Development and test of the CubeSIM payload for the CROCUS mission

CROCUS Mission team

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Brief History of Charging Events & Flight Anomalies Attributed to Charging

Credits : Minow 2014 (from Koons 2000)

Charging events at GEO/MEO/LEO:
SCATHA, LANL, Intelsat, New Skies, AMC-12, RBSP, Electro-L2, GPS, GOES-16, DMSP, Freija, Jason-3 …

ElectroStatic Discharges (ESDs) detected on
ATS-5-6, CRRES, SCATHA, TPM, CTS, Electro-L2, GPS (indirect), RBSP (indirect), Horyu …

Few modern spacecraft equipped with ESD sensors

Space Environment Impacts on Space Systems

Anomaly Diagnosis	Number	%
ESD-Internal, surface and uncategorized	162	54.1
SEU (GCR, SPE, SAA, etc.)	85	28.4
Radiation dose	16	5.4
Meteoroids, orbital debris	10	3.3
Atomic oxygen	1	0.3
Atmospheric drag	1	0.3
Other	24	8.0
Total	299	100.0%

Objectives of the ChaRging On CUbeSat mission (CROCUS)

- Develop and test a payload for the flight demonstration of new generations of ESD monitors (highest priority)
- Demonstrate the efficiency of a passive electron emitter developed with ESA (not illustrated)
- A 2U cubesat platform is targeted to demonstrate the feasibility of low-mass low-power payload

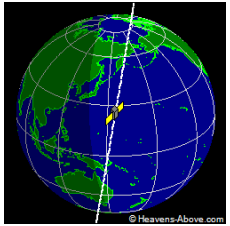
Content of this presentation

- CROCUS Mission Orbit
- Platform Preliminary Definition
- Payload Definition
- Test Campaign Results
- Programmatic Considerations

Orbit

- LEO cubesat meets financial constraints and LOS regulation
- SC Electrification occurs in auroral zones, night sector, above 600 km

SSO LTAN 9:00 PM - 3:00 AM
16 auroral zone crossings every day
3-min long each



Ph. Andersson, Characteristics of spacecraft charging in low Earth orbit, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, A07308, doi:10.1029/2011JA016875, 2012

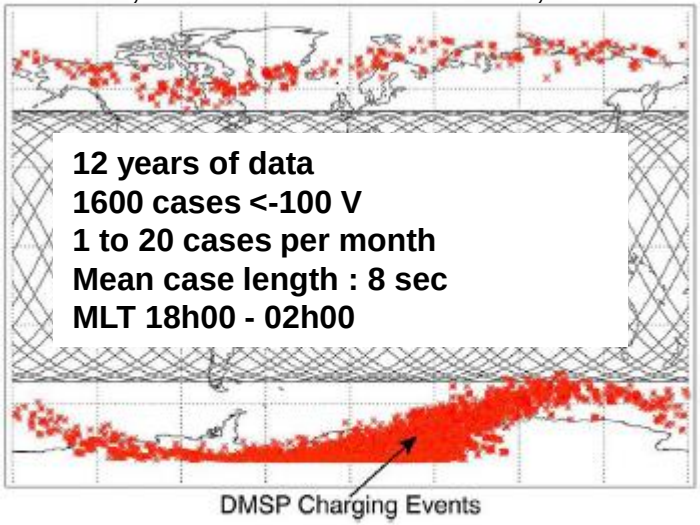
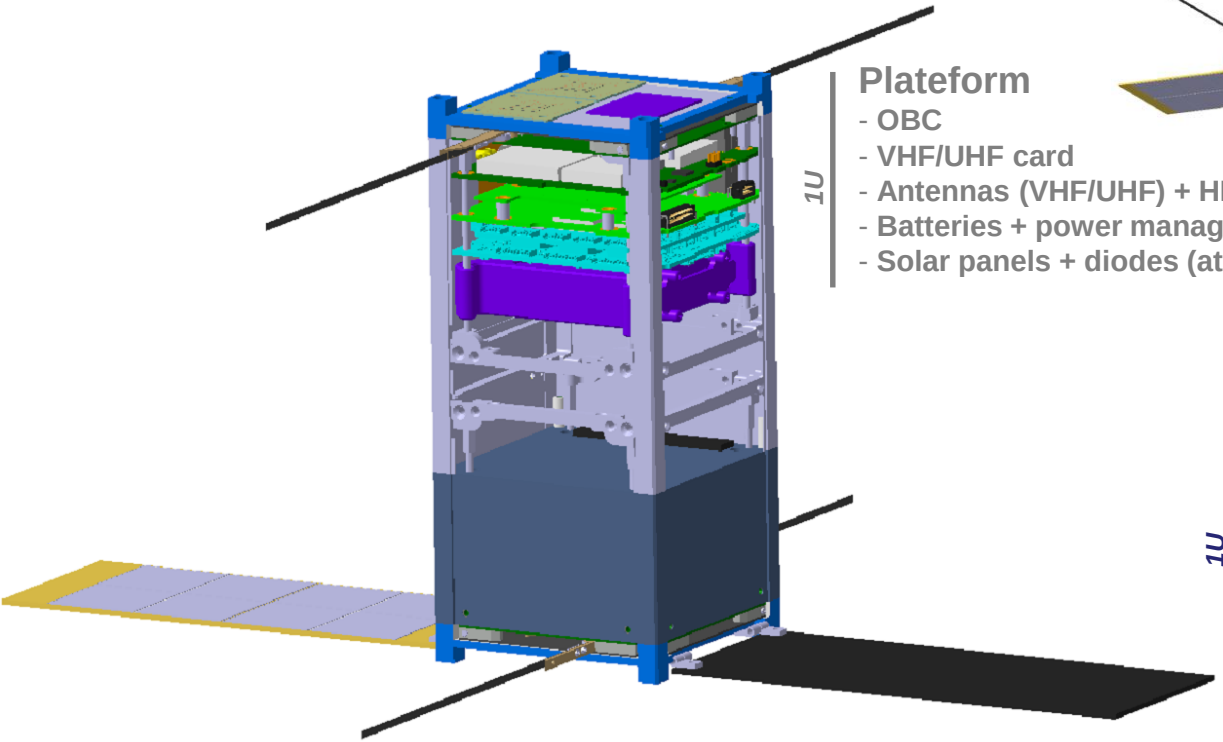
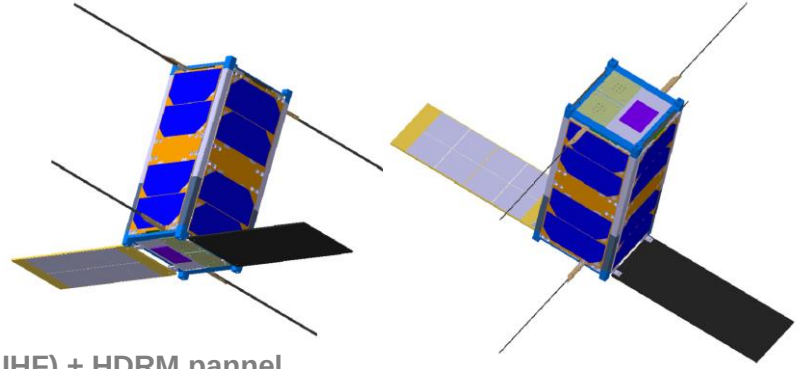


Figure 10. ISS orbit track over 24 h (black lines) and the location of the DMSP charging events (red asterisks).

CROCUS architecture(2U)





1U

Plateform
- OBC
- VHF/UHF card
- Antennas (VHF/UHF) + HDRM pannel
- Batteries + power management card (anti latchup, independant lines)
- Solar panels + diodes (attitude restitution)

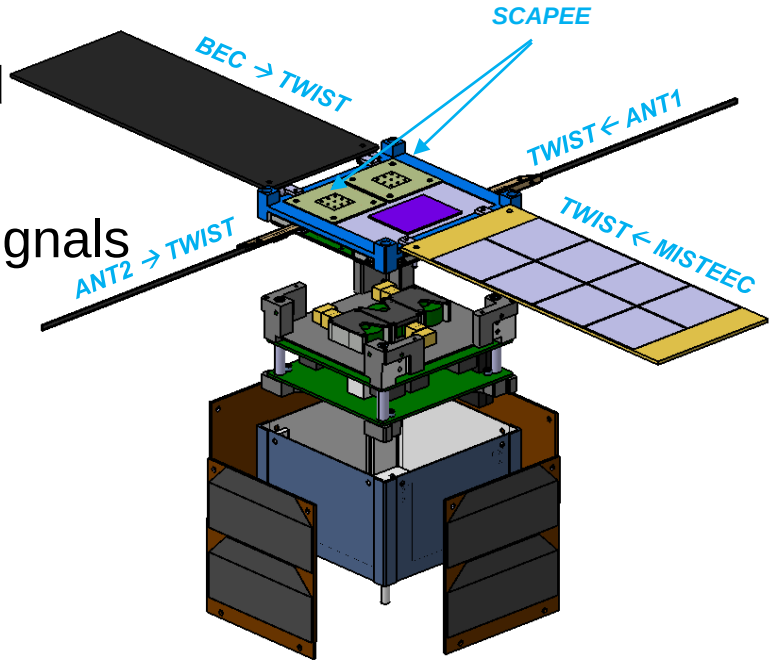
1U

CubeSIM
- FPGA (TWIST function)
- MISTEEC/BEC pannels
- Antennas (TWIST)
- Balun/Pearson
- SPARK
- SCAPEE, CPA, RESISTAK
- diodes (attitude), temperature probe

Payload instruments repartition on front and rear faces of the PF (identical design)

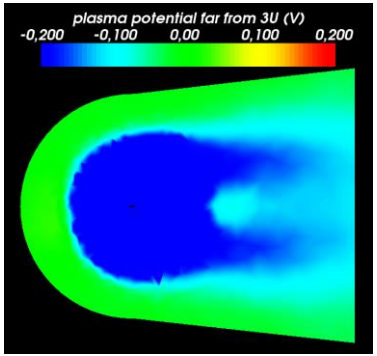
CubeSIM - Sensing Impulses and Mitigation

- PF provides power and link to OBC/ground
- Sensors + Analog Board detect transient signals
  - Detection by Pearson probe and antenna
- FPGA produces all data
- Payload independent from PF design
  - Removable BEC and MISTEEC panels

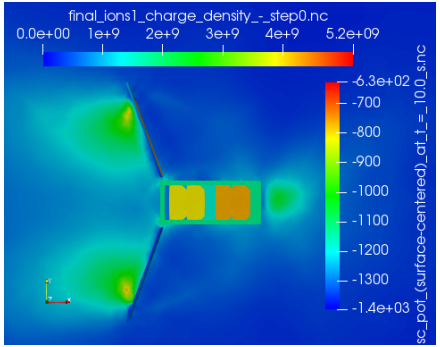


Justification of MISTEEC panels for CROCUS

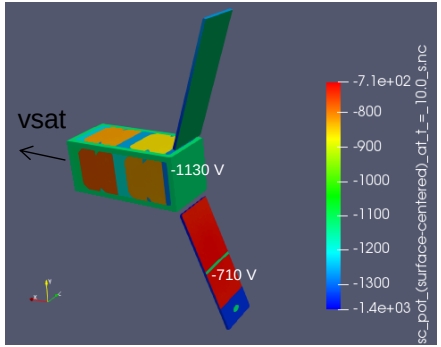
- Low frequency of spacecraft charging events in LEO
- Solutions :
  - BEC: Raising their effects by increasing the area of low SEEY materials
  - MISTEEC : Increasing the probability to trigger ESDs with high SEEY materials
- Design justification by numerical simulation with SPIS (www.spis.org) in ECSS WC env.



Metric sheath, Csat ~20 Pf



Complex wake effects

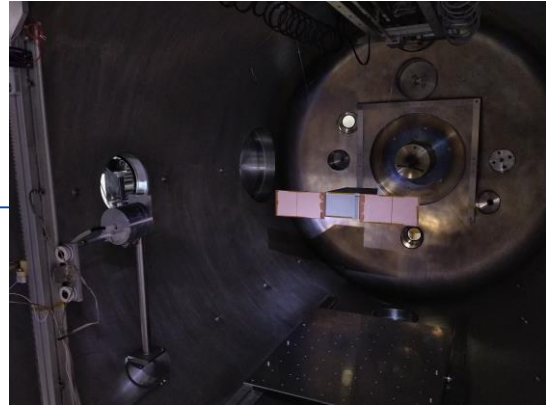


ESD possible on solar cells, more probable on CubeSIM

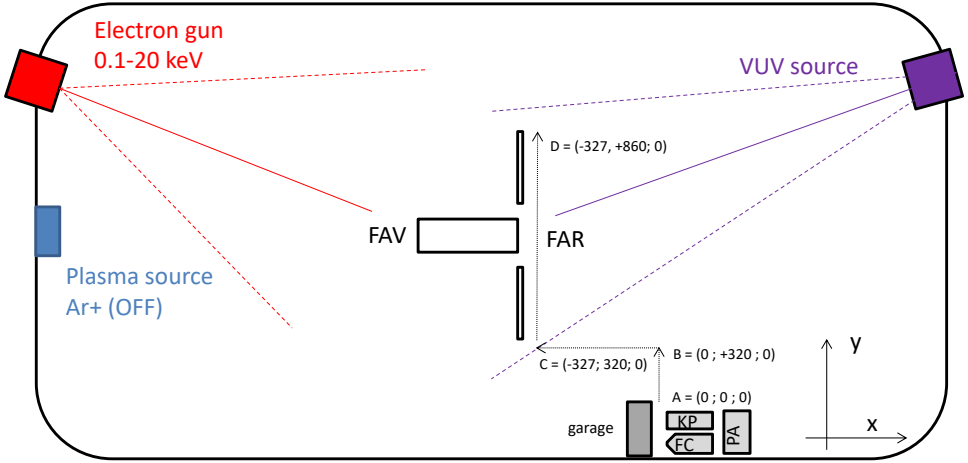
TWIST - ESD detector

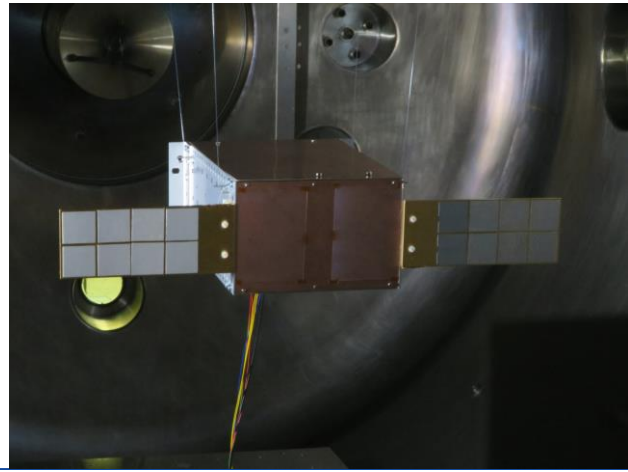
- Time stamps, high sampling rate wave shapes, continuous mode
- Detects the modulation of a repetitive wave shape by transient ESD signals collected by sensors
- Sensors
  - Pearson probes on selected harnesses
  - Monopole antenna on the external rear side of CubeSIM
- Performance
  - 13 mW per ch. / 10 MHz sampling rate / 6-8 bit resolution
  - 100 ns up to 100 µs events
  - 10 kbits by event

Test setup (with breadboard models)

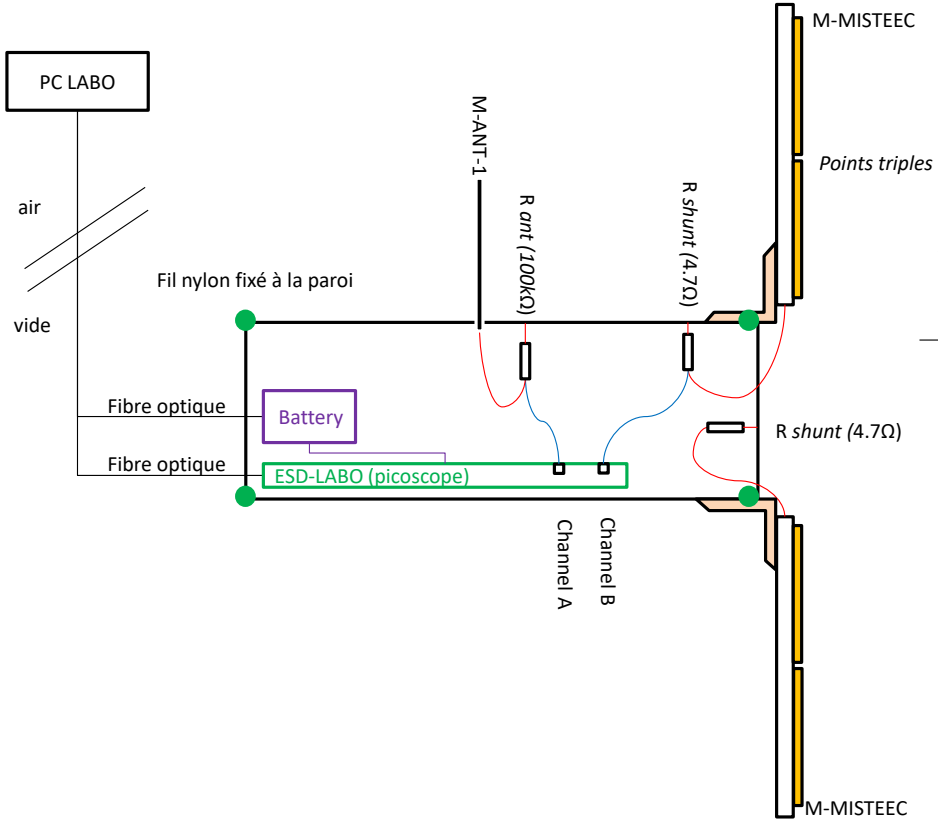


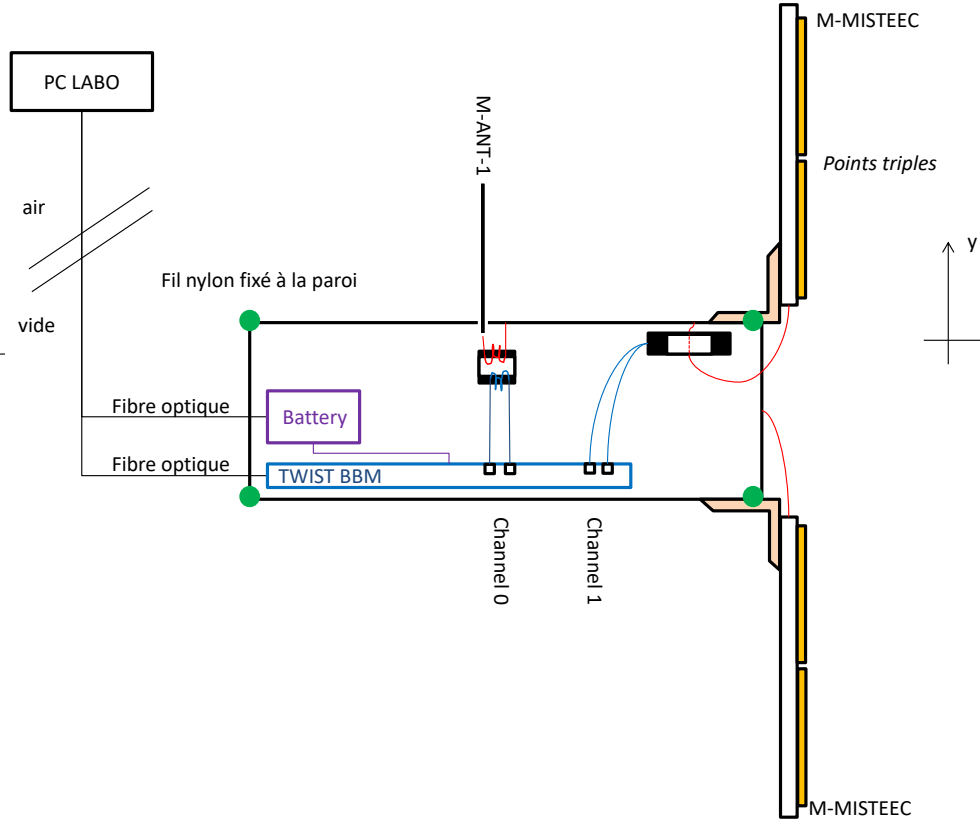
- Tabletop tests with pulse generator : OK
- Tabletop tests with electrostatic gun : OK
- Vacuum plasma chamber test (JONAS @ ONERA Toulouse) : floating wrt ground !





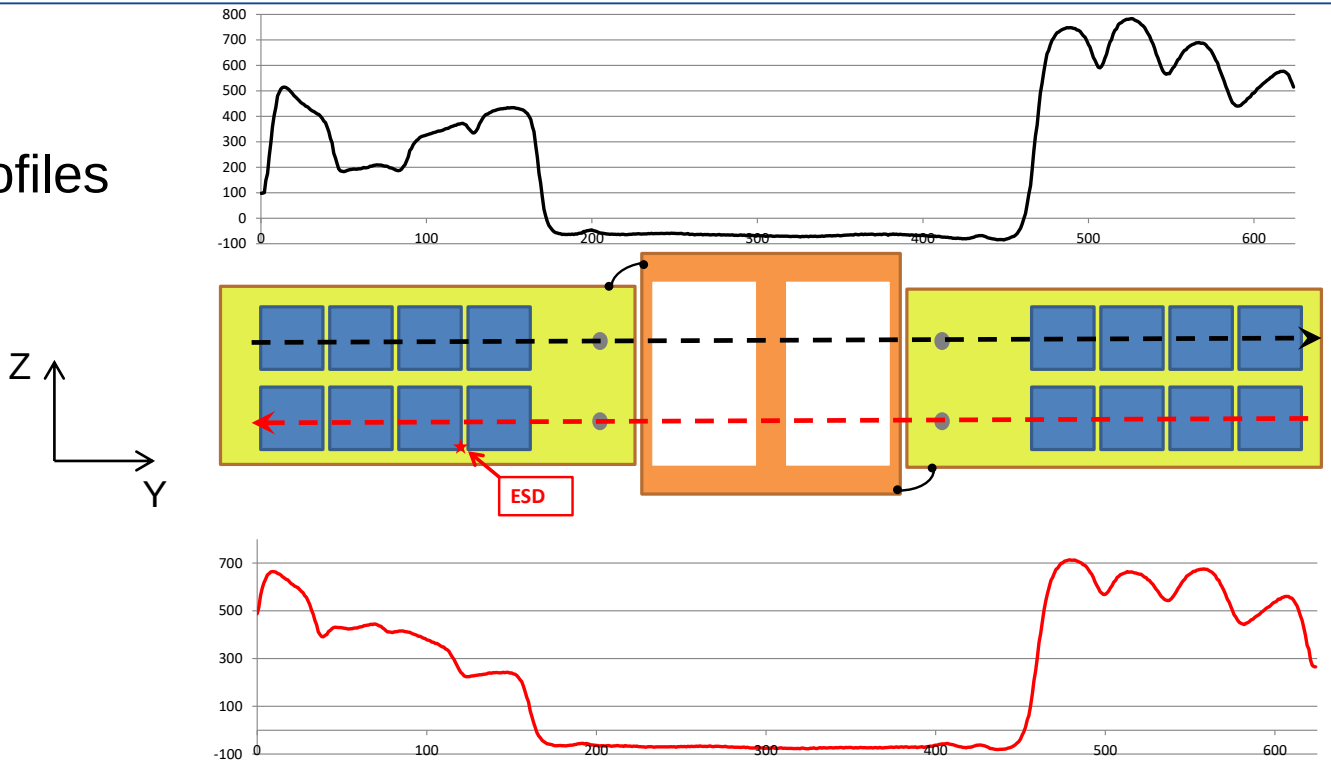
lab instr. Vs. TWIST BBM



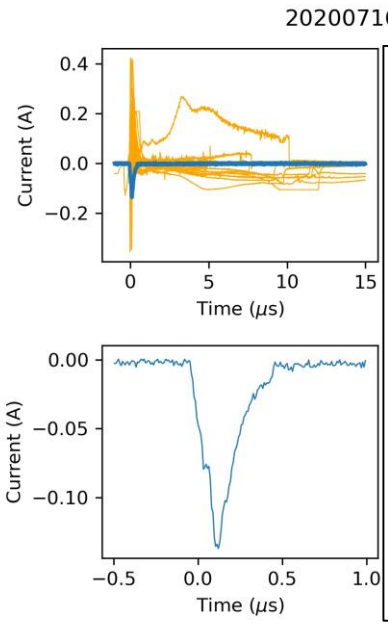


Assessing ESD location

- Video cam
- Potential profiles

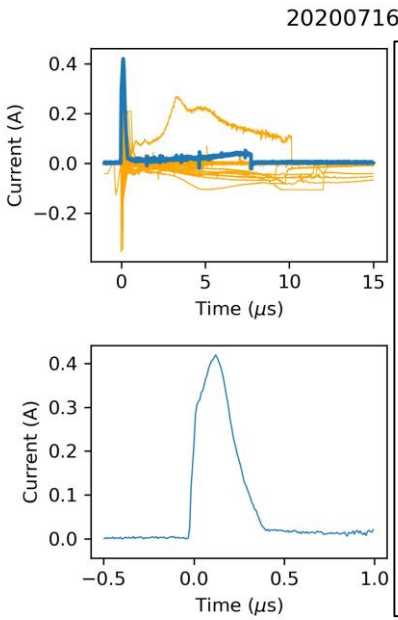


Typical waveforms on 2U



400 ns blow-off
- 130 mA peak

on the panel on the left



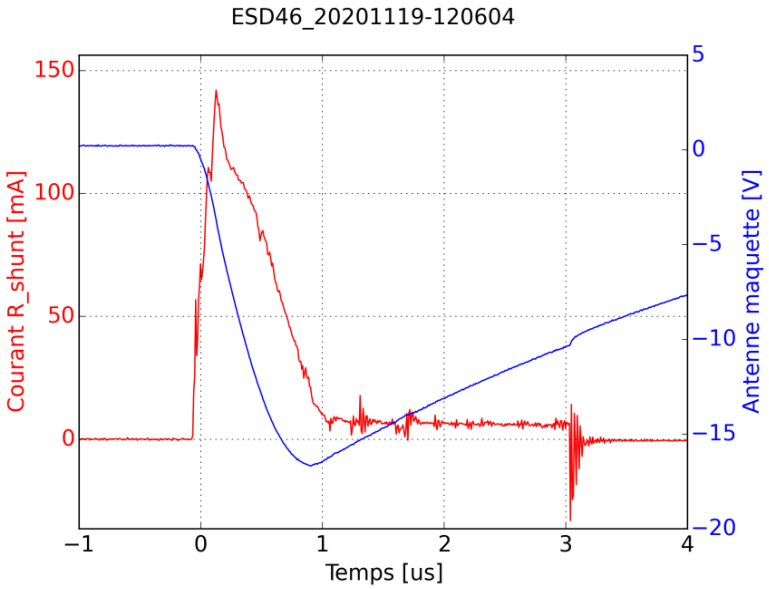
400 ns blow-off
+ 400 mA peak

7 µs duration flash-over
+10 mA

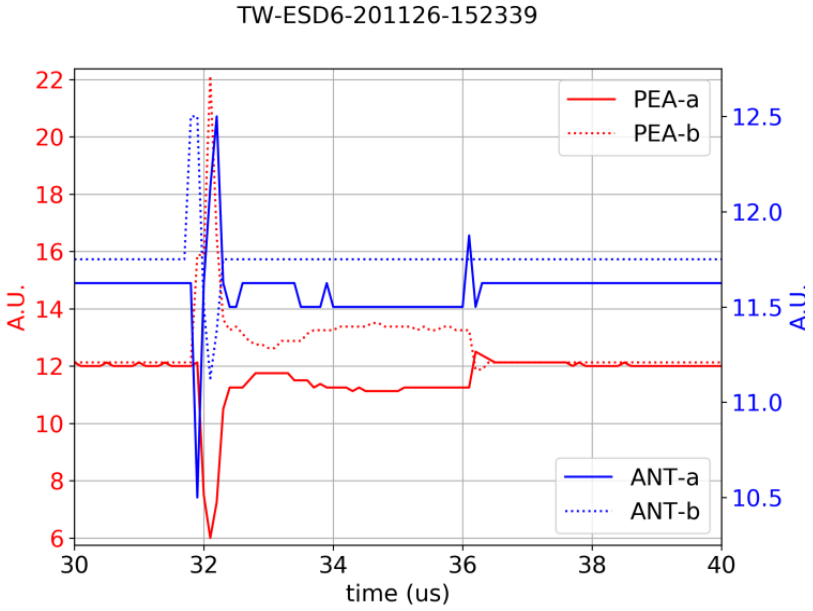
on the panel on the right

→ Duration from 200 ns up to 10 µs, current from 10 mA to 200 mA

Typical waveforms on 8U



Lab instr. ESD #46



TWIST ESD #6

In a nutshell and perspective

- Innovative tests with concluant and consistent results
- CubeSIM phase B successful

- Phase C for early 2022
- Meanwhile, PF development
- PF + payload AIT for 2023

Acknowledgments

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8U tests with lab. instr. has been funded by CNES R&D 2020