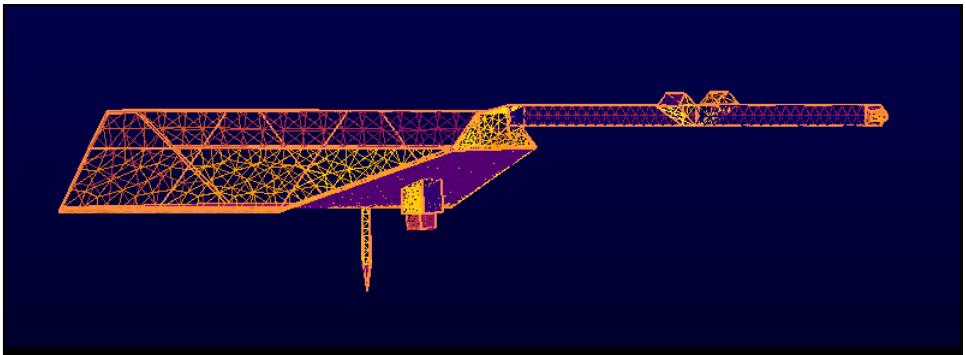

# CHAMP and SWARM Modelling

SPINE Meeting
13-14 November 2008
ESTEC

David Rodgers / ESTEC
Simon Clucas / ESTEC
Julien Forest / Artenum
Jean-Francois Roussel / ONERA

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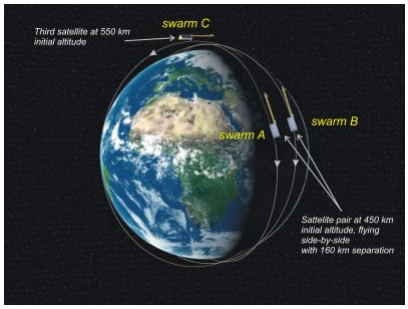
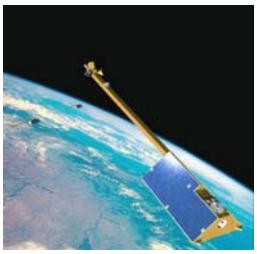
## SWARM

- 3-satellite mission
- Polar orbits
- 400 to 550km altitude
- Goal: Precise high-resolution B-field measurements



- CHAMP-like satellites
- Ram-facing conductive plate?

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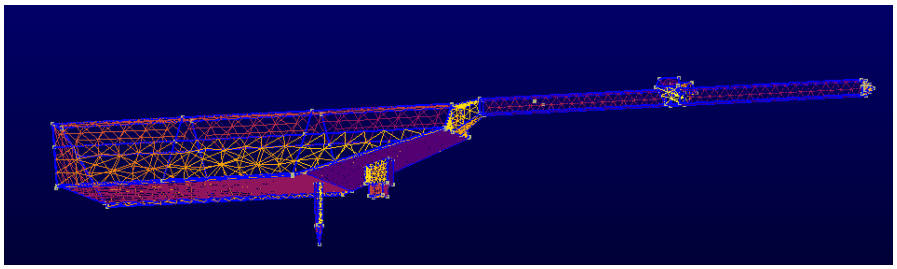
## SWARM analysis

- The goals of this study were to assess:
  - the floating potential of the spacecraft
  - the electric fields in the vicinity of the electric field instrument.
  - the changes that would be expected if there were no conductive plate, or if the plate were smaller
  - the effect of using a paint that was not as conductive as a metal



## Modelling CHAMP



Gmsh model input to SPIS

| **Surface Properties** | **Global parameters** |
|---|---|
| CERS | Ions=PIC |
| Teflon | Electrons=Global Maxwell Boltzmann |
| Aluminium Oxide | Vel=7710 m/s |
| Kapton | IonType = O+ |
| BLKC | |

## CHAMP inputs

- Three charging regimes were chosen from the environment data experienced by CHAMP
- Ion temperature was not available. IRI2001 indicates that this is nearly constant around 770K

| Case | Te (K) | Ti (K) | ni=ne density (/m3) | Sun/ Eclipse | Sun direction | Phi (V) |
|---|---|---|---|---|---|---|
| A | 994 | 770 | $2.74 \times 10^{11}$ | Sunlit | +y | -1.106 |
| B | 1984 | 770 | $8.64 \times 10^{11}$ | Sunlit | +y | -1.002 |
| C | 1719 | 770 | $4.46 \times 10^{11}$ | Sunlit | +y | -0.863 |

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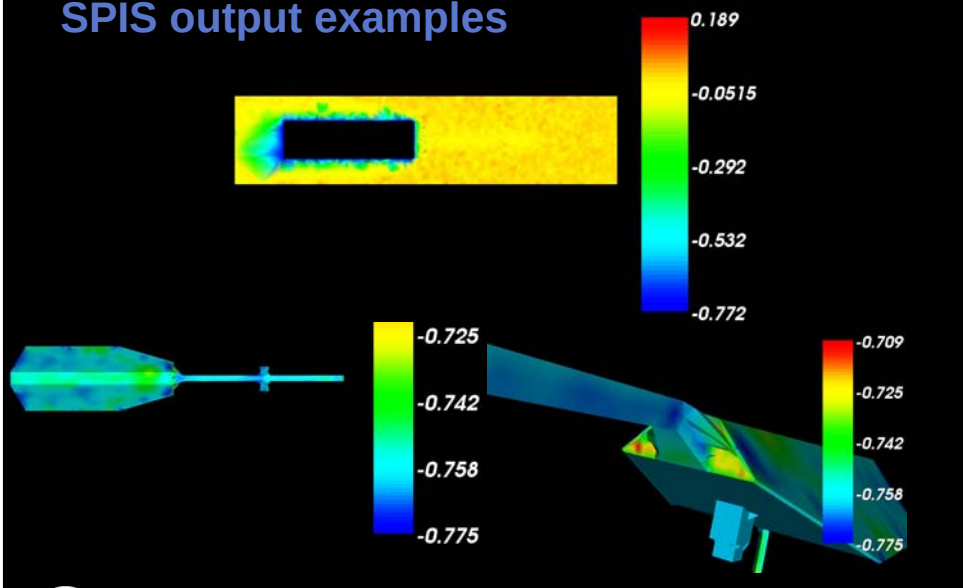
## SPIS output examples

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## CHAMP results

- In cases A, B and C, floating potential was the same in eclipse as in sunlight
  - i.e. floating potential was dominated by ion ram and thermal electron collection – photo-emission was of minor importance.
  - all floating potentials were negative

| Case | Te (K) | Ti (K) | Ion density (ions/m3) | Obs. (V) | SPIS (V) |
|---|---|---|---|---|---|
| A | 994 | 770 | $2.74 \times 10^{11}$ | -1.106 | -0.340 |
| B | 1984 | 770 | $8.64 \times 10^{11}$ | -1.002 | -0.685 |
| C | 1719 | 770 | $4.46 \times 10^{11}$ | -0.863 | -0.612 |

- SPIS simulated potentials less negative than observations
- However, Vsat does not have the expected relation to Te

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## SWARM Environment

| Case | Plasma density (cm-3) | Electron Temp. (eV) | Ion Temp. (eV) | Debye length (mm) |
|---|---|---|---|---|
| A | $1.24 \times 10^{6}$ | 0.116 | 0.083 | 2.27 |
| B | $1.75 \times 10^{5}$ | 0.232 | 0.131 | 8.53 |
| C | $5.72 \times 10^{5}$ | 0.125 | 0.109 | 3.46 |
| D | $8.88 \times 10^{4}$ | 0.237 | 0.144 | 12.1 |

- High and low densities were chosen for max and min altitude from IRI
- Velocity = 7700km/s
- Ions = $O^{+}$

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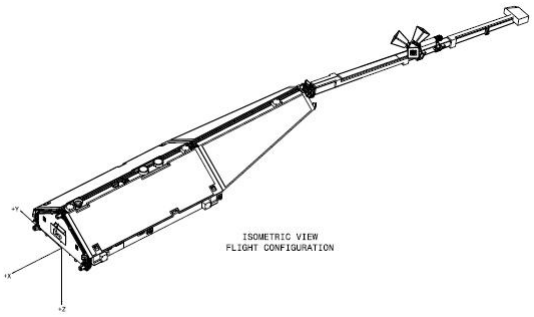
## SWARM




- Ram plate (0 to 0.35m2)
- Solar array
  - 64 strings of 24 cells. $V_{max}$ -60V, 0.075m$^2$ exposed conductor
  - There are 7860 interconnects and 128 string ends



## Modelling SWARM potential

- We cannot simulate the individual interconnects
- 2mm characteristic size compares with $\lambda_D$ from 2 to 12mm
- Amalgamating the interconnects may change the nature of the current collection
- Three approaches
  - Bound problem with thin and thick sheath approximations
  - Model interconnector to find I(V)
  - Model 3-d spacecraft

## Thin/Thick sheath approach

- Thin and thick sheath approximations for attracted species
- Boltzmann for repelled species
- Ion collection to ram given by spacecraft velocity

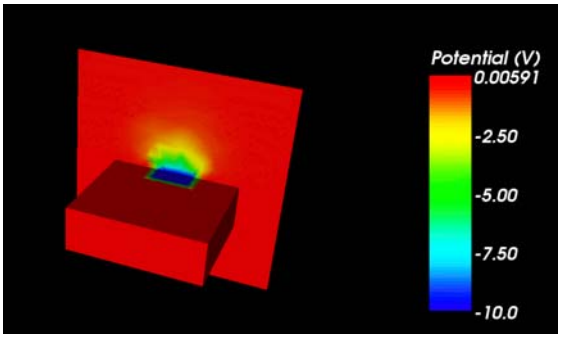
| Plate size $m^2$ | Environment | Photoemission | Potential (V) (thin sheath) | Potential (V) (thick sheath) |
|---|---|---|---|---|
| 0.35 | A | Yes | -0.238 | -0.082 |
| 0 | A | Yes | -0.412 | +0.592 |

- Potentials between +0.6 and -1.0V



## Interconnector modelling approach

- I-V curve simulated with PIC simulation

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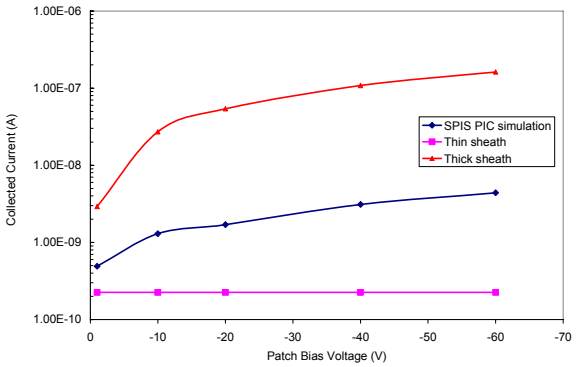


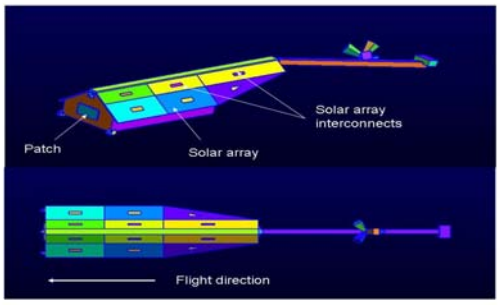

- Case A
- I(V) resembles thick sheath case divided by 10.
- I(V) closer to thin sheath than thick sheath

| Plate size m² | Environment | Photoemission | Potential (V) (thick sheath adjusted by factor 10 ) |
|---|---|---|---|
| 0.35 | A | Yes | -0.209 |
| 0 | A | Yes | -0.051 |

- Potentials between -0.5 and -0.05V

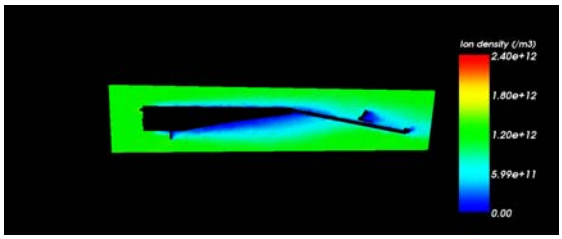


## 3-D SPIS Modelling

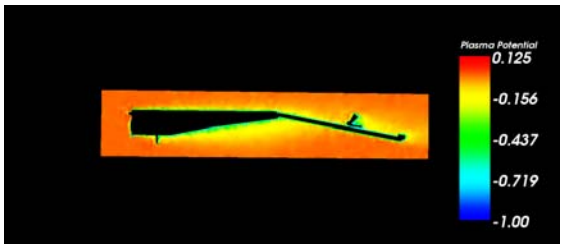



| Case | Plate $m^2$ | Photo-emission | Potential (V) Theoretical Thin sheath full | Potential (V) (thick sheath adjusted by factor 10 ) | Potential (V) SPIS |
|---|---|---|---|---|---|
| A | 0.35 | Yes | -0.238 | -0.209 | -0.23 |
| A | 0 | Yes | -0.412 | -0.051 | -0.065 |

Potentials between -0.2 and -0.6V




Case D

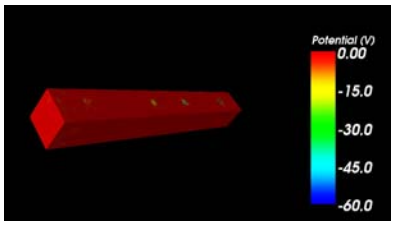





# Ram plate calculation

| environment | photoemission | Plate m2 |
|---|---|---|
| A | Yes | 0.14 |
| B | Yes | 0.065 |
| C | Yes | 0.11 |
| D | Yes | 0.06 |

Equating electron and ion current (thick sheath)




| Enivironment | photoemission | Plate m2 | Potential (V) |
|---|---|---|---|
| A | Yes | 0.35 | -0.25 |
| A | Yes | 0.125 | -0.24 |
| A | Yes | 0.05 | -0.25 |
| A | Yes | 0.01 | -0.4 |
| A | Yes | 0 | -0.42 |

| Enivironment | photoemission | Plate m2 | Resistance Ohms/square | Potential |
|---|---|---|---|---|
| A | Yes | 0.125 | 200 | -0.25 |
| A | Yes | 0.125 | 800 | -0.25 |
| A | Yes | 0.125 | 2.0E3 | -0.27 |
| A | Yes | 0.125 | 2.0E4 | -0.42 |

# Conclusions

- With a ram plate of sufficient size, the spacecraft will remain negative in the region of -0.2 to -0.6V
- With no ram plate, the floating potential will lie within the thin and thick sheath approximations, +0.6 to -1V
  - Potential will likely be -0.05 to -0.5V.
  - No high positive potentials because 1/3 of the array conductive surface is at spacecraft ground.
  - However, small design changes my affect this result
- SPIS simulations show that even for the longest Debye length case (D), it is possible to get away from the influence of the spacecraft with a probe boom of a few cm.
- To be certain of remaining in the “ram dominated” situation you need
  - a plate size of around 0.14m$^2$
  - a plate resistance of less than 1.7x10$^3$ Ohms/square

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THE END

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