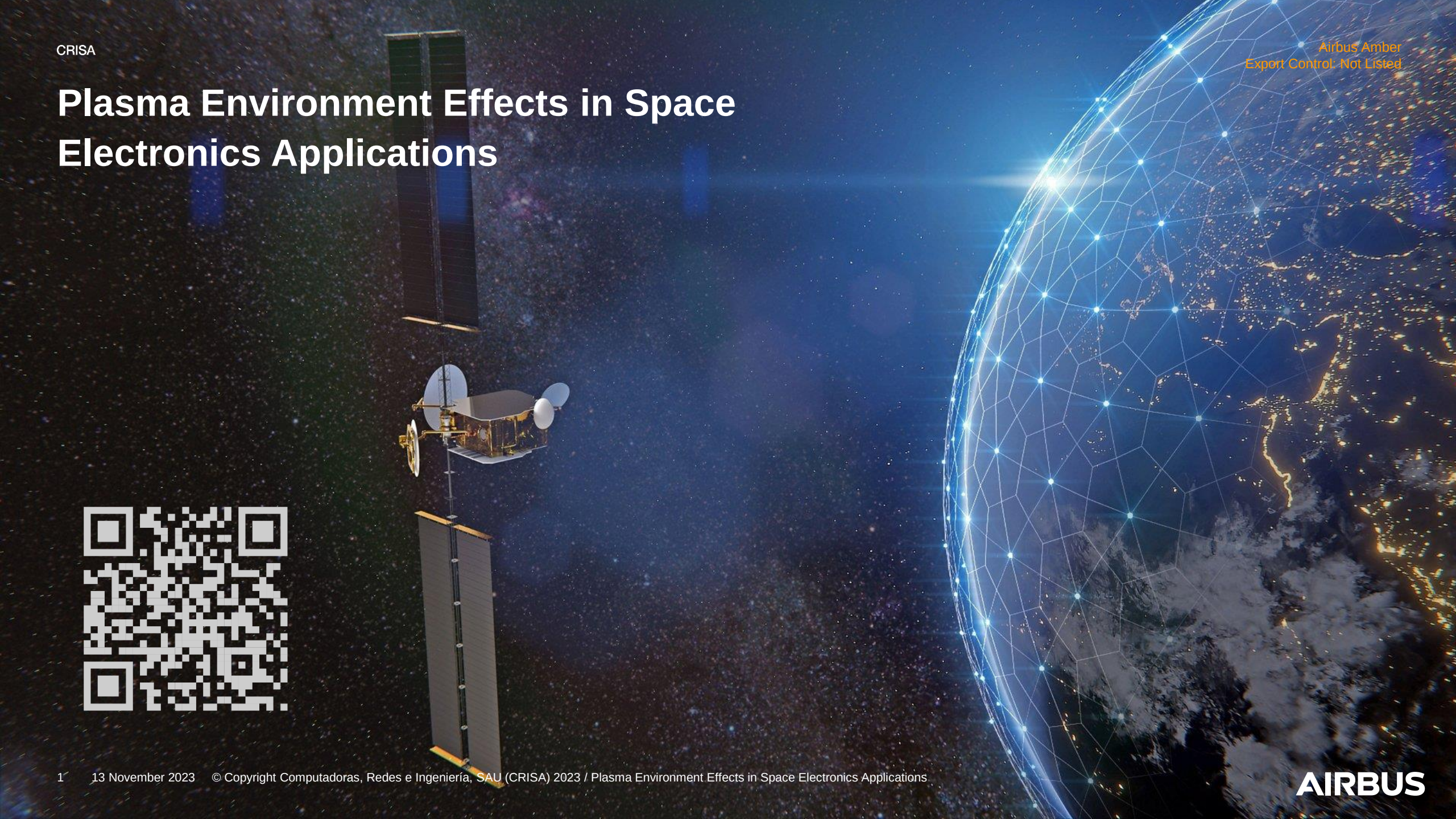
Plasma Environment Effects in Space Electronics Applications



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Plasma Environment Effects in Space Electronics Applications : Conclusions

- **Electronic for space** applications is an special case within electronics domain subject to specific and **unique environmental conditions**
- **Radiation** can cause spacecraft systems and electronics **units malfunctions** via different mechanism like parts parameters drifting or undesired transients
- **Plasma** leads to **spacecraft charging** that could potentially damage electronics.
- **Electric Propulsion** is a source of **plasma** that need to be correctly managed

What does Airbus Crisa do?

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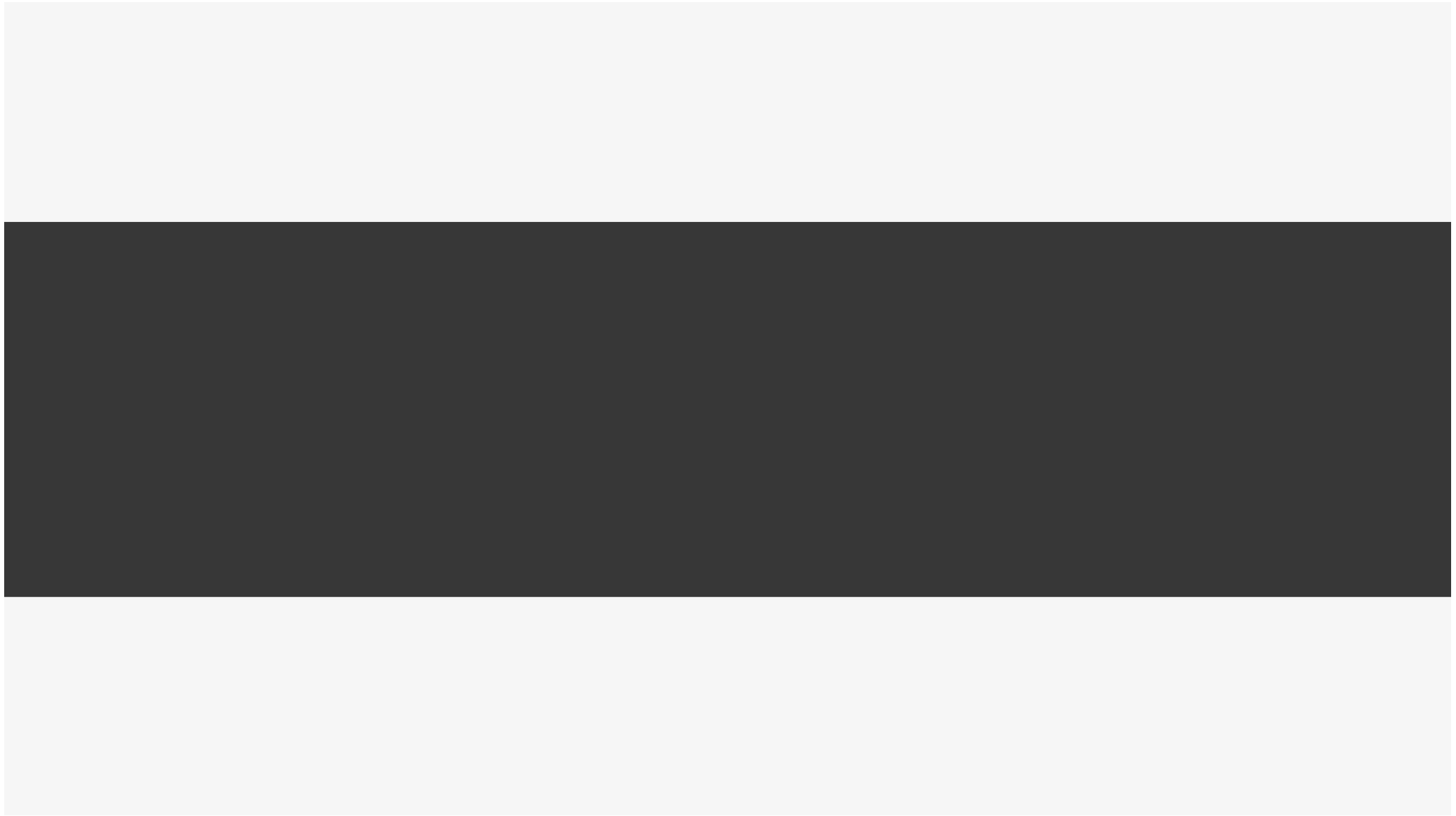

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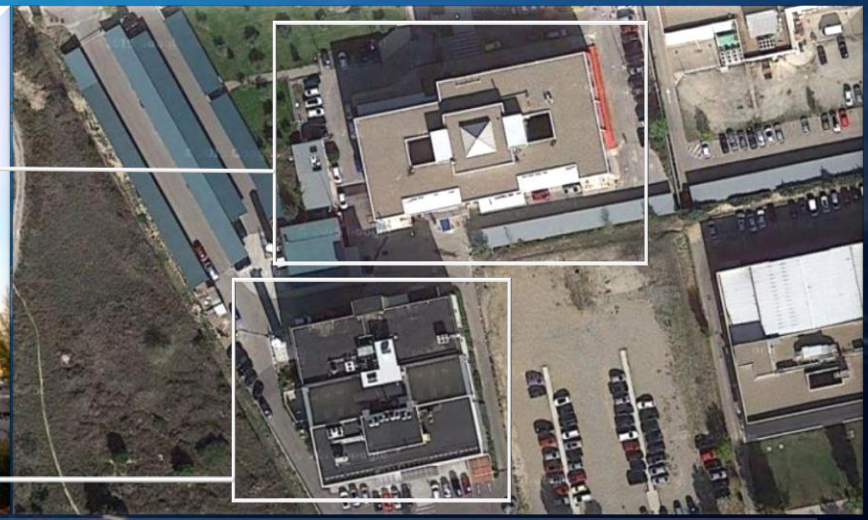
Airbus Crisa - Airbus Defence and Space affiliate located inTres Cantos (Madrid)



- Recognised leading position worldwide in **power, electric propulsion** and **launcher electronics**
- Positioned as **key national player**
- **Pioneering** the **Next Space** trend: **state of the art products** supported by our industrial capacity → Next Space production line in operation since 2021
- **Full E2E** engineering and production **capabilities and skills** available in-house.
- **Products Quality and Reliability** widely acknowledged by customers
- **Sustainable growth story** since its creation

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A solid background to build upon

CRISA

Airbus Amber

38 YEARS

Over **300** accomplished missions

>2000 flight units launched

8.700 kg launched

60 missions in progress

1992
HISPASAT 1A/B

1994
STS-64 GAS

1995
ISO
SOHO

1996
1er Ariane 5

1997
MINISAT
CASSINI-HUYGENS

2002
ENVISAT
INTEGRAL
HELIOS-2
MSG

2003
MARS EXPRESS
SMART-1

2004
ROSETTA
AMAZONAS-1
FORMOSAT
EUTELSAT W3A
1er EU300

2005
VENUS
XPRESS

2006
SPAINSAT
METOP A

2008
CHANDRAYAANa
ATV-1

2009
GOCE
HERSCHEL-PLANK
SMOS

2010
ASTRA 3B
ARABASAT 5A/B
Ka-SAT

2011
CURIOSITY
PLEIADES

2012
SPOT 6
METOP B
1st VEGA flight

2013
GAIA

2014
SPOT 7
KAZEOSAT-1
ISS

2015
SENTINEL 2
LISA PATHFINDER

2016
EXOMARS
SENTINEL 3

2017
SENTINEL 5P

2018
PAZ
BEPICOLOMBO
ADM-AEOLUS
INSIGHT
METOP C

2019
ONEWEB
CHEOPS

2020
PERSEVERNACE
SOLO
INGENIO
FALCON EYE 2
CSO
SENTINEL 2
MICROCARB

2021
JAMES WEBB SPACE TELESCOPE
PLEIADES NEO
EUTELSAT QUANTUM
TURKSAT 5B
INMARSAT 6

>2022
SPAINSAT NG
ONESAT
SENTINEL NG
JUICE
EUCLID
EXOMARS
VEGA C
ARIANE 6
HALO
MSR ERO

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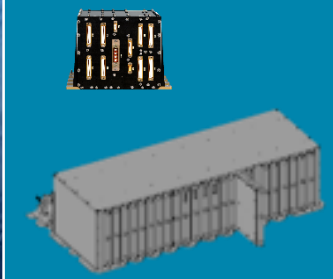
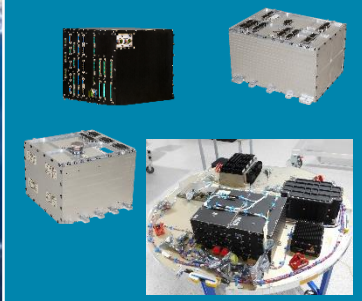
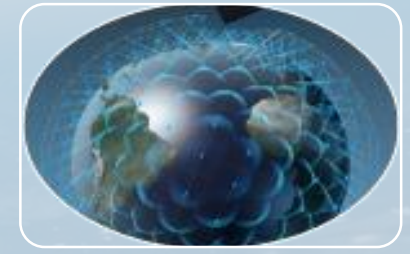
Diversified portfolio of **products** and **applications**

Human Exploration

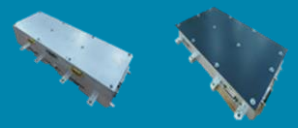


Launchers

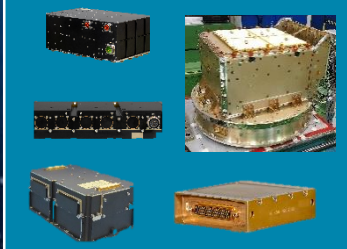




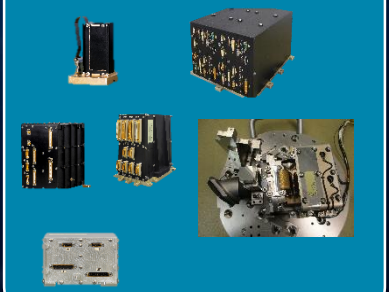
Constellations



Telecom (NEXT Space & NEO)



Earth Observation & Science



- **Technological innovation** is our guiding principle:
  we leverage innovation to anticipate the evolving needs and expectations of the space market.
- We have demonstrated our ability to meet requirements for **all mission types**:
  from large **telecommunication** satellites **to new space constellations**, **Earth observation** platforms to **scientific** and **deep space exploration** probes.

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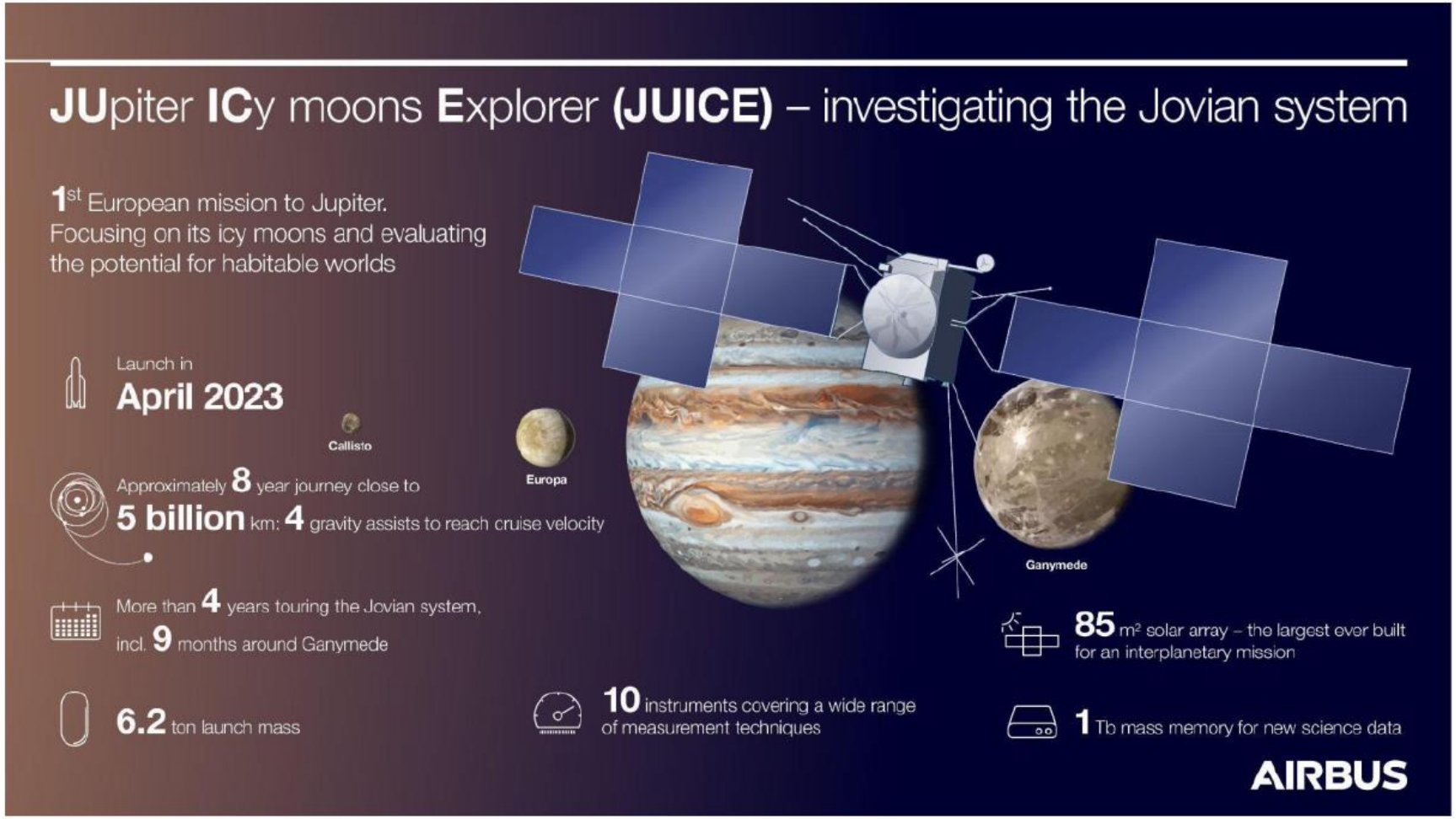
Programa Nacional de Observación de la Tierra por Satélite

SEOSAT Ingenio

PAZ

JUICE Power Conditioning and Distribution Unit (PCDU)



JUICE misión (Airbus)

PCDU (Airbus Crisa)

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Lunar Gateway Electrical Power Subsystem (EPS)

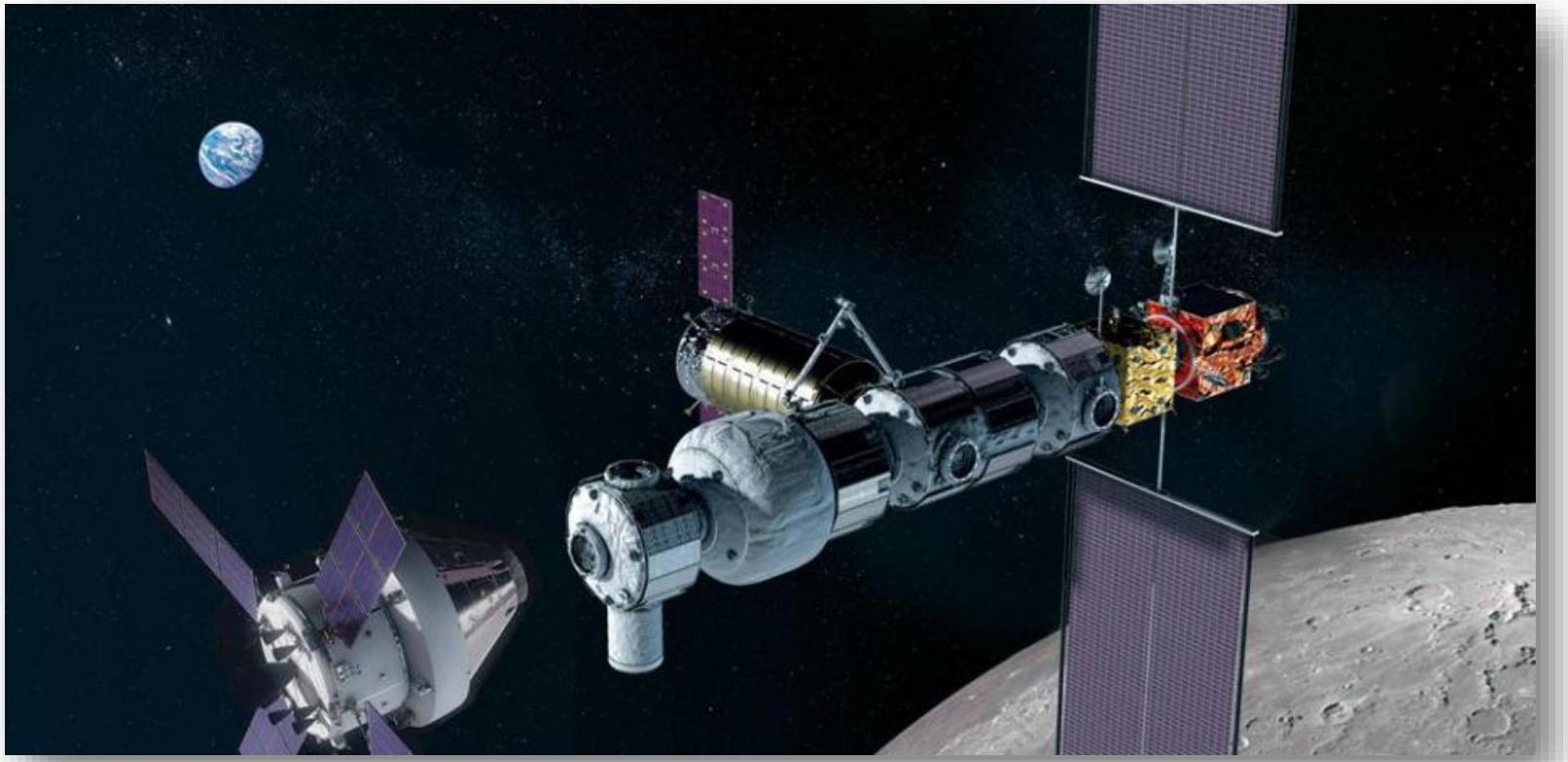
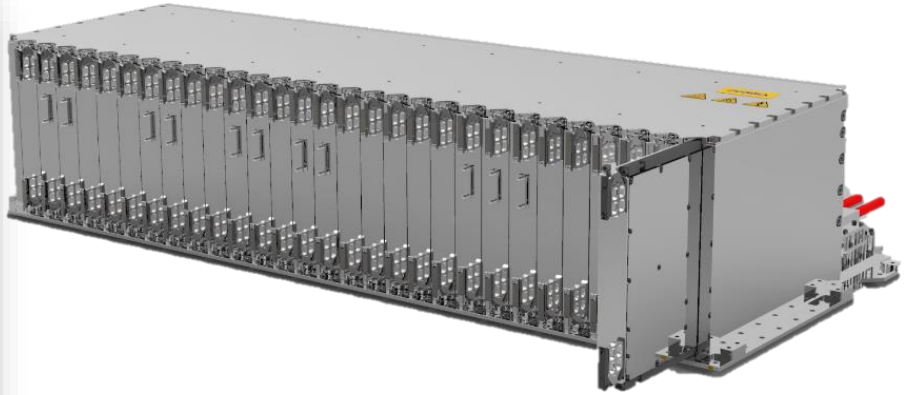
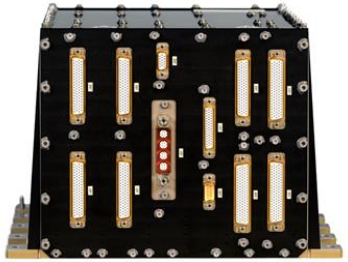


Imagen virtual de la estación espacial Gateway en órbita en torno a la Luna (NASA)



GHPS (Airbus Crisa)



TCU (Airbus Crisa)

Launch and Space Environment

ESA - Ariane 6

Lauch

- ❑ Shock
- ❑ Vibration
- ❑ Radiated Emissions

Space Environment

- ❑ Thermal : Solar radiation, albedo
- ❑ Meteoroids and debris
- ❑ Plasma : Ionospheric, Auroral, Magnetospheric
- ❑ Solar environment
- ❑ Ionozing radiation
- ❑ Magnetic field

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Space Environment :
EEE components Radiation effects

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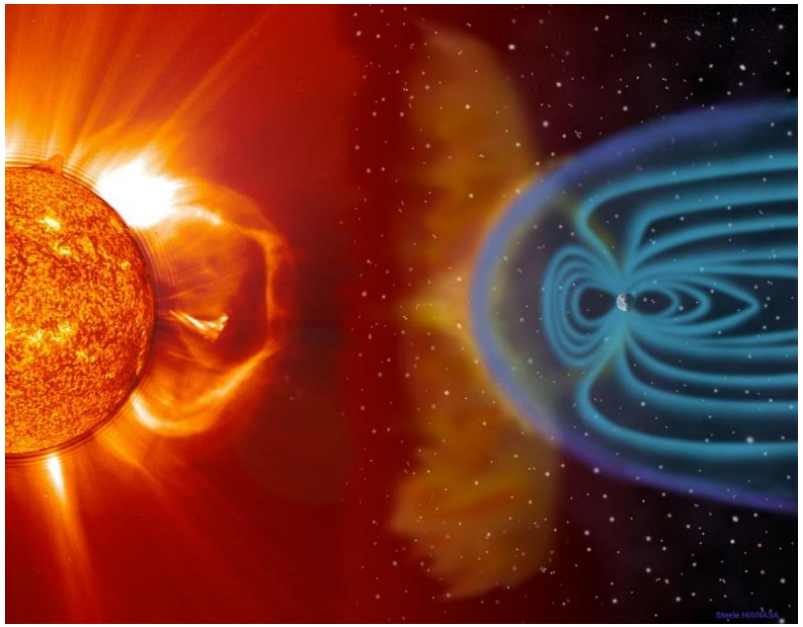
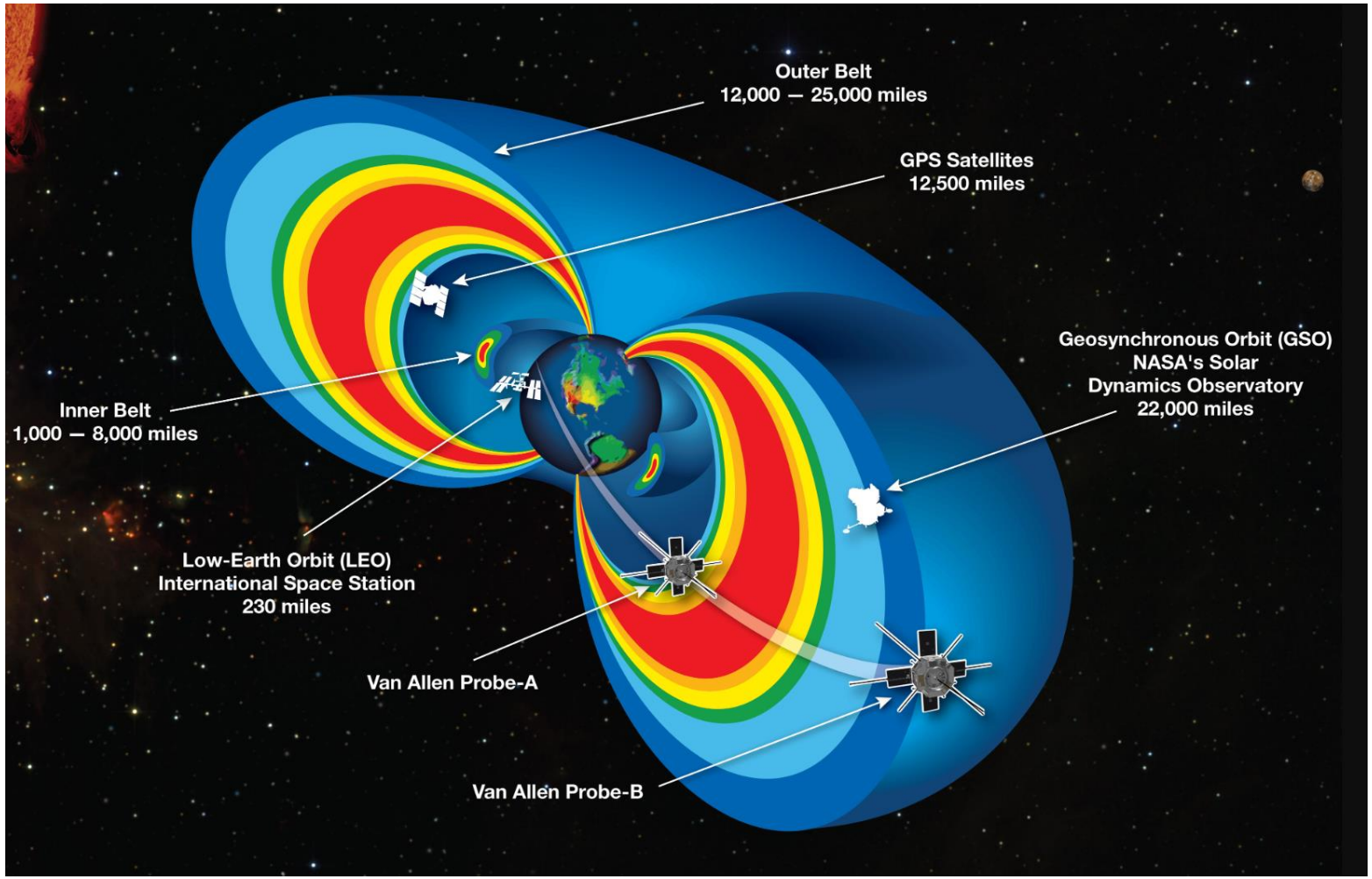
Solar, Plasma, Magnetic and Radiation Environment



https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter/Living_with_a_star

Table 1: Radiation effects versus orbit

Radiation effect	Orbit			
	GEO	LEO polar	LEO non-polar	MEO
Trapped electrons	+++	+	+	+
Trapped protons	-	++	++	++++
Total dose	+++	++	+	+++++
Heavy ions	+++	++	+	++
Solar flare protons	+++	+	-	++
- no effect	+ little effect		+++++	high effect



https://www.radiation-dosimetry.org/wp-content/uploads/2019/12/van-Allen-radiation-belts-satellites-min.png

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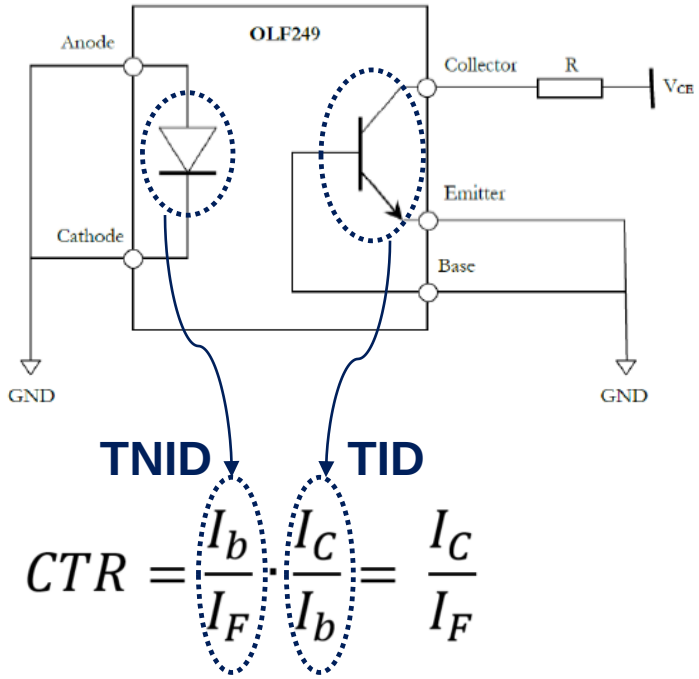
Total Dose

- Total Ionizing Dose (**TID**):
  - *Parameters degradation due to cumulated charge on the device die*
  - *Absorbed dose [rad(Si)]: 1 rad = 0.01 J/kg*
- Total Non-Ionizing Dose (**TNID**):
  - *Parameters degradation due to defects on the device crystal lattice*
  - *Fluence (Number of particles per unit area) [particles/cm2]*

Family	Sub-Family	TNIDL
CCD, CMOS APS, opto discrete devices	all	all
Integrated circuits	Silicon monolithic bipolar or BiCMOS	> $2x10^{11}$ p/cm² 50 MeV equivalent proton fluence
Diodes	Zener Low leakage Voltage reference	> $2x10^{11}$ p/cm² 50 MeV equivalent proton fluence
Transistor	Low power NPN Low power PNP High power NPN High power PNP	> $2x10^{11}$ p/cm² 50 MeV equivalent proton fluence



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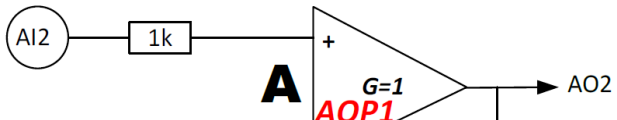
Single Events

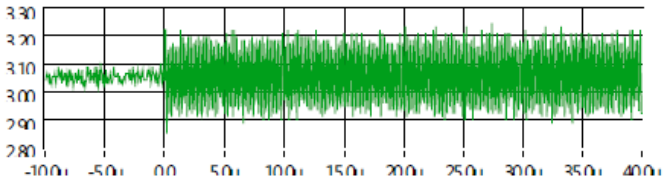
- Single Event Effects (SEE):
  - Average amount of energy that is lost per unit path-length as a charged particle travels through a given material [MeV·cm2/mg]

  - *SET/SEU: Single event transient/upset*
  - *MBU: Multiple bit upset*
  - *SHE: Single Hard Error (Stuck Bits)*
  - *SEFI: Single event functional interrupts*
  - *SEL: Single event latch-up*
  - *SEB/SEGR: Single event burnt out/gate rupture*

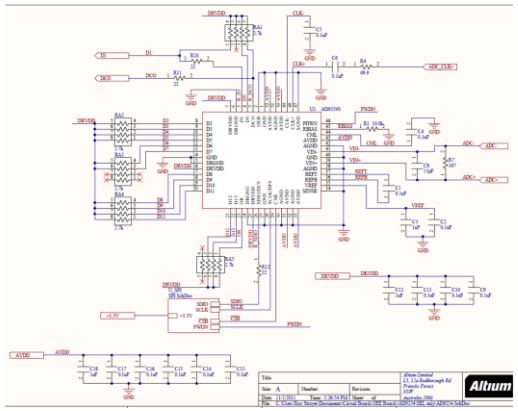
Single Events

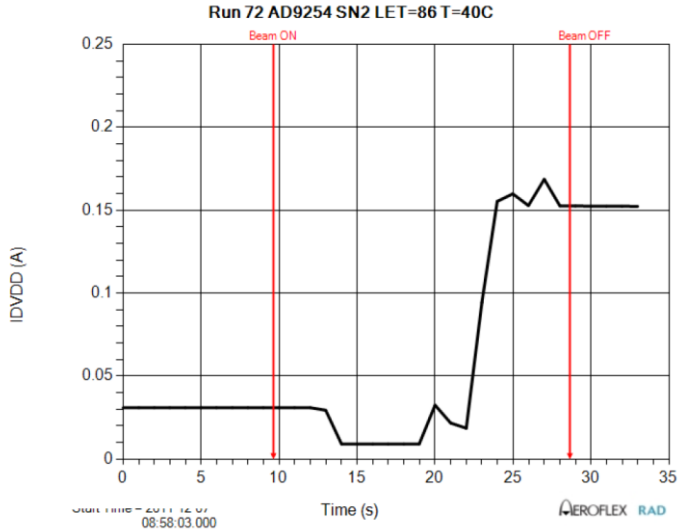
SET





SEL





MBU

1	0	0	0	1	0	1
0	0	1	0	0	0	1
1	1	0	1	0	1	0
1	0	0	0	1	0	1

$t = t_0$

1	0	1	0	1	0	1
0	0	1	0	1	0	1
1	0	0	1	0	1	0
1	0	0	0	1	0	1

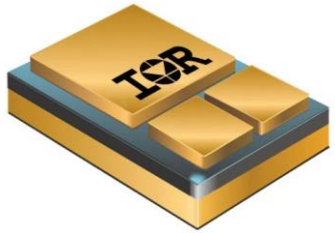
$t = t_1$

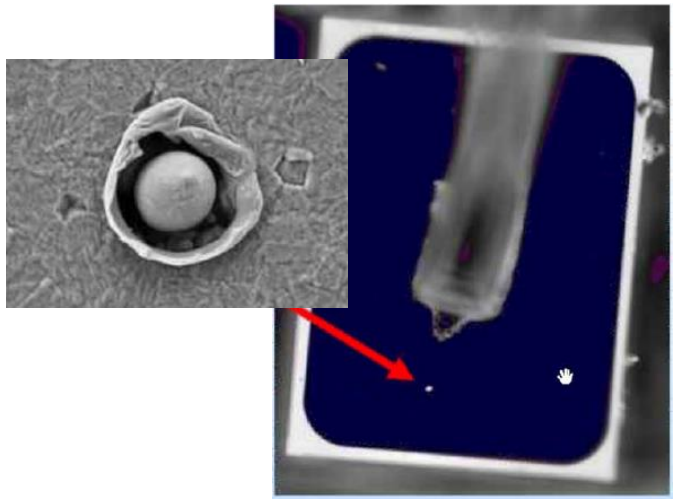
.
.
.

0	0	1	0	1	0	1
0	0	0	0	1	1	0
0	0	0	0	0	1	0
1	0	1	0	1	1	1

$t = t_n$

SEB





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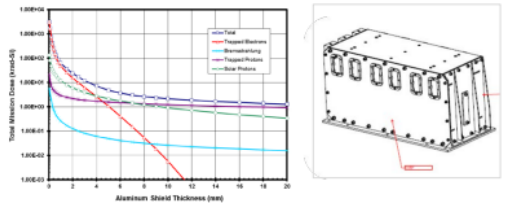
Radiation Effects Countermeasures

- Testing
  - ✓ Drifts
  - ✓ Transients
- Analysis
  - ✓ Ray-analysis
  - ✓ Total dose



→

- ✓ Current Limiters
- ✓ Transient filters
- ✓ Redundancies
- ✓ Error Detections And Correction (EDAC)
- ✓ Scrubbing
- ✓ Etc…

Space Environment : Spacecraft charging

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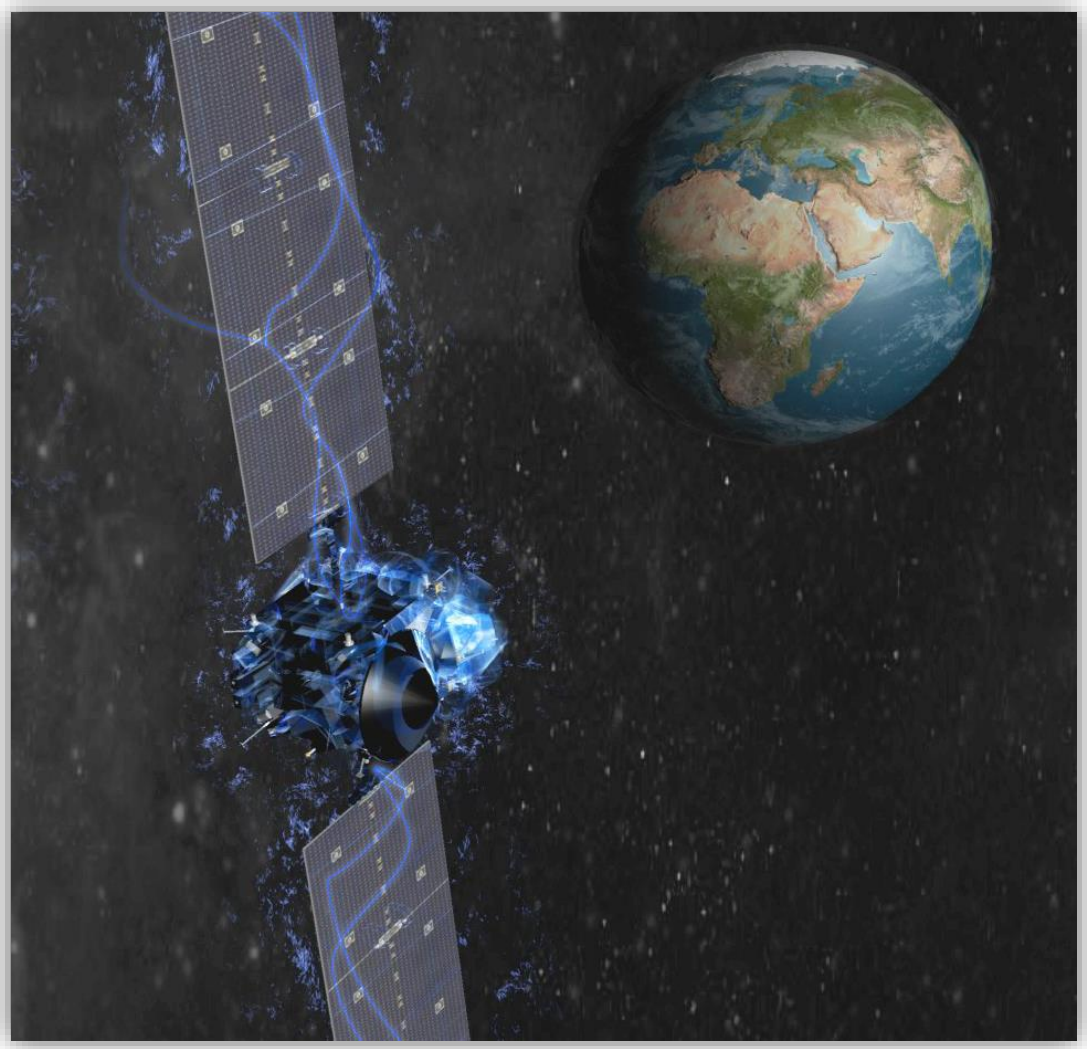
Spacecraft Charging

- Spacecraft **charging** occurs due to the **deposition of charge** on spacecraft surfaces or in internal materials **due to charged particles** from the environment resulting **high voltages** and **high electric fields** cause electrostatic discharges which are a hazard to many spacecraft systems.
  - **Surface**: caused by plasma particles with energy up to several 10s of keV.
  - **Internal** : caused by trapped radiation electrons with energy around 0,2 MeV and above.
- Both surface and internal charging have been associated with **malfunctions and damage** to spacecraft systems over many years



ESA opens an ITT: Electrostatic Discharge Characterization for In-Orbit Servicing – The Clean Space blog

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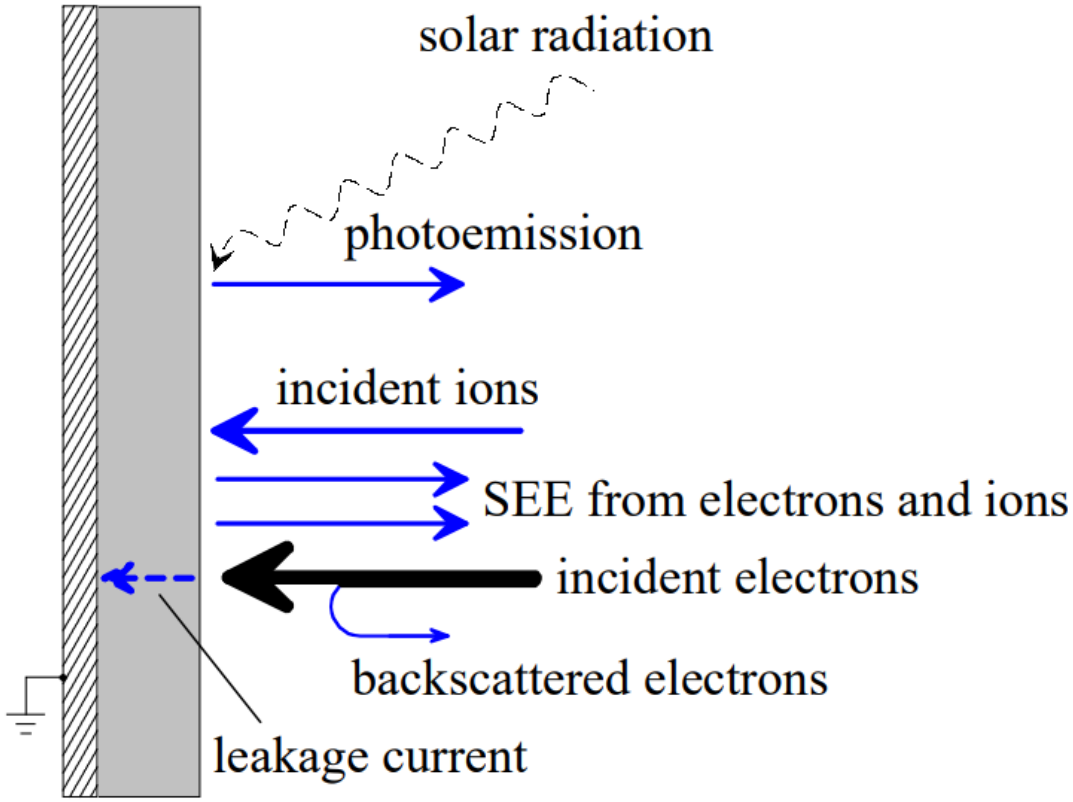
Spacecraft Charging

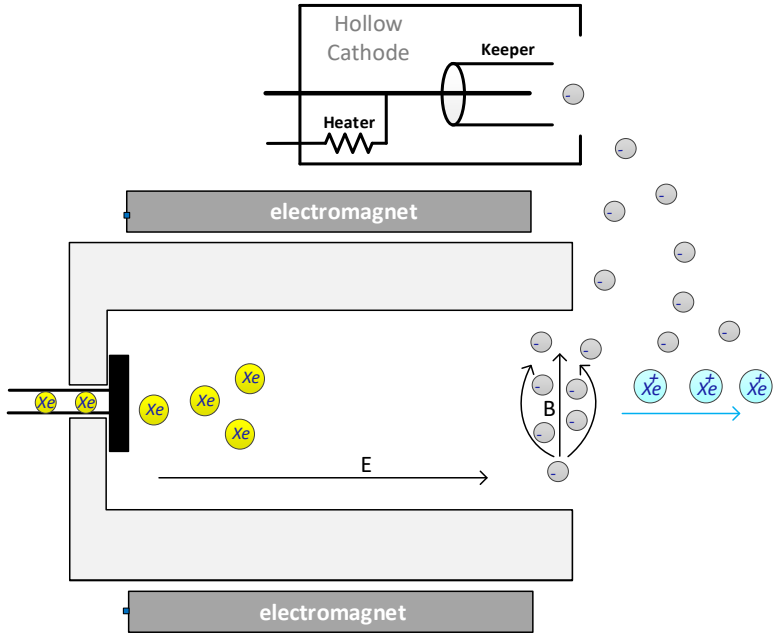
- Deposition of charge by:
  - Incident electrons
  - Incident ions
  - Photoemission
  - Leakage current
- The charging process continues until black and the blue currents are balanced
- Assessment of space worst case charging handbook (ECSS-E-HB-20-06A)



ESA opens an ITT: Electrostatic Discharge Characterization for In-Orbit Servicing – The Clean Space blog

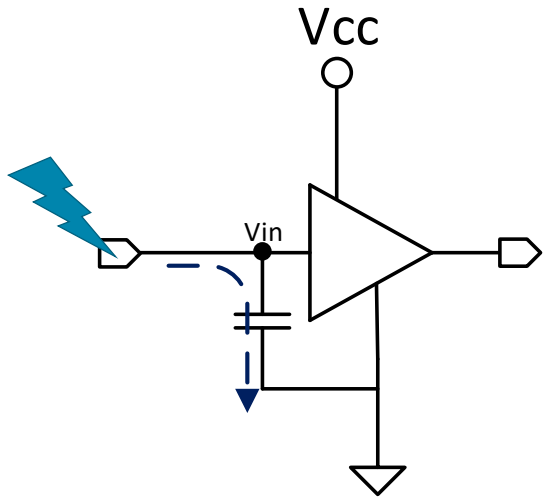
Spacecraft Charging special case: Electric Propulsion Systems

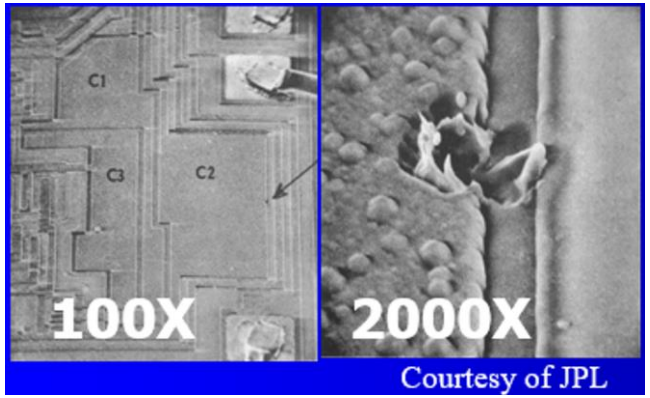
- Electric propulsion (EP) is prone, by nature, to emit charged particles to create thrust.
- The neutralizer expels an equal amount of electrons to make the total charge of the exhaust beam neutral.
- Without a neutralizer, the spacecraft would build up a negative charge and eventually ions would be drawn back to the spacecraft, reducing thrust and causing spacecraft erosion and interference with other systems and possible spacecraft damage.

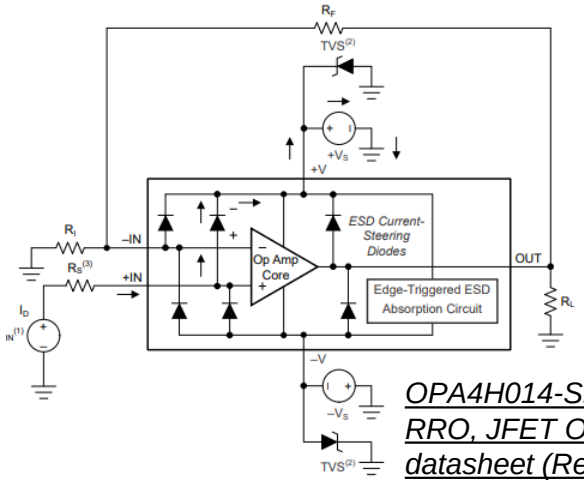


Spacecraft Charging : Review of the process, effects and countermeasures

1. When the potential becomes critical electrostatic discharges can occur either into space by electronic blow-off (expansion of electronic space charge), or differentially between several parts of the satellite.
2. Large current is produced into electronic circuits:
   a) By direct injection
   b) By indirect production of transient currents through electromagnetic coupling







- ❑ Countermeasures:
  - ✓ ESD diodes
  - ✓ TVS
  - ✓ Grounding
  - ✓ Etc…

OPA4H014-SEP 11-MHz, Precision, Low-Noise, RRO, JFET Op Amp in Space-Enhanced Plastic datasheet (Rev. A)

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Conclusions

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- **Electronic for space** applications is an special case within electronics domain subject to specific and **unique environmental conditions**
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Thank you