The Challenges of testing at European Irradiation Facilities

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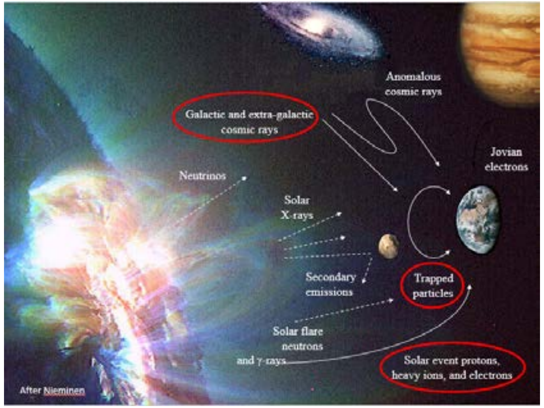
Radiation effects

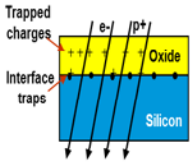
- Radiation belts trapped by planets' magnetospheres, consisting mostly of **protons and electrons**
- Particles originating from the activity of the Sun, which include also **heavy ions**
- And **cosmic rays** with very high energy



Ionising radiation in space

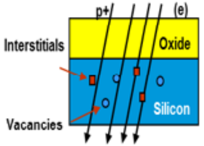
Particle		Energy range					
		ev	kev	10Mev	100MeV	500MeV	GeV
	Electrons		<-----TID------>				
				<--DD-->			
				<-SEE->			
	Protons				<--------------------TID----------------->		
				<---------DD------->			
					<--SEE-->		
	Heavy ions				<-------------------TID------------------->		
					<-------------------DD------------------->		
					<-------------------SEE------------------->		

Effect on the component



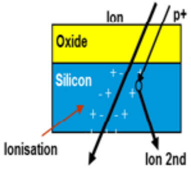
Total Ionising Dose

Electron-hole pairs generation in semiconductor oxides



Displacement Damage

Lattice Displacement Damage caused by energetic particles

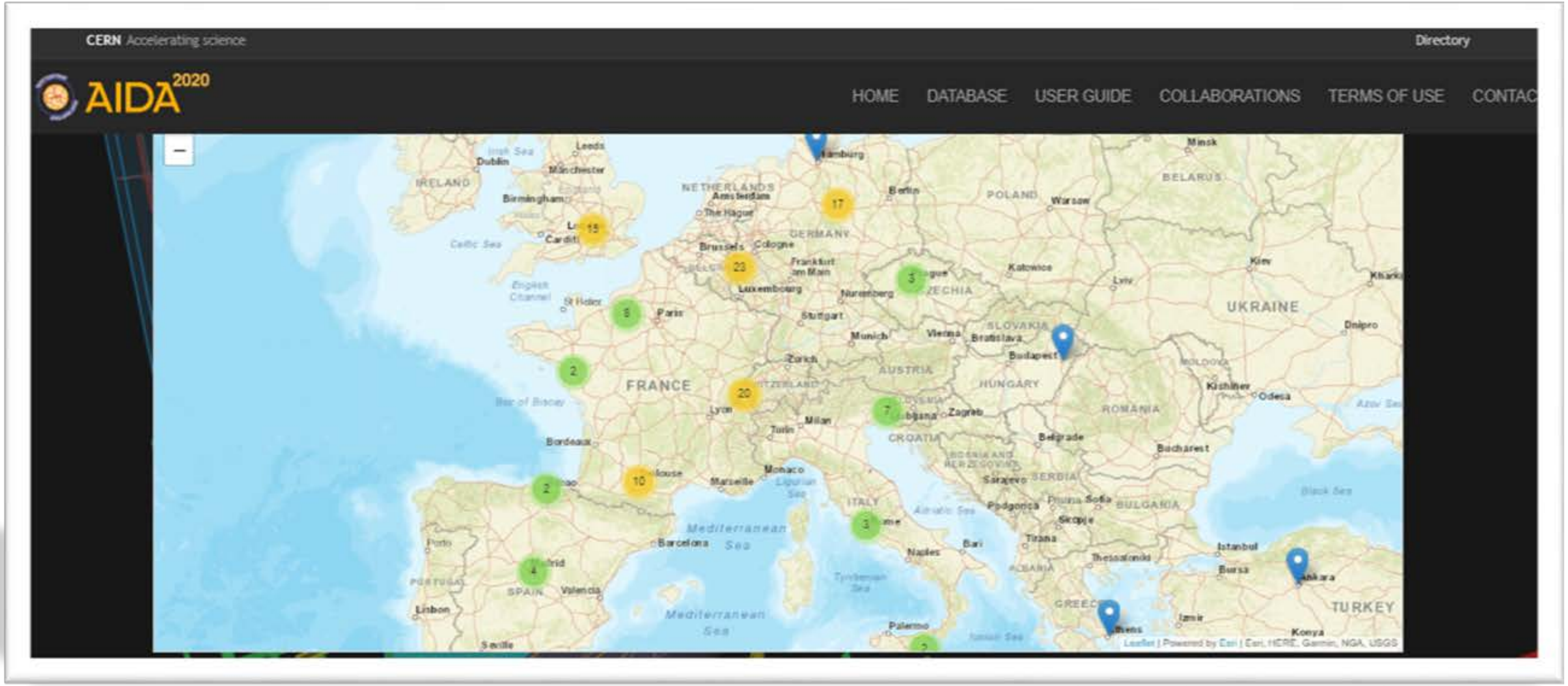


Single event effects

Ion deposits significant charge within device that directly affects its operation

Facilities (worldwide from CERN database)

https://irradiation-facilities.web.cern.ch/

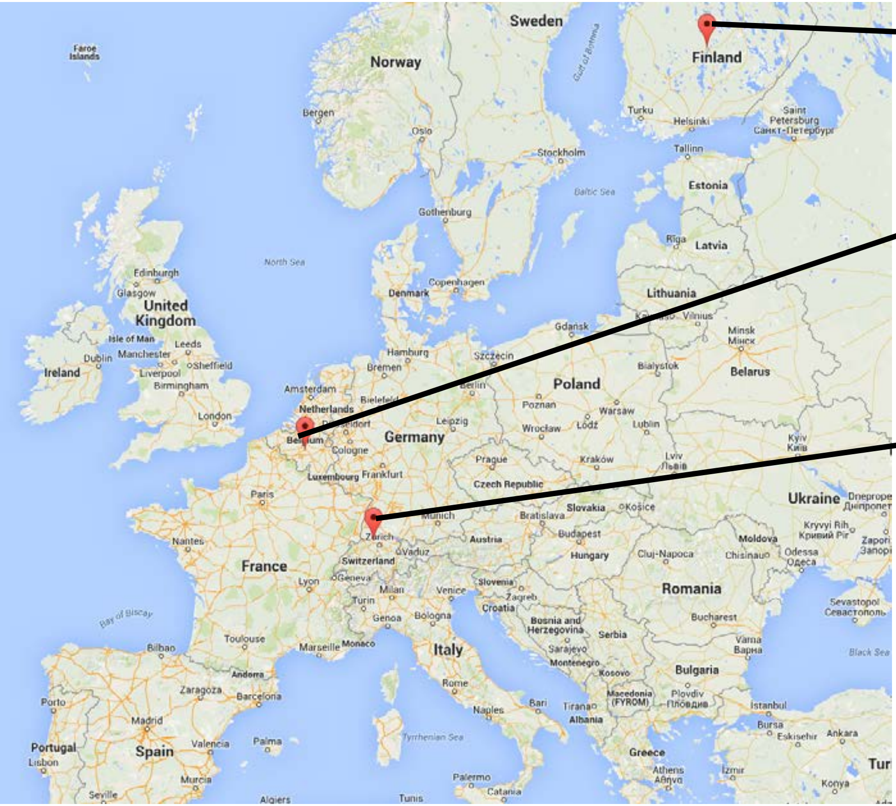


SEE testing in Europe

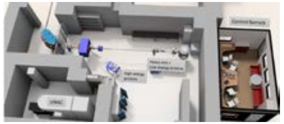
Standard Energy	<10 MeV/n
High Energy	10 - 100 MeV/n
Very High Energy	100 MeV/n – 5 GeV/n
Ultra High Energy	5-150 GeV/n

Facilities	Energy (MeV/nucleon)	Available cocktail	Availability per year
UCL HIF (Louvain-la- Neuve, Belgium)	8-10 MeV/n	9 species from C to Xe	About 16 weeks
RADEF (Jyväskylä,Finland)	22 MeV/n , 16.3 MeV/n, 9.3 MeV/n before	O, Fe, Kr 6 ion species, from O to Xe (7 ion species,from N to Xe)	About 12 weeks
KVI CART (Groningen, Netherlands)	30 MeV/n	4 species, from Ne to Xe	1-2 weeks
GANIL G4 (Caen, France)	27 to 60MeV/n	One species per experiment, Ar, Kr, Xe or Pb	1-2 weeks
GSI SIS18 (Darmstadt, Germany)	50 MeV/n to 1-1.5 GeV/n	One species per experiment, can be from proton to U	Less than 1 week Only scientific experiments
CERN CHARM or North Area (Geneva, Switzerland)	6-160 GeV/nucleon	One species per experiment	Less than 1 week

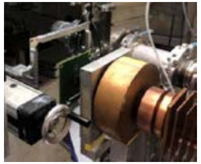
Irradiation test facilities (supported by ESA) – Heavy ions and protons and electrons



RADEF, JYFL Heavy ions, protons, electrons
Jyväskylä, Finland



UCL Heavy ions, protons
Louvain-la-Neuve
Belgium



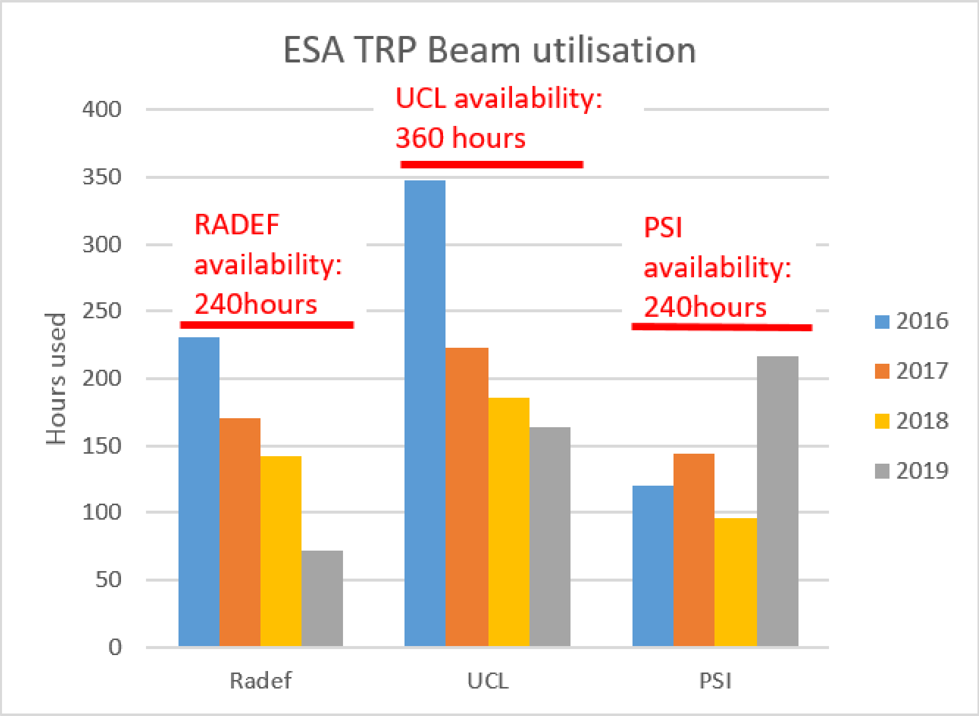
PSI Protons, electrons
Villigen Switzerland

TEC-QEC has been collaborating with these facilities for more than 25 years. PSI, UCL, since 1990-1992. RADEF since 2004 beam in 2007-2008

Aiming at continuous improvement of the quality of the beam, dosimetry and testing infrastructure

Stable flux and energy levels, high particle selectivity, accurate dosimetry, electrical/optical interfaces for cabling

ESA beamtime at supported facilities



Aim at support facilities developments on **beam quality, dosimetry and** includes an annual fixed amount of hours for irradiations tests for

ESA R&D developments

2021_02_24 CMOS image sensor development
2021_02_23 SDRAM memories
2021_02_23 SiC qualification and other mosfet screening
2021_02_18 TIR(detector)
2021_01_21 HERA
2020_10_07 ASIC
2021_01_18 GaN MIM Capacitors
2020_12_11 Small study - intradie SRAM testing
2021_11_24 HERA - cubesat payload only
2020_11_23 SEE laser COTS screening
2020_11_22 FYS
2020_11_02 MEMS pressure modues
2020_10_16 Latchup testing of digital isolator
2020_10_09 GPU

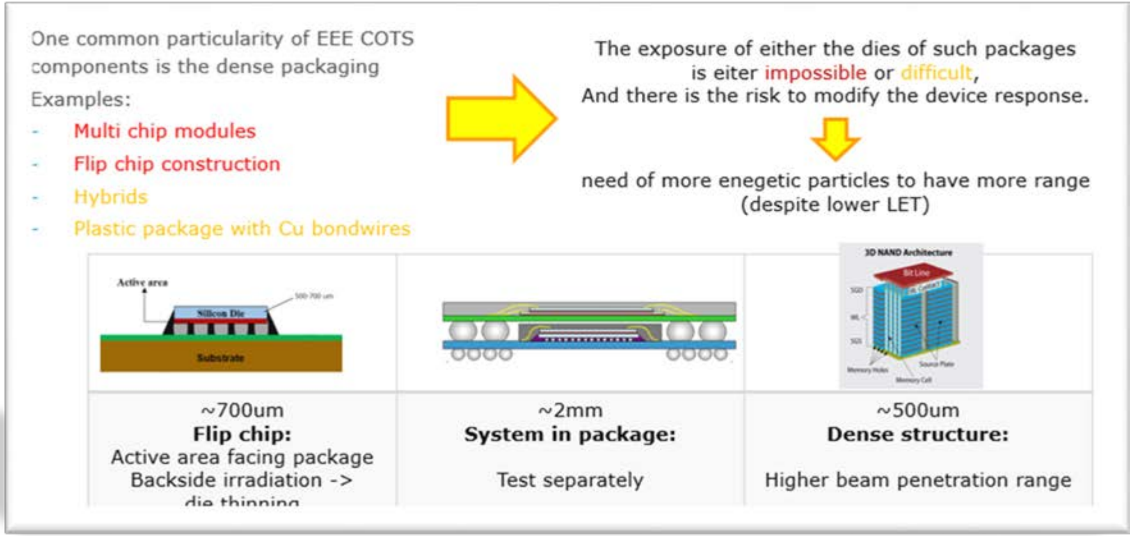
2020_09_28 Phototransistor
2020_09_08 RACOCO
2020_09_07 MPCG
2020_09_06 GPU processors
2020_09_04 RADEM
2020_09_03 3Dnand
2020_09_01 GaN Devices
2020_09_02 SET
2020_09_01 Stuck bits on SDRAM
2020_08_31 Optical Fibers
2020_08_30 Stuck bits on SDRAM
2020_08_10 Proba 3
2020_08_09 NG-LARGE
2020_08_08 NG-ULTRA

Challenges : limited range of heavy ions

Standard energy ions
require sample preparation
to reach the active area with sufficient LET for testing
=>It may be not technically possible for certain technologies

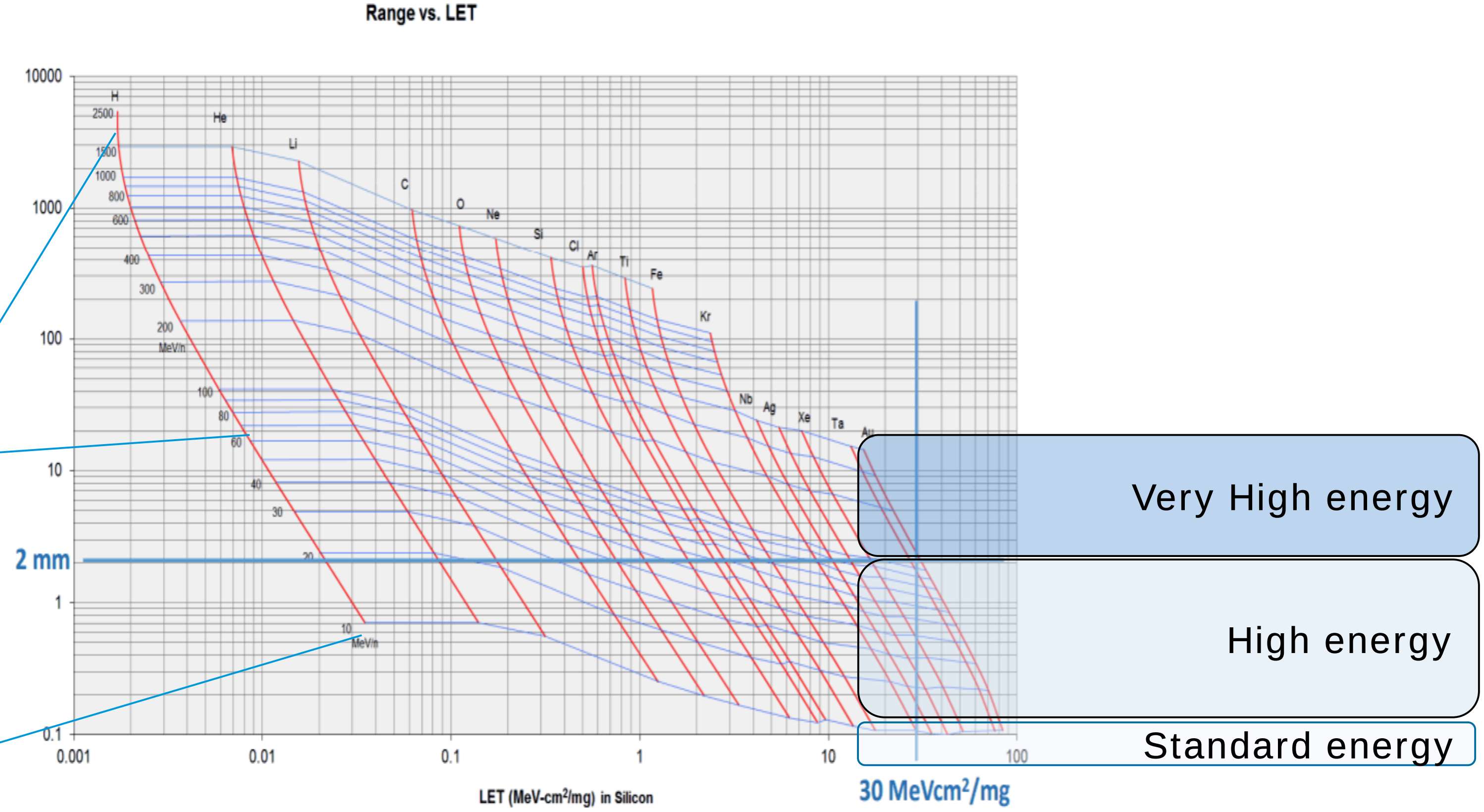
delidding/decapping

or Die thinning for flip chip



Linear energy transfer and range

Facilities	Energy (MeV/nucleon)	Range of heavy species (Xe) in silicon
CERN CHARM	6-160 GeV/nucleon	meters
GSI SIS18	50 MeV/n to 1-1.5 GeV/n	2.4 mm to 7.8 cm
GANIL G4	27 to 60MeV/n	50 µm to 685 µm
KVI CART	30 MeV/n	333 µm
RADEF	22 MeV/n , 16.3 MeV/n, 9.3 MeV/n	255 µm 155 µm 92 µm
UCL HIF	8-10 MeV/n	73 µm



High energy facilities

Europe

Facilities	Energy (MeV/nucleon)	Availability per year
GANIL G4 (Caen, France)	27 to 60 MeV/n	1-2 weeks
GSI SIS18 (Darmstadt, Germany)	50 MeV/n to 1-1.5 GeV/n	Less than 1 week Only scientific experiments

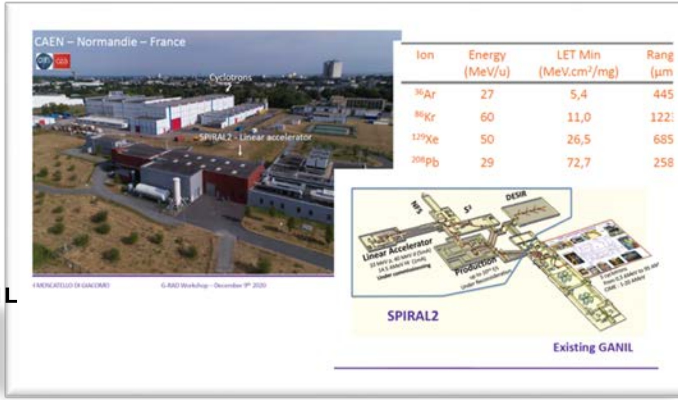
USA

Facilities	Energy (MeV/nucleon)	Availability per year
TAMU (College Station, TX, USA)	15 MeV/n 25 MeV/n 40 MeV/n	About 20-25 weeks
NSRL (Brookhaven, USA)	1500-217 MeV/n (light to heavy ions)	~20 weeks NASA funded or scientific proposals

In this scenario, the European space industry is in a **critical competitive disadvantage due to the lack of radiation testing opportunities of High Energy Ion beams.**

Currently only facilities in USA offer **High Energy Ion beams** and their use is not dependable, due to priority often given to the their national industry, and associated with additional constrains on costs and logistics overhead

GANIL



After:
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS
Marie-Hélène MOSCATELLO DI GIACOMO for the, G-RAD Workshop 2020

GSI

Initiatives for Irradiation facilities in Europe

ESA initiatives:

Objectives:

Development of **high energy beam (range and LET, intensity)** for radiation tests of highly integrated electronic components **in existing facilities**

to overcome the lack of beam availability to test complex EEE components

Contractual implementation:

- OSIP CALL
- TDE development

RADNEXT initiative:

RADNEXT is an H2020 INFRAIA-02-2020 infrastructure proposal with the objective of creating a network of facilities and related irradiation methodology for responding to the emerging needs of electronics component and system irradiation; as well as combining different irradiation and simulation techniques for optimizing the radiation hardness assurance for systems, focusing on the related risk assessment. => https://radnext-network.web.cern.ch/

Mitigation initiatives for COVID outbreak

Request to implement an infrastructure to cope with the situation

To execute test from remote, this to limit presence of number of visitors at the irradiation facility, and reduce travels

- -Full remote all setup installation and actions delegated to facility
- -Partial remote to reduced test-team presence at facility, with colleagues following from remote

Implementation (UCL, RADEF):

Communication between facility – remote user

- internet connection possibilities improved
- Communication and screen sharing (Skype, Zoom, Teams and phone)
- Webcams in the control area and inside of vacuum chamber

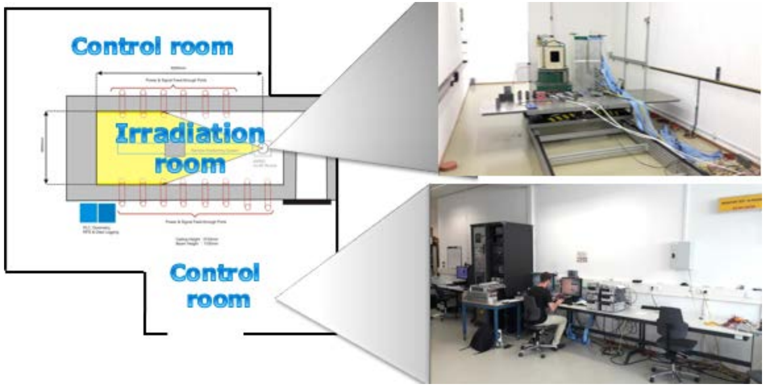
Monitoring on beam and equipment

- Streaming of beam status interface GUI (for RADEF possibility to control the HI beam status is in development)
- Webcams and internet access to irradiation chambers

Note:

Full remote testing poses lots of limitations to the execution, can be considered only for very simple setups

ESTEC Facilities for irradiation test and test preparation



Co60 Facility

80 TBq Co60 source for Total Ionising Dose tests

Dose rate window compliant with the ESCC22900 standard

(from 0.01 rad/s [Si] to 3rad[Si]/s)

ISO17025 accredited dosimetry

Cf252 “CASE”

for qualitative investigation on SEE

thermal control of DUTs [-30 °C ; 130°C]

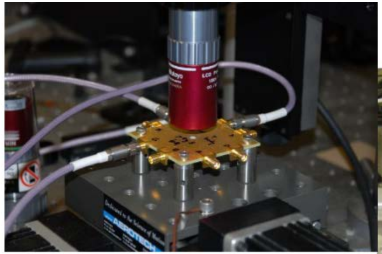
Decapsulation systems

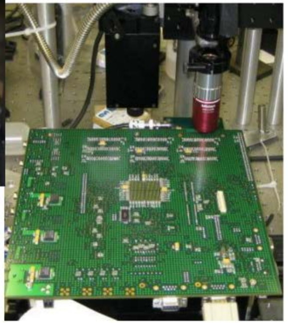
For plastic packaging (Laser, mechanical, acid)

New Acquisition: SEE laser test bench @ ESA/ESTEC

New SEE laser test bench:

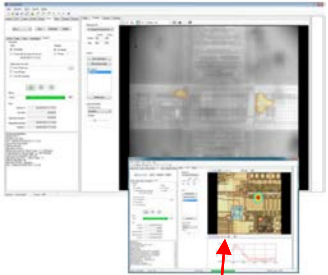
- PULSYS Rad by PULSCAN for
  - Single-Event Effects Testing
  - Design Debug
  - Defect localization
  - Reliability evaluation
  - Part screening and qualification





Dale McMORROW, "Fundamentals of the Pulsed Laser Technique for Single Event Effects Testing", SERESSA 2018, Noordwijk, Netherlands 15/11/2018

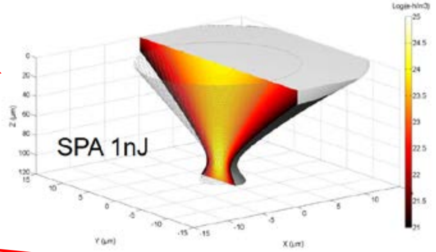
PULSYS-MICRO microscope

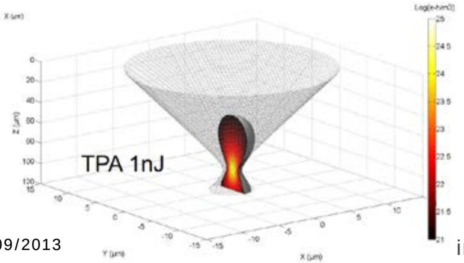


PULSWORKS software

Two different configurations:

- **SPA** (Single Photon Absorption) for surface injection
  - Laser wavelength: 1064nm
  - Pulse duration: 30ps
  - Max pulse energy at fiber output: 50nJ
  -
- **TPA** (Two Photon Absorption) for a localised injection
  - Laser wavelength: 1550nm
  - Pulse duration: 450fs
  - Max pulse energy at fiber output: 30nJ





V. Pouget - RADLAS - 20/09/2013

ESA Website for Radiation Test data

List of radiation test reports performed by ESA or European partners under ESA contracts

https://escies.org/labreport/radiationList

➔ New database to come (mid 2021)

HAS2 Proton TNID test	ON Semiconductors	HAS2	ON Semiconductor	02-05-2013	RA 0655			
HAS2 TID test	ON Semiconductors	HAS2	ON Semiconductor - SODERN	02-05-2013	RA 0656			
HAS2 electron tests	ON Semiconductors	HAS2	SODERN	02-05-2013	RA 0657			
HAS2 heavy ion test	ON Semiconductors	HAS2	SODERN	02-05-2013	RA 0658			
HAS2 Proton SET test	ON Semiconductors	HAS2	SODERN	02-05-2013	RA 0659			
ASIC and Microprocessors (4)								
SEE test report summary SCOC3 CD1034 - ATMEL ATC18RHA Spacecraft Controller On a Chip	ATMEL	SCOC3	EADS Astrium	01-01-2008	RA 0635			
Cf-252 testing of the LEON2-FT asic	Cobham Gaisler	LEON processor	Gaisler Research	10-07-2012	RA 0605			
GR740 System on chip	Cobham Gaisler	GR740, silicon revision 1 / Diffusion Lot nr. Q801934	Cobahm	24-05-2019	RA GR740-RADS-1-1-1			
Cf-252 testing of HIFAS asic	Omnisys	asic	Omnisys Instruments	01-01-2008	RA 0604			
CCD (1)								
Proton Testing at KVI	E2V	CCD204	n/a	01-01-2008	RA 0599			
FPGA (6)								
TID MFA-1 co-60	AMS	MFA-1	IWF / IIS	01-01-2008	RA 0513			
ATC18RHA TID ref.ADF-DE-R0564-CUP	ATMEL	ATC18RHA	ATMEL	31-03-2005	RA 0514			
ASIC Magnetometer Front End SEE	IWF + Fraunhofer	Magnetometer Front End	IWF	27-01-2006	RA 0545			
Single Event Transient Measurement - Microsemi A3P3000 FPGAs	Microsemi	A3P3000 FPGA	IROC	01-01-2008	RA 0707			
ProASIC3L FPGA SEE Test Report	Microsemi	A3PE3000L	Hirex	25-08-2011	RA 0584			
TID test on ProASIC3 FPGA from Microsemi (previously ACTEL)	Microsemi	A3PE3000L	n/a	20-02-2013	RA 0621			
GaAs/GaN (1)								
GaAs POWER DEVICES - MITSUBISHI MGF2430S - SUMITOMO FHX35LR -	NULL	NULL	n/a	01-01-2008	RA 0767			

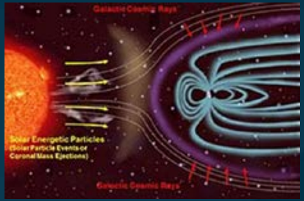
Technology Harmonisation Dossier of Radiation Environments & Effects

Anastasia Pesce

Head of the Radiation Hardness Assurance and Component Analysis Section (TEC-QEC)

Technology Harmonisation Dossier of Radiation Environments & Effects

Objectives of the Technology Harmonisation Dossiers:



“Fill strategic gaps” and “Minimise unnecessary duplications”

Consolidate European Strategic capabilities

Achieve a coordinated and committed European Space Technology Policy

Contribute to continuity and coherence between Technology and Industrial Policies

radiation environment measurement techniques

radiation environment modelling

radiation effects analysis tools

radiation hardening and radiation effects mitigation

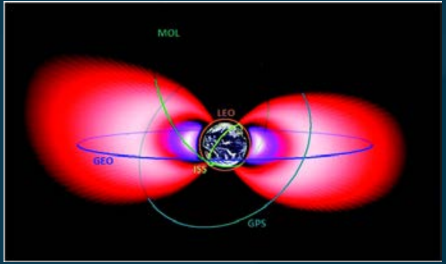
radiation effect mechanisms

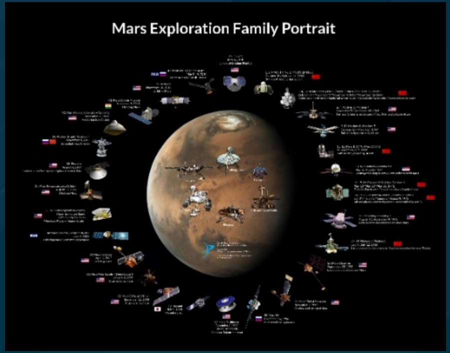
radiation effects testing methods

radiation facilities

Key Issues identified for radiation environment and effect technology harmonization

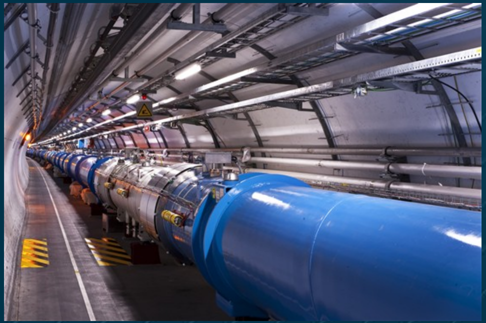
- Evaluation of new models in the context of European models and experience and further development of independent European capabilities, and update of related processes (e.g. standards)
- Radiation hazards at Jupiter and the other outer planets (environment modelling, shielding analyses, radiation hardness assurance and radiation monitoring are necessary)
- Radiation-induced detector background
- Miniaturisation of detection technologies
- Missions with orbit raising by electric propulsion, leading to higher radiation levels
- Miniaturisation of detection technologies
- Lengthening mission lifetimes, particularly for commercial spacecraft
- Growth in on-board complexity, particularly for Earth observation
- Anticipation of human missions beyond LEO
- Space weather radiation hazard prediction services
- Effects of extreme (“1-in-a-100+-year”) events on in-orbit infrastructures
- **Difficulty of RHA / testing of complex devices**
- **Increasing use of COTS technologies**
- **Proton induced SEE by direct ionization**
- **Calibration facilities and processes**
- **Facilities with increased capabilities, availability to space users at reasonable costs**

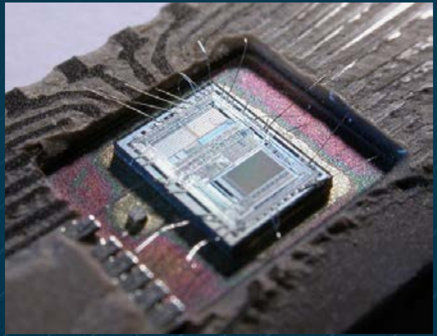


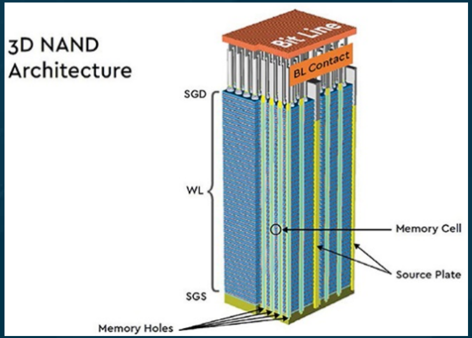


European Strategic Interest

- Independent access to environments and effects knowledge
- Radiation evaluation and qualification of European EEE components
- Characterisation of radiation effects in novel European EEE component technologies
- Knowledge of radiation behaviour of state-of-the-art European EEE component technologies will enable greater performance for European spacecraft both at platform and payload level
- Continuous evaluation and verification of European Radiation Hardness Assurance standard
- Improvement of European test facilities to ensure European non-dependence and compliance to rapidly evolving EEE component technologies







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ESCIES ESA Radiation webpage:
https://escies.org/webdocument/showArticle?id=227&groupid=6

Useful Links

https://escies.org/webdocument/showArticle?id=1068

Contacts for Beam info and requests

Info on external facilities

https://escies.org/webdocument/showArticle?id=921&groupid=6

e-mail: ERFbooking@esa.int

Info on ESTEC Co60

https://escies.org/webdocument/showArticle?id=251&groupid=6

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