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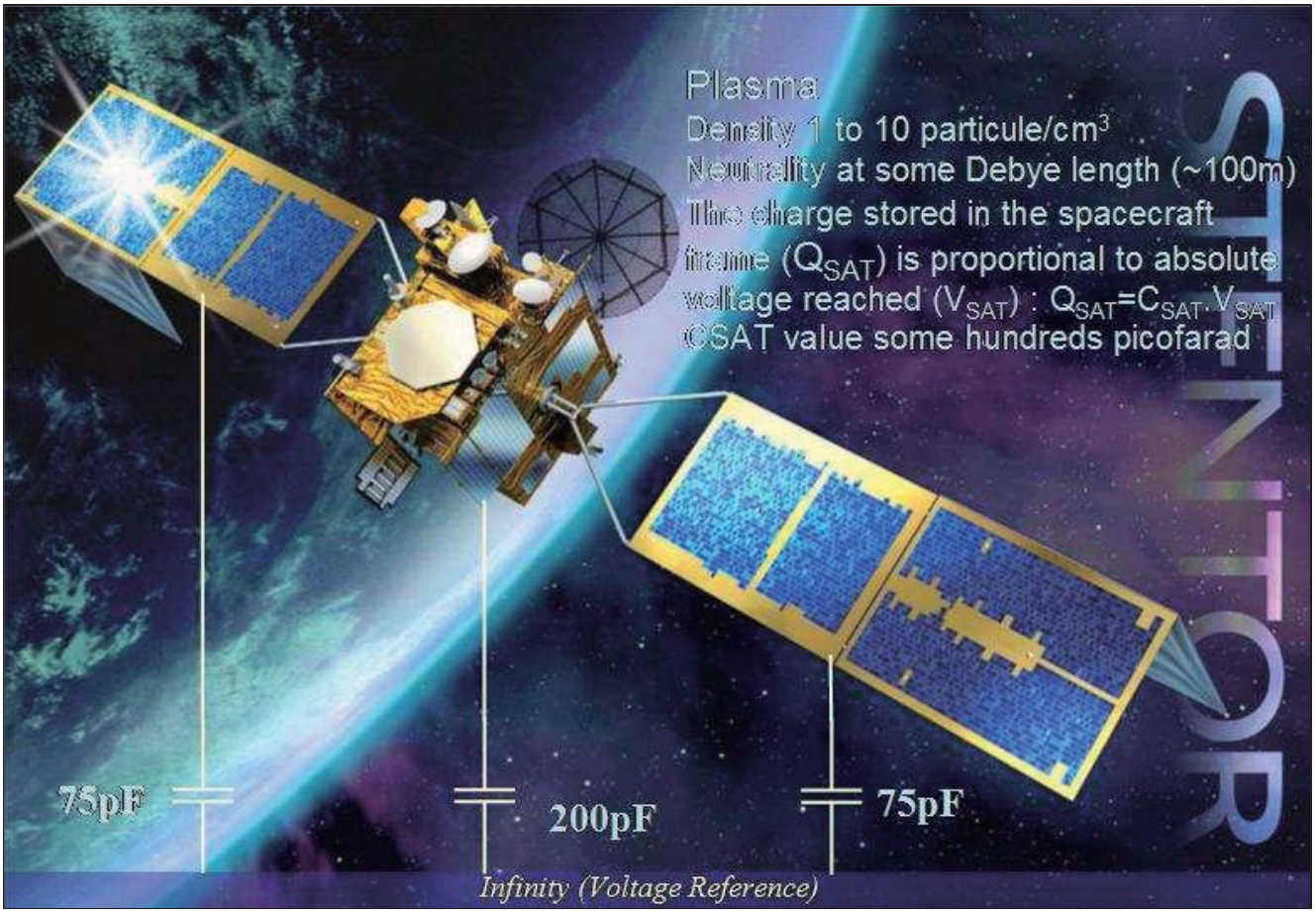




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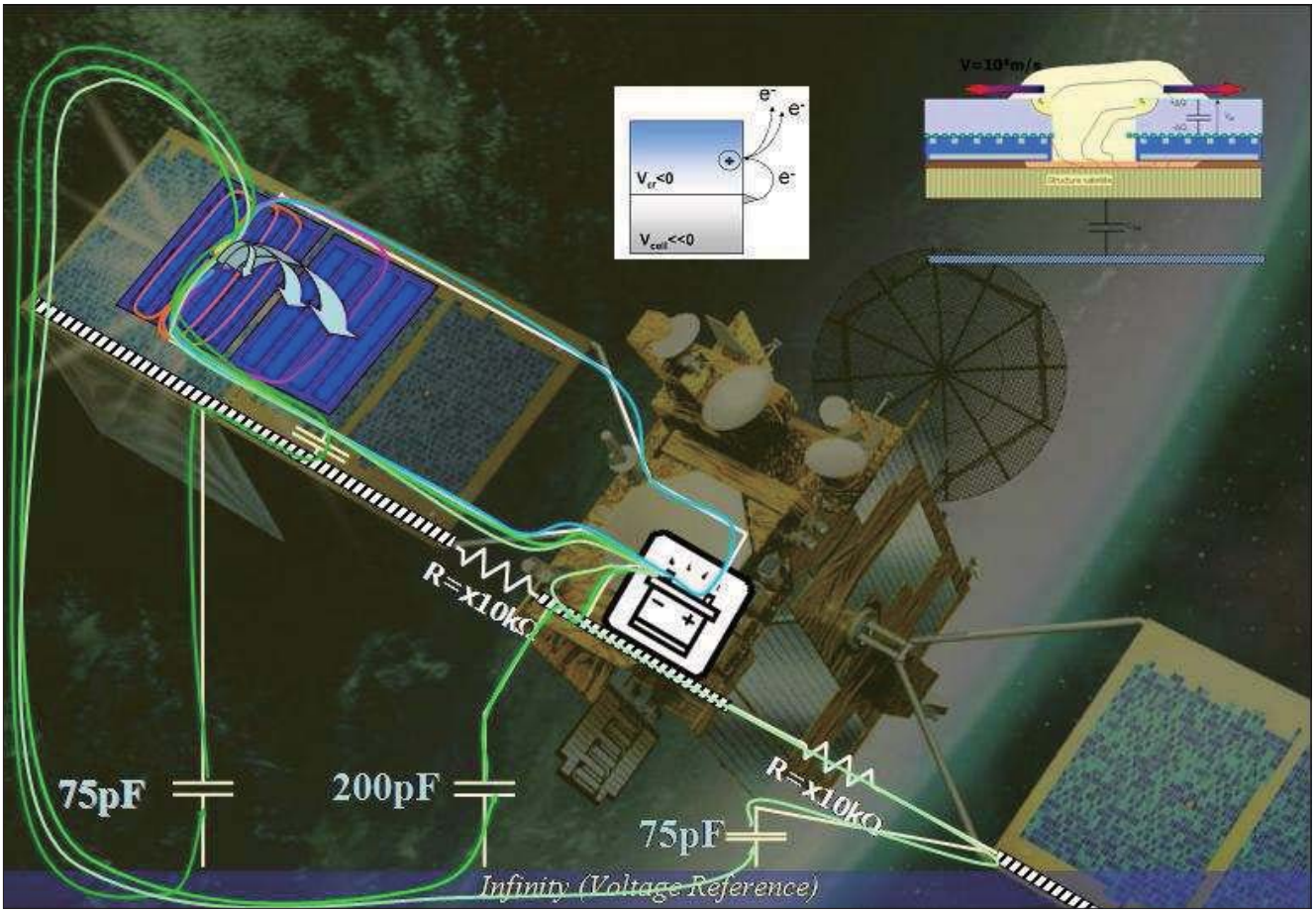


## The ESD

- The blow-off lasts some µs
  (charge stored in absolute capacitance leaving the spacecraft)
- The flashover starts after blow-off and lasts some hundreds µs
  (charge stored in coverglass capacitance neutralized during flashover propagation)
- The plasma makes the gap conductive in 100 ns
- Gap is conductive during the electrostatic discharge
- The secondary arc starts after 100 ns and lasts at least during the flash-over propagation
- All the energy stored and power available during that period of time shall be represented in the setup. The way this energy is released versus time shall be represented.
- If the secondary power (Solar array power) is sufficient the arc may be self sustain.
- Damages encountered drastically depends on the energy delivered





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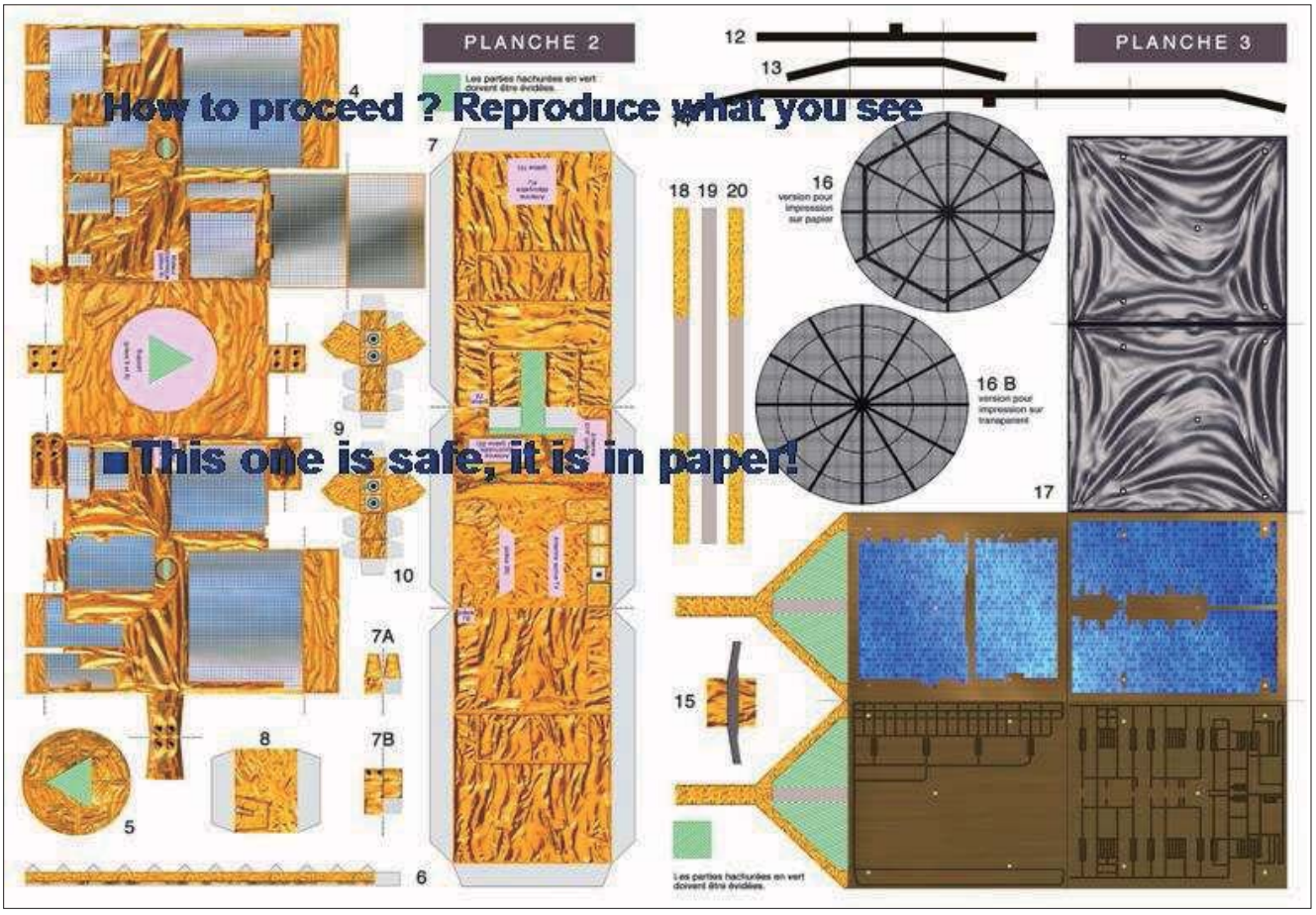





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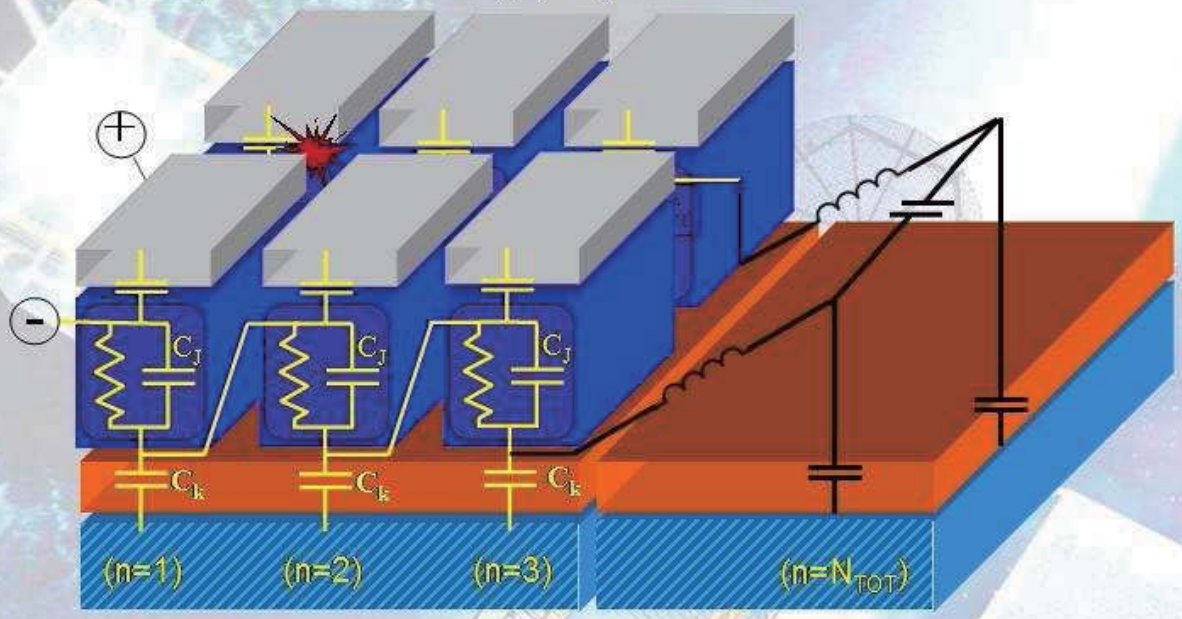
## How to reproduce a string (1/2)

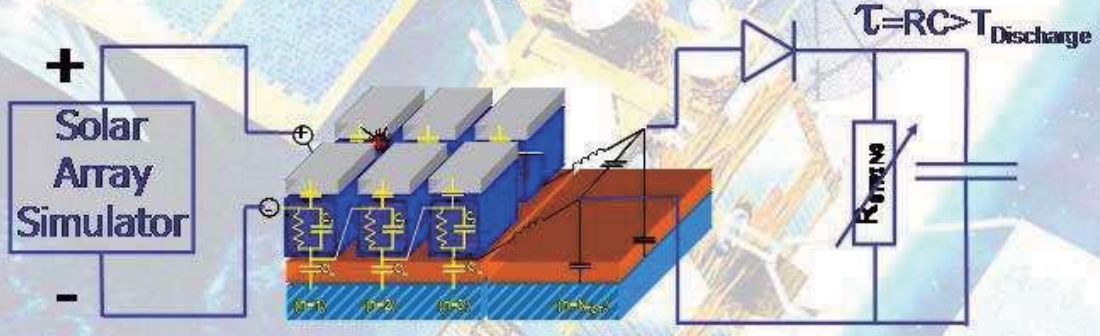



- Missing inductance and capacitance need to be adapted for each string configuration (more details and how to do in the paper)



## How to reproduce a string (2/2)

- The string has to be connected to a source able to provide the current in some hundreds nanoseconds and with a limited maximum current in the same range of time.
- To be representative in the very beginning of the secondary arc (remember 100 ns) the current shall already flow through the cells. (diode commutation time too big).




- Add section current or battery current if needed.





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## Samples in the vacuum chamber






## Representativity of test

- Inductance is generally not taken into account, parasitic capacitance more often. Wiring has to be reproduce.
- Take into account return current.
- Tests are made in plasma but the representativity is not fully achieved and demonstrated.
  - In plasma tests are made at lower voltage (around -500V instead of -5kV), to conserve energy ($E=1/2C.V^2$) capacitance should be increased by a factor of 100. In that case the way the energy is released is no more representative versus time
  - A capacitance of 300 pF empties out faster than a capacitance of 30 nF
- A flash-over is a slow process which need to be reproduced.





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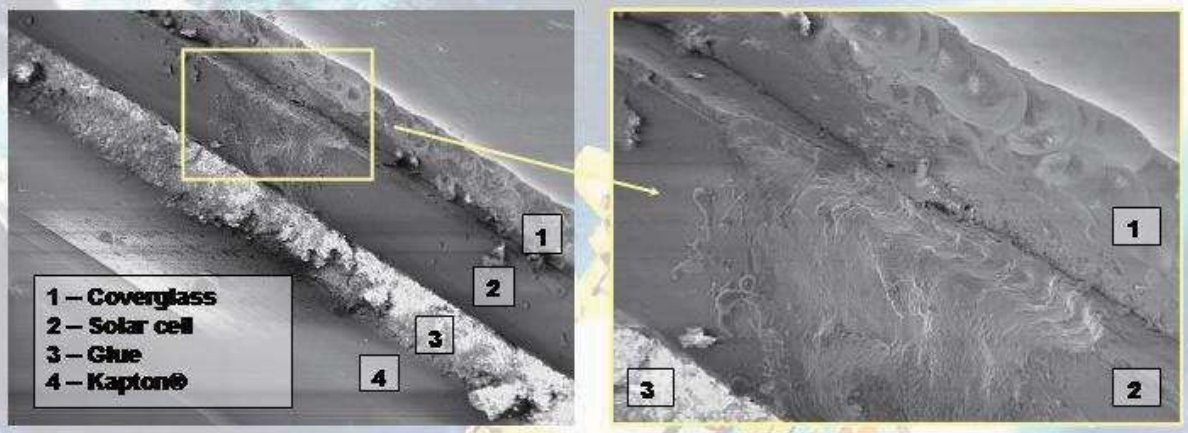
## A single ESD with $C_{SAT}$=300nF on a IBF Si Cell

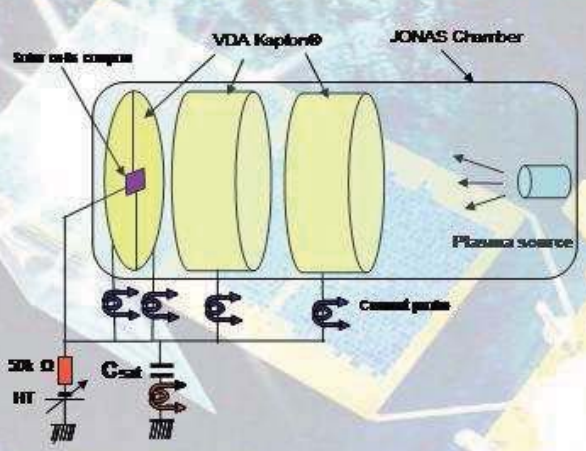


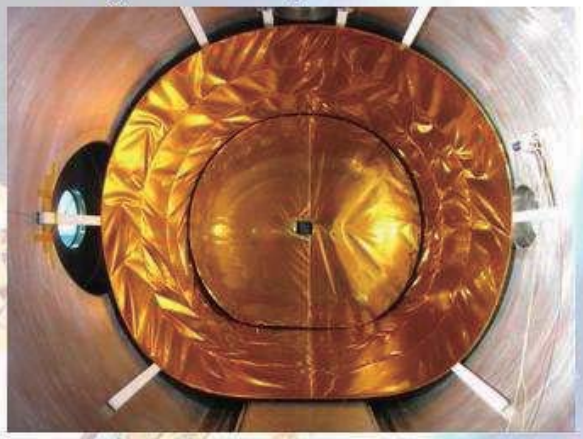

Is it representative ?

Yes, if the test setup was representative



## CNES-ONERA flashover simulator (patented)



$S_{tot}$ fully adaptable to each case – 13,4 m² was installed in the vacuum chamber.

The total capacitance charged was $C_p$ =8,25µF.

It is possible to drive the energy available thanks to adapted length of wire

| | | |
|---|---|---|
| 2nd Cylinder Surface : | 4,4 m² | → 2,71pF |
| 1st Cylinder Surface : | 6,6 m² | → 4,06pF |
| 1/2 disc surface (4 and 5) : | 1.2 m² | → 0,74pF |
| Total Surface : | 13,4 m² | → 8,25pF |





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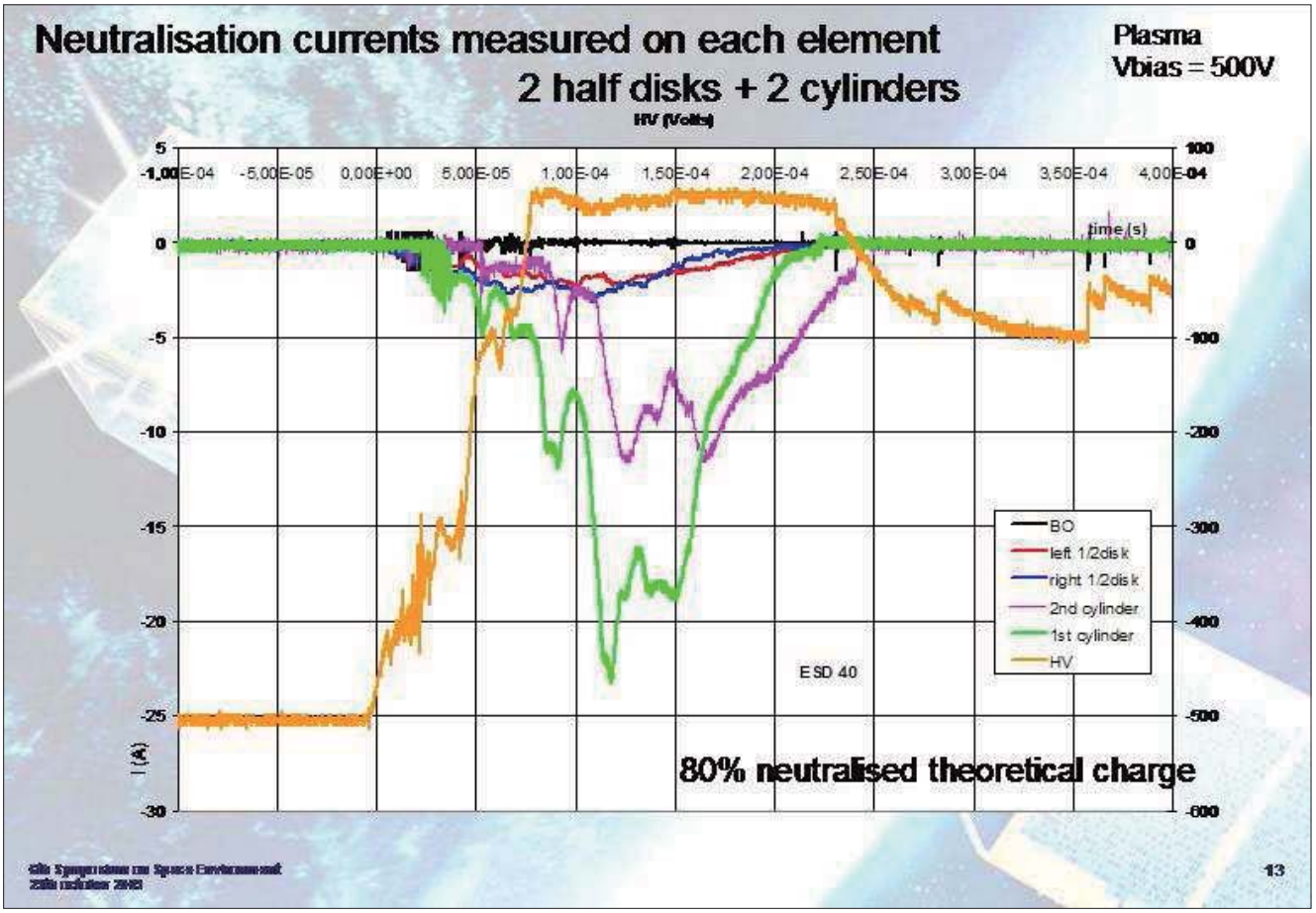


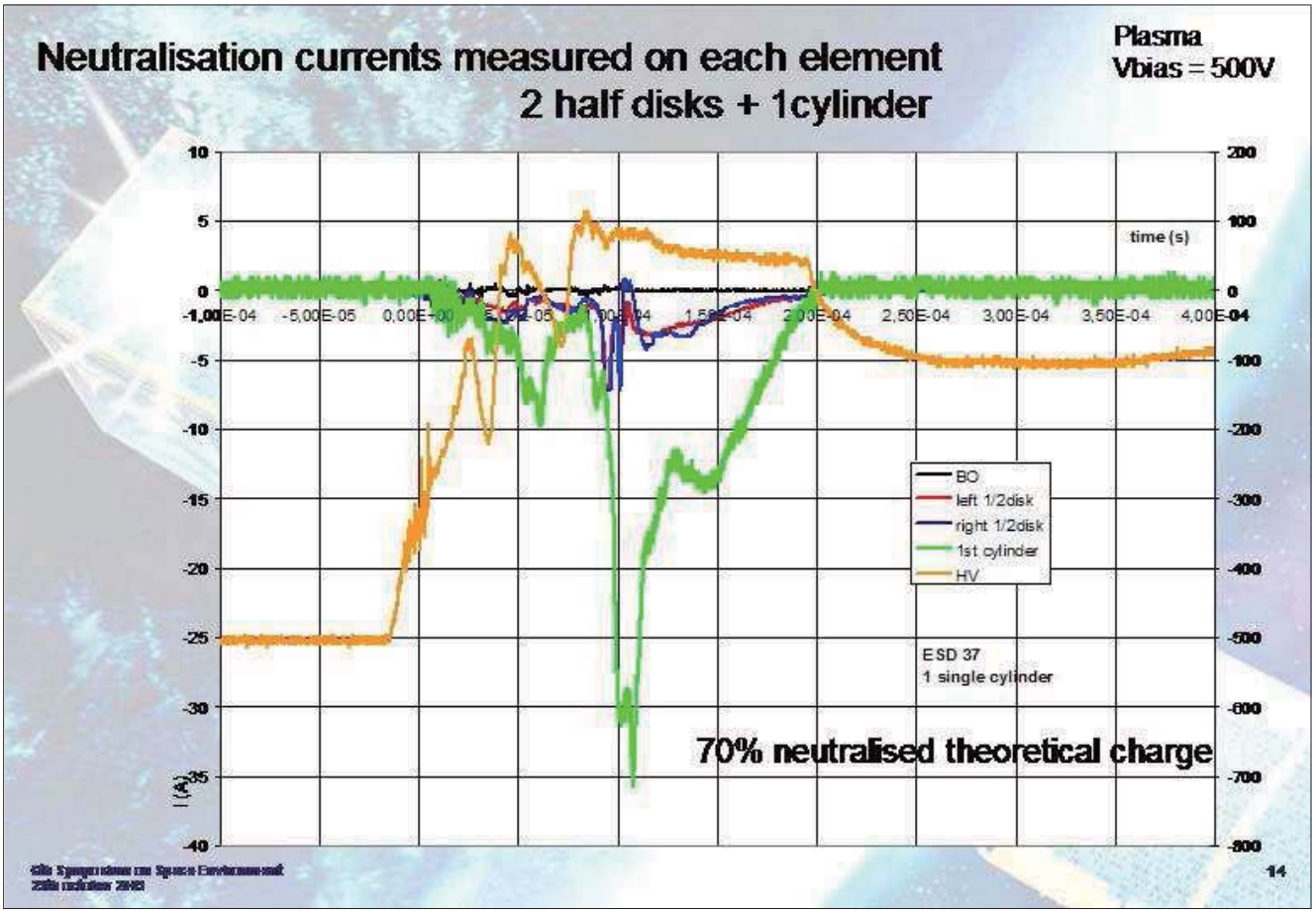




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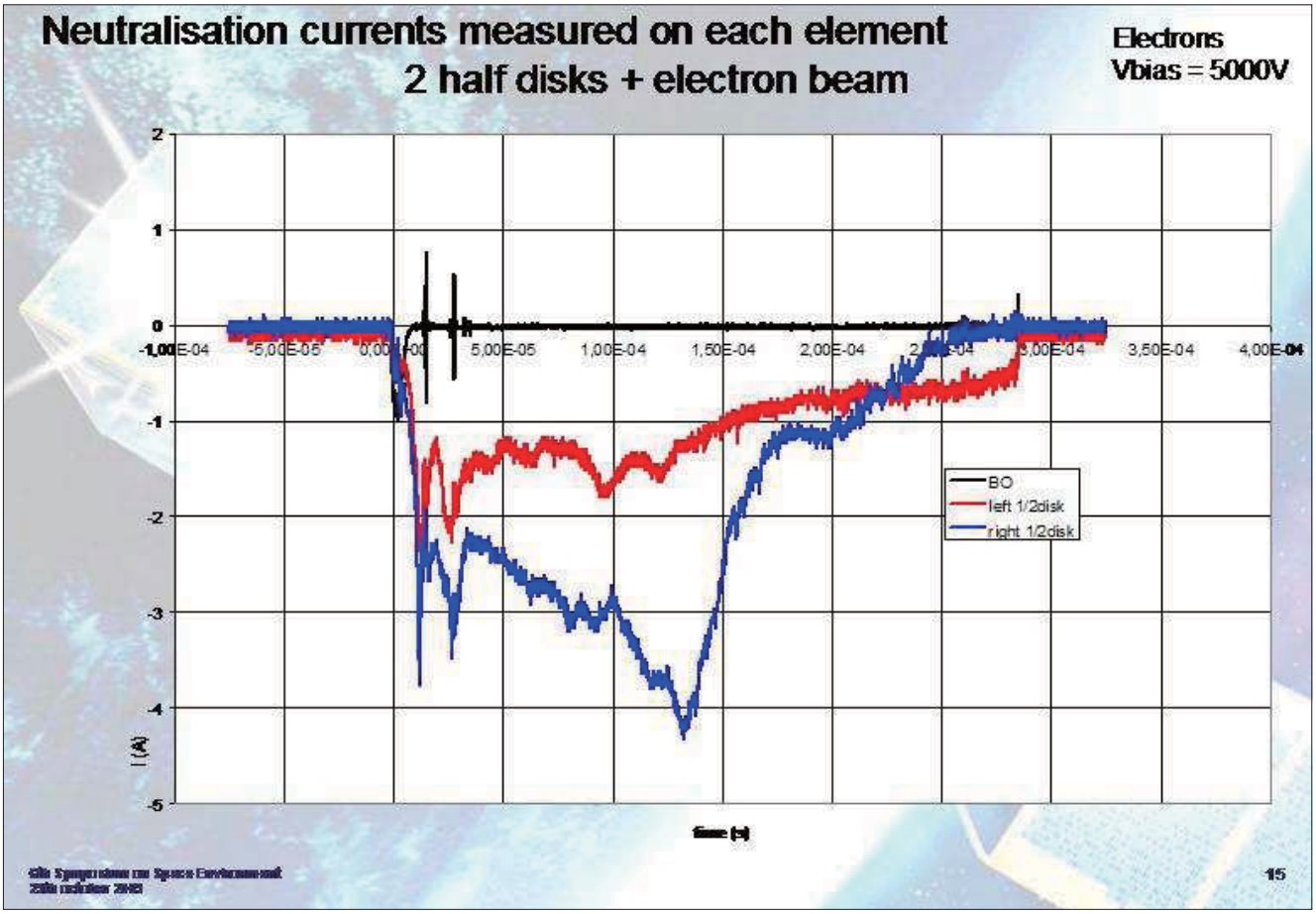


## Conclusion - Recommendations

- Reproduce what you see on your panel (It is not so difficult)
- Always keep in mind which energy is available in the setup and when it will be delivered if you want to be representative
- Be able to demonstrate the representativity of your setup shows that it is well understood.
- Validation of large flashover discharge still has to be done on a real flat panel. Here, flashover propagation distances are lower because the different panels are curved. This is only a simulator where 13.40m² of flashover were represented.

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