WP6, Investigation of Single-Event Effects for Space Applications: Instrumentation for In-Depth System Monitoring

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https://indico.cern.ch/e/radnext-2024

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Outline

Third year achievements and ongoing activities

- Summary of test campaigns and publications

Investigation of Single-Event Effects for Space Applications: Instrumentation for In-Depth System Monitoring

- Background
- Experimental instrumentation for complex systems
  - Objectives/Challenges
  - Proposed approach

Conclusion

Third year achievements and ongoing activities

	Source	Facility	Date	Experiments
1st year	High-Energy Protons	PSI	12/21*	SDRAM / HyperRAM
	Heavy Ions	RADEF	02/22	SRAM
	Atmospheric Neutrons	ChipIr	05/22*	RISC-V / SoC / NoC
	High-Energy Protons	PARTREC	06/22*	RISC-V / SoC
2nd year	Mixed-Field	CHARM	10/22	RISC-V / SoC
	Atmospheric Neutrons	ChipIr	11/22*	RISC-V / SoC
	High-Energy Protons	PSI	12/22	SRAM
	Pulsed Laser	ESTEC	05/23	SRAM
3rd year	**Atmospheric Neutrons**	**ChipIr**	~~**05/24**~~ 09/24	**ARM / RISC-V / AI accelerator**
	High-Energy Heavy Ions	**GSI**	**06/24***	**RISC-V SoM**
	High-Energy Protons	**PSI**	**09/24***	**RISC-V SoM**

Third year achievements and ongoing activities

Journal publications:

[1] André M. P. Mattos, Douglas A. Santos, et. al., “Investigation on Radiation-Induced Single-Event Latch-up in SRAM Memories on-Board PROBA-V”, TNS, 2024.

[2] André M. P. Mattos, Douglas A. Santos, et. al., “Investigation of Single-Event Effects for Space Applications: Instrumentation for In-Depth System Monitoring”, Electronics, 2024.

[3] D. A. Santos, P.M. Aviles, A.M.P. Mattos, M. Garcia-Valderas, L. Entrena, A. Lindoso, L. DiLillo, “Hybrid Hardening Approach for a Fault-Tolerant RISC-V System-on-Chip”, TNS, 2024.

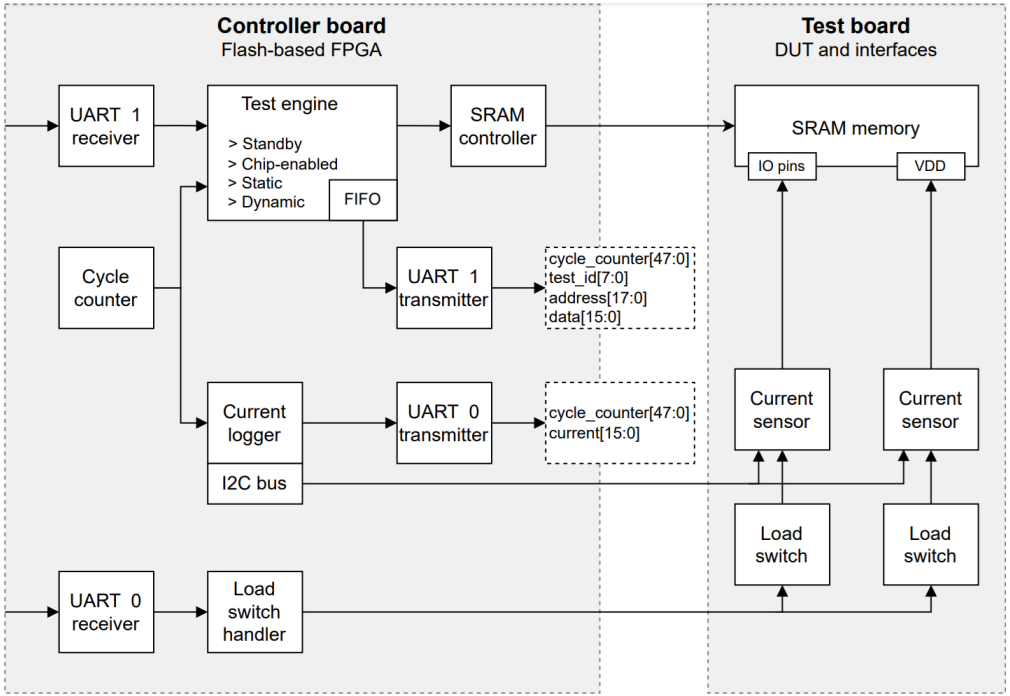
Background

Investigation of SEL in COTS SRAM memories onboard PROBA-V:

- Understanding the flight behavior and observed error rates
- Experiments: RADEF, PSI, ESTEC

Enhanced experimental setup:

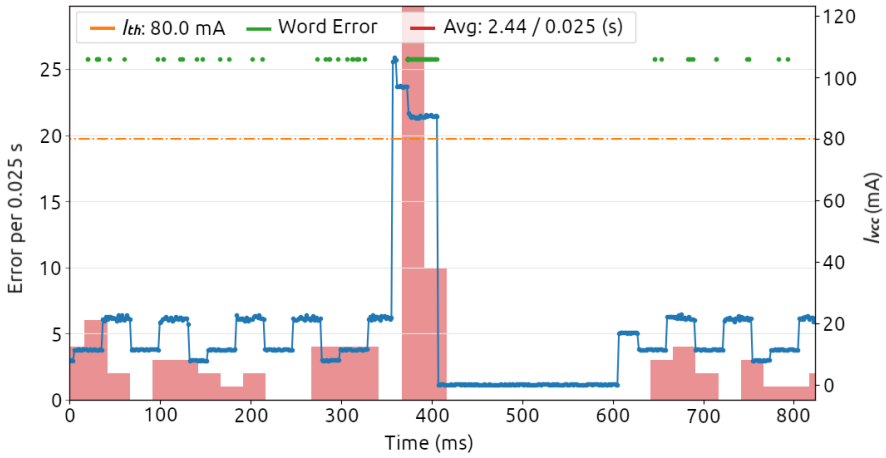
- Precise **timing** and current measurements
- **Coherent monitoring** between memory errors and current measurements
- Many test modes with **realistic stimuli**
- Robust and flexible test setup



Background

Outcomes (test setup):

- Analysis of various SEE with enhanced synchronization
- Superposition of different parameters (e.g., current/errors)



Cross Section [1,2]	LET [MeV·cm²/mg]					Weibull Fitting			
	1.5	7.2	13.3	24.5	48.5	W	S	XS_{sat}	LET_{th}
XS_{SEU} [cm²/bit]	4.62×10^{-12}	4.15×10^{-9}	1.09×10^{-8}	2.24×10^{-8}	1.20×10^{-8}	14.6	1.7	2.06×10^{-8}	1.5
XS_{SEL} [cm²/device]	9.97×10^{-8}	3.65×10^{-7}	1.61×10^{-6}	3.46×10^{-3}	7.64×10^{-2}	25.5	7.4	1.03×10^{-1}	7.2
XS_{SEFI} [cm²/device]	9.07×10^{-8}	-	-	3.59×10^{-3}	6.87×10^{-2}	-	-	-	-

[1] Only cross sections for perpendicular incidence in one DUT (same as flight lot) are shown; [2] All tested modes included for SEL cross section and only static/dynamic for SEU and SEFI cross sections.

Experimental instrumentation for complex systems > Objectives/Challenges

Objectives:

Performing tests on complex systems-on-chip

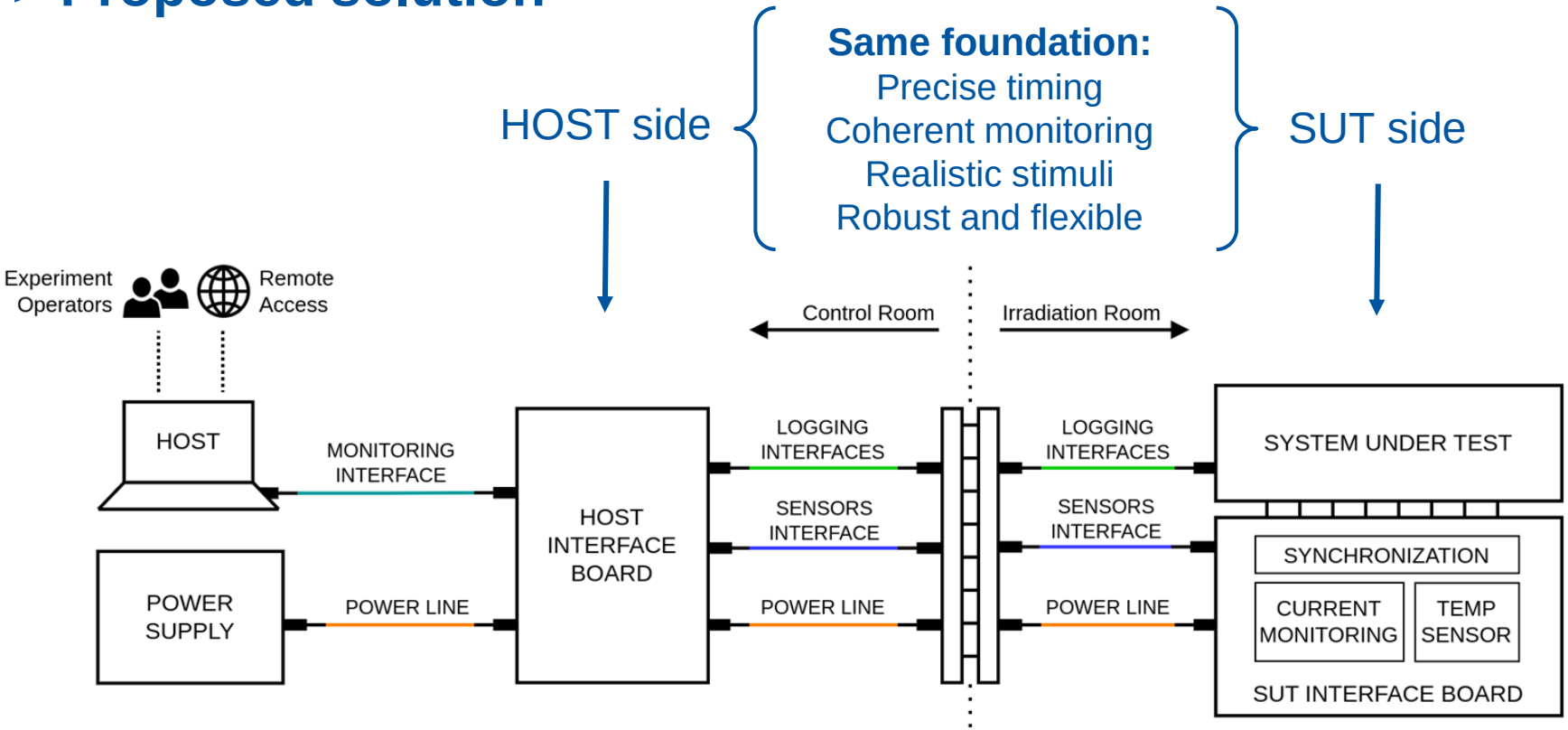
- Provide the necessary circuitry to operate these systems
- Provide the necessary circuitry for radiation testing needs
- Provide additional features to support enhanced observability

Challenges:

- Design a compact and robust solution
- Maintain costs comparable to COTS development kits
- Provide reliability to the test setup itself (secondary particles, industrial environment)

Project driven by real testing needs

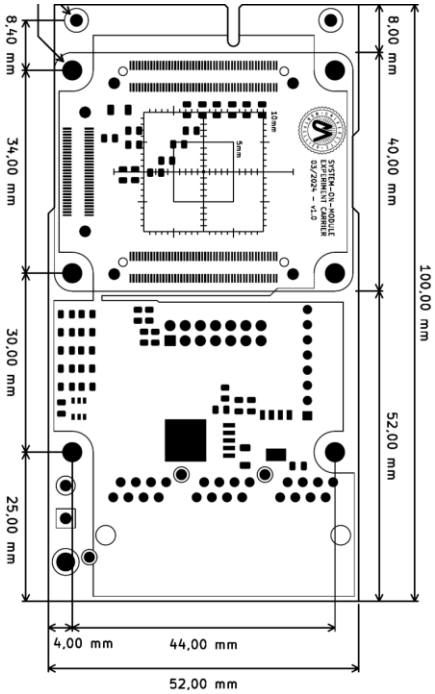
Experimental instrumentation for complex systems
> Proposed solution



Experimental instrumentation for complex systems
> Proposed solution: SUT Side

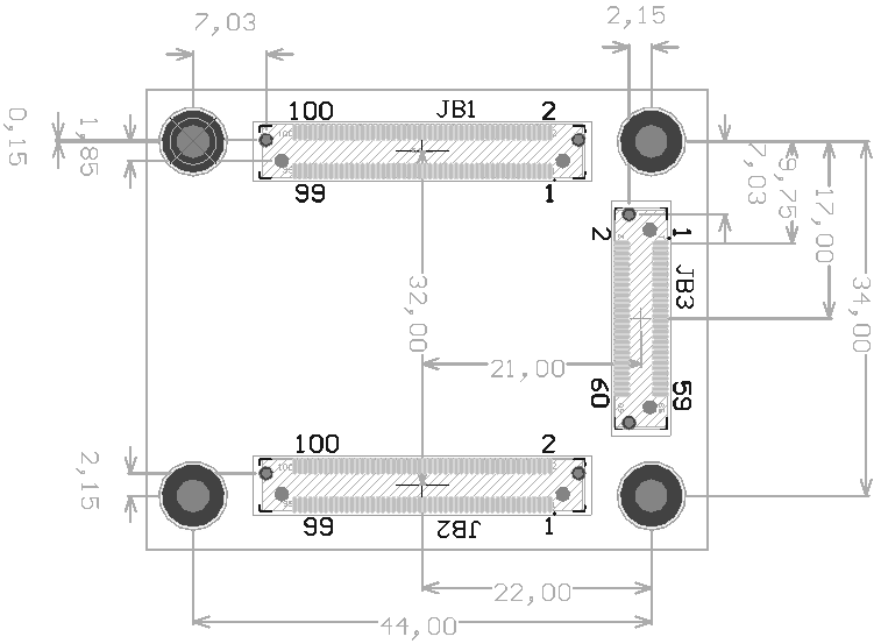
Functions supporting in-depth testing:

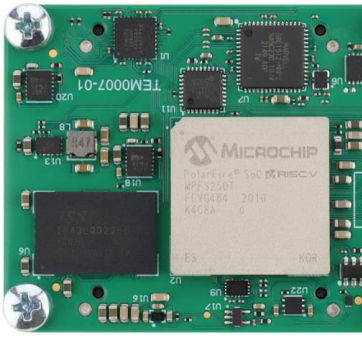
- SUT logging interfaces (>100 meters)
- Setup interface (>100 meters)
  - Voltage/Current for the SUT (with protection)
  - Board temperature
  - Configurable external watchdog timer
  - User GPIOs (control on HOST side)
- JTAG programming interface (~20-50 meters)
- Onboard power regulation (>100 meters)
- DIP switch for easy hardcode configuration
- Edge extension connector (e.g., add-on DUT)
  - 48x high-speed data signals
  - Length matching / impedance control
  - Access to setup interface
- Indication LEDs (power good, boot, interface test)

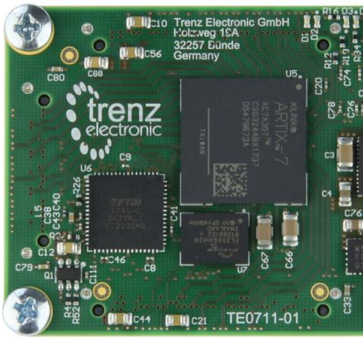


Carrier: 100x50mm
SoM: 50x40mm

Experimental instrumentation for complex systems
> Proposed solution: SUT Side

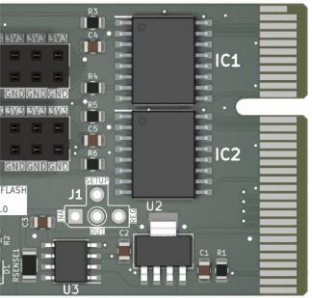






Many “low-cost” COTS options available in this form factor for rapid test development, but a fully custom solution can also be designed

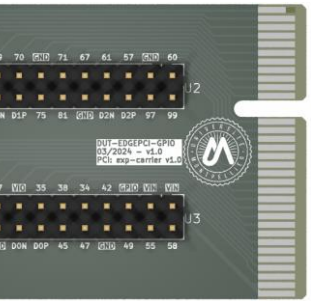
Experimental instrumentation for complex systems
> Proposed solution: SUT Side



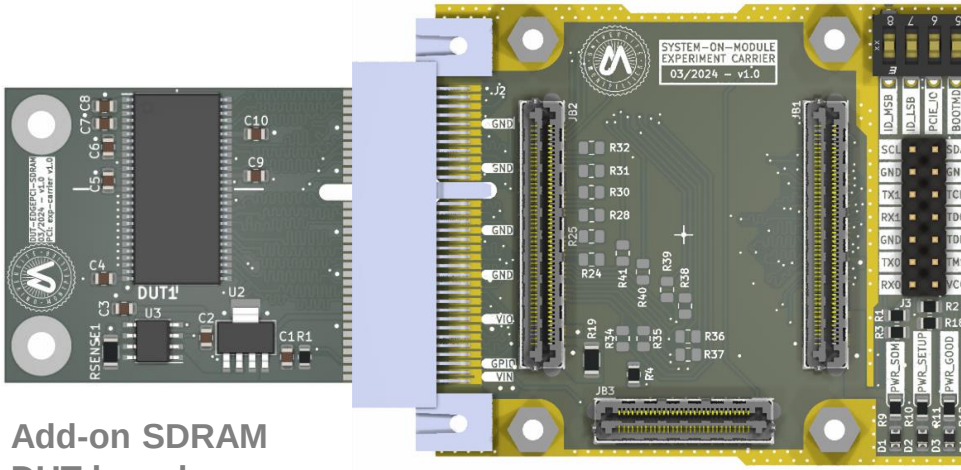
Add-on non-volatile
memory expansion

Extension boards:

- Add-on DUTs
- Debugging boards
- Function extension
- Test fixtures



IO breakout
for debugging



Add-on SDRAM
DUT board

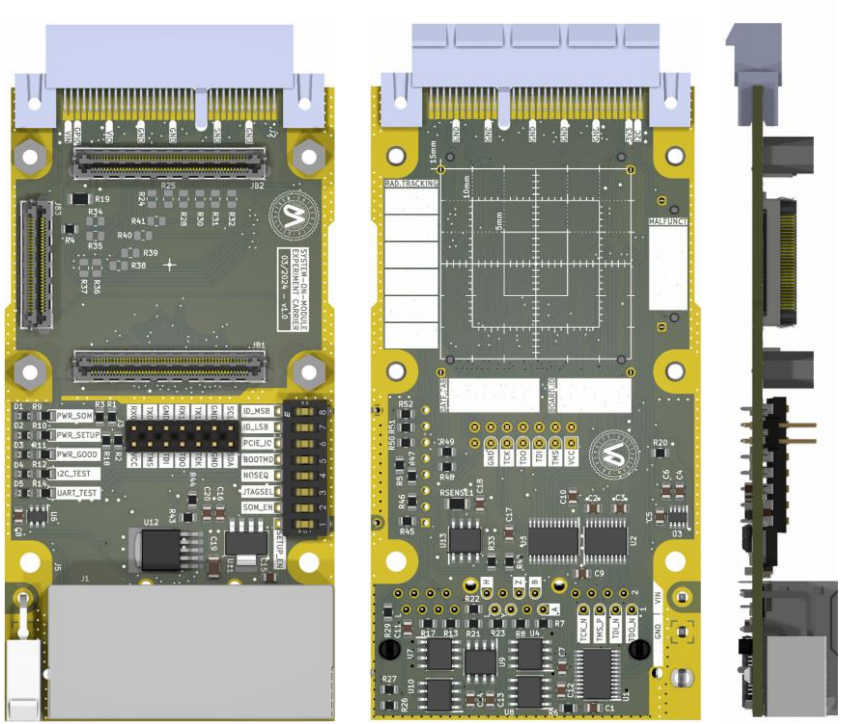
Experimental instrumentation for complex systems > Proposed solution: HOST Side

Functions supporting in-depth testing:

- Data interfaces (connected to SUT side)
  - Logging, setup, and JTAG
- FPGA for handling experimental operation
  - Manage user requests (e.g., turn ON/OFF the SUT)
  - Enable fast SEL monitoring/protection/reporting
  - Append precise timestamp for all SUT log data and sensor measurements received (without HOST computer “jitter/desynchronization” nor overheads)
- Single USB interface with HOST computer using a serial converter
  - Four channels (SUT#1, SUT#2, SENSE, and CMD)
  - Even with computer jitter/desynchronization in the reception, all data was precisely timestamped beforehand in the FPGA
- Compact (easy to mount on the facility), simple to operate, and highly automated (reducing human error)

Conclusion

- Development of custom, compact, and robust test setup targeting complex devices:
  - Adequate radiation testing fixtures
  - Enhanced SUT observability
  - Synchronization / coherence
- Support to different projects:
  - Development standard hardware platform for radiation testing (KUL / UM)
  - Characterization of a high-performance multicore RISC-V SoC and a low-cost RISC-V soft-core (UM)
    - GSI (06/24) and PSI (09/24)
  - … and potentially to other future partners interested on the developed platform



Thanks for your attention!

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