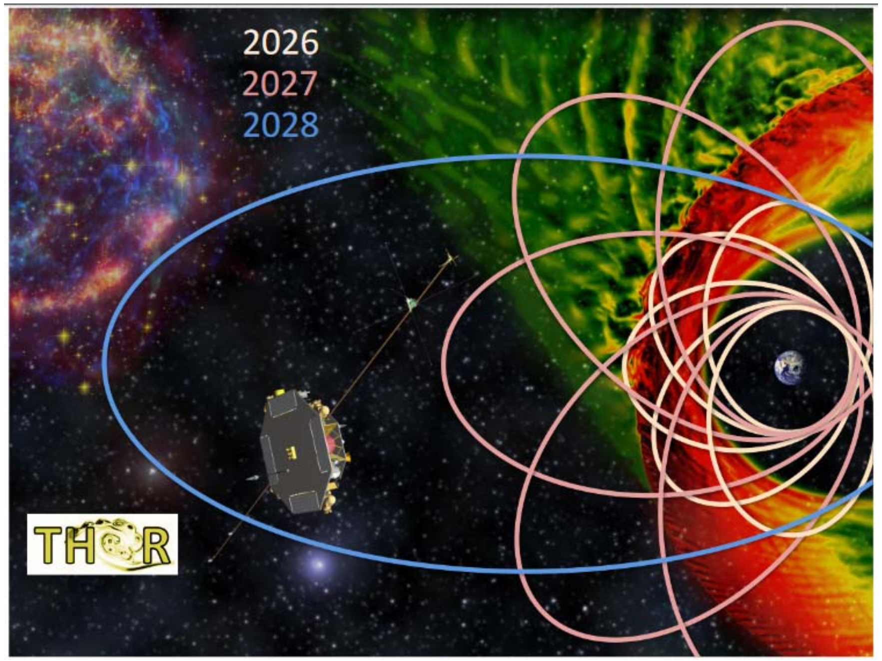
- Mission selected during ESA M4 call (June 2015)
- Phase 0/A ending ~ June 2017, selection to follow (ARIEL and XIPE)
- Launch 2026

To understand:

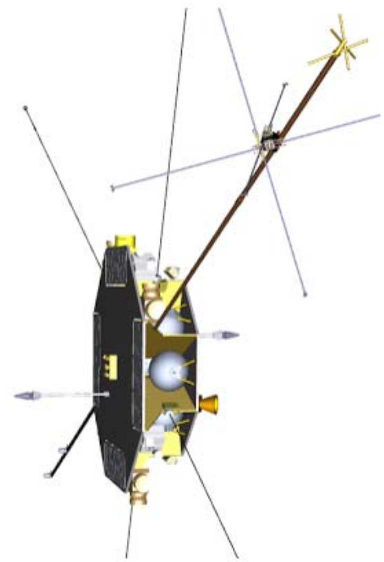
✓ heating processes and particle acceleration by turbulent fluctuations
✓ partitioning of dissipated energy between heating and acceleration of particles
✓ the operation of dissipation in different regimes of turbulence

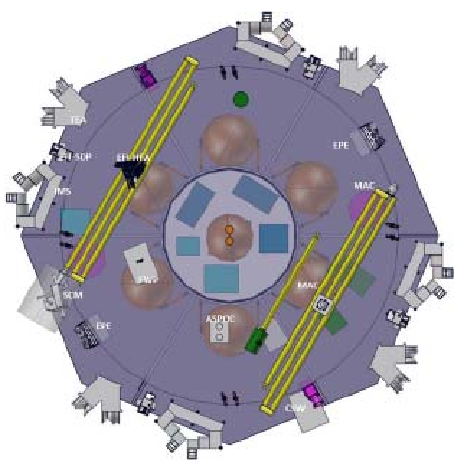
Earth orbiting, orbital plane close to ecliptic, 3 phases:

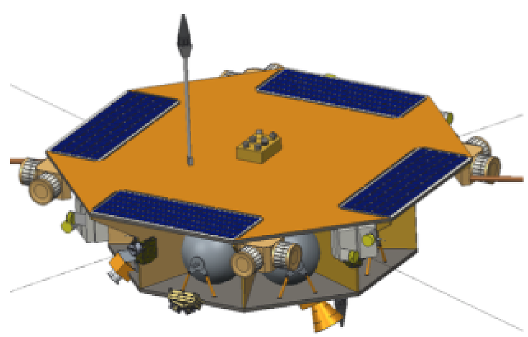
- Year 1 (bow shock / magnetosheath) - 6 x 15 Re
- Year 2 (solar wind / foreshock) - 6 x 26 Re
- Year 3 (solar wind / interplanetary shocks) - 6 x 45 Re

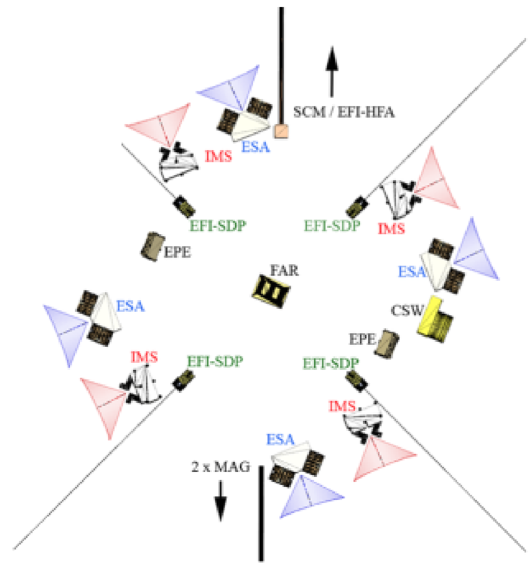


	Instrument	Measurement	Teams (PI, Co-PI, *Lead-CoI*)
FIELDS	**MAG**	B field DC	IWF(AU), ICL(UK)
	SCM	B field AC	LPP(FR), LPC2E(FR)
	EFI	E field DC/AC	IRF(SE), SSL(US), *SRC-PAS(PL), KTH(SE)*
	FWP	E&B data products	IAP(CZ), SRC-PAS(PL), *U.Sheffield(UK), LESIA(FR)*
PARTICLES	**ESA**	e^- spectrometer	MSSL(UK), NASA/GSFC(US)
	CSW	Cold solar wind ions	IRAP(FR), BIRA-ISAB(BE)
	IMS	H^+, He^{++}, He^+, O^+	LPP(FR), UNH(USA), *ISA/JAXA(JP), MPS(DE)*
	PPU	Particle data products	INAF-IAPS(IT)
	FAR	Faraday cup	MFF(CZ)
	EPE	Energetic particles	IEAP(DE), U.Turku(FI)









S/C potential estimates

- Solving current balance equation Ie + Iph + Ii(drifting) + Iaspocs=I(Vsc)
- Assuming various photoelectrons current laws (see IEEE paper)

- J(Vsc) = Jph*$e^{-eVsc/kTph}$ (Maxwellian)

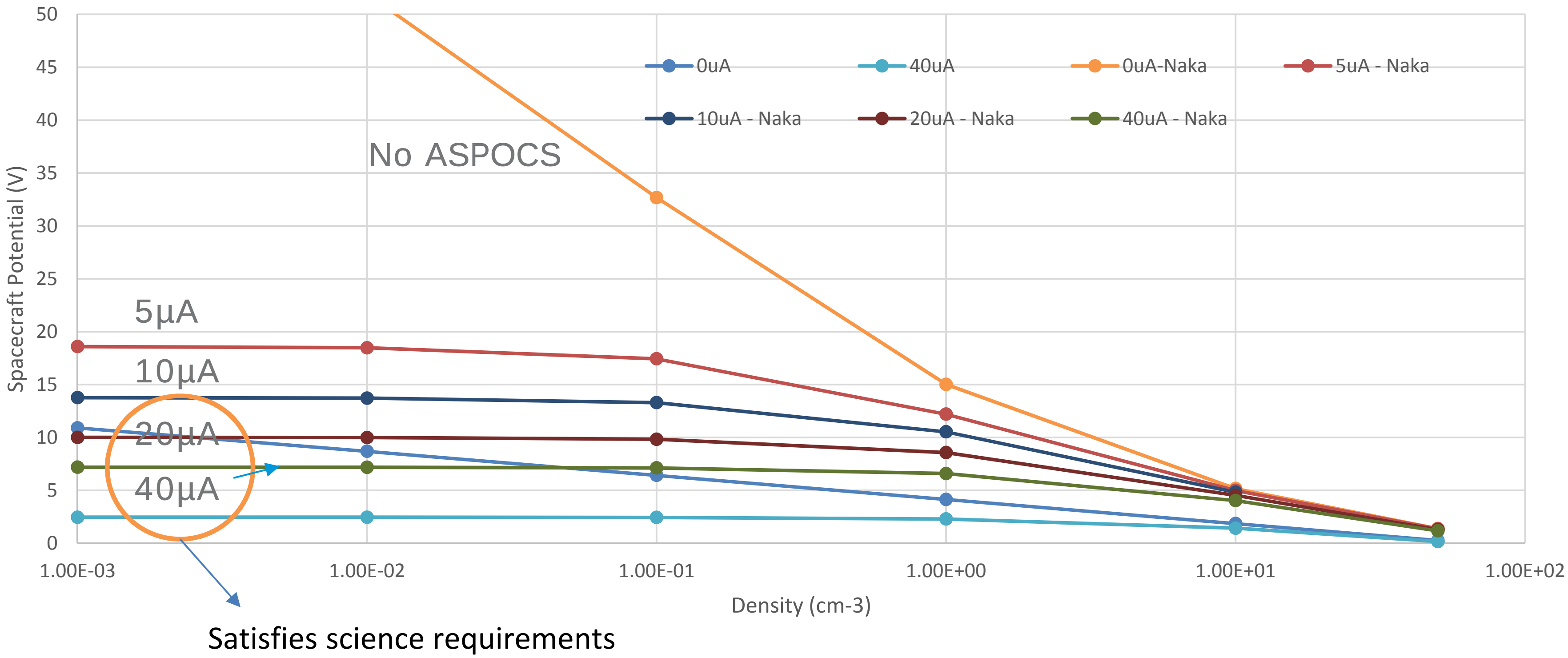
$$J(\phi_{sc})\ [\mu\mathrm{Am}^{-2}] = 53\exp\left(-\frac{\phi_{sc}}{1.6}\right) + 21\exp\left(-\frac{\phi_{sc}}{3.0}\right) + 4\exp\left(-\frac{\phi_{sc}}{8.9}\right), \quad (22)$$

GEOTAIL (5 years data)

- Jph = 85*exp(-Vsc/0.92) + 7.8*exp(-Vsc/4.16) + 2.4*exp(-Vsc/10.0) Cluster (spring 2002)

- ASPOC currents

Example in Magnetosheath (Te=100 eV)



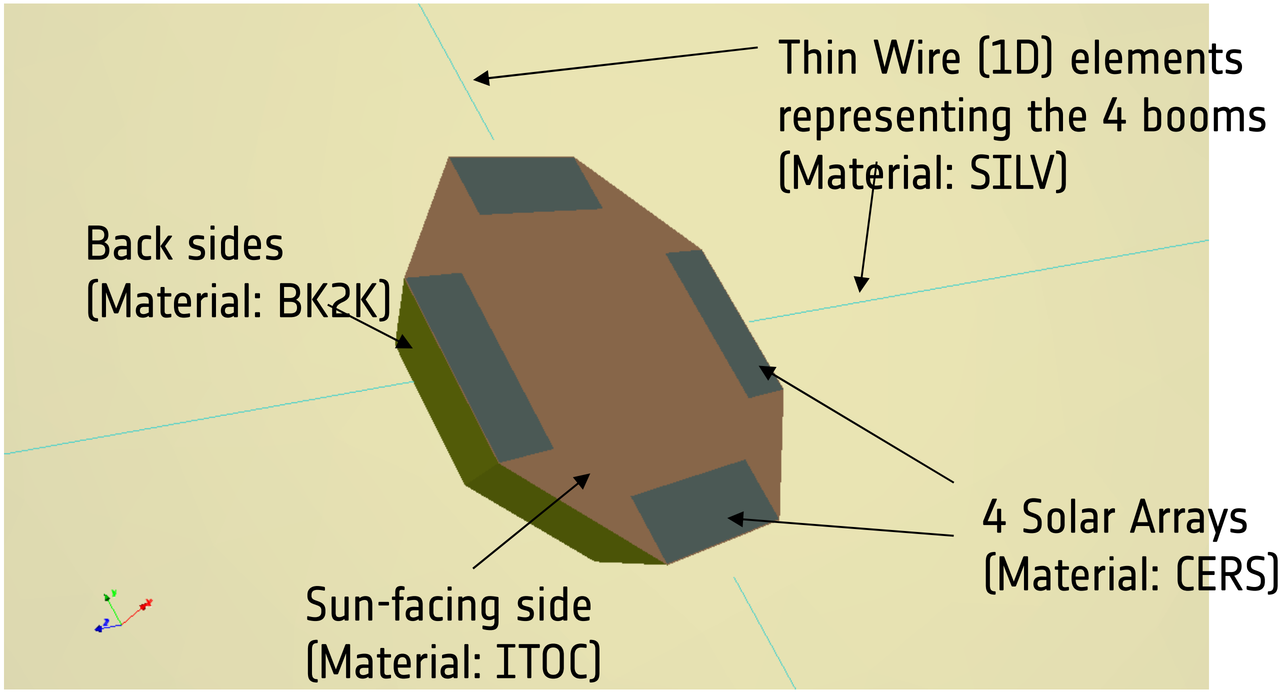
Example in Solar Wind

Floating potential	Fast SW (600km/s)	Slow SW (350km/s)
ne = 10cm-3	18.20	17.71
ne = 1cm-3	7.88	7.62
ASPOCS 1x20uA	Fast SW	Slow SW
ne = 10cm-3	9.26	9.20
ne = 1cm-3	6.41	6.25

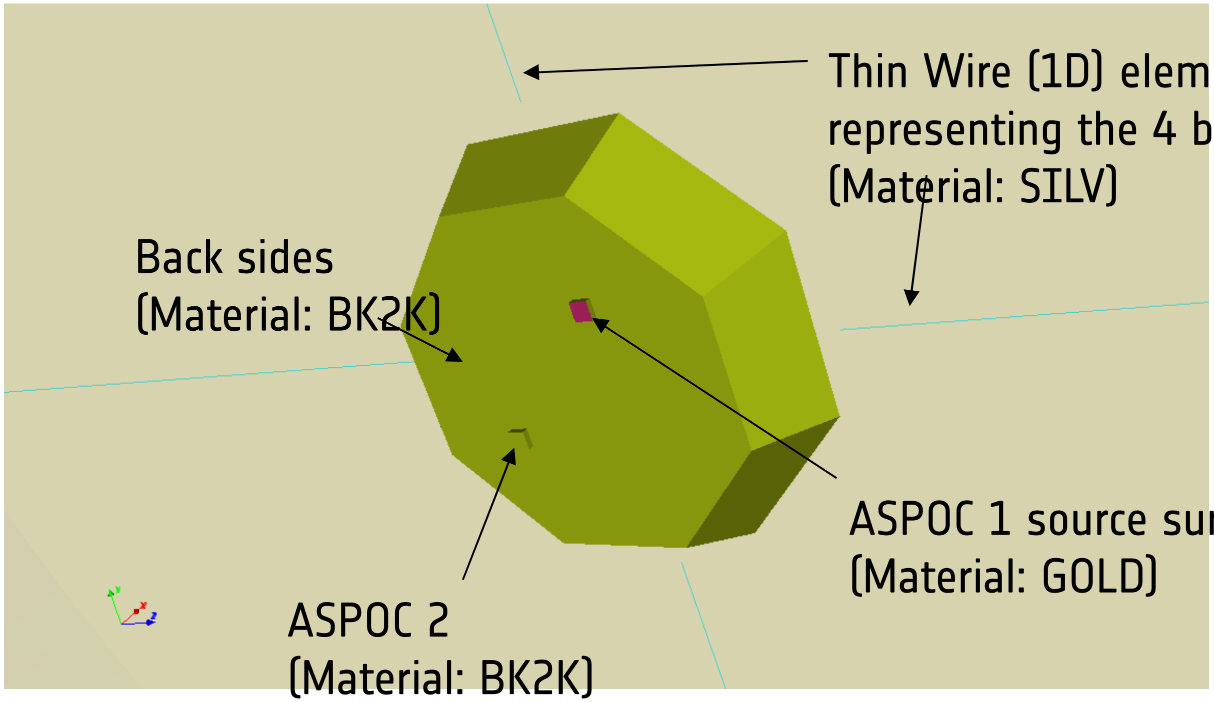
SPIS simulations : Vsc ~8.3 (noise±0.2V) with 1x20μA to Vsc ~6.5 with 2x20μA in Slow SW (with ne=6.5cm^{-3})

ASPOC current > 20μA needed to satisfy science requirements (Vs/c<10V)

THOR spacecraft model : sun facing

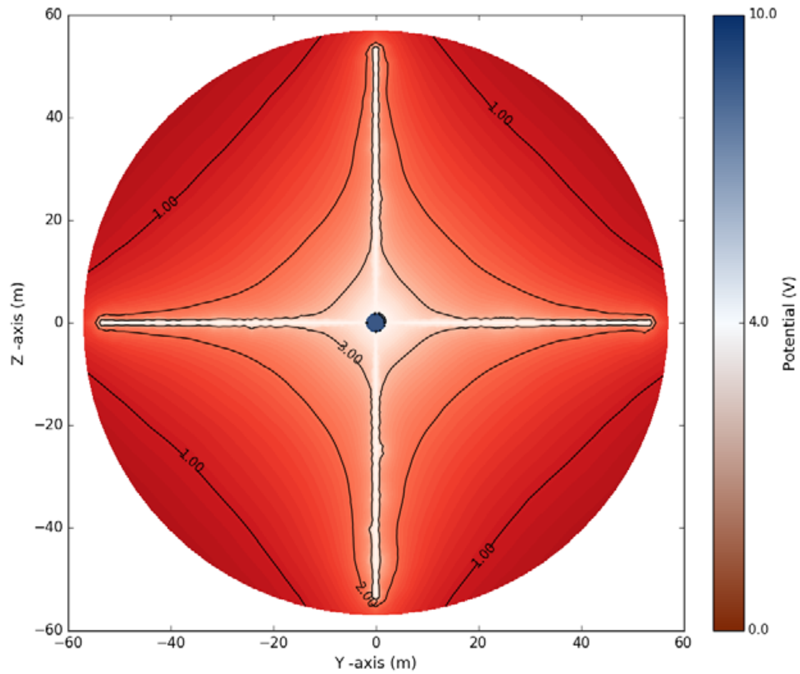


THOR spacecraft model : aspocs side

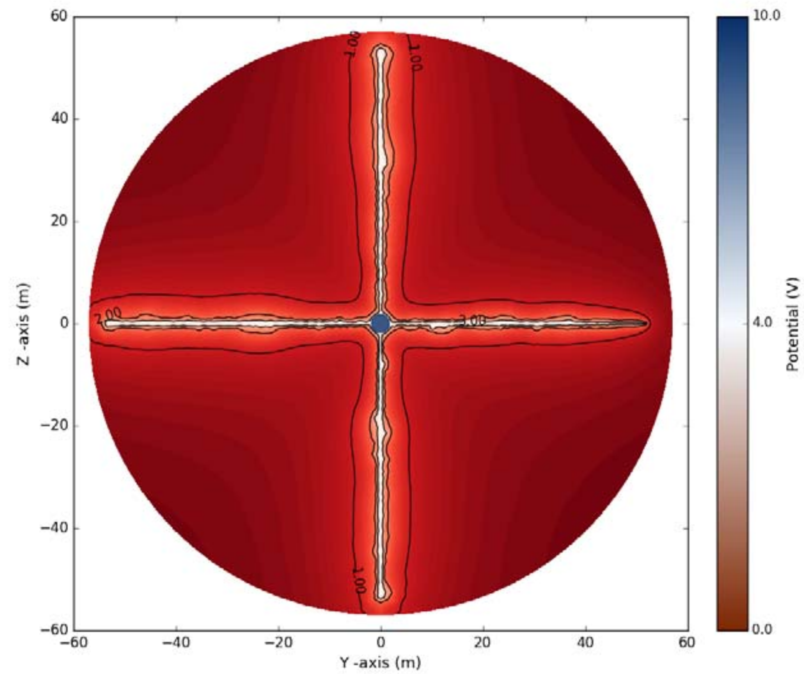


THOR: Eclipse vs. Sunlight test simulations with ASPOC ON (I=10μA)

Potential cuts in YZ-plane



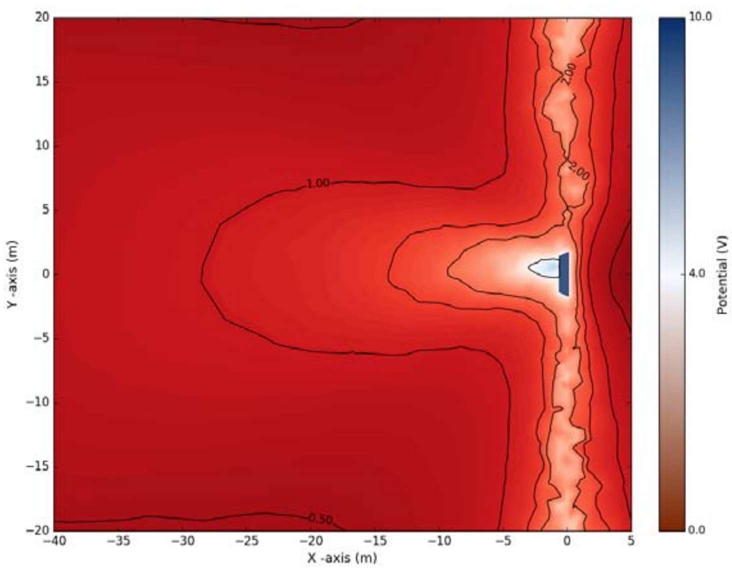
Eclipse



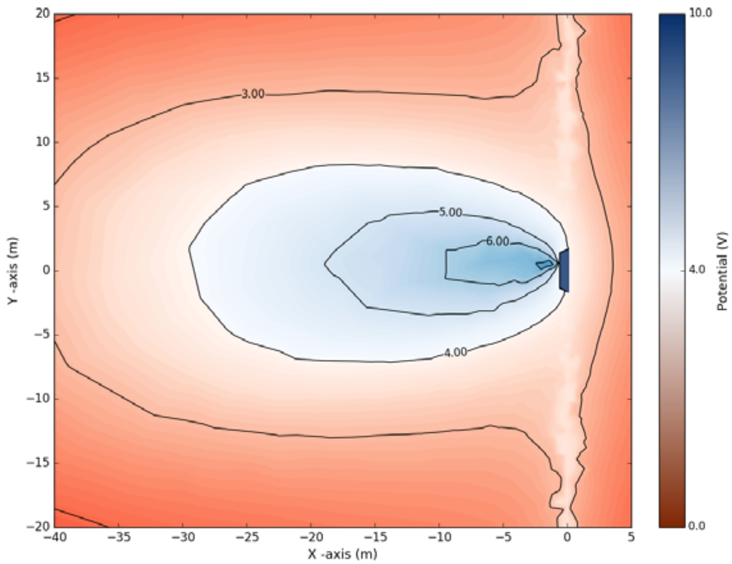
Sunlight

THOR: Eclipse us. Sunlight test simulations

Plume potential reduction due to photoelectrons

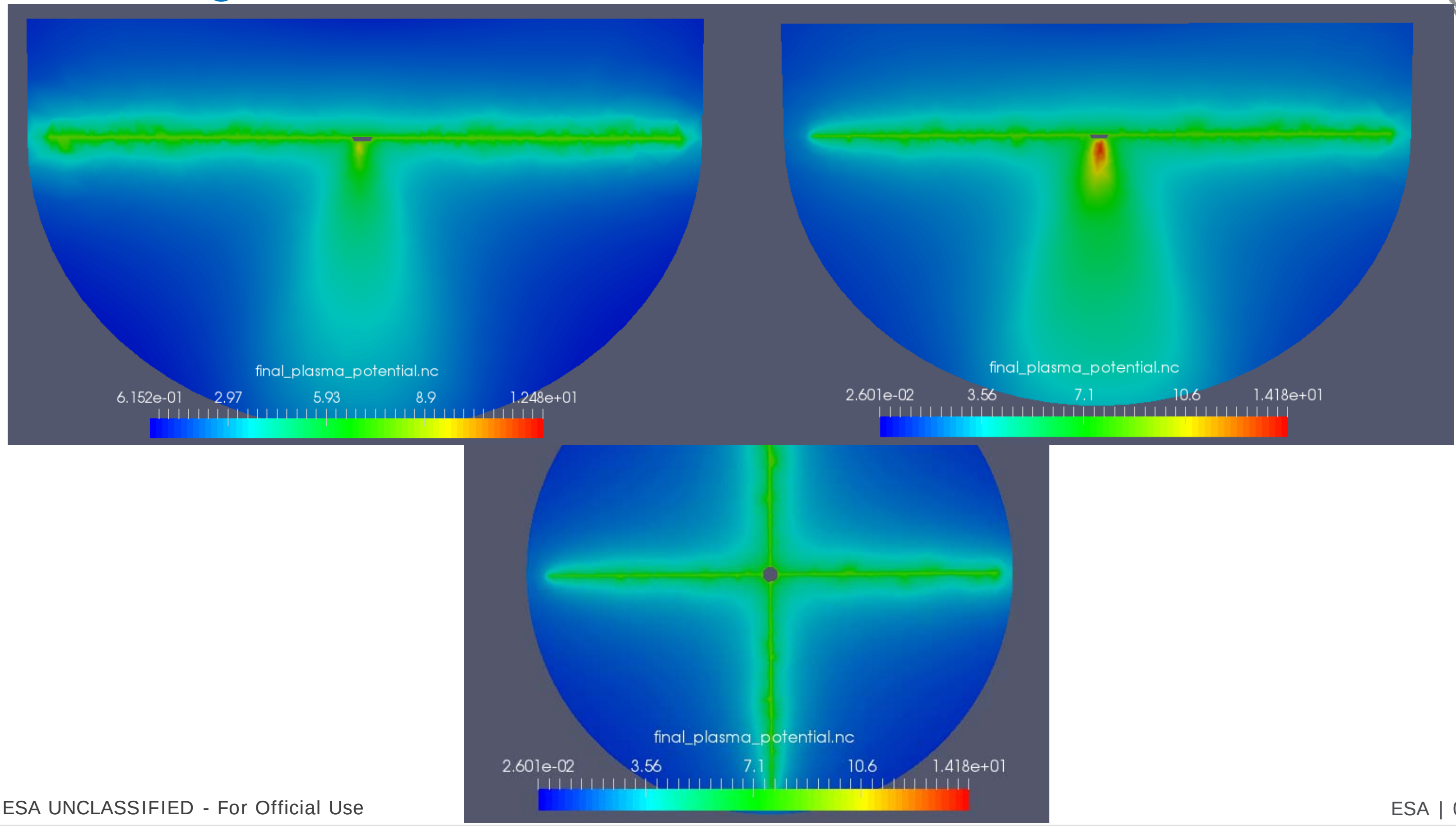


Sunlight



Eclipse

Floating S/C



final_plasma_potential.nc
6.152e-01
2.97
5.93
8.9
1.248e+01
final_plasma_potential.nc
2.601e-02
3.56
7.1
10.6
1.418e+01
final_plasma_potential.nc
2.601e-02
3.56
7.1
10.6
1.418e+01

Summary

- sensitivity study wrt photoelectrons distributions
- MMS : best fits and model prediction for data analysis correction (s/c geometry with probes to be given to IRFU)
- THOR : floating potentials predictions and ASPOCS characteristics sizing
- R&D activity on Electrostatic Cleanliness of Ion emitting spacecraft to follow in the next 2 years (start 2018)

→ improved plume models (reduce uncertainties on plume potential)

→ impact on E-field instruments

→ Possibly investigate EM solver