Spacecraft potential controller (ASPOC) on the Magnetospheric MultiScale (MMS) mission Comparison between observations and simulations

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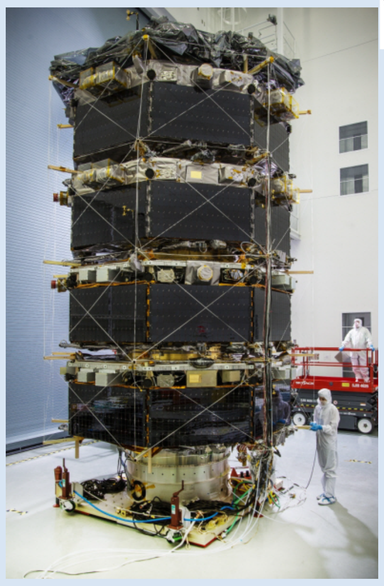
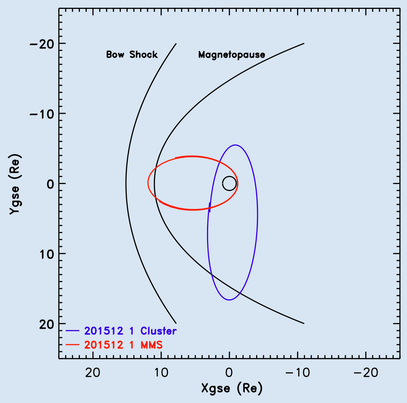
1 Introduction

- The NASA Magnetospheric Multiscale (MMS) mission is a Solar-Terrestrial Probe mission comprised of four identically instrumented spacecraft that is using the Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. MMS was launched in March 2015.
- The Active Spacecraft Potential Control (ASPOC) system, based on the emission of an ion beam, is used to reduce the platform electrostatic potential from 10s of volts to a few volts positive while the spacecraft is operating in tenuous plasma environments.
- A 3D numerical model of MMS has been built in order to characterize the electrostatic environment of the spacecraft during ASPOC operations. A recent finding, during ASPOC operations, was the correlation between the spacecraft potential and the ambient electric field. Preliminary results from a simulation including the electric field are presented.

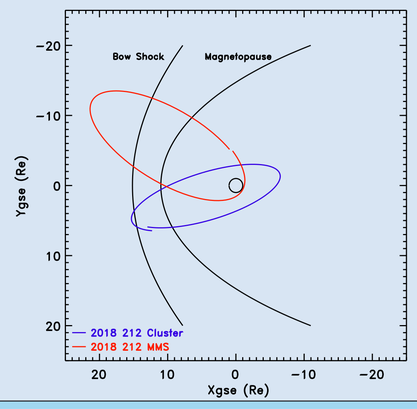
2 MMS: four identical spacecraft in launch configuration



3 MMS and Cluster orbits

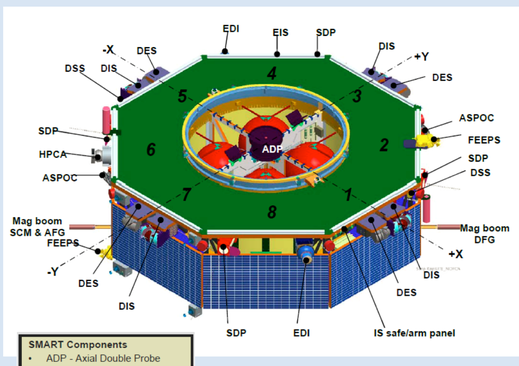


2015
1 Dec.



2018
12 Feb

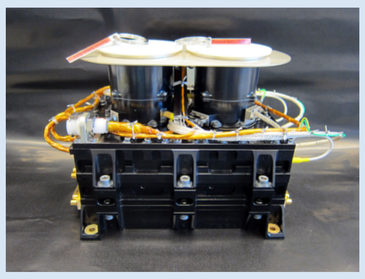
4 Spacecraft structure and instruments



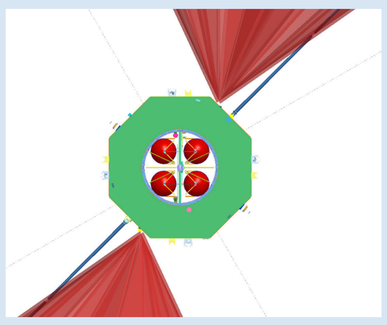
SMART Components

- 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

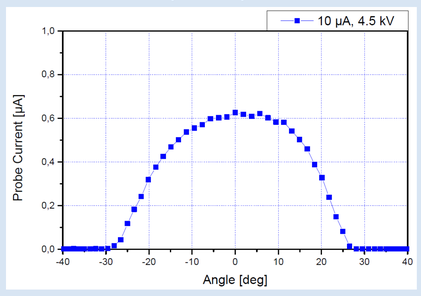
ASPOC instrument



5 ASPOC ion beam direction

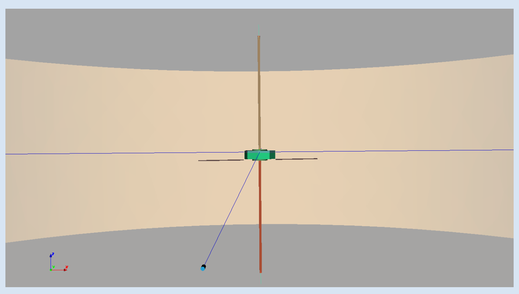


Beam envelope at 10 μA
Indium ions, 4.5keV, FWHM=20°

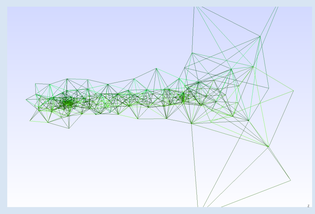


Currently 10 μA used

6 Spacecraft model in PIC simulation



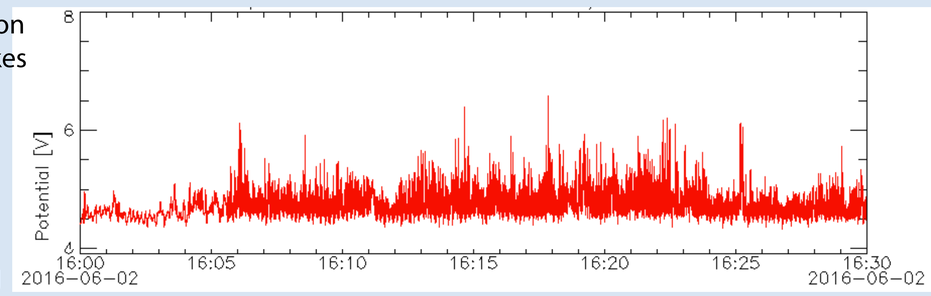
- Spacecraft shape and surfaces properties as close as possible to reality
- Four wire booms 120m tip to tip
- Two axial booms 30 m tip to tip
- Two magnetometers booms (5 m each)



- Mesh:~400000 tetrahedrons of 1m and 0.1m
- $2x10^6$ plasma electrons and ions (each)
- $4x10^6$ photoelectrons

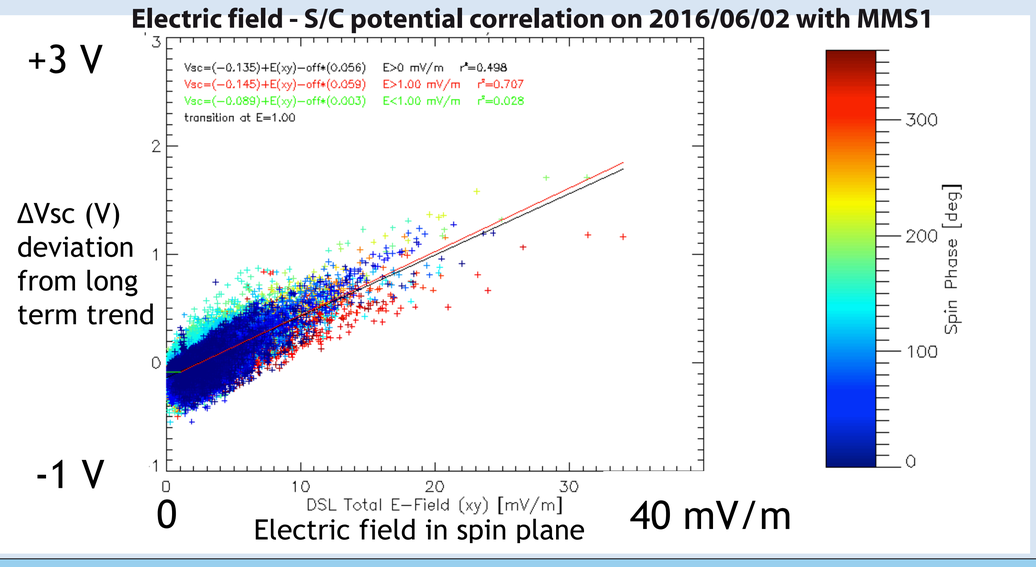
7 Spacecraft potential on 2016/06/02 with MMS1

High time resolution data show Vsc spikes not related to Ne



but to Electric field

Electric field - S/C potential correlation on 2016/06/02 with MMS1

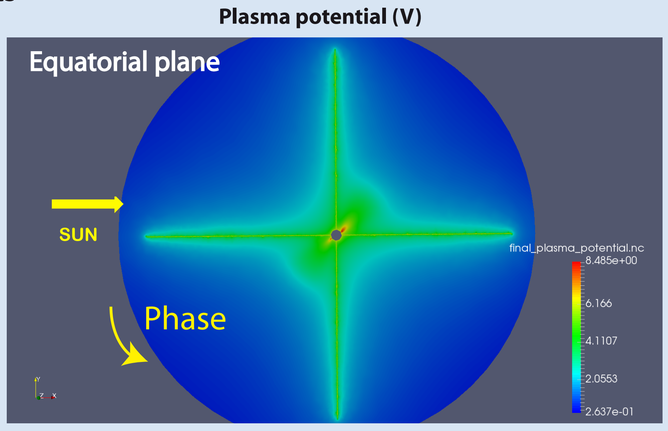


8 Simulation results

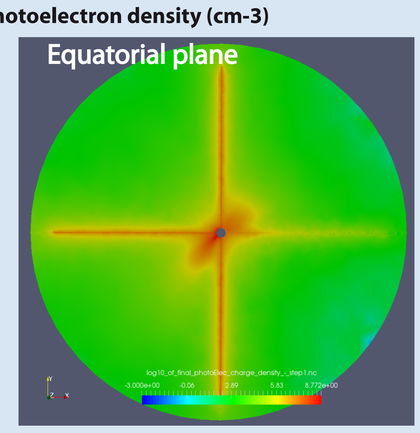
Simulation for 2016/08/14 event:
- ASPOC current: 2x10 μA
- $n=0.6\ cm^{-3}$
- Te=500 eV

- New: By=70 nT
- New: Vz= 70 km/s, Ex=5mV/m

Plasma potential (V)



Photoelectron density (cm-3)

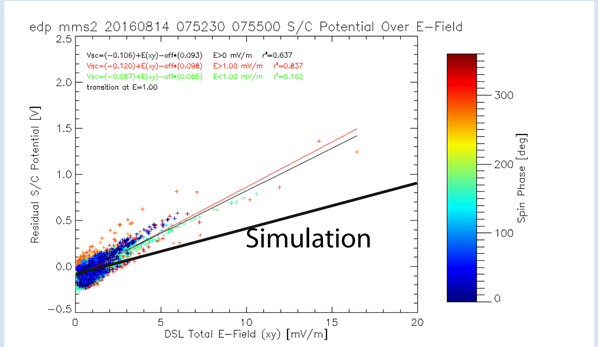


9 Comparison: MMS2 data and simulations

(multiple runs to simulate three electric field intensities)

E field (mV/m)	Vsc (V) (0 phase angle)
0mV/m	5.27
50mV/m	6.78
100mV/m	10

Vsc=0.047*Efield+4.98 (R=0.98)



Simulations, although underestimating the effect, observe also correlation between Spacecraft potential and Electric field

10 Summary and conclusion

- MMS has embarked ASPOC instruments to reduce the spacecraft potential and its effect on low energy plasma measurements (already observed)
- While beneficial for plasma instrument it alters the electric field (EFI) measurements (although not seen all the time) since the beam is fired in between the electric field booms
- Here we study the effect of ASPOC on EFI using Particle-in-cell (PIC) simulations using the Spacecraft Plasma Interaction Software (SPIS).

- We made new runs for the new plasma regions visited by MMS (magnetotail and lobes in summer 2016)
- An unexpected correlation between the ambient electric field and the spacecraft potential was observed in MMS data (also seen on Cluster afterwards)
- Magnetic field was successfully included in the simulations
- Electric field was successfuly included in the simulations
- Correlation between ambient electric field and spacecraft potential was observed in simulations, although with a smaller slope

Future work:
- include the probes (including bias current) at the end of the wire boom
- repeat above simulations and check if probes play a role in the electric field-spacecraft potential relation
- correct ASPOC effects on electric field measurements and derive density from spacecraft potential measurements when ASPOC is on