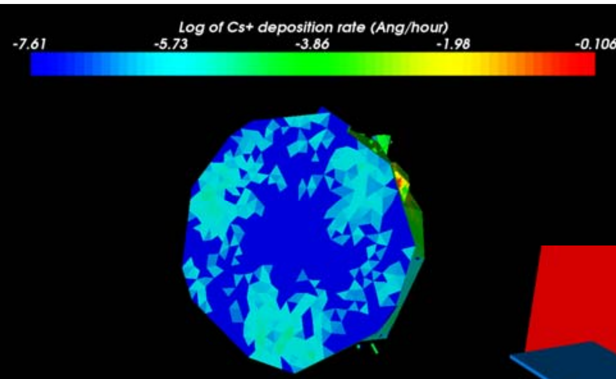
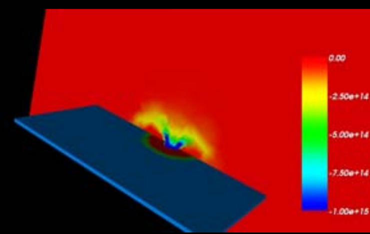




Lisa Pathfinder Contamination Study

David Rodgers / ESTEC
Simon Clucas / ESTEC
Bjarne Andersson / SSC

SPINE Meeting
13/14 Nov 2008
ESTEC

Introduction

- Brief review of work topics
  - Lisa Pathfinder Contamination
  - Basic Neutraliser simulation
- Desirable future upgrades

Red comments indicate where improvements to SPIS would be benficial

Lisa Pathfinder (LPF)

- LISA Pathfinder will pave the way for the LISA mission by testing in flight the concept of the gravitational wave detection
- It will put two test masses in gravitational free-fall and control and measure their motion. This is achieved through technology comprising the inertial sensors, the laser metrology system, the drag-free control system and an ultra-precise micro-propulsion system.

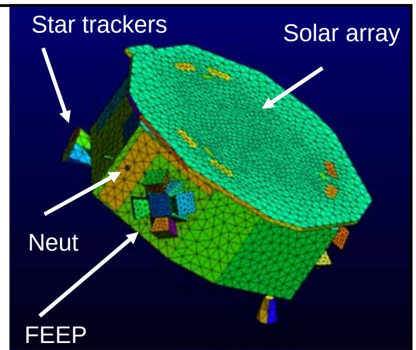
Contamination from the FEEP thrusters maybe of concern to solar arrays, optical instruments and the radiators

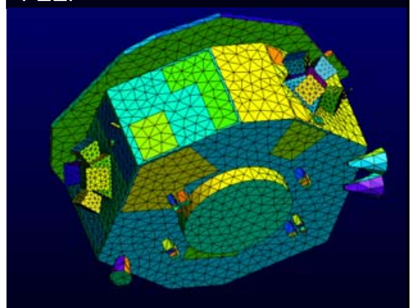
Contamination

- Work is a continuation from a the work performed by Bjarne Andersson - contamination rates modelled with FEEPs (Cs, In) and neutralisers.
- Continuation activities included:
- SPIS default CEX x-sections were replaced with more accurate data
- Multiple species sources were introduced into SPIS to allow the FEEPS to emit (Cs^{+}, Cs^{2+}, together)
- Effect of S/C potential on contamination deposition rate
- The solar array was modelled with metallic interconnects and bus bars

LPF Geometry

- Seven defined surfaces (SA, thrusters, NA, radiators …
- Multiple volumes to increase mesh fidelity
- Representative solar wind environment
- Bjarne Andersson
  - Create complex SC mesh
  - Floating potential determined from SW
  - Neutraliser bias trade off
  - Neutraliser allocation trade off
  - Cs and In contamination assessment





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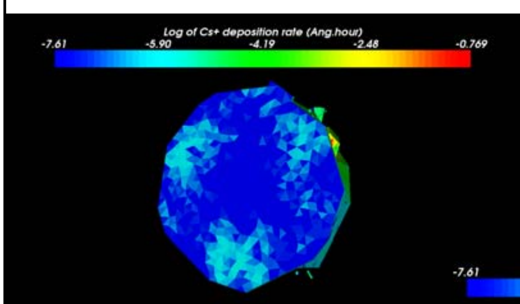
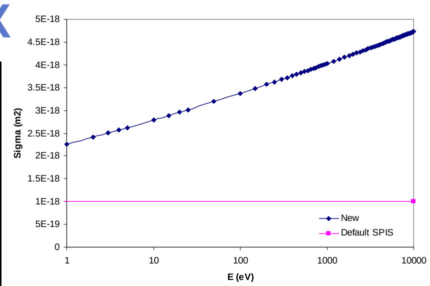
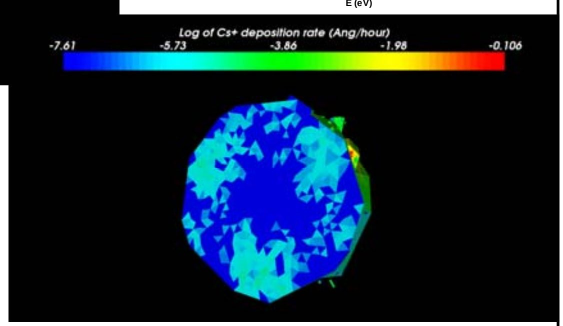
LPF – Improved CEX





SPIS default x-section (Xe)



New x-section

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Multi Species Source

- Currently, SPIS only supports single species sources.

- LPF Cs FEEP
  - mass efficiency 80%
  - (~82% Cs^{+}, ~12% Cs^{+2}, and ~4% Cs^{+3})
  - 20% neutrals

- LPF In FEEP
  - mass efficiency 70%
  - (~98% In^{+}, ~2% In_2^{+})
  - 30% charged droplets, 100nm, 200 charges – challenging to transport?
  - Measurements suggest that the neutral number density equals In^{+} density

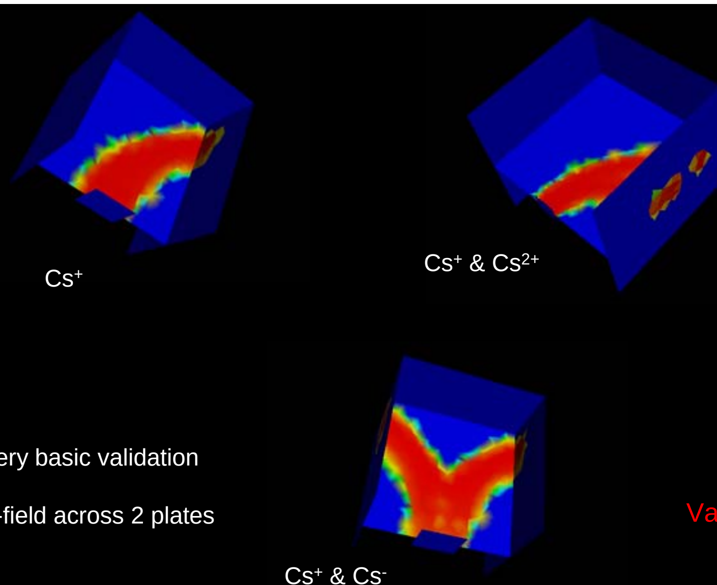
- LPF colloidal emits charged droplets with 190000 particles, 570 charges

Multi Species Source

- Developed a new source for SPIS. Details of the source are contained within an XML file.

- Multi-sources can have any number of tracked or untracked species of any charge, mass, temperature or mach number. They can be any source type (e.g. LocalMaxwellian etc)

- The contamination rate is not significantly altered by the addition of a multi-species plume – although we can't simulate the droplet volume interaction physics



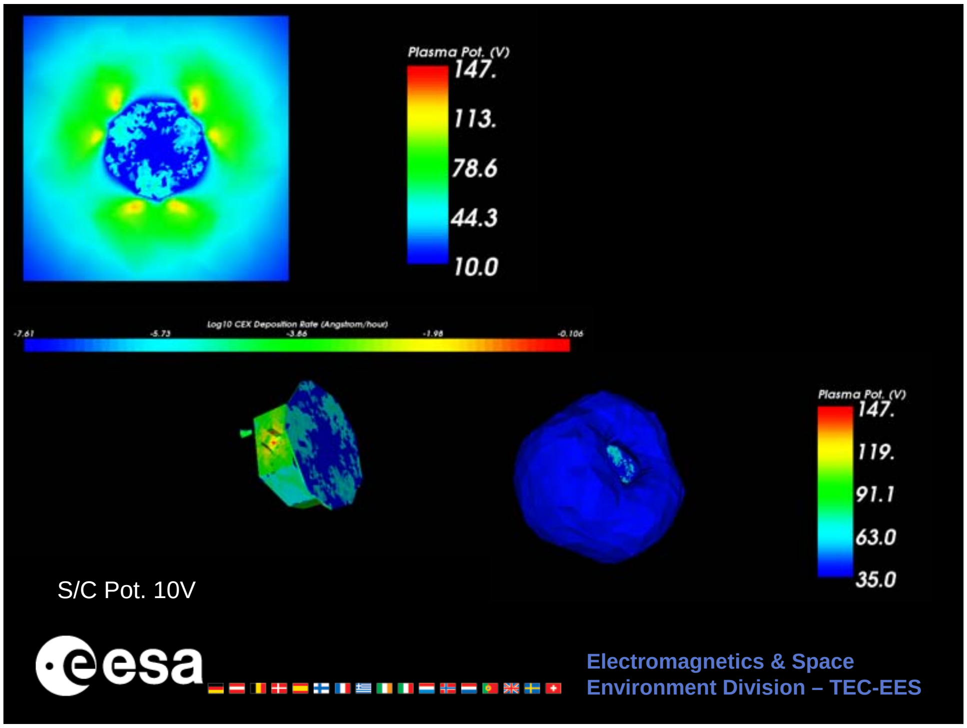
Very basic validation

E-field across 2 plates

Validation?

Contamination vs. S/C Potential

- The CEX contamination on the spacecraft should be sensitive to the floating potential
- In the absence of active S/C potential control, the floating potential should be governed by the details of the neutralisation
- SPIS simulations do indeed show a dramatic reduction in contamination deposition rate as the spacecraft floating potential increases from 10V to 150V
- Easy, accurate text deposition rates


Plasma Pot. (V)
147.
113.
78.6
44.3
10.0
Log10 CEX Deposition Rate (Angstrom/hour)
-7.61
-5.73
-3.86
-1.98
-0.106
Plasma Pot. (V)
147.
119.
91.1
63.0
35.0
S/C Pot. 10V
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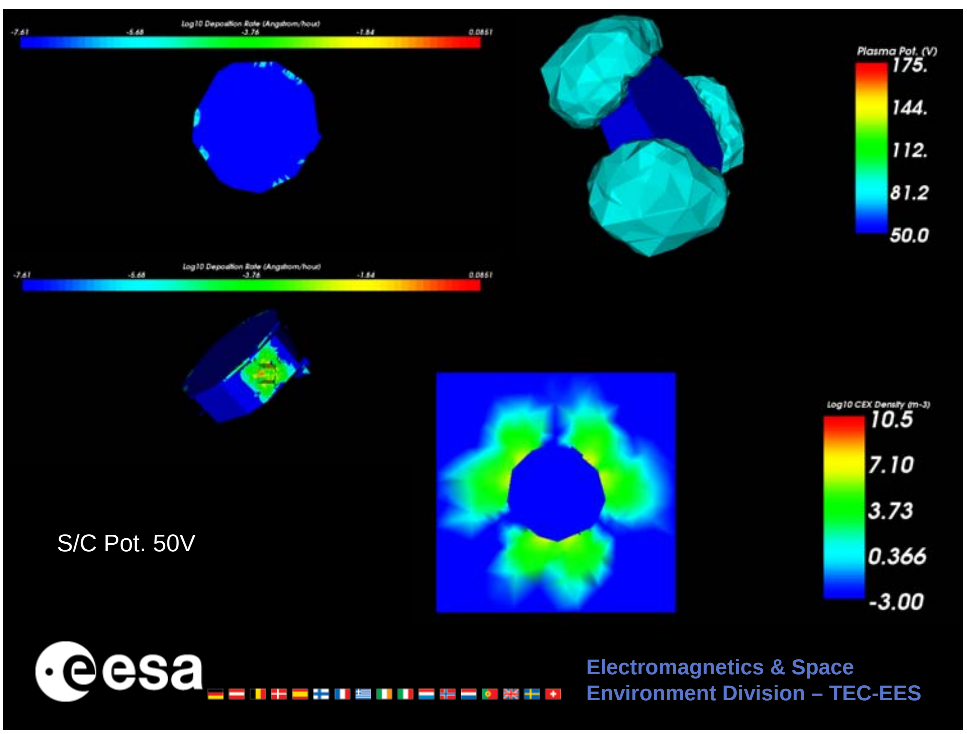
Log10 Deposition Rate (Angstrom/hour)
-7.61
-5.68
-3.76
-1.84
0.0851
Plasma Pot. (V)
175.
144.
112.
81.2
50.0
Log10 Deposition Rate (Angstrom/hour)
-7.61
-5.68
-3.76
-1.84
0.0851
Log10 CEX Density (m-3)
10.5
7.10
3.73
0.366
-3.00
S/C Pot. 50V
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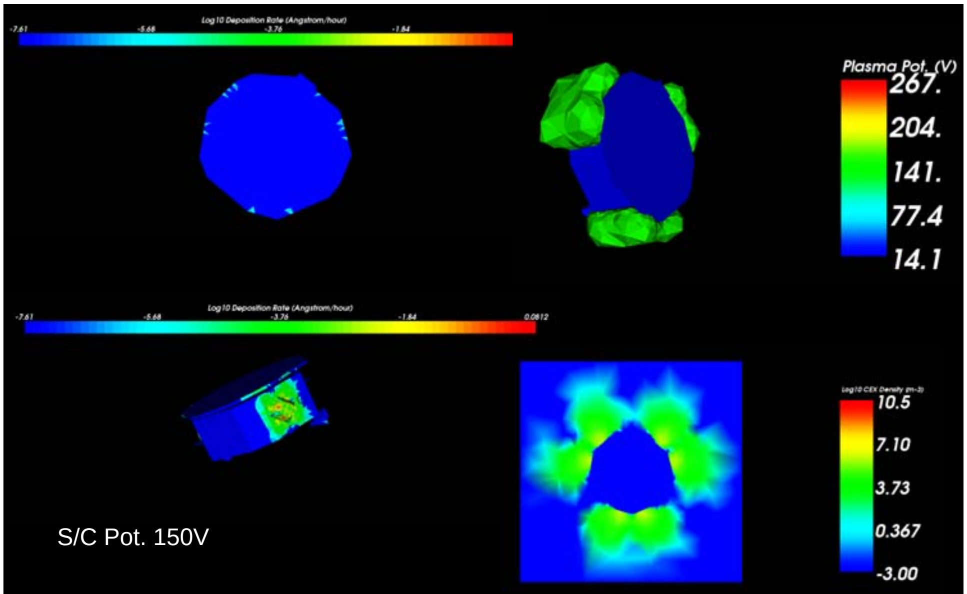

Solar array interconnects

- There exists a significant area of metallic interconnects and bus bars on the LFP solar array.
- The array is negatively grounded so there will be bus bar areas of 0V and +56V, with interconnect areas ranging in voltage.

- Due to meshing constraints, SPIS is currently unable to model these interconnects and bus bars correctly.

- The only realistic approach currently is to model large patches of comparable area.

- For this study, 3 patches of 0V and 3 patches of +56 V were placed on the solar array.

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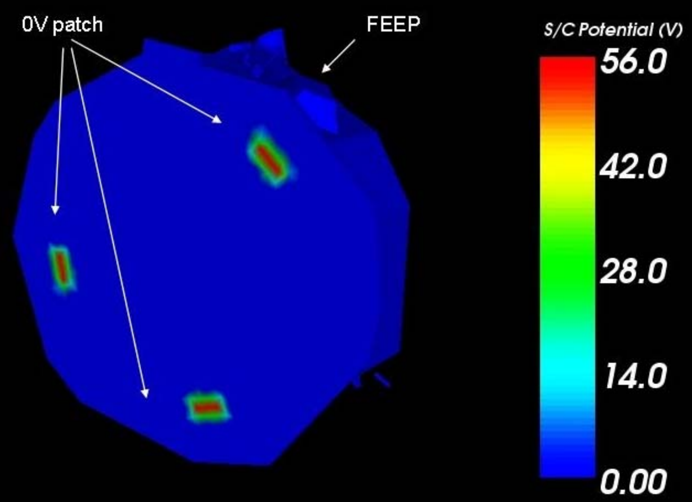
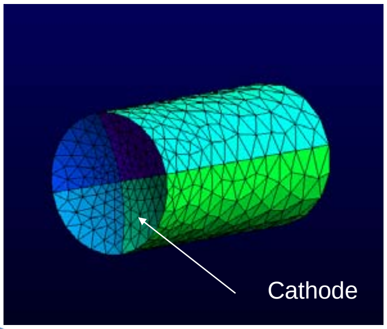


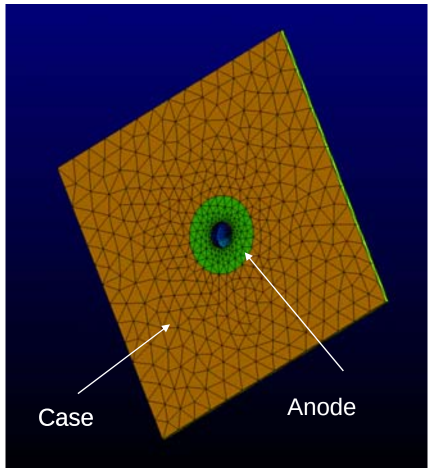
Observations

- S/C potential – very significant
- Correct CEX x-section – significant
- Multi-species source – important but not significant
- Solar array interconnects – Not fully simulated yet, but thought only significant if they effect the S/C floating potential as the array is negatively grounded so would result in a repulsive process wrt CEX ions.

Neutraliser

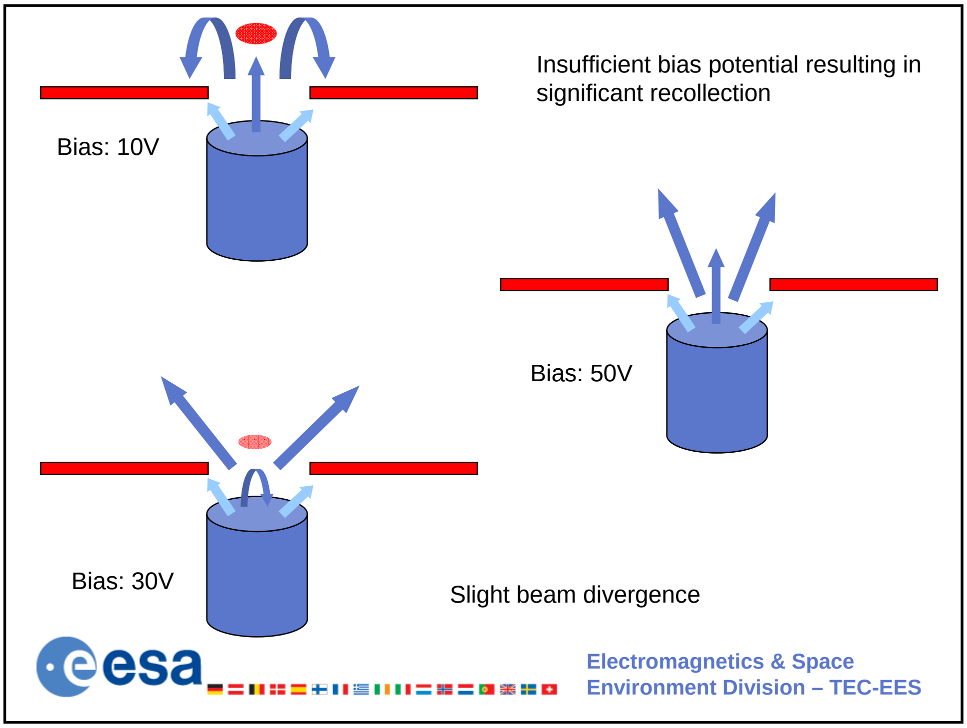
- Some preliminary work has been performed to model a thermo-ionic electron neutraliser
- Consists of an emitting cathode plate (concave) placed behind an anode ring





Neutraliser

- Concave cathode, ring anode
- Electrons are Maxwellian, no drift, with a temperature of ~0.1eV (1200k)
- Anode/cathode potential fixed at 75V, variable cathode/SC bias potential
- Previous work suggested that large bias voltages (up to150V) were required between the cathode and S/C ground to overcome space charge effects that would prevent efficient electron emission.
- Performed SPIS simulations varying the cathode bias from 10 to 30 volts, whilst keeping the anode-cathode potential at 75V


Insufficient bias potential resulting in significant recollection
Bias: 10V
Bias: 50V
Bias: 30V
Slight beam divergence
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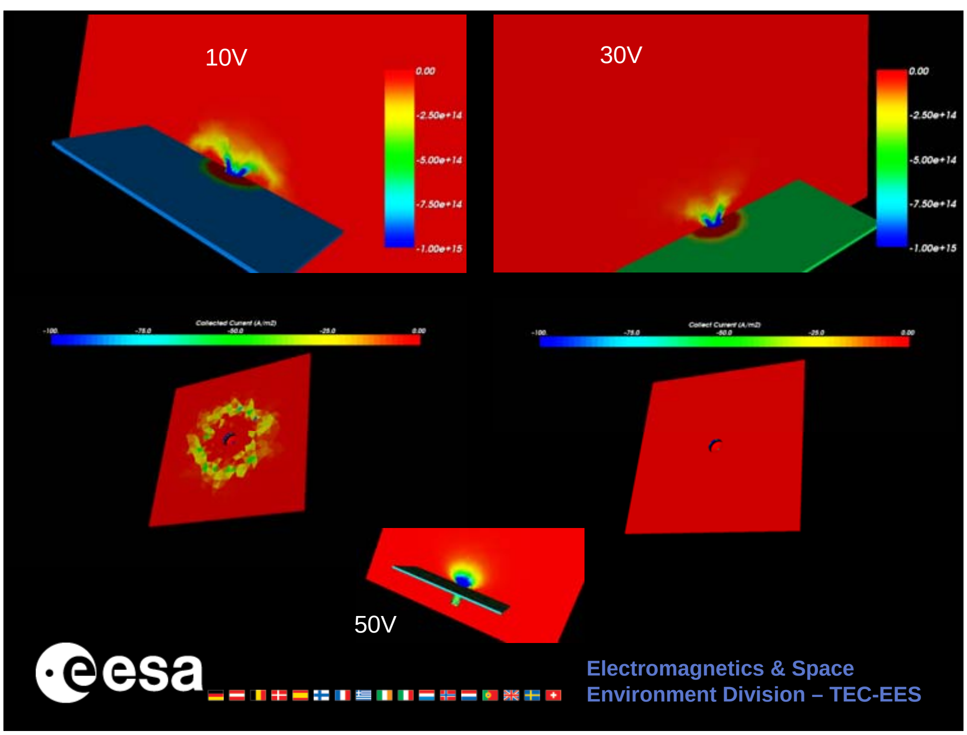
10V
0.00
-2.50e+14
-5.00e+14
-7.50e+14
-1.00e+15
30V
0.00
-2.50e+14
-5.00e+14
-7.50e+14
-1.00e+15
50V
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Neutraliser

- Efficient electron emission was observed for biases >20V, although at 30V, some beam divergence due to space charge effects was seen
- With a cathode bias of >30V, no recollection is seen back to the spacecraft.
- In all simulations, roughly 20% of the neutraliser current was recollected by the anode

Anode(V)	Cathode(V)	S/C collected current (% of emitted)
65	-10	-0.00376 A (66%)
55	-20	-0.00126 A (22%)
50	-25	-6x10-5 A (0.1%)
45	-30	0 A (0%)

Conclusion / Upgrades

- Some key SPIS improvement would greatly help these simulations
  - Multi-species sources and treatment of neutrals
  - Additional volume interaction physics models
  - Dynamic simulation variables, such as SC capacitance, speed ups etc
  - Easy access to ASCII data from VTK plots (maybe, click to get numerical value)
  - Validation framework to provide confidence in any upgrades