FUSION FOR ENERGY

Design challenges and strategies for the design of a rad-hard multiplexer and camera for ITER remote handling applications

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29 January 2026

Outline

Remote handling systems and their radiation environment

MARCO Multiplexer

Camera

Conclusion

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Environmental conditions and space constraints

The Remote Handing (RH) will be exposed to high radiation environment.
Target 150Gy/hr and **1MGy (TID)**

Cubicles containing control electronics are placed in radiation free areas located at long distances (150m)

Limited space for cable umbilicals between RH devices and cubicles, and maintenance-free equipment during 6-months RH operations campaign, lead to the need of radiation hard electronics for:

- miniaturized **cameras** for surveillance of RH operations or perform inspections
- **multiplexing systems** located on board of the RH equipment to reduce substantially the number of cables

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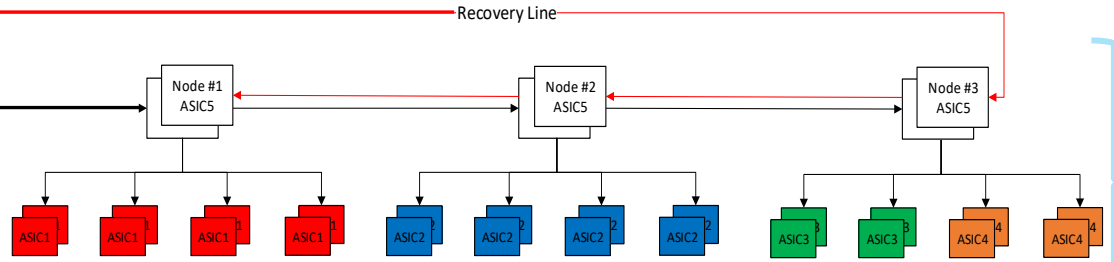
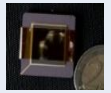
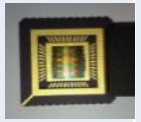
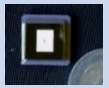
Multiplexer

BiSS Controller in cubicle

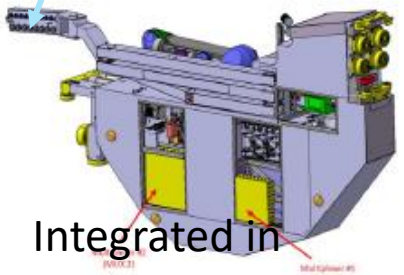
150m



#	Signal Type		Function	Status
ASIC1		RESOLVER/LVDT INPUT (x1)	Resolver or LVDT read-out	Small batches produced and tested to validate design iterations
ASIC2		ANALOG INPUTS (x4)	Analog signals as for pressure sensors, temperature sensors, Strain gauges, etc.	Small batches produced and tested to validate design iterations
ASIC3		DIGITAL INPUTS (x10)	Digital ON-OFF input signals as for limit switches, brakes statuses, etc.	Manufactured and gamma assessment done
ASIC4		DIGITAL OUTPUTS (x8)	PWM Configurable either as a digital output signal for commanding relays, or for driving solenoids.	Manufactured and gamma assessment done
ASIC5		N/A	For BiSS nodes communication over the BiSS bus. Can control up to 4 ASICs through SPI	Small batches produced and tested to validate design iterations

MAGICS

BiSS Modules



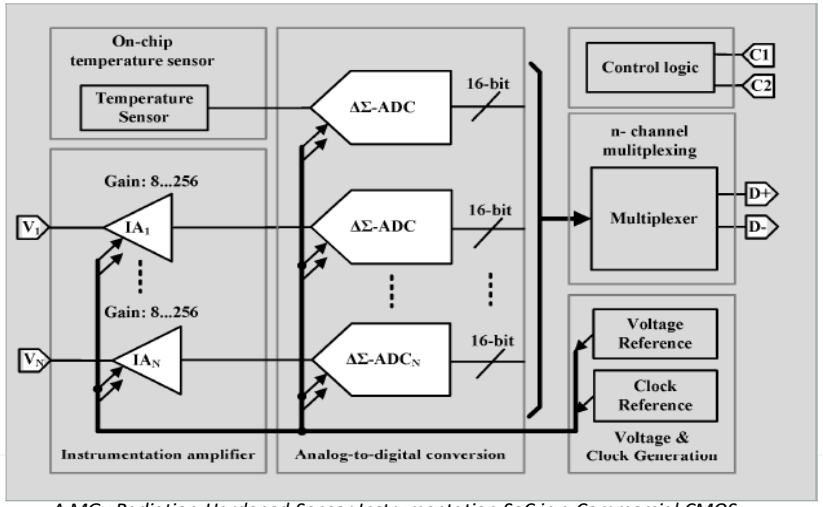
Integrated in the RH system

Radiation safe area

Radiation exposed area

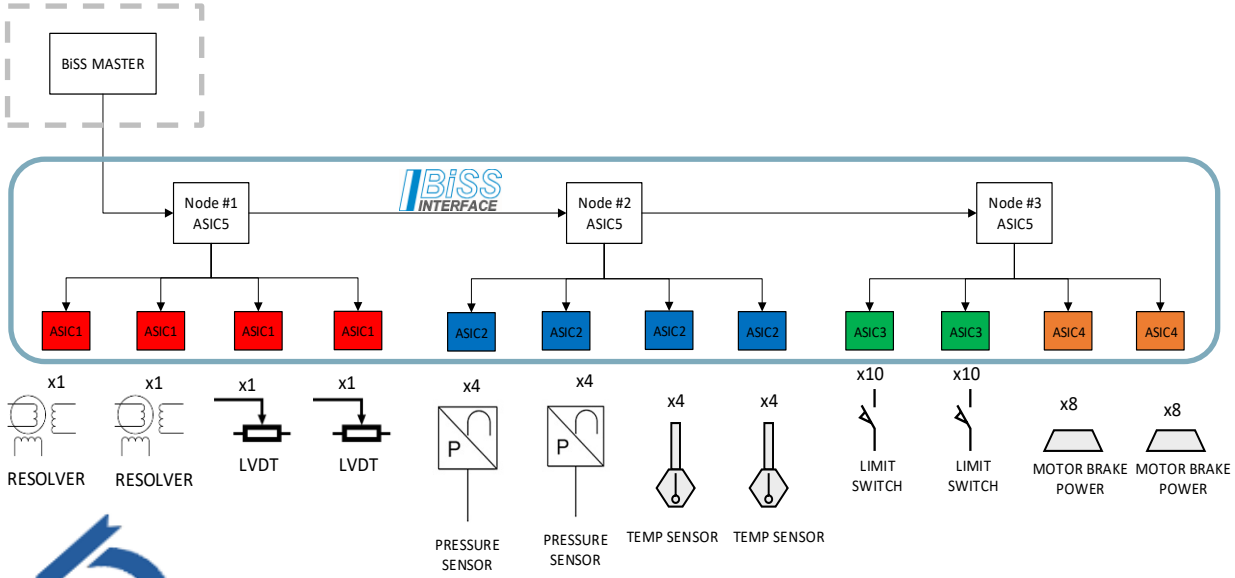
Multiplexer development – staged approach

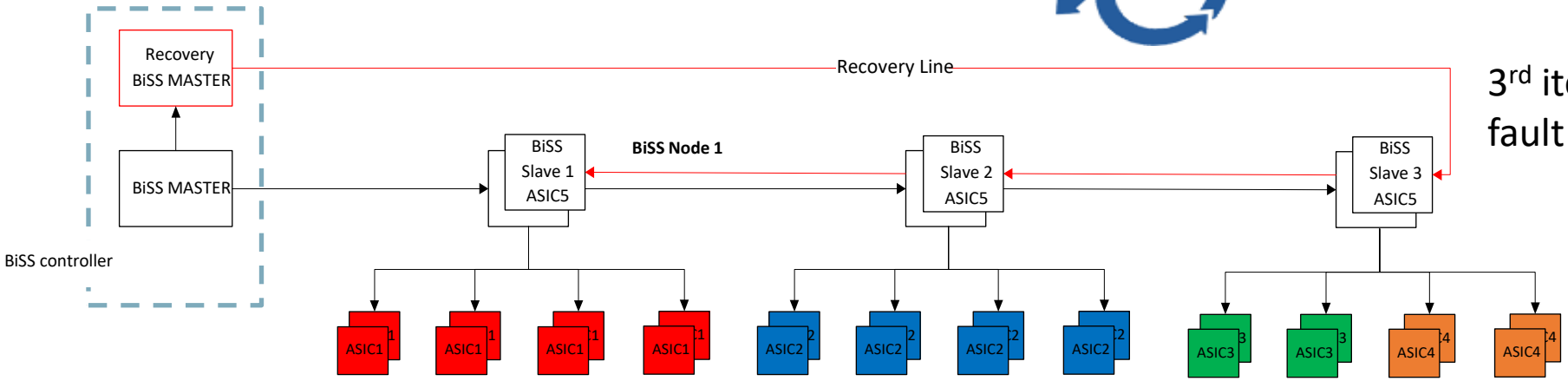
1st iteration, single chip that amplifies, digitizes and multiplexes sensor signals, validating main building blocks



A MGy Radiation-Hardened Sensor Instrumentation SoC in a Commercial CMOS Technology- Y. Cao- NSREC 2014 Poster

2nd iteration, 5 chip typologies and communication BiSS protocol

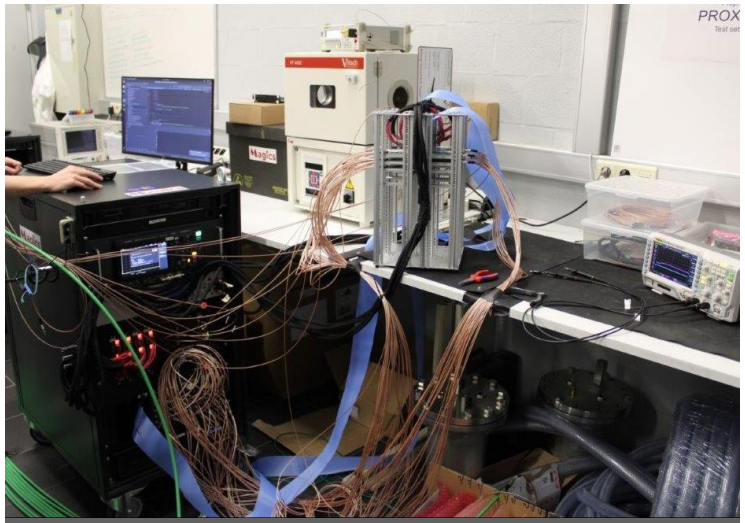




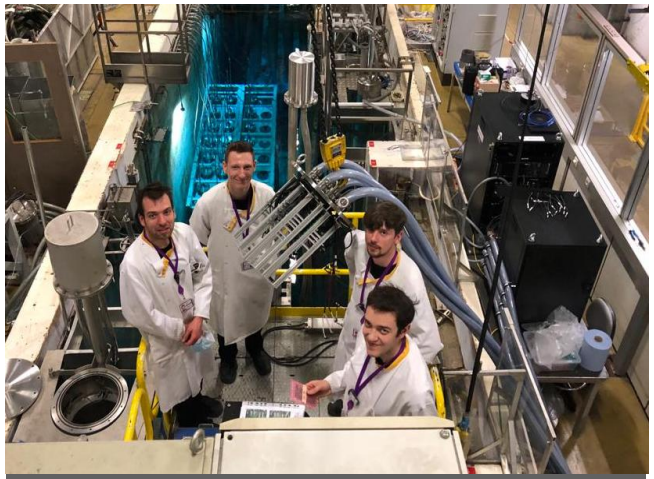
3rd iteration, introduction of ASIC fault tolerance and recoverability.

Design iteration:
-IC design
-Manuf & testing
-Irradiations
-Bugs resolution

Multiplexer development – Some tests performed



Test tower containing test samples being characterized at different T and V levels before irradiation experiment.



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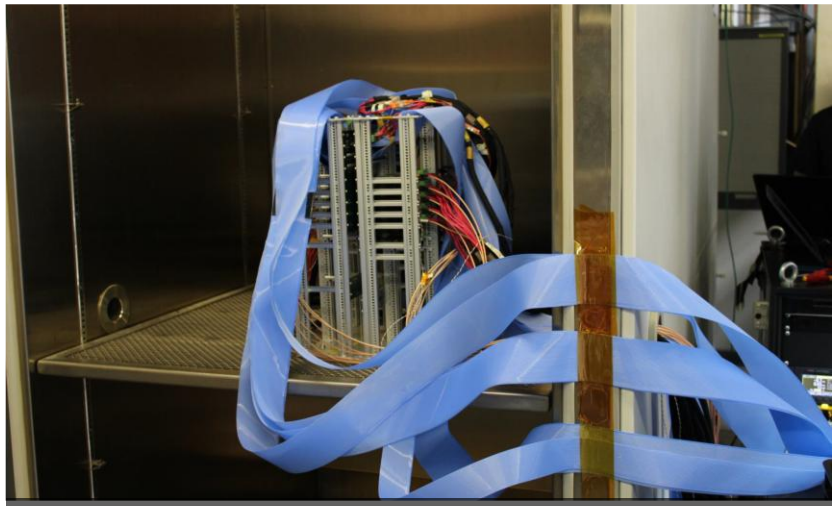
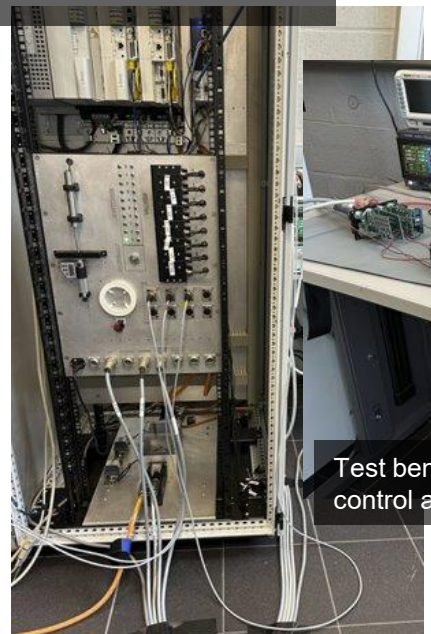
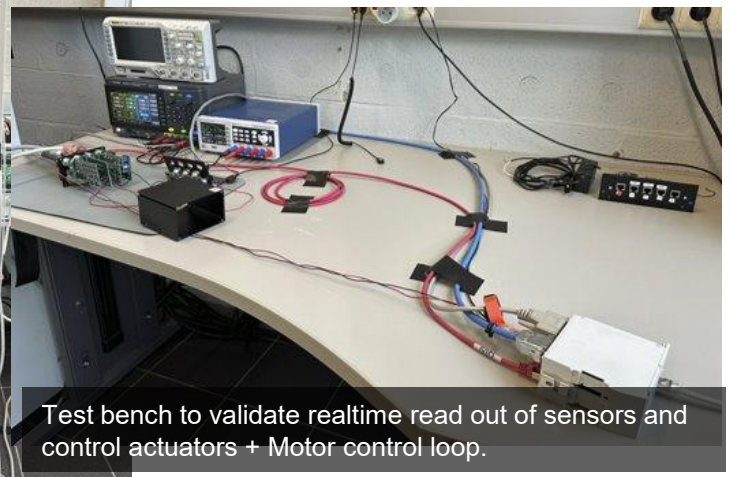


Test tower prepared for the post irradiation tests

Test of 16 redundant ASIC5 connected in a daisy chain.





Test bench to validate realtime read out of sensors and control actuators + Motor control loop.

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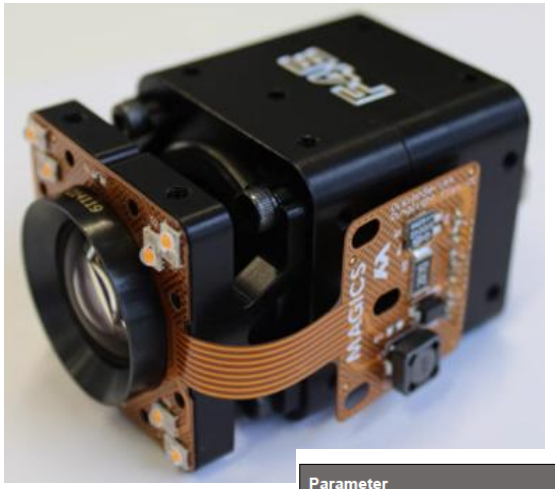
Rad Hard camera

Frame grabber in cubicle

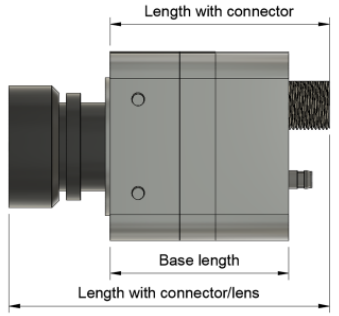
150m

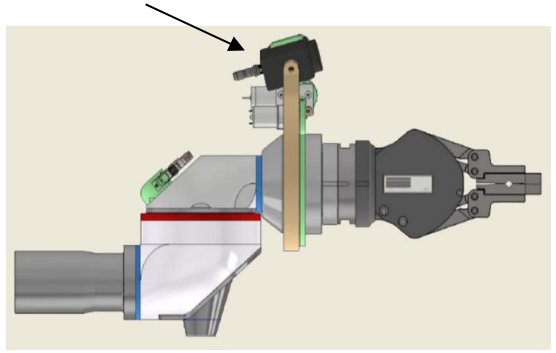


The F4E camera is small-size, black&white or colour, CMOS based, radition tolerant up to 1MGy, and follows the GenICam and CoaXPress standards.

The F4E camera basic configuration delivers VGA video streams at 25 frames/second through a 1.25 Gbits/s CoaXPress 2.0 interface.

Parameter	With LEDs Power PCB [mm]	Without LEDs Power PCB[mm]
Width	40	40
Height	40	40
Base length	37,1	29,5
Length with connector	46,9	39,2
Length with connector/lens	68,5	60,8



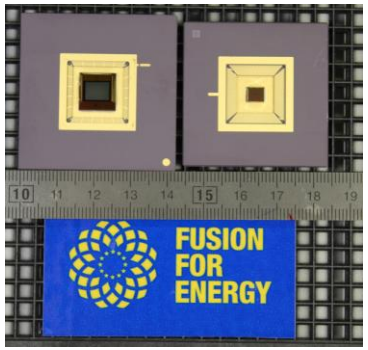


Integrated in the RH system

Radiation safe area

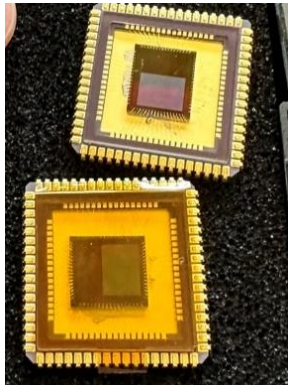
Radiation expose

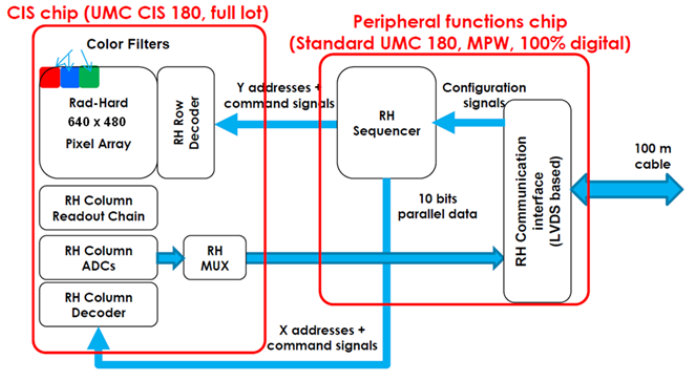
Rad- Hard camera – staged approach



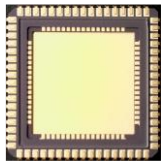
1st iteration, main building blocks

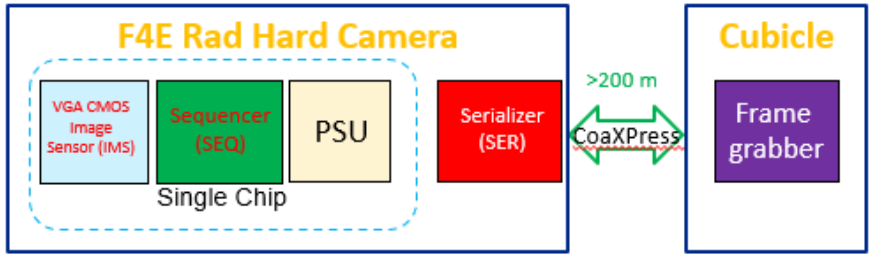
256 x 256 pixel evaluation image sensor
10bit ADC





2nd iteration
VGA pixel array + readout blocks
Sequencer (communication chip)

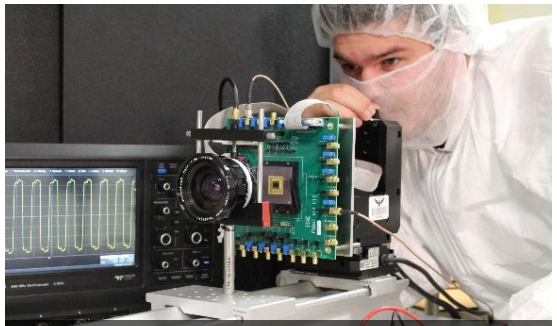




3rd iteration
Image sensor+sequencer+psu
Serialiser (coaxpress)

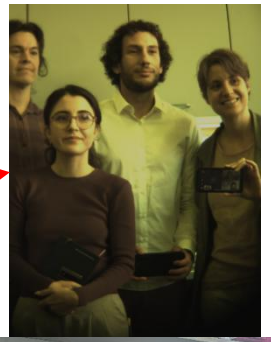
Design iteration:
-IC design
-Manuf & testing
-Irradiations
-Bugs resolution

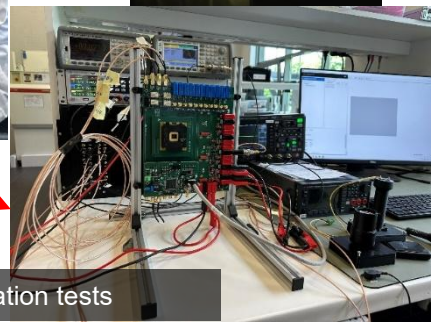
Rad-Hard camera development – Staged approach



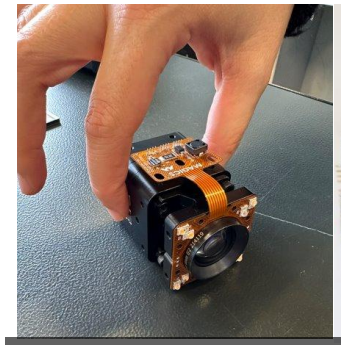
Validation tests on Peripherial functions chip

Picture after 1MGy irradiation (X-ray)

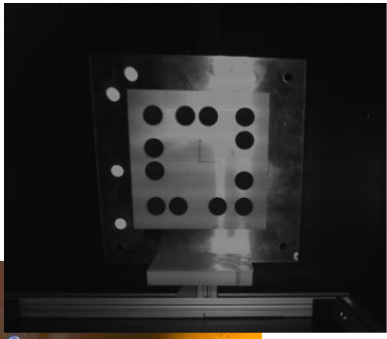


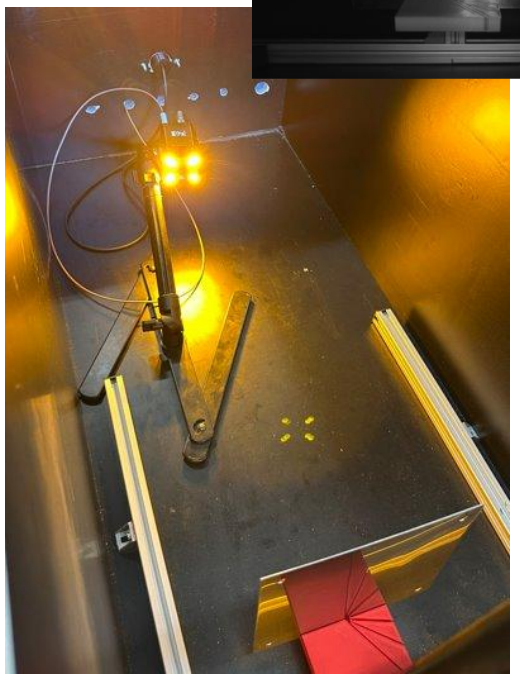


Test set-up Characterisation tests



Camera proto fully rad-hard with LEDS and lens. 40x40x68mm.





Test setup to replicate typical RH scene (3D node markers) + dark conditions to evaluate if visible with onboard illumination.

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Multiplexer and Image sensor developments have been successfully designed and validated and irradiated up to 1MGy (TID) with no degradation in performance observed

To perform these delevelopments:

- Collaboration with experienced industrial partners from Magics Technologies, ISAE-Supaero University of Toulouse, Veolia Nuclear Solutions, Ansaldo Nucleare, SCK-CEN…
- Followed incremental steps in complexity, validated through simulations and tests
- No dedicated standards for such high radiation environments, the ESCC 22900 standard for space applications was used as a reference.

Next steps:

- Full wafer manuf of the remaining chips
- Finalisation BiSS controller
- Radiation assessements
- Integration into RH systems & technologies

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