TWINRELECT

Twinning for excellence in reliable electronics

D2.2

DELIVERABLE REPORT

D2.2 1st Report on Scientific Training Activities

WP2: Enhancement of Scientific Capacity

TWINRELECT
TWINNING FOR EXCELLENCE IN RELIABLE ELECTRONICS

Document information

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Contents

Executive Summary

This deliverable presents the activities implemented under WP2 "Enhancement of Scientific Capacity" at the University of Thessaly (UTH) during the reporting period M1-M17, in accordance with the Scientific Capacity Enhancement Plan (D2.1). WP2 aims to strengthen UTH's long-term research excellence in reliable electronic systems through structured researcher development, international collaboration, and advanced training and joint experimental activities.

The document summarizes the recruitment and dual supervision of Early Stage Researchers (ESRs), the execution of staff exchanges with consortium partners (CNRS, IHP, MAN), the organization of partner-hosted training schools, and the advancement of joint experimental activities, including irradiation campaigns and tool-based validation work. These actions enabled effective knowledge transfer, reinforced collaborative research activities, and supported active integration of UTH within the project's cross-layer reliability research framework.

Overall, the report provides a comprehensive overview of the progress achieved and the implementation status of WP2 activities during M1-M17. The completed actions have substantially enhanced UTH's scientific capacity, reinforced international research collaboration, and established a sustainable foundation for continued excellence in reliable electronic systems research.

1. Introduction

As part of Work Package 2 (WP2) on "Enhancement of Scientific Capacity" of the University of Thessaly (UTH), this deliverable reports on the scientific activities undertaken for developing the next generation of researchers and building sustainable research excellence in the design of reliable electronic systems at UTH. This report demonstrates the implementation and outcomes of the capacity-building strategy defined in D2.1, the Scientific Capacity Enhancement Plan [1]. More specifically, this document details the selection, supervision, and training of Early Stage Researchers (ESRs), whose development plays a pivotal role in ensuring the long-term scientific capacity of UTH. Also, it reports on the execution of staff exchanges and the organization of targeted training schools and joint experiments carried out during the reporting period. The subsequent sections will provide a detailed overview of these activities, comparing outcomes against the planned strategy.

2. Supervision of Early Stage Researchers (ESRs)

The development and efficient supervision of ESRs is critical not only for the successful implementation of this project, but also for laying the foundation for long-term academic excellence at UTH. This section reports on the actions implemented and the results achieved during the reporting period to address these objectives. It presents the recruitment and assignment of the researchers under the dual-supervision framework, detailing their training and contributions to the project's Work Packages, as well as the reporting of the progress validated by the supervisors.

2.1 Selection of ESRs

The selection of ESRs aims to efficiently align human resources with the project's research priorities, while strengthening the scientific capacity of UTH in the field of reliable electronics through structured supervision, multiple training sessions, and targeted exchanges.

According to the initial plan [1], six ESRs are expected to be involved in the project throughout its duration. At the current stage of the project, five PhD candidates have been selected as ESRs, and two supervisors, one from UTH and one from a partner institution, have been assigned to each of them. Table 1 summarizes the selected PhD students and their research topics along with the assigned supervisors. The PhD topics reflect the complementary expertise of the ESRs, covering all research aspects of the project and ensuring its successful implementation. The assignment of the supervisors was performed based on the alignment between each ESR's PhD topic and the respective expertise of the partner institutions. This approach ensures that the PhD students benefit from specialized guidance, access to cutting-edge resources, and a collaborative research environment. Finally, during the selection process, efforts were made to achieve a gender balance within the ESR team, in compliance with EU principles and policies.

UTH PhD Student	Start Date	Defense Date	Topic	UTH Supervisor	Co-Supervisor (CNRS/IHP/MAN)
Nikos Chatzivangelis	Sep. 2024	2027-2028	STA, Timing Models, Radiation effects, Fault Analysis	Christos Sotiriou	Luigi Dilillo (CNRS), Marko Andjelkovic (IHP)

Katerina Tsilingiri	Mar. 2024	2027-2028	Parasitic Extraction, Field Solvers, Aging, EMI	Christos Sotiriou	Fabian Luis Vargas (IHP)
Nikolaos Zazatis	Sep. 2024	2027-2028	EDA & ML, Fault Analysis	Christos Sotiriou	Davide Bertozzi (MAN), Milos Krstic (IHP)
Christos Georgakidis	Sep. 2019	Sep. 2026	Fault Analysis, Radiation Hardening	Christos Sotiriou	Marko Andjelkovic (IHP)
Kainat Naeem	Apr. 2025	2028	Parasitic Extraction, ML, EMI	Christos Sotiriou	Fabian Luis Vargas (IHP)

Table 1: UTH PhD Students Supervisor Assignment

2.2 Supervision Framework and Implementation

Following the recruitment of the ESRs and the establishment of the dual-supervision scheme, emphasis during the reporting period was placed on the effective operational implementation of this framework and the systematic monitoring of research progress.

From M3 to M17, the supervision model functioned through structured and regular interaction between ESRs and their supervisors. Continuous communication was ensured via scheduled online meetings, while more in-depth technical discussions were carried out during consortium events and staff exchanges under WP2.3 and WP2.4. In addition to this interaction, a formal progress evaluation meeting was organised, during which each ESR presented research achievements, encountered challenges, and upcoming milestones to the joint supervisory committee, which in turn provided scientific feedback and strategic guidance. This structured review process enabled critical assessment of progress against planned objectives, ensured transparency, and supported timely refinement of research directions where necessary. Overall, the cross-institutional supervision scheme strengthened the integration of the ESRs' research activities within the objectives of the project's WPs, enhanced their exposure to international research standards and practices, and contributed to the broader capacity-building goals of the project.

The effectiveness of this implementation phase is reflected in the scientific output achieved during the reporting period. The ESRs have contributed to seven conference publications and two journal articles. In addition, four conference papers and two journal manuscripts have been submitted and are currently under review within the framework of WP6.5. These results demonstrate the productive functioning of the supervision scheme and confirm the steady progress of the ESRs toward high-quality scientific dissemination.

3. Report on Staff Exchanges

A significant part of this project is the implementation of short-term visits of UTH staff to the other partner institutions (IHP, CNRS, MAN) and short-term visits of IHP/CNRS/MAN staff to UTH. The purpose of the staff exchanges is to facilitate knowledge transfer and foster research collaboration among the involved institutions, as well as to enhance the scientific capacity of all participants through theoretical and hands-on training activities and joint research on cutting-edge topics.

3.1 Short-term visits of UTH Staff to other partners

UTH team members (i.e., ESRs and research staff) were planned to spend up to 10 months in total at each partner institution (IHP, CNRS, MAN) in the form of short-term visits [1]. At the time of preparing this report, two visits have been conducted, namely at IHP and CNRS. Although the initial schedule anticipated that the first visits would begin in M10 of the project (i.e., July 2025), the actual start occurred in M13 (i.e., October 2025). This shift was primarily due to administrative and logistical constraints as well as the increased workload associated with other events organized by the UTH team (e.g., 1st Research Workshop and 1st Business Forum), while reduced availability during the summer period also contributed.

3.1.1 Short-term visit to IHP [07.10.2025 - 15.12.2025]

1st visit to IHP

The first visit to IHP, held from *07.10.2025* to *15.12.2025*, was carried out with the participation of *Nikolaos Zazatis*.

Nikolaos Zazatis is involved in the TWIN-RELECT project as a PhD candidate at UTH. His research topic focuses on investigating scalable machine learning methods in EDA, specifically for radiation effects such as Single Event Transients (SETs) and Single Event Upsets (SEUs). His work aims to develop efficient, reliable, and environmentally sustainable ML models capable of predicting and mitigating radiation-induced faults in modern Integrated Circuits (ICs).

On one hand, the purpose of the visit was to deepen the networking capacity of UTH by participating in meetings with researchers and groups that do not participate in the TWIN-RELECT program and promoting the importance of reliable electronics. On the other hand, another important aspect of the visit was to collaborate with IHP members in order to contribute to the research of reliable electronics topics.

<u>Visit Agenda</u>

In the first two weeks, Nikolaos participated in meetings with different IHP members and discussed possible collaboration topics. Specifically, the IHP members are Dr. Marko Andjelkovic, Dr. Fabian Luis Vargas, Alessandro Veronesi and Dr. Letícia Maria Bolzani Pöhls. The details of the discussed topics and the involved supervisors from IHP are listed in Table 2. The next weeks, Nikolaos researched the following topics under the guidance of the IHP Supervisors and scheduled regular meetings to track each project separately.

Topic	Supervisor(s)
Single Event Transient pulse prediction and mitigation techniques using Machine Learning	Dr. Marko Andjelkovic Dr. Fabian Luis Vargas
Reliability Analysis of Deep Neural Networks	Alessandro Veronesi Dr. Letícia Maria Bolzani Pöhls Dr. Marko Andjelkovic
On-chip Aging Sensors for Lifecycle Chip monitoring and Aging Mitigation Techniques using Machine Learning	Dr. Fabian Luis Vargas Dr. Marko Andjelkovic

Table 2: UTH's short-term visit to IHP - Research topics and supervisors

Visit Outcome

The main outcome of the visit was the submission of 2 scientific papers on the aforementioned related topics. The details of the papers are shown on Table 3. Furthermore, those publications set the ground for future collaborations while also promoting the importance of reliable electronics to a broader audience of researchers.

Paper Title	Status	Conf
Machine Learning Approach for Cross-Technology Prediction of the Generated Single Event Transient	Accepted	ETS 2026
On-Chip Reliability Sensor Analysis Under Combined Effects of Aging and Power-Supply Noise	Submitted	DDECS 2026

Table 3: UTH's short-term visit to IHP - Publication Outcome

Figure 1: Group photo with IHP and UTH members during the short-term visit of Nikos Zazatis at IHP

Investing in future generations of researchers:

In addition to Nikos Zazatis' visit at IHP, three undergraduate students (Konstantinos Varakliotis, Konstantinos Adrikopoulos and Marios Stamos) from UTH also joined IHP in the form of an internship. Working under the supervision of IHP experts and in close collaboration with Nikos, the students engaged in research related to aging effects and ML-based SET prediction, aligning with TWIN-RELECT goals. This initiative reflects UTH's commitment to training future researchers and highlights the strong partnership with IHP. Although not originally included in the DoA, the consortium believes that involving young researchers in these activities provides a vital opportunity for future PhD development and spreads knowledge beyond the core project team.

3.1.2 Short-term visit to CNRS [Ongoing]

1st visit to CNRS

The visit of Nikos Chatzivangelis at CNRS began on *October 20th, 2025*, and is currently ongoing. As part of the TWIN-RELECT project, the researcher aims to investigate methodologies for analyzing and mitigating radiation-induced faults in modern electronics. His work specifically focuses on modeling Single Event Transients (SETs) in modern semiconductor technologies, investigating advanced STA-based methodologies for SET propagation, automated gate characterization, and variation-aware analysis to support robust, fault-tolerant circuit design.

The primary objective of this visit is to receive training on the preparation and execution of irradiation test campaigns under the supervision of prof. Luigi Dilillo (RADIAC group). The training also includes the design of specialized hardware setups for TID, and SEE experiments, equipping the student with comprehensive knowledge of the challenges of experimental validation under harsh radiation environments and how to mitigate them. Finally, the visit emphasizes on simulating radiation effects in scaled technologies (sub-30 nm CMOS) using in-house tools PredicSEE and ECORCE, along with data analysis techniques for extracting reliability insights from simulation results. The student is engaging in technical discussions, with the developers of these tools, to construct a detailed technical plan on the tools interface with the Cross-Layer EDA Tool Flow for reliability analysis.

Between October 20, 2025, and December 19, 2026, the researcher attended expert guest lectures organized by the RADMEP master's program. These sessions covered topics ranging from radiation testing and hardening to deep space exploration, including:

- "Deep Space Exploration with Small Satellites" – Philippe Adell (JPL/NASA)
- "Test bench and facilities for radiation tests" – Françoise Bezerra and Arnaud Dufour (CNES)
- "Radiation Hardness Assurance from an industrial point of view" – David Truyen (Microchip)
- "The challenge of Nuclear Dismantling" – Khalil Amgarou and Didier Carle (CEA)
- "Radiation Test of advanced technologies" – Luis Entrena (Carlos III University of Madrid)

During this period, a journal paper titled *"Reliability Analysis of Clock Networks and Critical Paths under Radiation-Induced Transients Using Custom Simulation Tools"* was submitted to the *Microprocessors and Microsystems (MICPRO)*. Co-authored with Frederic Wrobel, the paper focuses on the PredicSEE - UPSET interface, which is part of the TWIN-RELECT's cross-layer reliability analysis EDA tool flow. Particularly, an analysis of SETs in clock networks and critical paths is presented using PredicSEE as a means for accurate SET generation and UPSET as a means for fast SET propagation and evaluation of the error rates in the designs.

Furthermore, from January 26–28, the researcher participated in a joint irradiation test campaign with IHP and the Federal University of Ceará (UFC). The campaign focused on evaluating the effectiveness of aging monitors developed by IHP for the monitoring of the TID effect. The results of these experiments are scheduled for submission to RADECS 2026.

Finally, for the remainder of his stay in Montpellier, the researcher is scheduled to participate in two additional irradiation campaigns to further consolidate his expertise in testing radiation effects on integrated circuits. Additionally, he plans to submit a paper to a special session of the VLSI Test Symposium (VTS 2026). This work will focus on simulating SETs within the NVDLA MAC Unit and proposing associated hardening techniques.

Figure 2: Social event with colleagues from CNRS & IHP during the short-term visit of Nikos Chatzivangelis at CNRS

3.1.3 Short-term visit to MAN [Planned]

The first short-term research visit at the University of Manchester is currently in the administrative phase, with hosting procedures underway for the ESR from the UTH. The secondment is scheduled to start in September 2026 for a duration of five months.

The primary objective of this visit is to develop efficient and accurate reliability assessment frameworks for Neural Networks (NNs), a critical requirement for deploying resilient AI in safety-critical domains. The research scope encompasses:

- **Architectures**: Traditional Deep Neural Networks (DNNs), Dynamic Neural Networks (DyNNs), and Spiking Neural Networks (SNNs).
- **Error Models**: Evaluation of both simulation software-based and emulation hardware faults
- **Resilience**: Development of cross-layer mitigation techniques to ensure robust AI performance.

Nikolaos Zazatis has been selected as the candidate from UTH, as his specialized research expertise directly aligns with the technical goals of this collaboration.

3.2 Short-term visits of IHP/CNRS/MAN staff to UTH

3.2.1 Visit of MAN staff to UTH

3.2.1.1 Context of the visit

In the first year of the project, the main goal of the University of Manchester was to provide training to the University of Thessaly on the operation of hardware accelerators for both artificial and spiking neural networks, thereby establishing a joint research goal focused initially on characterizing the impact of hardware faults on their behaviour (T1.2) and, subsequently, on designing appropriate protection circuits (T1.3). Specific devices under test are the NVDLA accelerator for deep learning inference and the TaBuLA asynchronous network-on-chip, which is the sensitive communication fabric of a multi-core neuromorphic processor (NeoCorAI) currently at the forefront of neuromorphic computing for edge applications.

The initial focus was on permanent faults. On the one hand, these faults are traditionally addressed through post-production testing, which is effective in identifying manufacturing defects before deployment. However, testing of asynchronous circuits (which are vital for biologically-plausible neuromorphic computing platforms) is lagging far behind the consolidated methods and tools of synchronous designs, and is a fundamental roadblock toward industrial adoption. On the other hand, in modern electronic technologies, permanent faults are increasingly becoming a concern for long-term reliability too, as they may also emerge during operation in the form of runtime-induced degradation mechanisms such as time-dependent dielectric breakdown (TDDB) and electromigration. As a result, they can silently degrade system behavior, thus representing a critical challenge for the long-term reliability of AI devices deployed in mission-critical systems.

In the context of multi-core neuromorphic processors, while neuron- and synapse-level faults have been extensively investigated, spike routing faults have been significantly underexplored in neuromorphic literature, despite their potential to severely disrupt system operation. In fact, spiking neural networks have large fan-in and fan-out, which can amplify the impact of communication faults on neural processing. One of the main reasons for this gap is that the communication architecture of neuromorphic systems is typically asynchronous, both for efficiency and for biological plausibility. However, asynchronous design is neither simple nor widely adopted in mainstream digital design flows, which has limited the development of systematic protection methods from permanent faults in this domain, both at post-production testing and at runtime. To bridge this gap, the University of Manchester provides a cost-effective asynchronous network-on-chip architecture (TaBuLA) supported by a synthesis tool flow based on mainstream industrial CAD tools. This enables targeted training activities and supports the development of a joint research effort with UTH on the characterization of communication faults and their mitigation in neuromorphic processors.

3.2.1.2 Training and collaboration activities

This research and collaboration framework was the context for the short term visit of UoM to UTH in 2025, which lasted one week and was carried out by the Post-doctoral Research Associate Giuseppe Chessa in fulfillment of T2.4. He is member of the Advanced Processing Technologies Group and technical staff member of the International Center on Neuromorphic Computing at University of Manchester, with an area of expertise in digital communication hardware. His paper on a synthesis tool flow for implementing asynchronous networks-on-chip on FPGAs got a best paper award nomination at the prestigious 29th International Symposium on Asynchronous Circuits and Systems (ASYNC) 2025 in the US.

The visit was aimed at advancing both training and collaborative research in the field of asynchronous communication for neuromorphic computing. Its main objectives encompassed four complementary dimensions: (i) providing in-depth training to the UTH team on the synthesis process for asynchronous bundled-data NoCs using mainstream industrial CAD tools; (ii) achieving a research collaboration milestone through the joint development of synthesis scripts for a new TaBuLA variant, fully asynchronous and compatible with standard DfT methodologies, thus fostering innovation in neuromorphic computing and asynchronous communication in general; (iii) facilitating hands-on student supervision to enable the effective transfer of MAN's expertise to MSc and PhD students at UTH; and (iv) consolidating UTH's knowledge in asynchronous NoCs, equipping the local team to independently design and synthesize new test-enabled TaBuLA variants and to apply their reliability analysis expertise to a new and emerging class of AI devices.

3.2.2 Visits of IHP and CNRS staff to UTH in 2026

In 2026, short-term visits of experts from IHP and CNRS to UTH are scheduled in order to further strengthen knowledge transfer and facilitate the joint research activities and the co-supervision of the ESRs, in line with [1]. Both visits share common objectives aimed at enhancing scientific capacity and academic excellence of UTH. During the visits, a set of lectures will be delivered to a broad audience of UTH academic staff, researchers, and students. In parallel, the ESRs will present their research progress and define publication strategies jointly with the partner supervisors. In addition, the visits will support hands-on collaboration in ongoing research activities, targeted training on advanced methodologies and tools, and dedicated technical meetings to address complex research challenges and accelerate progress in project tasks.

The visit of IHP experts is planned for the period April-May 2026 (after Easter) and is currently foreseen to involve Marko Andjelkovic, Fabian Vargas, Alessandro Veronesi, and Felipe Kuentzer, subject to final confirmation. The activities will focus on advanced techniques for reliable electronic systems and reliability testing methodologies. Lectures and collaborative sessions will address topics such as the design of fault-tolerant standard cells and hardened cells, selective fault tolerance techniques for processors, sensors for on-chip detection of transient and permanent faults and system status monitoring, and reconfigurable fault tolerance in multi-core processors. Finally, emphasis will be placed on reliability testing and qualification, including test circuits design and experimental setups for ASICs, as well as aging, electromagnetic interference (EMI), radiation and laser testing procedures for custom-designed ASICs.

The CRNS visit is planned for early autumn 2026 and is indicatively expected to involve Luigi Dilillo and Douglas Almeida dos Santos. The visit will focus on advanced reliability modelling, radiation-aware design techniques, and reliability testing methodologies. In particular, activities will cover analysis of radiation effects at both transistor and circuit level using in-house simulators (i.e., ECORCE and PredicSEE) and modelling of the physical mechanisms underlying radiation effects in electronic devices. Additionally, topics such as design techniques for reliable systems, including hardening approaches for memories and commercial processing platforms, as well as the development and evaluation of radiation sensors as standalone devices, will be covered. Finally, the visits will provide insights on reliability testing and qualification procedures, such as irradiation testing and EMI testing for commercial microcontrollers, FPGAs, and memory devices.

4. Training Schools

A fundamental element of the scientific capacity enhancement strategy is the organization of dedicated training schools designed to facilitate knowledge transfer, foster networking among ESRs of UTH, and strengthen interdisciplinary skills. Four training schools, each hosted by a different partner institution, are planned to be organized throughout the project duration. These sessions are organized to include three main features, including scientific lectures, transferable skills training, and presentation of ESR's work. As a complementary activity, each training school includes a tour of the host's facilities, offering participants valuable insights into infrastructures, technologies, and ongoing research status of the corresponding partner institution. The following subsections report on the training schools organized by CNRS, IHP, and MAN.

4.1 Training School at CNRS

The First TWIN-RELECT training week was successfully convened by CNRS in Montpellier from January 6th to January 10th, 2025. Held across the IES and the University of Montpellier (Campus Triolet), this productive event brought together project consortium members and students, including collaboration with the RADMEP master's program. The primary objective was to provide a comprehensive theoretical and practical foundation regarding radiation harsh environments, radiation-matter interaction, and the modeling of faults in electronic systems to support the project's research goals.

The curriculum opened with a robust introduction to the physics of radiation environments, covering natural and artificial sources, particle ranges, and cross-sections. Experts from CNRS led sessions on the critical mechanisms of component degradation, specifically detailing Single Event Effects (SEE), Total Ionizing Dose (TID), and Displacement Damage (DD). To ensure operational readiness for future experiments, the training also included a mandatory safety certification module focused on the proper access and use of irradiation facilities.

A significant portion of the schedule was dedicated to hands-on technical training with specialized simulation software. Participants engaged in a three-day workshop on the ECORCE tool to simulate ionizing particle interactions with specific topologies, followed by a session on PREDICSEE for retrieving predictive device cross-sections. These practical trainings equipped attendees with the skills to install and utilize these tools to model fault behaviors and predict system reliability under radiation stress. The week concluded with advanced seminars delivered by partners from IHP, focusing on gate-level mitigation techniques and the combined effects of radiation and EMI.

Three PhD students from the UTH, along with two other PhD students from the University of Montpellier and two partners from IHP, participated in the training week. During this event, the TWIN-RELECT team had the chance to exchange ideas and knowledge with students from abroad and discuss common challenges in radiation hardness assurance. This cross-institutional interaction, combined with the final advancement meeting and preliminary discussions on tool harmonization, successfully aligned the consortium's technical strategies and solidified the roadmap for upcoming project deliverables.

Figure 3: Training school of TWIN-RELECT at CNRS

4.2 Training School at IHP

The Second TWIN-RELECT Training School took place at IHP, on 19th and 20th May, 2025. The main topic of the school was “Design of Reliable Integrated Circuits”. The program included 2 keynote talks and 8 lectures by the experts from the consortium and one external invited speaker. The lectures have covered the aspects related to design of ASICs for space, reliability of emerging technologies, and fault tolerance analysis methodologies. Besides lectures, a visit to IHP’s clean room and test laboratory was organized.

A PhD Forum was organized as a special session dedicated to presentation of the PhD students’ ongoing work. A total of 7 PhD works have been presented. Each PhD candidate introduced the work through a 5-minute presentation and a poster. A selected Evaluation Committee has evaluated the works of all PhD students and discussed the results with the candidates.

The school was attended by 26 participants, 9 of which are PhD students. Besides the TWIN-RELECT partner institutions, two external universities and one company have also attended the school. All attendees had the opportunity to evaluate the event by filling in an evaluation form. The comments were generally positive, with suggestions for improving the catering service.

Figure 4: Training school of TWIN-RELECT at IHP

4.3 Training School at MAN

The Third Workshop on Research Management and Administration took place at University of Manchester (MAN) on January 13. It consisted of 4 main talks: on structuring research support services, on research data management, on research communications, impact and the role of AI, on how to take ideas from research to commercialization and on European calls for collaborative research projects. Roughly 15 people attended the workshop from 3 institutions (UTH, Taltech and Univ. of Nis).

The Third Training School on Fault-Tolerant AI Systems took place at MAN from January 14 to 16, 2026. It consisted of 3 keynotes, 11 technical training talks, 3 hands-on sessions and 2 training sessions on soft skills.

The keynote speeches have concerned i) the ChipIr UK beamline dedicated to the irradiation of microelectronics with atmospheric-like neutrons, ii) fault tolerance methods in emerging neuromorphic computing devices and iii) perspectives from a neuromorphic computing pioneer on the management of large-scale research projects. Two technical talks have covered hot topics in the field of chip design for space applications and AI verification. Experimental and formal techniques for fault analysis have been addressed by 3 talks, and reliability of AI accelerators by 2 talks. A special day with 4 talks has been devoted to neuromorphic computing and its reliability requirements, finalized by a visit to the Spinnaker machine. 3 hands-on sessions have allowed attendees to put their hands on fault injection tools (EMBER, asynch. NoC injector) and on spiking neural network modeling and simulation tools (snnTorch).

Finally, a professional training has been delivered on the development of soft skills for researchers, in particular on team working capabilities. The sessions were given by people from the The Teams Build Dreams programme at MAN, which aims to increase awareness and application of collaborative team research principles in delivering research.

The Training School was attended by roughly 30 participants from 9 institutions (7 from UTH, 1 from CNRS, 1 from Univ. of Sorbonne, 1 from TU Wien, 3 from IHP Microelectronics, 3 from Taltech, 5 from Univ. of Nis, 7 from the two Manchester universities).

Figure 5: Training school of TWIN-RELECT at MAN

5. Training Through Joint Experiments

The joint experiments constitute a significant part of the scientific capacity enhancement strategy, since their purpose is not only to serve the scientific and technical objectives of the project, but also to enhance the technical skills of the ESRs and further strengthen the collaboration among the partners and participating institutions. These experiments build upon existing national and international projects in which the partners are involved, adding remarkable value through shared expertise and complementary methodologies by facilitating the active participation of UTH researchers.

Five joint experiments were planned for implementation throughout the project duration, covering a wide range of techniques and addressing critical aspects of fault-tolerant design. At the time of preparing this document, two experiments have already been successfully executed, and two other proposals have been accepted, one by RADNEXT at the PARTREC facility in the Netherlands and another one at ChipIR in the UK.

5.1 On-Chip Reliability Sensor Validation under TID and SEU Radiation

The joint irradiation experiment "**On-Chip Reliability Sensor Validation under TID and SEU Radiation (OCHRES)**" is a key activity within the project's joint research and experimental validation strategy. It is led by IHP and the Federal University of Ceará (UFC), with CNRS and UTH participating. The experiment targets Artix UltraScale+ (16 nm FinFET) commercial FPGA samples. Each FPGA hosts hundreds of instances of a novel on-chip reliability sensor integrated into a 32-bit RISC-V VCE2 (CROC) processor. The sensor advances the state of the art by combining online monitoring of timing-critical path aging with transient-fault masking in flip-flops via a Triple Modular Redundancy (TMR) architecture, auto-tuning/self-calibration capabilities, and a clockless self-correction mechanism.

To validate this sensor comprehensively, OCHRES is structured into two dedicated irradiation campaigns, one focusing on Total Ionizing Dose (TID) effects and the other on Single Event Upset (SEU) behavior.

In the TID irradiation campaign, the primary goal is to validate the auto-tuning and self-calibration mechanism and to assess the sensor's ability to track time-slack erosion as a function of accumulated dose. The Artix UltraScale+ boards were subjected to X-ray irradiation at the University of Montpellier and CNRS facilities in Montpellier, France, from 26 to 28 January 2026, reaching a total dose of up to approximately 3 Mrad. During irradiation, the sensor outputs were monitored over time and dose to reconstruct a "TID evolution history" of critical paths under TID stress and to verify that the sensor can reliably detect slack reduction and performance degradation. This campaign also serves to benchmark and refine the simulation models and critical-path selection process used for sensor instantiation in the TWIN-RELECT cross-layer EDA flow, directly enhancing UTH's expertise in aging- and TID-aware design and validation.

In the SEU irradiation campaign, planned for March 2026 at the PARTREC facility in the Netherlands, the focus shifts to validating the sensor's clockless error-correction features and its capability to mask radiation-induced transient faults in flip-flops and logic under proton irradiation. Using the same FPGA platform, the devices will be exposed to a proton beam representative of atmospheric and space radiation conditions. The objectives are to (i) demonstrate that the TMR-based, clockless self-correction mechanism can effectively handle SEU-like events without external timing support and (ii) identify the limits of the sensor's own reliability by determining the proton flux and energy conditions at which its functionality starts to degrade. Both campaigns are designed in line with ESA Standards 22900 and

25200, ensuring that the experimental methods and data are compatible with space-grade qualification practices.

Taken together, these two irradiation campaigns provide a thorough validation of the on-chip sensor under cumulative TID and single-event conditions. For TWIN-RELECT, they offer high-value experimental data for calibrating and validating the project's cross-layer reliability models, and they enable UTH to test and improve its ageing simulation, SET/SEU propagation analysis, and critical-path-selection methodologies on an advanced FinFET platform representative of future AI and RISC-V-based systems.

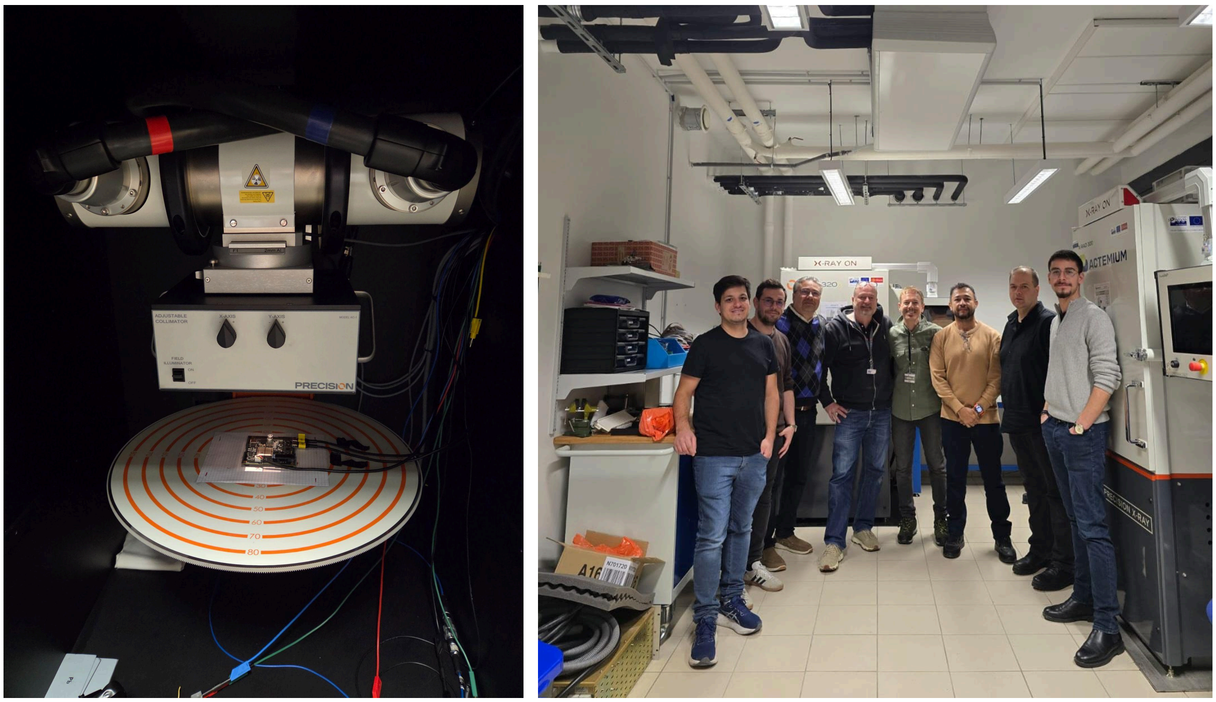

Figure 6: X-RAY experiments at Montpellier; collaboration among IHP, UFC, CNRS and UTH

5.2 Neutron Irradiation of Network-on-Chip Architectures

A neutron irradiation proposal titled "Comparative Neutron Irradiation Study of Asynchronous and Synchronous Network-on-Chip Architectures (CINAS-NoC)" has been submitted to and accepted by the ChipIr facility in the UK, with irradiation planned for September 2026. The experiment will use an atmospheric-like neutron spectrum to evaluate and compare the radiation-induced fault tolerance of two FPGA-implemented NoC architectures: an asynchronous bundled-data 2D mesh NoC optimised for ultra-low-power, event-driven workloads (e.g. neuromorphic systems), and a synchronous AXI-based NoC that incorporates classical fault-tolerant techniques such as TMR, ECC and hardened FSMs.

Both NoCs will be instantiated on comparable FPGA-based platforms with similar topologies and router structures, and will be driven by synthetic traffic generators to emulate realistic communication patterns during irradiation. Each design includes a monitoring infrastructure capable of logging packet transmissions, detecting transmission errors (corruption, loss, duplication), control failures and register-level faults (e.g. handshake failures, deadlocks), enabling precise localisation of error sources in the interconnect. The beam request targets a neutron energy range of 1–800 MeV, a flux of about 5×10^6 particles/cm^2·s, and a total fluence of 5×10^{12} particles/cm^2, representative of atmospheric avionics conditions.

The campaign's goals are to (i) quantify and compare SEU sensitivity and dominant failure modes in asynchronous and synchronous NoCs, (ii) identify the most critical components in each architecture (handshake logic, FSMs, buffer registers, etc.), and (iii) assess the scope for fault-tolerant enhancements within realistic power and area budgets. The results will directly support TWIN-RELECT's objectives on cross-layer reliability of communication fabrics by providing hard experimental data on NoC robustness under neutron irradiation, and will inform the design of resilient, energy-efficient interconnects for SoCs deployed in radiation-prone environments.

5.3 X-Ray Irradiation of Ferroelectric RAM

As part of the training during the short-term visit of UTH at CNRS, an irradiation campaign of an I2C Ferroelectric RAM (FRAM) was conducted in February 2026 at Montpellier to evaluate its reliability in high-radiation environments. The primary goal of the experiment was to determine how much radiation the device can withstand before its performance degrades or it fails completely. Unlike standard memory, FRAM uses ferroelectric crystals that are naturally robust, but the surrounding control circuitry remains susceptible to ionized charge buildup.

The testing process involved exposing the MB85RC256V I2C FRAM to a controlled X-ray source while it performed a continuous "March-C" memory test at its maximum operating frequency. This specific test sequence was used to scan for any bit flips or communication errors in real-time. Throughout the exposure, we strictly monitored the chip's power consumption and current draw. Tracking these metrics allowed us to detect high current increases, which serve as an early warning sign that the internal transistors are beginning to degrade even before data errors appear.

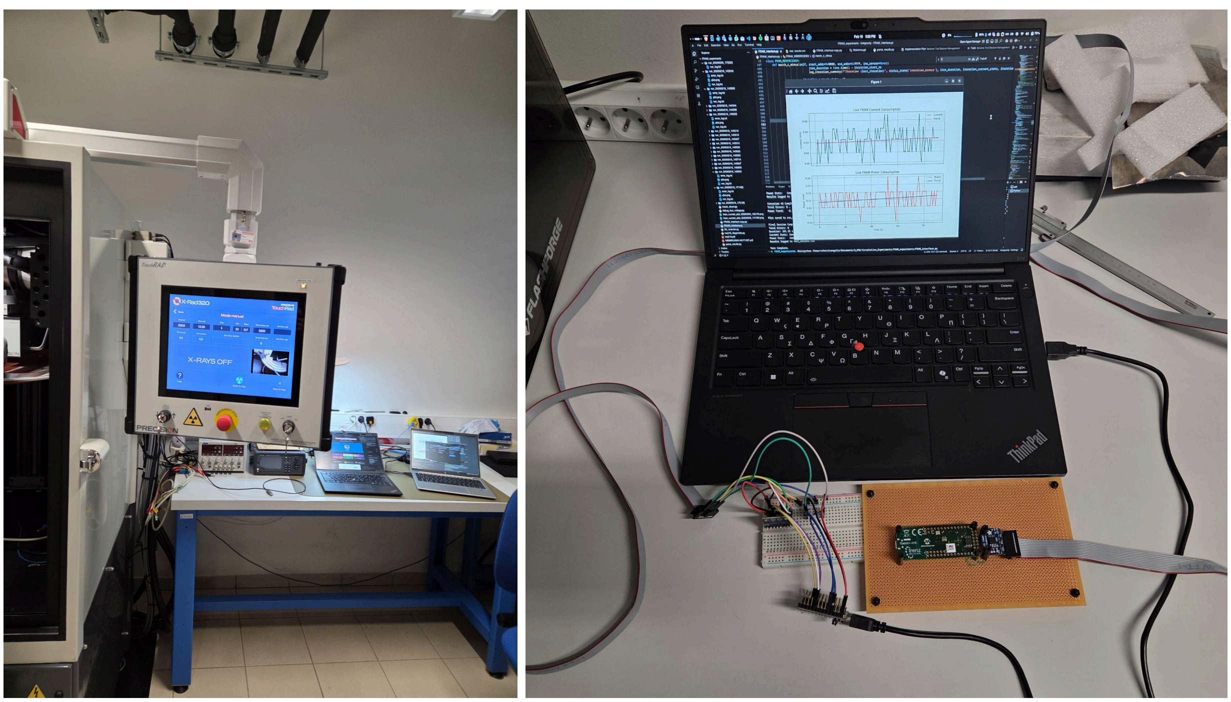

Figure 7: TID experiments on a FRAM COT device at CNRS

To ensure a comprehensive analysis, the experiment also looked for temporary glitches caused by the radiation beam that do not cause permanent damage. By pausing the X-ray source and power-cycling the device after multiple detected failures, we could distinguish between temporary interference and permanent hardware destruction. Furthermore, by dynamically adjusting the I2C communication frequency when radiation-induced wear made higher speeds unstable, we were able to map the exact performance limits of the chip. This methodology provides a precise "threshold of failure" critical for certifying the component for high-reliability industrial or aerospace applications within the EU.

6. Annual Project Meeting

The continuous monitoring of the project's progress ensures the seamless workflow and contributes to the successful achievement of the project's goals and KPIs, while aligning with the project plan and enabling early identification of challenges and the implementation of appropriate corrective actions. To this end, the annual project meeting is critical, serving as a formal mechanism for all consortium partners (UTH, IHP, CNRS, and MAN) to review the execution status of the project's plan.

In total, three project meetings were scheduled (July 2025, July 2026, and July 2027). The first annual project meeting took place on 24th of July, 2025, during the 1st Scientific Workshop and the 2nd Research Management & Administration Workshop held at UTH in Volos (21-25 July 2025).

Figure 8: Social dinner after Annual Project Meeting at Volos, July 2026

6.1 Key outcomes

The meeting, which was attended by representatives from all partner institutions, focused on establishing a publication strategy for the upcoming months, coordination of technical activities, preparation of internship visits, and alignment of upcoming experimental campaigns.

6.1.1 Publication strategy

Partners agreed on a coordinated publication roadmap targeting major conferences (DATE, ETS, ATS, RADECS) and journals (TCAD, special issues). Several manuscripts are already in preparation, covering reliability analysis of DyNN and asynchronous NoC designs, ECORCE/PredicSEE simulation studies, UPSET optimizations, and results related to EMBER. Also, the dissemination efforts will ensure compliance with Article 17 requirements on acknowledgements and open access.

Completed publications to date include ASYNC, SMACD, and IWASI contributions.

6.1.2 Training and staff exchange planning

Partners concluded a detailed plan for the initial ESR internship, including the specific technical tasks and timelines for collaboration with CNRS, IHP, and MAN.

A structured staff exchange plan was defined:

- Nikos Chatzivangelis internship at CNRS (starting October 2025) to gain hands-on training in irradiation experiment setup, SEE/TID testing, and participation in the RADMEP educational program.
- Additional training activities in December 2025 at CNRS, including specialist lectures and supervised experimental practice.
- Nikolaos Zazatis visit to IHP, scheduled for October 2025, to begin SPICE-based SET/SEU/aging characterization and ML-modeling work.

These mobility actions support scientific capacity enhancement and ensure alignment with TWIN-RELECT technical objectives.

6.1.3 Technical collaboration

Partners also discussed about the upcoming technical collaborations:

- MAN - UTH collaboration:
  Reliability and fault-tolerance analysis of NVDLA and TaBuLA NoC accelerators, with defined deadlines and expected publications (DATE 2026).
- IHP - UTH collaboration:
  SPICE simulations for SET generation, propagation, aging, and ML-based prediction.
  Development of datasets, LUTs for UPSET, and preparation for potential irradiation campaigns.
- CNRS - UTH - MAN collaboration:
  ECORCE and PredicSEE simulation workflows and planning of RADNEXT proposals (sec 5.1, 5.2).

Workshops, testing campaigns, and joint experimental opportunities, including FPGA-based studies with embedded sensors, were also outlined.

6.2 Strategy for the forthcoming months

Based on the meeting discussions, the consortium agreed on the following strategic actions:

- Prepare and submit RADNEXT Transnational Access (TA) proposals for SEE and TID testing (deadline September 2025) to secure beamtime for joint irradiation testing of multi-purpose sensors integrated into RISC-V/NOC architectures.
  - Plan early prototypes and test setups for FPGA-based sensor evaluation under SEE/TID conditions.
- Execute the planned ESR exchanges to CNRS (September 2025) and IHP (October 2025).
  - Prepare training material and logistics for the December 2025 training experiments at CNRS.

- Begin SPICE and ML-based modeling activities for SET, SEU, and aging effects at UTH and IHP.
- Advance technical work in T1.2 and T1.3 to meet publication deadlines (ETS 2026, DATE 2026).
- Initiate groundwork for co-organizing the DFTS in Greece in 2027 and exploring a special session at SMACD 2026.

6.3 Risks addressed with countermeasures

During the meeting, the partners reviewed potential risks related to the implementation of the project activities, and the possible impact on progress and outcomes. Several mitigation measures were discussed for each identified risk in order to ensure timely implementation of the plan. Table 4 summarizes the identified risks along with the potential impact and the proposed countermeasures.

Risk	Impact	Countermeasures
Administrative delays in staff exchanges	Delay in training and technical progress	Early initiation of documentation, close coordination with host institutions
Overambitious publication load	Missed deadlines or reduced quality	Prioritization, internal review schedule, distribution of authorship across partners
RADNEXT TA proposal not accepted	Delay in irradiation experiments	Prepare multiple proposals, identify alternative facilities, adjust experiment timeline
Imbalance of effort across partners	Bottlenecks in WP1 progress	Redistribute subtasks, involve additional ESRs

Table 4: Identified risks and countermeasures

7. Activities Summary

A tentative schedule of the activities related to WP2 was introduced in the Scientific Capacity Enhancement Plan (D2.1) [1]. This section summarizes the activities scheduled for the reporting period (M1-M17), presenting their current status and highlighting any deviations from the initial plan. Table 5 provides a high-level comparison between the activities planned in D2.1 and their implementation status up to M17 of the project.

Training Schools: Four training schools (one hosted by each partner) were planned to be organized. Training schools in CNRS, IHP, and MAN were successfully completed on the planned date. The training school by UTH was initially scheduled for M10 (July 2025). However, UTH, in coordination with the other partners, decided to reschedule this event to a later date within the project duration. This decision was made because, during that period, UTH was responsible for organizing four other major events (i.e., the 1st Scientific Workshop, the 2nd Research Management and Administration Workshop, the 1st Business Forum, and the 1st Webinar). Organizing an additional large-scale event, such as the training school, would have required excessive demands on resources and potentially compromised the quality of its outcomes. Moreover, postponing this event does not adversely affect the progress of the research activities or the implementation of other scheduled project events.

Joint Experiments: One training experiment with CNRS was initially scheduled for Spring 2025, in which UTH researchers would participate as outside spectators to gain experience on irradiation experimentation deployment. However, this activity was canceled due to facility restrictions and large administrative overheads from both UTH's and the facility's sides, which made the mission unfeasible and impractical to complete. The 1st joint experiment, initially planned for October 2025, was successfully performed in January 2026 at CNRS. The experiment was followed by researchers from both UTH and IHP, aligning perfectly with the project's goals, while the participation of UFC facilitated international exchanges for UTH, fostering new relations for future collaborations. These adjustments do not affect the overall objectives of the project, as the activities will be completed within the project timeline. The next experiments are planned for March 2026 (proton irradiation of aging monitors) and September 2026 (neutron irradiation of NoC architectures).

Staff Exchanges: Short-term visits between UTH staff and the partner institutions are ongoing. During the reporting period, one UTH ESRs completed a visit at IHP and another is currently positioned at CNRS. Additionally, expert staff from MAN visited UTH, in October 2025, contributing to training, collaborative research, and ESR supervision activities. Finally, the next staff exchanges are already being scheduled for later in 2026, while the plan for 2027 will be defined during the next annual meeting of the consortium in June 2026.

PhD Supervision: Taking into account the PhD topics and the expertise of the partner institutions, two supervisors were assigned to each PhD candidate. Regular meetings were held throughout the reporting period to monitor the research progress. This progress was formally assessed and validated with the biannual progress reports, ensuring the effective monitoring of the research activities.

Annual Project Meetings: The first annual project meeting was successfully held in July 2025 at UTH (Volos). During the meeting, the progress of the project was reviewed, and the strategy for the following months was discussed. Additionally, several scientific and administrative issues were addressed, facilitating coordination among partners and alignment with the project's goals.

Activity Type	Activity	Initially planned	Status	Comments
Training schools	**CNRS Training School**	M4	Completed	
	IHP Training School	M8	Completed	
	UTH Training School	M10	Postponed	To be rescheduled according to other WP's activities
	MAN Training School	M16	Completed	
Joint experiments	**Training Experiment, Spring 2025**	M6-M9 (Spring 2026)	Canceled	See above
	Joint Experiment #1	M13 (October 2026)	Postponed	Performed in January 2026

Activity Type	Activity	Initially planned	Status	Comments
	Joint Experiment #2	M17 (March 2026)	On-track	Proton Irradiation of Aging and SEE monitors.
	Joint Experiment #3	July 2026	Moved for September 2026	Neutron Irradiation of NoC Architectures.
Short-term visits	**Staff Exchanges**	M10-M35	Ongoing	Visits of UTH staff to other partners and partners staff to UTH initiated; Additional exchanges scheduled
PhD supervision	**1st Progress Report**	M9	Completed	
	2nd Progress Report	M15	Completed	
Annual project meeting	**Annual Meeting**	M10	Completed	

Table 5: Status of WP2 Scheduled Activities according to Initial Plan [1] for Reporting Period M1-M17

8. Impact

The scientific training activities implemented under WP2 during the reporting period M1-M17 have directly contributed to the enhancement of scientific capacity of the UTH. Through structured supervision, targeted mobility actions, and participation in joint experimental and training activities, the selected ESRs from UTH have strengthened their expertise in radiation-aware modelling, fault analysis, and cross-layer reliability evaluation.

Short-term visits to partner institutions (CNRS, IHP) as well as expert visits to UTH enabled direct knowledge transfer and active engagement in shared research tasks, including tool-flow integration, modelling activities, and irradiation-supported validation. These exchanges enhanced methodological alignment across partners and facilitated the development of joint scientific outputs.

The strategic inclusion of three additional undergraduate students in the short-term visits to IHP further extended the project's scientific training impact beyond current ESRs, highlighting the commitment of UTH in investing in future generations of researchers. By participating in research directly linked to TWIN-RELCT goals, these students gained essential foundational training for future doctoral studies, while their active contribution to two conference papers accelerated the project's joint research activities and strengthened dissemination goals.

Training schools and joint experiments further reinforced this impact by providing hands-on experience with advanced tools, experimental infrastructures, and reliability evaluation methodologies, thereby strengthening UTH's long-term research capacity in reliable electronic systems.

At the same time, the established co-supervision of the selected ESRs along with the training mechanisms provide a sustainable framework for continuous scientific capacity enhancement throughout the project duration.

9. Conclusions

During M1-M17, UTH successfully implemented the main WP2 capacity-building actions planned in D2.1, with five ESRs recruited and supported through a dual-supervision framework and structured progress monitoring. Mobility actions, training schools, and joint experimental activities enabled effective knowledge transfer and strengthened collaboration with CNRS, IHP, and MAN, while also supporting dissemination through conference and journal submissions.

Although some activities were rescheduled due to logistical constraints, mitigation measures were applied and the overall objectives remain on track. The implemented supervision and training mechanisms provide a strong basis for the forthcoming period, with planned exchanges and experimental campaigns expected to further consolidate UTH's long-term scientific capacity in reliable electronic systems. It's worth noting here that

References

[1] TWIN-RELECT. *Deliverable D2.1 - Scientific Capacity Enhancement Plan*. HORIZON-WIDERA-2023-ACCESS-02, Grant Agreement No. 101160314, European Commission, December 2024.