BVS ABR SPACE RADIATION WORKSHOP

RADIATION PROTECTION OF ELECTRONICS IN SPACE

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CEO

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MAGICS

ABOUT

Magics Instruments NV, a spin-off of KU Leuven and SCK-CEN, was founded by Ying Cao and Jens Verbeeck on 4th of August 2015, currently employing 30 people, still growing and turning revenues above 3 Million Euro.

The spark for MAGICS is a shared conviction that autonomous machines are the keys to exploring other planets and unlocking secure, sustainable sources of energy, food and materials on these worlds and on our own. Our Belgium headquarters is home to a world-leading research and development team, bringing together the core disciplines of radiation hardening, integrated circuit design and machine learning that underpins the next generation of autonomous machines.

AUTOMATION & RELIABILITY

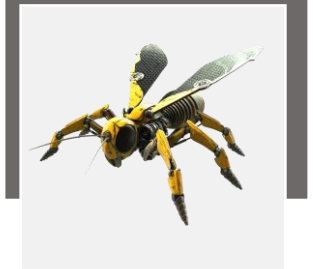
for autonomous machines

Automation

Motion control solutions

Radiation hardened chips

Object detection & Path planning



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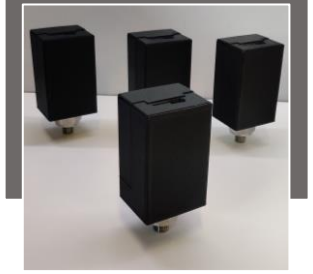
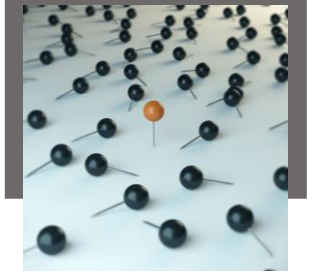
Reliability

Industrial IoT



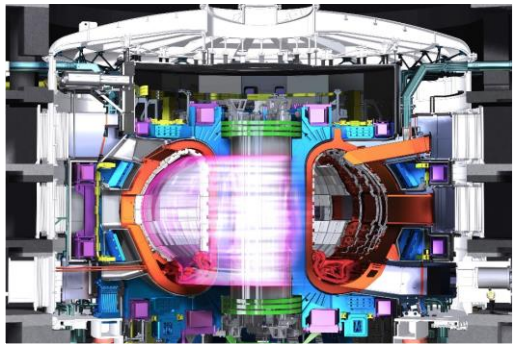
Plantscope

Anomaly detection

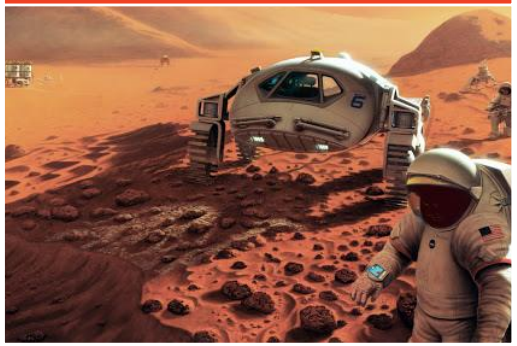


FROM NEW ENERGY APPLICATIONS TO BROADER MARKETS

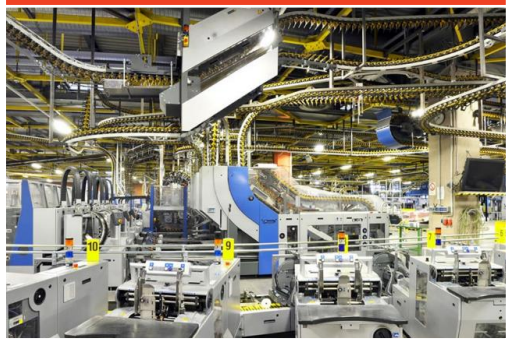
ENERGY



SPACE



DECOMMISSIONING



MANUFACTURING

FROM INPUT REQUIREMENT TO PROTECTED ELECTRONICS

Input

System requirements

Radiation requirements

TID effects / SEE effects

ASIC design

Schematic design and simulation

Layout design and verification

ASIC fabrication

Out-sourced wafer production

Packaging

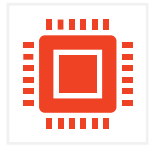
Qualification

Lab testing

Temperature assessment

Radiation assessment

Software



Rad-hard ASIC

System implementation of rad-hard ASICs

MAIN RADIATION ENVIRONMENT IN SPACE

Cosmic radiation

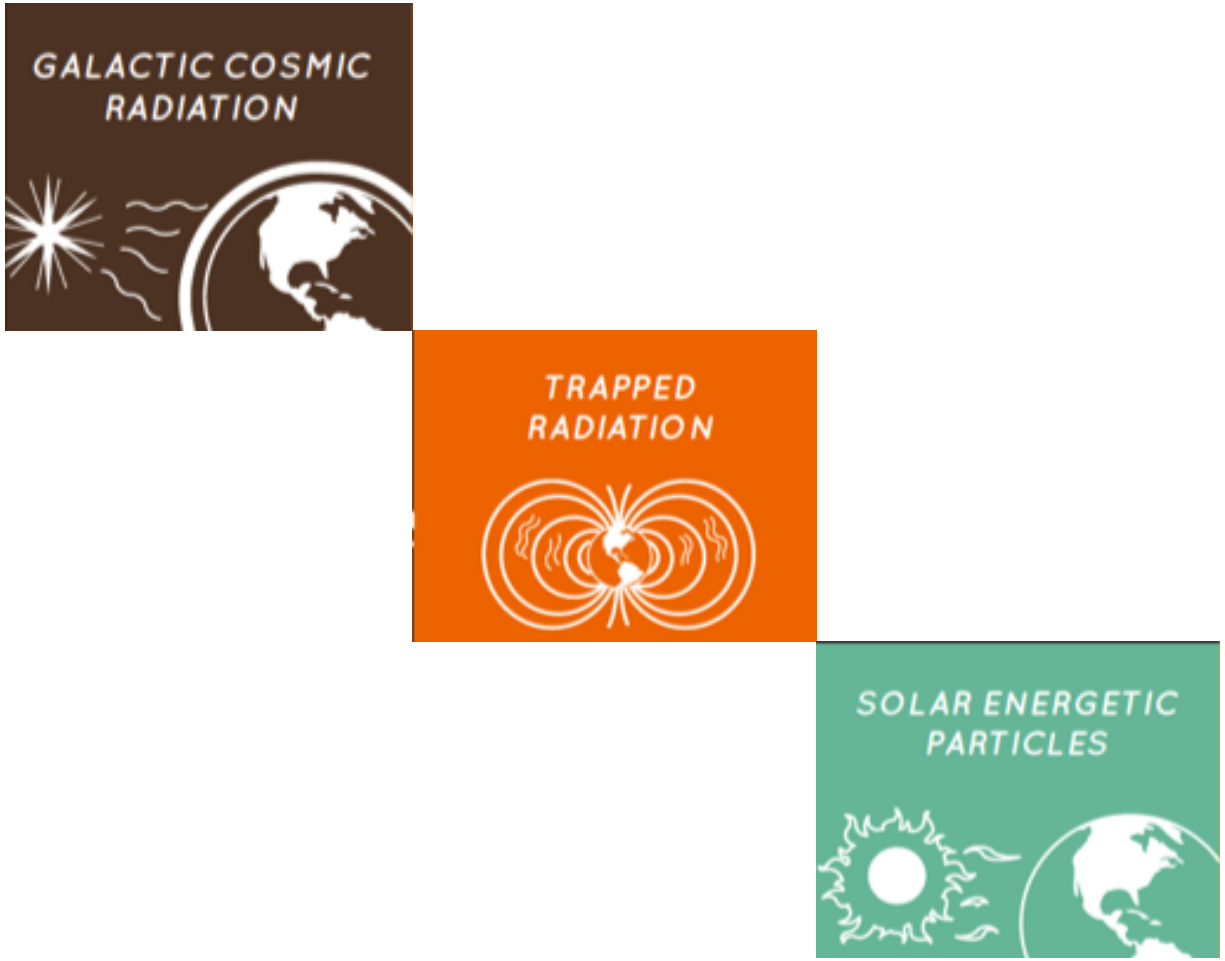
- This type of radiation is emitted as immense clouds of high-energy charged particles thought to originate from supernovas.
- High energy charged particles, Heavy ions

Trapped radiation

- This type of radiation occurs when charged particles become trapped in Earth's magnetic field and spiral around inside the field
- Proton and Electrons

Solar radiation

- Solar energetic particles are released by the Sun in solar particle events. This can result in sudden, intense storms.
- Protons, heavy ions, electronics, neutrons, gamma rays, X-rays,…

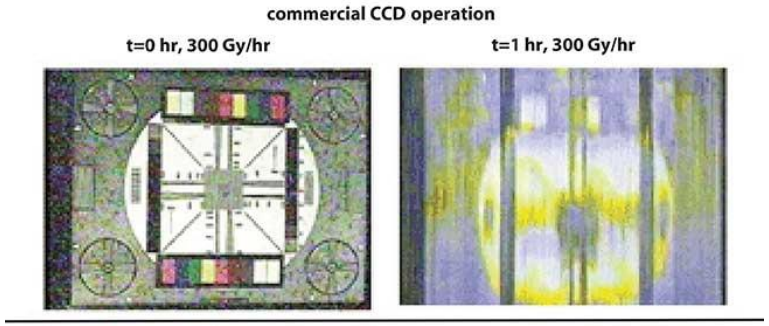


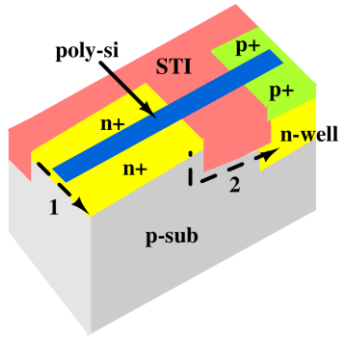
Source: https://www.nasa.gov/sites/default/files/np-2014-03-001-jsc-orion_radiation_handout.pdf

MAIN IMPACT ON INTEGRATED CIRCUITS

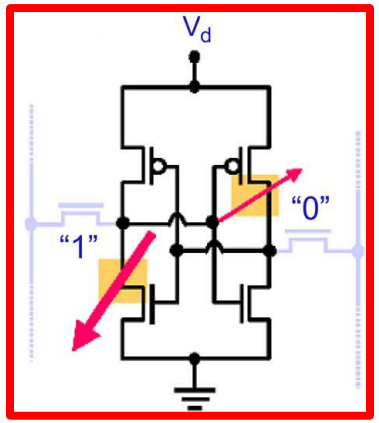
Ionizing radation creates two main effects on integrated circuits:

- **Total ionizing dose effects**
  - Edge transistor leakage
  - Inter-device leakage
  - Threshold-voltage shifts
  - …
- **Single event effects.**
  - Single-Event Upset
  - Single-Event Transient
  - Single-Event Latch-up
  - …





SRAM



Leakage paths in bulk CMOS technology. Taken from J. Schwank et al., «Radiation effects in MOS oxides», IEEE Transactions on Nuclear Science, Vol. 55, No. 4, 2008

RADIATION-HARDENING OR “PROTECTION”

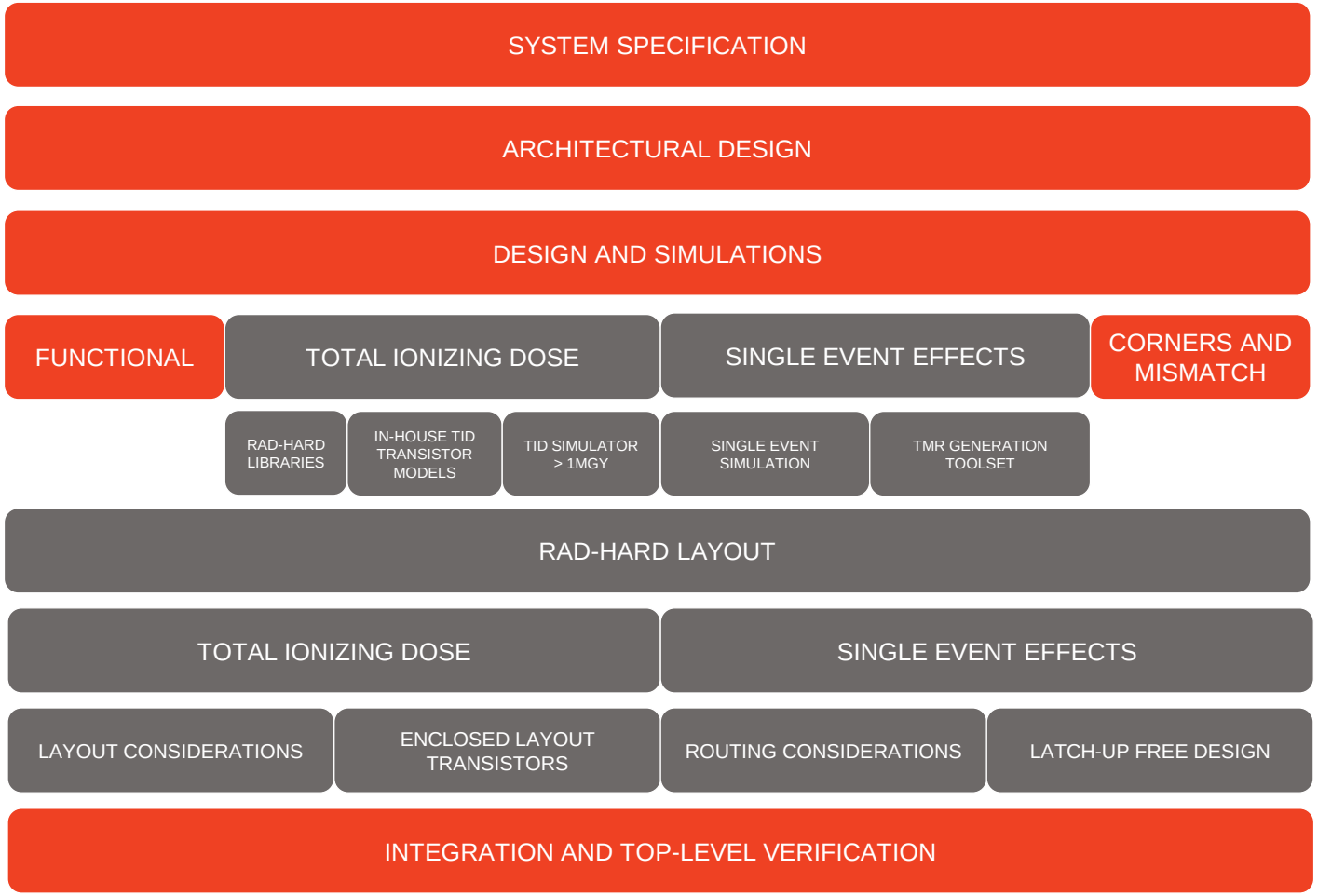
- ✓ **RHBS: Radiation-Hardened-by-Shielding**
- ✓ **RHBP: Radiation-Hardened-by-Process**
- ✓ **RHBD: Radiation-Hardened-by-Design**

	RHBS	RHBP	RHBD
Feature Size	✓✓	✗	✓
Radiation Hardness	✓	✓✓	✓
Availability	✓✓	✗	✓
Yield	✓	✗	✓
Cost	✗	✗	✓✓
Product Size	✗	o	✓✓

RADIATION "PROTECTION" BY DESIGN

A rad-hard IC design environment to achieve high first-time-right rate and high reliability:

- Industrial standard EDA tools for: model simulation; schematic edit, simulation and layout; digital design and implementation; physical verification and sign-off.
- Experimentally verified transistor radiation model for TID (total-ionizing-dose) simulation.
- In-house proprietary TMR (triple modular redundancy) generator and SET simulator for single-event simulation.
- A wide range of qualified rad-hard analog/mixed-signal IP blocks (e.g., PGA, ADC, PLL, Clock reference, Bandgap, LDO, Temperature sensor, etc.).

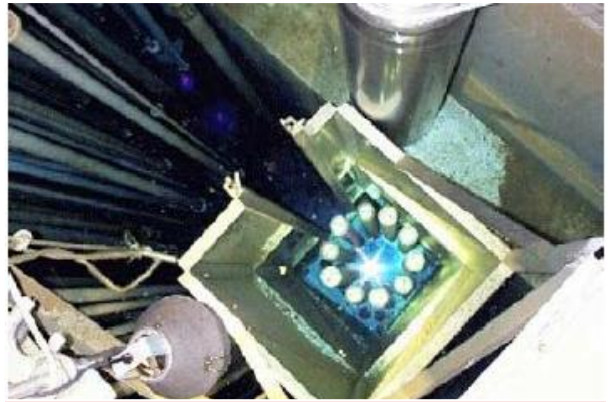


BELGIAN RADIATION QUALIFICATION FACILITIES

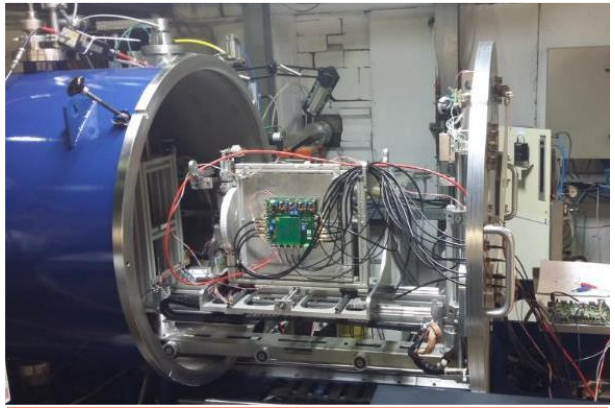
Tests are performed in different kinds of irradiation facilities, e.g., x-ray, two-photon laser, gamma ray, heavy ion, proton. To emulate all the radiation effects occurring in space.

(following ESCC 22900 and ESCC 25100 standards)

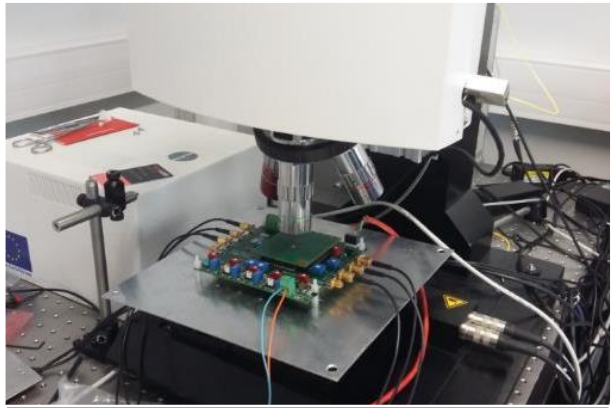
X-ray @ KUL



γ-radiation @ SCK•CEN



Heavy-ion @ UCL



Two-photon laser @ KUL

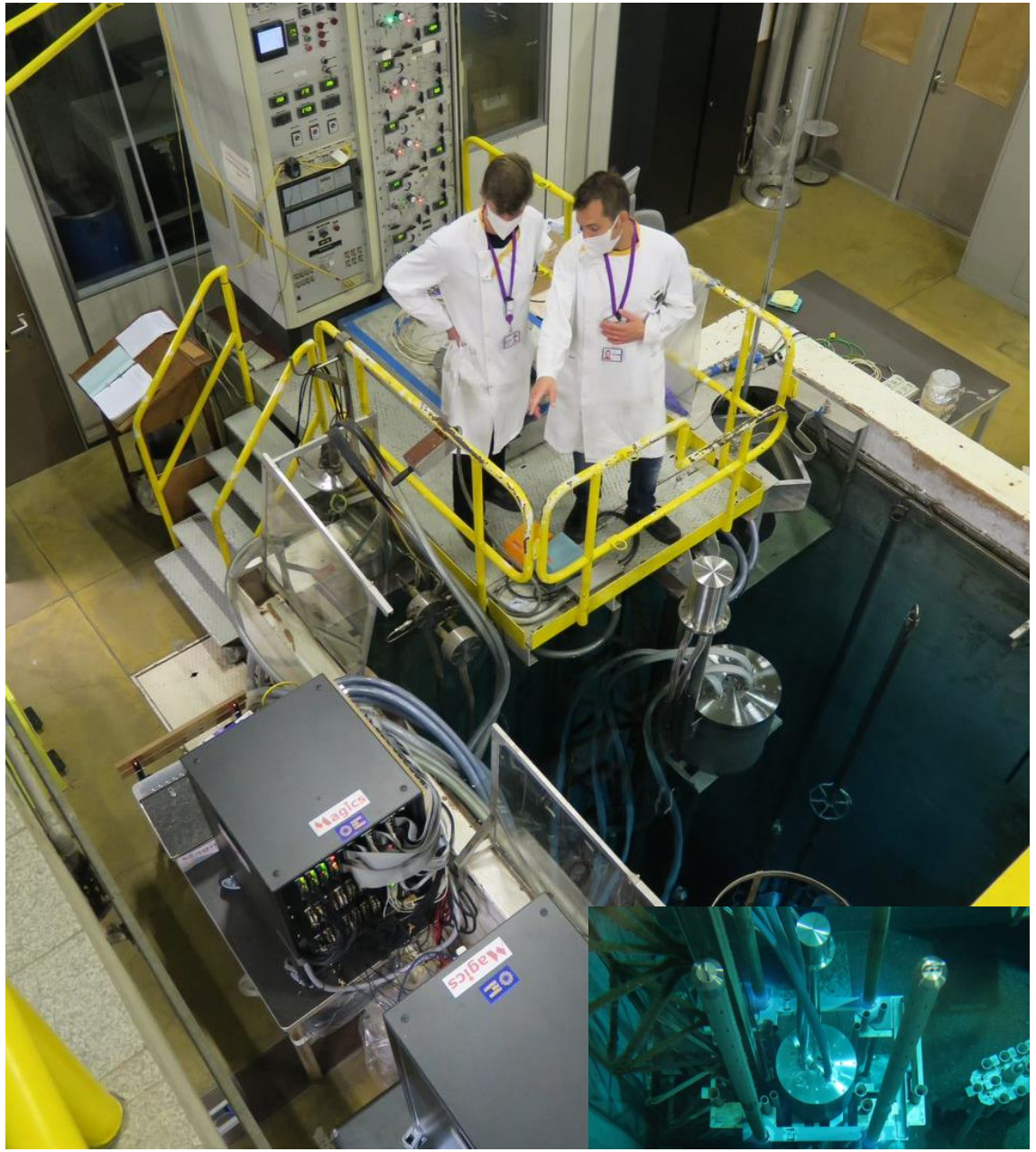
MODELLING RADIATION EFFECTS @ SCK-CEN

Fully automated measurement setups. (MATER)

- **Multiplexing of measurement equipment**
- **Multiplexing of signal sources**
- **Complex signal generation**
- **Configurable digital I/O's**
- **Configurable power supplies**

50 ASICS tested at the same time.

Cobalt 60 radation sources.



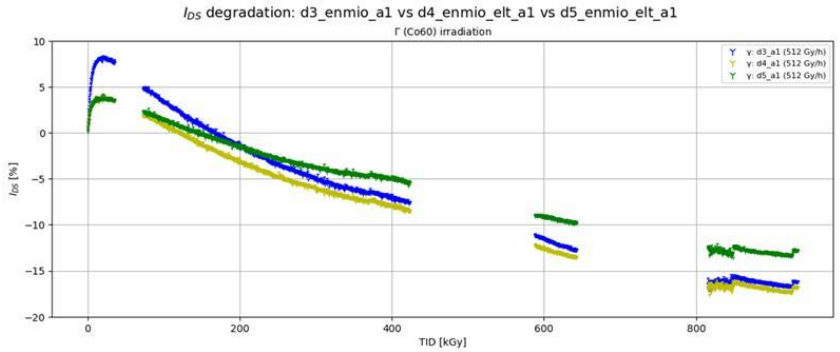
CHARACTERIZATION MODELLING AND LAYOUT

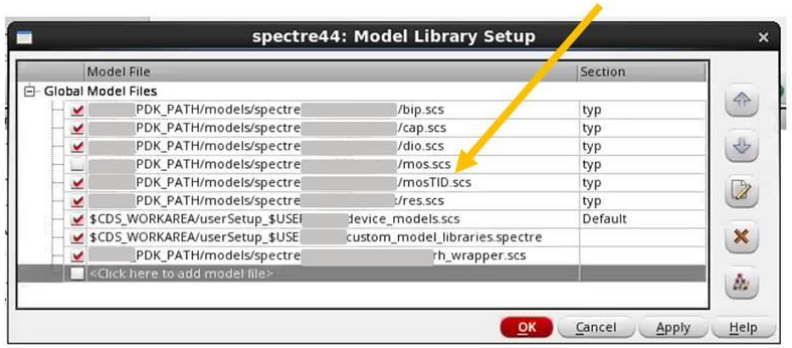
Characterization of the technology

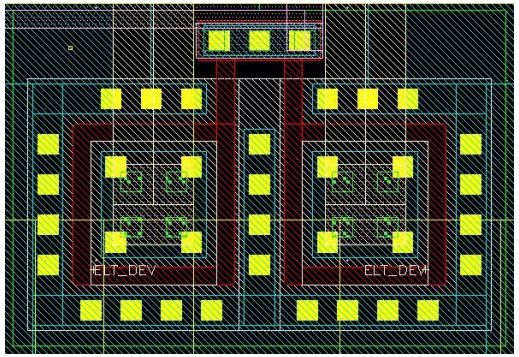
Transferring characterization results into models

Incorporating models in design flow

Dedicated layout strategies

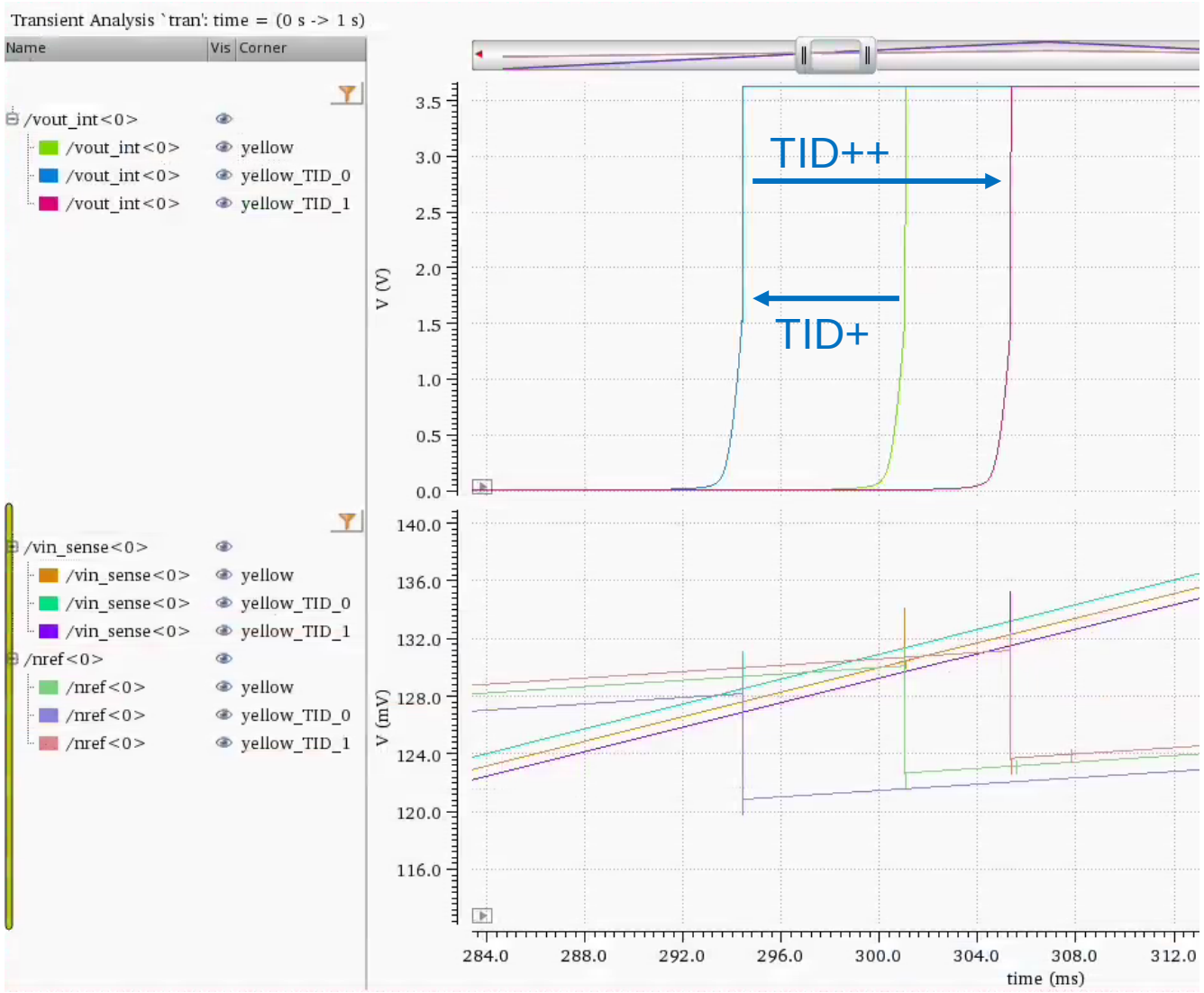






TID SIMULATION

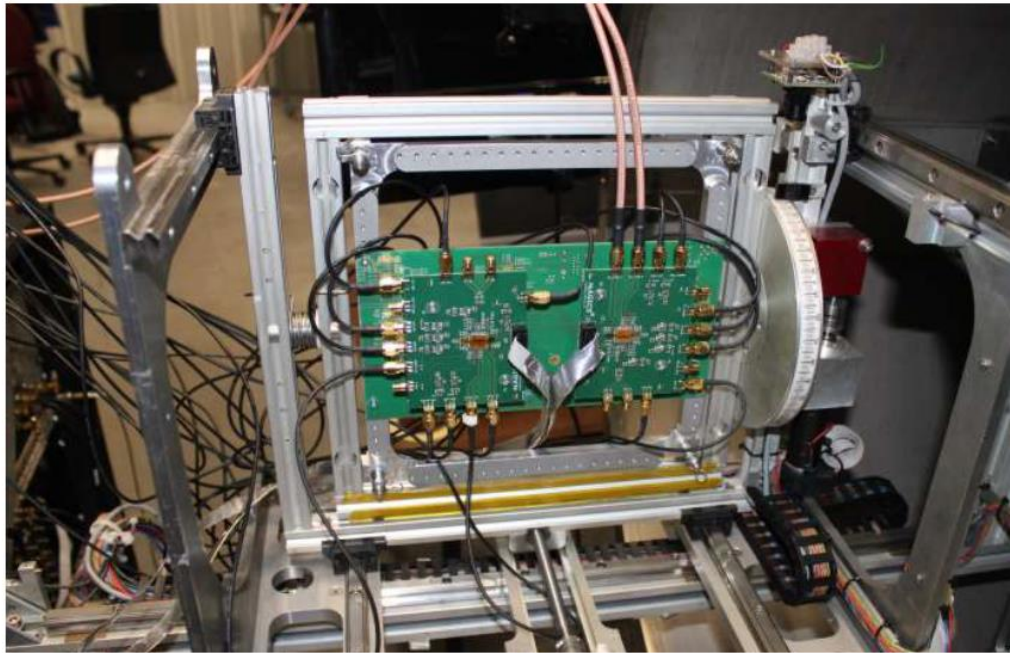
Simulation of effects of accumulated dose: 0 Gy → rebound → 1 MGy

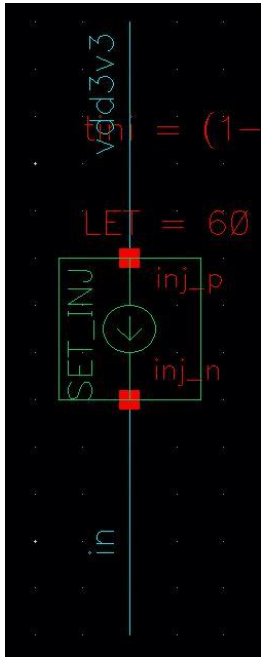


0 Gy Rebound 1 MGy

Output	yellow	yellow_TID_0	yellow_TID_1
/dut<1>/in			
Hyst	24.95 mA	24.3 mA	25.29 mA
i_driver			
LTP	276.1 mA	270.1 mA	280 mA
UTP	301 mA	294.4 mA	305.3 mA
Vdown	2.71	2.198	2.71
v_nref	96.99m	95.79m	97.59m

SIMULATION OF SINGLE EVENT EFFECTS IN THE DESIGN TOOLS





Tools to model and simulate single event effects and bit flips.

Modeling single event transients in simulation

Experimental verification and qualification

Heavy ion tests @ UCL

TMR TOOL SET

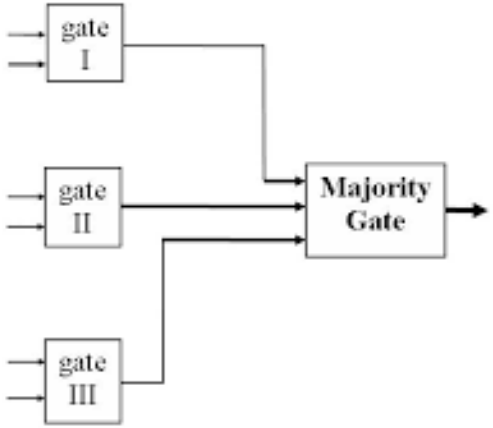
Key Features

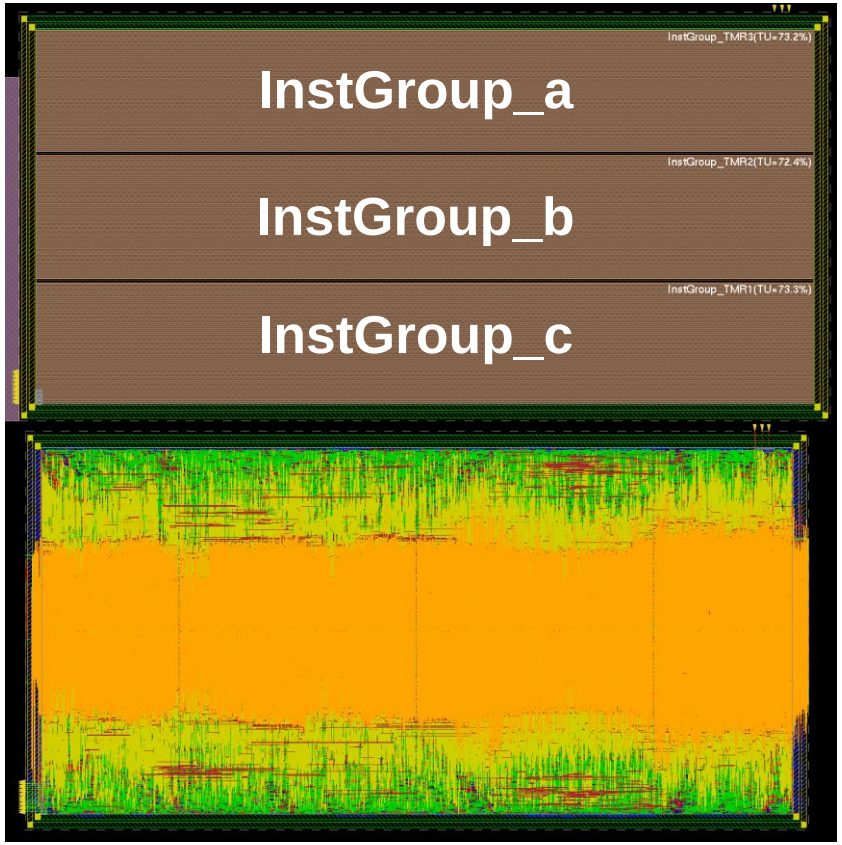
In House Designed Outputs Verified using Industry Proven LEC

Silicon Proven

Tested and verified at Radiation Facilities

Flexible: Module Level TMR Strategy





EXAMPLE OF A RADIATION “PROTECTED” COMPONENT

All digital PLL

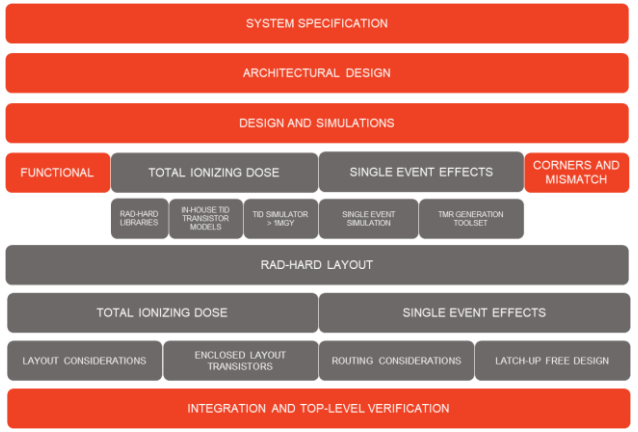
Integrated VCO, loop filter, charge pump

- Resulting in an easier qualification and acceptance tests
- Reduction in board area of > 50 %
- Reduced development time

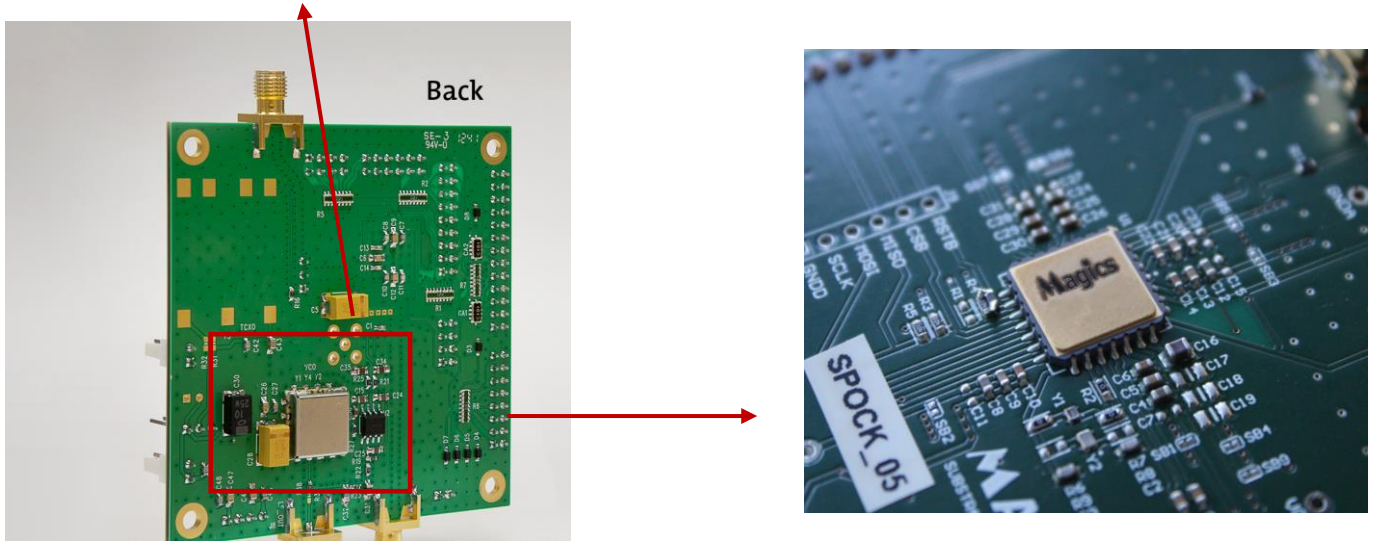
Large flexibility and reconfigurability

- Adjustable loop filter coefficients
- Tunable on-chip crystal oscillator
- Trading power consumption for noise performance

The fully integrated digital architecture is more robust against single-event transients



External Loop filter and VCO



CREATING INDEPENDENCE THROUGH TECHNOLOGY

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