14 PhD positions in the EU Horizon 2020 Marie Skłodowska-Curie Project:

e TERNITY

European Training Network
on Electromagnetic Risks
in Medical Technology

Applications are invited for 14 PhD positions ("Early Stage Researchers") to be funded by the Marie-Skłodowska-Curie Innovative Training Network "ETERNITY –European Training Network on Electromagnetic Risks in Medical Technology" within the Horizon 2020 Programme of the European Commission. The ETERNITY Beneficiaries are 3 high-technology companies in the area of medical technology: Philips Medical (NL), PLUX (PT), and Ficosa (ES). The consortium is completed by 5 universities: TU Eindhoven (NL), University of Twente (NL), KU Leuven (BE), Universitat Politècnica de Catalunya (ES), and FCT/UNL Lisboa (PT). Together, these universities have a proven track record in the management of electromagnetic interference (EMI), medical engineering, system engineering and risk management, and are the leaders in their field in Europe. The essential clinical involvement is arranged via 2 hospitals, which are Partner Organisations in ETERNITY: Hospital Utrecht (NL) and Hospital CIMA Sanitas (ES). The industrial involvement is completed by 3 Partner Organisations: Eurofins (BE), Barco (BE) and the start-up Plasmacure (NL). Each of the 14 ESRs will be trained to work in multi-disciplinary and multi-cultural teams, with a new mindset tuned towards the inclusion of the three main elements of a risk-based approach into innovative design methods (e.g., concurrent engineering and agile/scrum design methods). For this inclusion to occur, each ESR will develop through their research the missing dedicated tools and techniques, and apply them to a representative set of medical devices under development. This hands-on training is supplemented with several scientific professional courses and an immersive training where the ESRs can fine-tune their skills for the Jobs of tomorrow, while addressing the societal challenges of the ETERNITY program.

Key dates:
- **1 Sept 2020: Launch of 14 ESR Positions**
- **30 Nov 2020: Deadline for on-line application**
- **15 Jan 2021: Circulation list "ETERNITY preselected candidates"**
- **2 March 2021: ETERNITY Recruitment Event**
- **15 March 2021: Circulation list "recruited ETERNITY ESRs"**
- **1 Sept 2021: Targeted starting date for ESR contracts**

Key background info

EU FUNDING

This project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No. 955.816.

Number of positions available
14 PhD Positions

Research Fields
Electrical/Electronic Engineering – Medical Engineering – Safety Engineering – System Engineering – Communications Engineering - Risk Management

Keywords
Electromagnetic Interference – Electromagnetic Compatibility – Medical Equipment – Risk Analysis – Risk Reduction – Safety Assurance

Career Stage
Early Stage Researcher (ESR) or maximum 4 years of equivalent research experience.

Benefits and salary
The successful candidates will receive an attractive salary in accordance with the MSCA regulations for Early Stage Researchers. The exact (net) salary will be confirmed upon appointment and is dependent on local tax regulations and on the country correction factor (to allow for the difference in cost of living in different EU Member States). The salary includes a living allowance, a mobility allowance and a family allowance (if applicable). The guaranteed PhD funding is for 36 months (i.e. EC funding, additional funding is possible, depending on the local Supervisor, and in accordance with the regular PhD time in the

country of origin). In addition to their individual scientific projects, all fellows will benefit from further continuing education, which includes internships and secondments, a variety of training modules as well as transferable skills for the Jobs of Tomorrow acquired through a unique immersive learning.

On-line Recruitment Procedure (see Appendix 1 for full description)
All applications proceed through the on-line recruitment portal on the www.eternity-project.eu website. Candidates apply electronically for one to maximum three positions and indicate their preference. Candidates provide all requested information including a detailed CV (Europass format[1] obligatory), a motivation letter and transcripts of bachelor and master degree[2]. During the registration, applicants will need to prove that they are eligible (cf. ESR definition, mobility criteria, and English language proficiency). The deadline for the on-line registration is 30 **Nov 2020**. The ETERNITY Recruitment Committee selects between 20 and maximum 30 candidates for the Recruitment Event which will take place in Eindhoven (The Netherlands) (2 **March 2021**). The selected candidates provide a 20-minute presentation and are interviewed by the Recruitment Committee. Candidates will be given a domain-relevant peer-reviewed paper (prior to the recruitment event) by their prioritised Supervisor and will be asked questions about this paper during the interview to check if the candidate has the right background/profile for the ESR position. Prior to the recruitment event, skype interviews between the Supervisors and the candidates are recommended, along with on-line personality tests. In order to facilitate their travel, selected candidates (from outside The Netherlands) receive a fixed, lump sum of 250 euro (paid by the prioritised Supervisor). In order to avoid delays in reimbursements, candidates are asked to keep all invoices and tickets (cf. train, plane, hotel...). If local circumstances in the country of residence of a candidate or supervisor do not allow for travels (e.g due to COVID-19 restrictions), a good quality digital connection will need to be organised. The final decision on who to recruit is communicated shortly after the Recruitment Event (estimated 15 March 2021). The selected ESRs are to start their research as quickly as possible (target date: 1 Sept 2021).

Applicants need to fully respect three eligibility criteria (to demonstrated in the Europass CV):
1. **Early-stage researchers** (ESR) are those who are, at the time of recruitment by the host, in the first four years (full-time equivalent) of their research careers. This is measured from the date when they obtained the degree which formally entitles them to embark on a doctorate, either in the country in which the degree was obtained or in the country in which the research training is provided, irrespective of whether or not a doctorate was envisaged.
2. **Conditions of international mobility of researchers**: Researchers are required to undertake transnational mobility (i.e. move from one country to another) when taking up the appointment. At the time of selection by the host organisation, researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organisation for more than 12 months in the 3 years

immediately prior to their recruitment. Short stays, such as holidays, are not considered.
3. **English language**: Network fellows (ESRs) must demonstrate that their ability to understand and express themselves in both written and spoken English is sufficiently high for them to derive the full benefit from the network training.

The 14 available PhD positions
(see **Figure 2** for interactions between ESRs/WPs)

ESR1: EMI footprint characterization of medical devices
Host: TUe (NL)
Main supervisor: Dr. A. Roc'h (A.Roch@tue.nl)
Co-supervisors/mentors: Prof. F. Leferink (UTwente – NL), Ir. E. González Amat (CIMA – ES)
Duration: 36 months
Required profile: Electrical Engineering, System Engineering
Desirable skills/interests: Statistics, Computational Electromagnetics, Measurement Technology, Electromagnetic Interference
Objectives: This ESR position is about developing a generic approach to quantify the impact of a medical device on an environment in terms of EMI. Both contributions and reactions, after being placed in an environment, are addressed. The novel concept of "EMI footprint" comprises a set of characteristic curves obtained from stand-alone measurements on a device. It is combined with a statistical approach making it possible to combine the extra reactions a device can have with a system. Evaluating this footprint allows us to characterize beforehand EM environments for diverse scenarios.

ESR2: Characterization of medical electromagnetic environments for the use of new digital communication systems
Host: UPC (ES)
Main supervisor: Dr. M. Azpúrua (marco.azpurua@upc.edu)
Co-supervisors/mentors: Prof. M. Fernández (UPC – ES), Dr. Mark Van Helvoort (PHC – NL)
Duration: 36 months
Required profile: Electronic Engineering, Communication Engineering
Desirable skills/interests: Electromagnetism, Electromagnetic Compatibility, Telecommunication, Electronic instrumentation, Analysis software (Matlab, Python etc.), Risk analysis
Objectives: This ESR position is about characterizing EMI in scenarios where new digital communication systems (DCS) (including IoT) are being deployed together with medical devices. Standard testing procedures only measure the EMI frequency spectrum, which is not enough to perform a comprehensive evaluation of the performance degradation caused by multiple interferences. Hence, such EMI risks cannot be properly estimated. Figure of Merit (FoM) for DCS will be evaluated in the time domain. The resulting evaluation is based on statistical metric figures that meaningfully link a DCS to its reconfigurable environment.

ESR3: Application of system thinking and system safety to EMI risk assessment of medical applications

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[1] https://europass.cedefop.europa.eu/documents/curriculum-vitae

[2] Master students who will graduate in the next coming months are welcome to apply. In that case, please provide an overview of the transcripts that are already available.

Host: KU Leuven (BE)
Main supervisor: Prof. D. Pissoort (davy.pissoort@kuleuven.be)
Co-supervisors/mentors: Prof. G. Vandenbosch (KU Leuven - BE), Ir. R. Kleihorst (Philips - NL)
Duration: 36 months
Required profile: Electronic/Electrical Engineering, Systems Engineering, Safety Engineering
Desirable skills/interests: Electromagnetism, Systems Thinking, Hazard-and-Risk-Analysis
Objectives: This ESR will study the application of the recently proposed and revolutionary hazard-and-risk-analysis methods STAMP (System-Theoretic Accident Model and Processes) and STPA (System-Theoretic Process Analysis) to the EMI risk analysis of medical applications. Starting from the concepts out of Systems Thinking and Systems Theory, STAMP, STPA reformulate safety as a system-control problem rather than simply component-failure problems. However, so far, EMI robustness has not been looked at with STAMP/STPA. Therefore, the aim of this ESR is to integrate EMI into these techniques and apply this to two case-studies from different medical-application domains during secondments. The results of the STAMP/STPA analysis will be compared to those obtained with the classic hazard-and-risk-analysis methods (FTA, FMEA).

ESR4: Risk-Based EMI-Aware Design of Complex Systems
Host: UTwente (NL)
Main supervisor: Prof. F. Leferink (frank.leferink@utwente.nl)
Co-supervisors/mentors: Dr. A. Roc'h (TUe - NL), Dr. Hugo Silva (PLUX - PT)
Duration: 36 months
Required profile: Electromagnetic Compatibility, Electromagnetic Fields
Desirable skills/interests: Electromagnetic Compatibility, Electromagnetism, Systems Engineering, Risk Management
Objectives: This ESR develops an EMI-aware design process starting from the risk and hazard analyses of the medical system-under-development in its operational electromagnetic environment. The system and environment are divided into tangible items at lower subsystem levels (i.e., use of zoning), which are transferred to the design process by means of an EMI risk-management plan (EMI-RMP). Based upon the EMI-RMP, the most effective EMC measures will be chosen and implemented. The EMI-RMP borrows state-of-the-art configuration management from system engineering to establish and maintain the system's performance throughout its full life-cycle, including future upgrades or modifications. Finally, the EMI-RMP will be used as the input for an EMI-aware verification and validation process. The EMI-RMP will be logged and reviewed and if needed checked by an independent authority.

ESR5: Optimal Digital Communication Systems in electromagnetically noisy medical environments
Host: UPC (ES)
Main supervisor: Dr. M. Pous (marc.pous@upc.edu)
Co-supervisors/mentors: Prof. M. Fernández (UPC - ES), Dr. B. Zepper (PMC – NL)
Duration: 36 months
Required profile: Electronic Engineering, Communication Engineering
Desirable skills/interests: Electromagnetism, Electromagnetic Compatibility, Telecommunication, Electronic instrumentation, Analysis software (Matlab, Python etc.)

Objectives: This ESR develops a methodology to select the best-possible DCS and its optimal scheme in harsh medical electromagnetic environments. An important type of EMI in medical scenarios is broadband impulsive noise disturbances that propagate as radiated signals, affecting digital communication receivers as in-band interferences. Procedures and algorithms will be proposed to improve the electromagnetic immunity of medical devices through the appropriate selection and configuration of their DCS, for a diverse operational electromagnetic environment. Real-time observation of the communication channel allows an adaptive approach in the selection of an EMI-resilient DCS.

ESR6: EMI- Resilient Sensor and Communication Networks for complex medical systems-of-systems
Host: KU Leuven (BE)
Main supervisor: Prof. D. Pissoort (davy.pissoort@kuleuven.be)
Co-supervisors/mentors: Prof. G. Vandenbosch (KU Leuven - BE), Dr. B. Zepper (PMC - NL)
Duration: 36 months
Required profile: Electronic/Electrical Engineering, Systems Engineering, Safety Engineering
Desirable skills/interests: Electromagnetism, Wireless Networks, Fault-Tolerance
Objectives: Many technological innovations in medical applications will rely on distributed sensors and (wireless) communication networks. This brings major safety and reliability challenges as there will be more reliance on the (wireless) interconnections to operate reliably for all scenarios, and this over the system's entire life-cycle. As such, it is necessary to guarantee the connectivity's robustness, considering a combination of stresses, including EMI disturbances, environmental conditions, aging, etc. For complex distributed sensor and communication networks, this can only be achieved by a holistic approach that covers at the same time the software, middleware and hardware layers. Therefore, this ESR-project aims to develop novel software, middleware and hardware techniques to obtain fault-tolerant and/or fault-operation behaviour for the overall system-of-systems.

ESR7: Behavioural EMI Risk-based testing of medical devices
Host: TUe (NL)
Main supervisor: Dr. A. Roc'h (A.Roch@tue.nl)
Co-supervisors/mentors: Prof. F. Leferink (UTwente – NL), N. Rodriguez, MSc (FICOSA – ES)
Duration: 36 months
Required profile: Electrical Engineering, System Engineering
Desirable skills/interests: Statistics, Computational Electromagnetics, Measurement Technology, Electromagnetic Interference

Objectives: In an EMI risk-based approach, medical devices would need to be tested before deployment, while considering the environment in which they will be placed. It is, however, often not possible to recreate complex in-situ scenarios involving, for instance, large equipment from other manufacturers. This approach will consist of establishing equivalent reconfigurable simple structures that reproduce key couplings, as seen from the device under test while deployed. It makes it possible to test diverse, identified risks of couplings and interactions before deployment. The validation of the risk assessment would be made possible for diverse scenarios.

ESR8: Improvement of digital communication systems immunity tests to include complex electromagnetic disturbances
Host: UPC (ES)
Main supervisor: Dr. M. Pous (marc.pous@upc.edu)
Co-supervisors/mentors: Prof. F. Silva (UPC - ES), Dr. Hugo Silva (PLUX – PT)
Duration: 36 months
Required profile: Electronic Engineering, Communication Engineering
Desirable skills/interests: Electromagnetism, Electromagnetic Compatibility, Telecommunication, Electronic instrumentation, Analysis software (Matlab, Python etc.), Statistics
Objectives: This ESR will define new tests to evaluate the immunity of digital communication systems in the presence of complex electromagnetic disturbances. Current medical devices work and communicate inside an increasingly complex electromagnetic environment that includes, besides the traditional disturbances, multiple or cumulative interference sources, and impulsive noise. To protect these medical systems, it is necessary to test beyond the conventional standards to evaluate properly the effect of electromagnetic interferences on digital communication systems. This ESR-project focuses on the definition of new immunity-testing procedures that consider at the same time multiple, cumulative and impulsive interference sources.

ESR9: Development of EMI sensors
Host: KU Leuven (BE)
Main supervisor: Prof. D. Pissoort (davy.pissoort@kuleuven.be)
Co-supervisors/mentors: Prof. G. Vandenbosch (KU Leuven - BE), Dr. Hugo Silva (PLUX – PT)
Duration: 36 months
Required profile: Electronic Engineering, Communication Engineering, Physics
Desirable skills/interests: Electromagnetics, Sensor Design, Analogue and Digital Circuit Design, Computational Modelling, RF and Electromagnetics Measurement and Analysis
Objectives: This ESR will build sensors that can continuously monitor the real EMI disturbances that a medical device encounters during its operational life. First, the bit error rate (BER) of one or multiple communication channels will be tracked as a means to estimate the EMI. Second, the amplitude of harmonics will be monitored in the frequency domain. Initially, these options will be assessed on the basis of simulations, after which they will be validated in practice. The sensors will be fabricated and validated as stand-alone sensors. After that they will be integrated into a system to validate their final effectiveness.

ESR10: Risk management in collaborative medical system development
Host: Philips (NL)
Main supervisor: Dr. M. van Helvoort (mark.van.helvoort@philips.com)
Co-supervisors/mentors: Prof. F. Leferink (UTwente – NL), Prof. D. Pissoort (KU Leuven – BE)
Duration: 36 months
Required profile: System Engineering, Electrical Engineering
Desirable skills/interests: Pragmatic, Convincing, Experience in conducting measurements, Simulation experience, Standardisation, In Situ Measurements, Old fashioned RF Communication as well as Power Electronics

Objectives: This ESR position is about identifying extra system-specific tests to be performed in addition to the existing and formalized EMI characterization of single systems, before integration. System-of-system integration, such as integrating MRI and PET, typically takes place at the site of the clinical researchers. The system needs to be certified (e.g., CE), which includes an EMC assessment and underlying proof. Due to the collaborative way of working and on-site installation, testing can take place only at the component level or in-situ. It is known that in-situ measurements are cumbersome and often not unreliable, therefore a better method for assessing EMC performance and managing EMC risk has to be developed.

ESR11: Evidence for quantitative correlation(s) between different room test environments at different hierarchy levels of system integration
Host: Philips (NL)
Main supervisor: Ir. R. Kleihorst (rob.kleihorst@philips.com)
Co-supervisors/mentors: Dr. A. Roc'h (TUe – NL), Prof. F. Silva (UPC – ES)
Duration: 36 months
Required profile: Electrical Engineering, System Engineering, Electronic Engineering, Software Engineering
Desirable skills/interests: Statistics, Measurement Technology, Electromagnetic Interference, Safety-Critical / High Integrity Systems, Programming Languages, Regulatory and Norm-compliance
Objectives: This ESR position is about the study of the correlation between EMC test results in an open environment versus EMC test results in a full reflective environment and versus EMC test results in representative use clinical settings (lead test bay, outpatient clinic, etc.). EMC test results are studied at the Unit, Subsystem and System level and the results will be key for the risk-based approach process with inputs in the following documents: EMC risk management, EMC Risk Control and EMC Compliance lines. The correlations will, in a second stage, be expanded to predict EMC emission levels of configuration permutations with the individual unit and subsystem test results.

ESR12: EMI from connected, autonomous and electrical vehicles on Driver Monitoring Systems
Host: FICOSA (ES)
Main supervisor: N. Rodriguez, MSc (noelia.rodriguez@ficosa.com)
Co-supervisors/mentors: Prof. M. Fernández (UPC - ES), Dr. A. Roc'h (TUe – NL)
Duration: 36 months
Required profile: Data scientist, Software Engineering, telecommunications engineering
Desirable skills/interests: Digital signal processing, deep learning techniques for noise/dimensional reduction, wired- and wireless data communication, data communication, and EMC measurement techniques, applied physics and electromagnetism, risk management, reliability engineering
Objectives: Modern driver-monitoring systems require measuring the real-time physiological parameters of drivers to assess their physical and attention state. Those monitoring systems are very important in autonomous vehicles when returning the human driving functionalities. The measurement of such signals represents a challenge in a crowded electromagnetic scenario such as a modern vehicle. Connected vehicles use many wireless technologies: LTE,

Bluetooth, NFC, 4G and 5G, etc. Meanwhile hybrid /electric vehicles are a new challenge regarding EMI due to the generation of low-frequency disturbances. Both types of interference can simultaneously affect the correct operation of the new driver-monitoring systems. This ESR position is about evaluating the effect of the cumulative EMI in the monitoring systems and defining the tests to check the correct operation and to ensure the reliability of the future automotive ADAS.

ESR13: EMI Risk assessment in Medical Device Innovation Process - from design to production
Host: PLUX (PT)
Main supervisor: Dr. Hugo Silva (hsilva@plux.info)
Co-supervisors/mentors: Prof. H. Gamboa (FCT – PT), Prof. M. Fernández (UPC – ES)
Duration: 36 months
Required profile: Electromagnetic Compatibility, Electromagnetic fields, Wireless Communication
Desirable skills/interests: Electromagnetic Compatibility, Electromagnetism, Risk Management, Resilience Engineering, Biomedical Engineering.
Objectives: Adapting wearable technology into a medical device takes a long certification process, which is highly demanding for an SME, due to a lack of intrinsic design and production methodologies to mitigate EMI. This ESR position is about developing new process guidelines to include EMI management in product design, prototyping and production in wireless wearable sensor technologies, which facilitate compliance with quality and safety, improving the time-to-market. An example from PLUX will be selected to follow a complete innovation process, to implement novel mechanisms improving EMI risk, quality and development time. Knowledge on base sensing principles used in the medical devices industry to study the production process will be applied. In a later stage, contents will be produced in the format of tutorials that will guide developers of new clinical applications through the EMI assessment of new wireless wearable medical devices.

ESR14: Towards standardized EMC assurance case patterns for the certification of medical equipment
Host: KU Leuven (BE)
Main supervisor: Prof. D. Pissoort (davy.pissoort@kuleuven.be)
Co-supervisors/mentors: Prof. F. Leferink (UTwente - NL), Ing. R. Deseine (Barco - BE)
Duration: 36 months
Required profile: Electronic Engineering, Safety Engineering
Desirable skills/interests: Electromagnetic Interference, Risk Analysis, Dependability Assurance
Objectives: In the end, both the EMC and Medical Directives require the manufacturer to clearly document all steps taken and decisions made to guarantee and check the conformity of the product in the so-called Technical Documentation. The purpose of the Technical Documentation is to make it possible for an external independent, external assessor or for the final user to (i) reproduce the whole reasoning followed by the manufacturer, (ii) assess the conformity of the product as well as (iii) get an overview of all (design) measures that were needed to get to that conformance or any assumptions that there might concerning the use or installation of the product. Unfortunately, there is no standardized way to write down the Technical Documentation. As a result, Technical Documentation can look very different, making it quite difficult to interpret and follow them. Looking outside of the field of EMC, standardized notations to structure and present arguments are available. More specifically, different types of graphical notations have been developed for safety assurance cases for safety critical systems, such as the Goal Structuring Notation (GSN), the Claims-Arguments-Evidence (CAE) notation and very recently the Structured Assurance Case Metamodel (SACM) language. In this ESR project, the use of these graphical notations for documenting the overall EMC assessment of medical equipment is explored in depth, leading to a set of EMC assurance case patterns or templates.

ETN ETERNITY project abstract and key project information

Electromagnetic interference (EMI) is not just an annoyance. With increasing numbers of safety-critical devices communicating wirelessly, ensuring that equipment functions correctly is an ever-increasing concern. Nowhere is this truer than hospital environments. Europe is a leader in many areas of medical technology, with companies like Philips at the forefront of research. However, with highly complex interactions between devices becoming the norm, guaranteeing safety requires that we start to assess new equipment using a risk-based approach rather than the conventional rules-based approach, a method that is increasing inappropriate for harsh EMI environments. The ETERNITY ETN will train 14 ESRs through a combination of research, doctoral schools, network-wide events and secondments at the Participants, which include 8 Beneficiaries (4 academic and 4 from industry) and 5 Partner Organisations from across Europe. In combination, these Participants can offer the ESRs research training that is international, interdisciplinary and intersectoral. The 14 ESRs are set to benefit from excellent supervision, with a triple-supervisor system that combines leading researchers from academia and industry, and to have access to some of Europe's finest research facilities. The training programme on offer will go beyond the needs of the ESRs in terms of technical hands-on training and taught courses focusing on the necessary aspects of engineering, with a wide range of complementary and transferrable-skills training that will equip them for their future careers in academia, industry, the public sector or, perhaps, their own start-up. ETERNITY is about maximising opportunities; giving the ESRs the chance to really benefit from a carefully crafted research-training programme; and allowing them to learn and develop as individuals who will make a difference to a vitally important area in terms of people's safety and well-being in an increasingly technologically complex world.
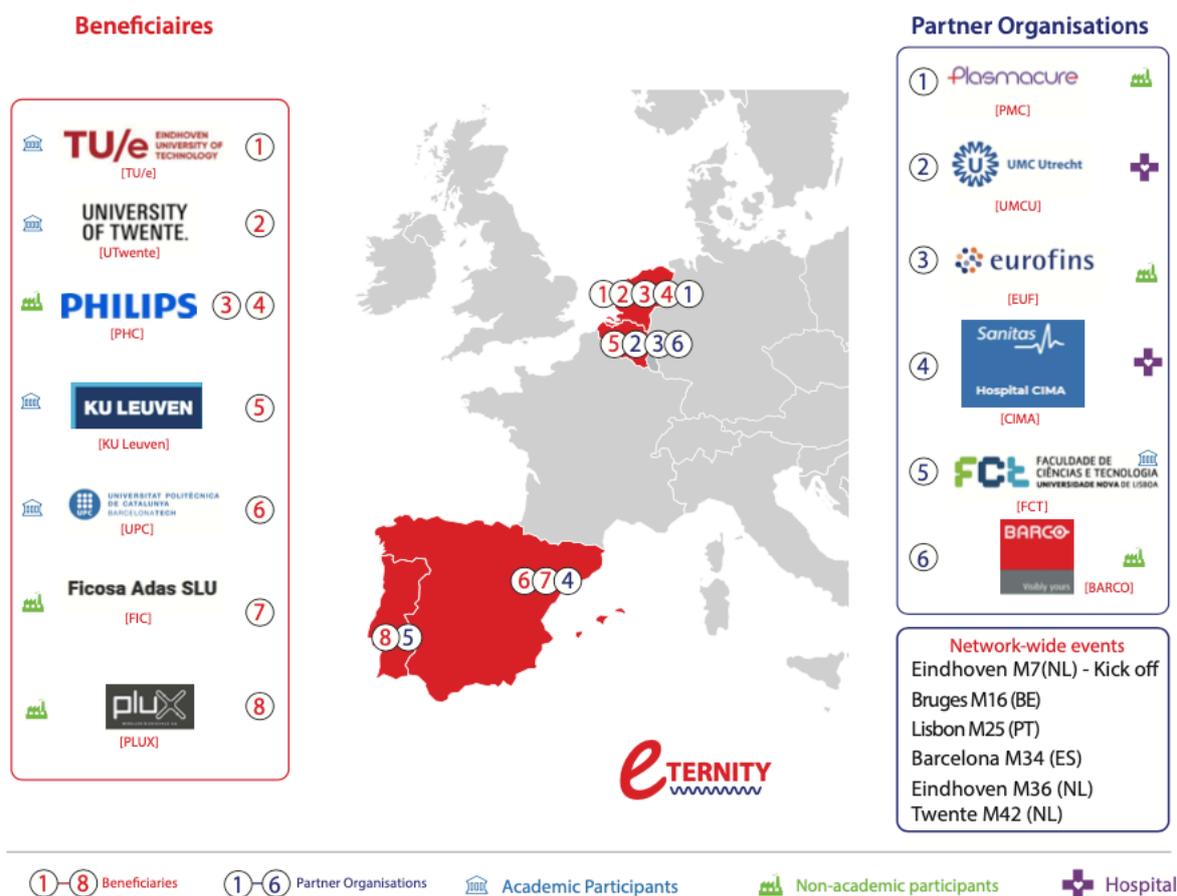

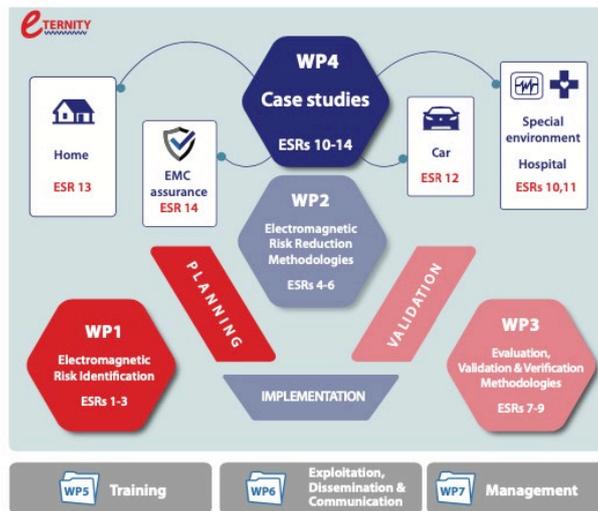**Figure 1:** ETERNITY Consortium

Figure 2: ETERNITY WPs and ESRs

The Work Packages (WPs) of the ETERNITY program are consistent with a large industrial development program in the area of future medical systems and devices. The solid diversity of industrial cases, covering most of the relevant environments and devices, at different stages of the design process, will ensure that the network runs smoothly, while strengthening the interactions and the exchange of academic and non-academic resources. From the regulatory perspective, ETERNITY covers all 4 key medical environments: hospital, homecare, transportation and the special environment of medical imaging and treatment systems. The inter-relation between each ESR projects and their corresponding core WP are described below.

WP1: Electromagnetic Risk Identification

WP1 focuses on the left part of the risk-based approach's V-model (**Figure 2**), i.e., the identification of EMI-related risks and their criticality. The goal is to characterize the EMI-related risks stemming from the operating electromagnetic environment and/or the susceptibility of the medical system under development. **ESRs 1 and 2** will develop approaches to effectively characterize a medical environment in terms of EMI risks for general medical devices (**ESR1**) and digital communication systems (DCS) (**ESR2**) more specifically. Complementary to that, **ESR3** will work on holistic methods to identify EMI risks for large medical systems comprising multiple devices.

ESR1 will develop the concept of an *"EMI footprint"*. It is a set of characteristic curves obtained from stand-alone tests on a device, which are combined with sets of statistical curves encapsulating the electromagnetic interactions occurring within a complete, interconnected system. **ESR2** will take up the challenge to *characterize EMI in a medical environment with time-domain approaches*. For historical reasons, current standards mainly aim to protect analogue communications and, therefore, set limits in the frequency domain. However, modern digital communication is much more susceptible to transient/pulsed EMI, which can be characterized more effectively in the time domain. Dedicated time-domain EMI analysis methods will be developed for DCS. **ESR3** will *extend the revolutionary hazard-and-risk-analysis methods STAMP and STPA* – based on Systems Thinking and Systems Theory – to the EMI robustness of large medical systems. While STAMP (Systems-Theoretic Accident Model and Process) and STPA

(Systems Theoretic Hazard Analysis) are only a decade old, research has already shown that they are much more powerful at identifying the safety risks of a complex system compared to classic methods, like FTA, FMEA, etc. Unfortunately, STAMP and STPA have so far never thoroughly considered EMI, nor have EMI risks been identified with STAMP or STPA.

ESRs 1, 2 and 3 will collaborate and apply their techniques to a medical imaging system (PHC) and its integration in a hospital (CIMA) as used by **ESRs 10** and **11**, WP4. In addition, **ESR2** will apply the time-domain characterization to a driver-monitoring system (FIC) as used by **ESR12**, WP4, while **ESR3** will apply STAMP and STPA to a wearable bio-sensing platform (PLUX) as used by **ESR13**, WP4.

WP2: Electromagnetic Risk-Reduction Methodologies

WP2 contributes to ETERNITY's second step in the risk-based approach with techniques and measures (T&Ms) that effectively reduce the EMI risks (identified with the methods of WP1) to the level that they are acceptable for safety. Methodologies in hardware, middleware and software are considered. **ESR4** will directly support the designers of medical systems with the *risk-based EMI-aware design of medical systems*, while **ESR5** and **ESR6** will work together on *increasing the EMI-robustness of medical devices by ensuring the EMI resilience of wireless communication systems*.

ESR4 will break down a medical environment into manageable parts and establish an *EMC risk-management plan (EMI-RMP)*. Following system-engineering principles, this EMI-RMP will drive the design, installation, operational use and maintenance of a medical system. This EMI-RMP will also *identify which risk-reduction T&Ms should be chosen*. Unfortunately, current risk-reduction T&Ms applied in system safety engineering do not specifically target EMI. Therefore, **ESR5** will develop specific *time-domain-mitigation techniques* to overcome the risks and hazards caused by transient EMI. The focus will be on *real-time channel monitoring* – leveraging the work of **ESR2** (WP1) – with the final aim being to develop EMI-resilient DCS**.** Complementing this, **ESR6** will work at the *level of medical interconnected systems-of-systems*. The target is to improve the system-of-systems' overall EMI resilience from a holistic perspective: *novel hardware-, software- and middleware-based techniques* will be investigated and result in a robust system-of-systems that is fault-tolerant under diverse types of EMI.

ESR4 will make a detailed EMI-RMP for a medical imaging system (PHC) – starting from the analysis of **ESRs 1, 2** and **3** (WP1) and serving as extra inputs for the work of **ESRs 10 and 11** (WP4) – as well as on a wearable bio-sensing platform (PLUX) – starting from the analysis from **ESR3** (WP1) and serving as extra inputs for the work of **ESRs 12** and **13** (WP4). **ESRs 5** and **6** will exchange insights intensively through mutual visits and implement their T&Ms on a cold-plasma healing device (PMC).

WP3: Validation & Verification Methodologies

WP3 completes the risk-based approach's V-cycle and targets novel methodologies to verify, validate and argument that the applied risk-reduction (WP2) effectively addresses the identified risks (WP1) over the full lifecycle.

ESRs 7 and **8** have roles that run parallel to those of **ESRs 1** and **2** in WP1. On the one hand, **ESR7** takes up the challenge to *establish equivalent, reconfigurable, simple, set-ups that reproduce the complex interactions (for diverse scenarios) that a medical device encounters in its real environment*. On the other hand, **ESR8** will define *time-domain EMI immunity tests that consider multiple, transient interference sources* and, as such, increase the EMI testing coverage for medical DCS. While **ESRs 7** and **8** mainly consider verification and validation before system deployment, **ESR9** will focus on EMI verification and validation after system deployment with *novel low-cost EMI sensors that continuously monitor the EMC environment as well as the effectiveness of the applied EMI risk-reduction techniques during operation.*

ESR7 will apply the developed set-ups to 2 real-life case studies, i.e., a medical imaging system integrated at a participating hospital (UMCU) (as used by **ESRs 10** and **11**, WP4) and a wearable bio-sensing platform at PLUX (as used by **ESR13**, WP4). **ESR8** will apply and assess the effectiveness of the time-domain tests in practice at PLUX (as used by **ESR13**, WP4) on a complete bio-sensing platform, and a driver-monitoring system (FIC) (as used by **ESR12**, WP4). **ESR9** will visit UT to gather previous experience with EMI sensors, while prototypes will be validated at PLUX on a complete bio-sensing platform (as used by **ESR13**, WP4).

WP4: Application Case Studies

WP4 pilots ETERNITY's risk-based EMI approach, combining the previous 3 WPs. In total, 5 ESRs will be working on case studies covering the full design cycle from early concept to final certification, in 4 different medical environments (hospitals, homecare, transportation, and "special environment" in which medical imaging and treatment systems operate). These case studies will not only use the results of the ESRs from WPs 1–3, but also provide them with essential practical feedback.

ESR10 will take up the challenge of a *risk-based EMC assessment of collaborative medical systems-of-systems* (e.g., the integration of MRI and PET) operating inside the above-mentioned special environment. **ESR10** will aim to minimize the number of required in-situ tests inside the hospital as these tests are known to be cumbersome and are often unreliable. This methodology will be applied on a collaborative medical imaging system at UMCU. In order to do so, a detailed hazard-and-risk-analysis will be carried out

together with **ESR3** (WP1), after which an EMI-RMP will made together with **ESR4** (WP2).

The goal of **ESR11** is to investigate *how tests in a standardized EMC testing environment (i.e., Semi-Anechoic Room) correlate with the actual environments in a hospital* where many reflections and interactions occur. To do so, **ESR11** will combine and extend the work of **ESR1** (statistical combination of EMI footprints – WP1) and **ESR7** (simplified equivalent set-ups for early testing – WP3). The whole approach will be extensively validated within the two participating hospitals UMCU and CIMA.

ESR12 will be one of the first to evaluate *the effect of cumulative EMI inside a modern vehicle* and develop dedicated tests to validate *the correct operation of wearable biosensors*, which will be a key element in future driver-monitoring systems. **ESR12** will search out links with the work carried out by **ESR11** on the correlation between a standardized EMC testing environment and those within highly reflective environments (which the passenger cabin of a vehicle obviously is). The effectiveness of the newly defined tests will be investigated in the certification facilities of EUF.

ESR13 will focus on the *home-care scenario* and *develop adequate risk-reduction techniques for wearable medical devices based on bio-sensors*. For this, knowledge about bio-sensor design will be gathered at FCT, while the mitigation techniques will be evaluated at the certification facilities of EUF, together with **ESR12**.

Finally, **ESR14** will focus on the development of clear and convincing *generic, graphical notations for a so-called EMC assurance case*, summarizing all claims, arguments and evidence that EMI risks have been adequately addressed and the system is indeed acceptably safe for use in its intended medical environment. Here, an EMC assurance case is defined as "*A structured argument, supported by a body of evidence that provides a compelling, comprehensible and valid case that a product/system exhibits a level of EMC that is acceptable for a given application in a given operating environment*". **ESR14** will leverage from the latest evolutions in standardized notations like the Goal Structuring Notation (GSN), the Claims-Arguments-Evidence (CAE) notation and the very recent Structured Assurance Case Metamodel (SACM) language. An EMC assurance case will be made for a collaborative imaging system in PHC (as used by **ESRs 10 and 11**, WP4) and a driver-monitoring system (FIC) (as used by **ESR12**, WP4). The work of **ESR14** is especially relevant due to its position at the end of the design cycle, overarching the 4 other case studies and providing inputs to enable the standardisation of the risk-based method.

Coordinator for ETN ETERNITY:

Dr. Ir. Anne Roc'h (TU Eindhoven)

info@eternity-project.eu

+ 31 (0) 40 247 8823

ETN ETERNITY WEBSITE: https://eternity-project.eu/

Appendix 1: Recruitment Procedure and Principles

Advertisement Process: The search for appropriate candidates is initially based on normal recruitment strategies (e.g., publication on ec.europa.eu/euraxess, etc.; personal contacts of the network partners). All the recruitment is in line with the European Charter for Researchers, providing the overarching framework for the roles, responsibilities of both the researchers and employers. The Code of Conduct for the Recruitment of Researchers functions as a set of principles and ensures that the selection procedures are transparent and fair. The recruitment strategy for ETERNITY will fully comply with the Code of Conduct's definition of merit. For example, merit is not just measured on researchers' grades, but on a range of evaluation criteria, such as teamwork, interdisciplinary knowledge, soft-skills and awareness of the policy and economic impact of science. The Recruitment Committee (RC) has members of each gender and considers the promotion of equal opportunities and gender balance as part of the recruitment strategy. A special focus will be made to attract female ESRs from EU's new Member States.

Selection Process: The pre and final selection will be made in a collective progress, led by the Recruitment Committee (RC), which consists of all the people who will be involved in the supervision process. Every member of the RC will receive 4 hours of training on recruitment procedures and will be made aware of factors like unconscious gender bias. The candidates can apply for a maximum of three projects and list their order of preference. The 30 most suitable candidate ESRs are invited to a Recruitment Workshop (Eindhoven, the Netherlands). Each candidate gives a presentation and is interviewed. The committee selects the ESRs (1) based on their scientific background and potential, (2) based on the expected benefit of the scientific exchange between the trainees' home countries and institutions and the hosts, and (3) in accordance with gender equality and minority rights. The candidates are ranked, and a collective decision is made, considering the order of preference. In this way a complementary team of ESRs can be assembled. All non-selected candidates will receive a letter explaining the reasons why they were not selected (in line with the Code of Conduct). The ESRs are employed on fixed-term contracts and are registered as staff candidates for their PhD degrees. Therefore, they are entitled to pension contributions, paid holidays, and other employment benefits, as governed by the universities, non-academic partners and industrial companies.

In case not all 14 ESRs can be recruited during the collective Recruitment Event, the recruitment procedure is "decentralised", meaning that the involved supervisors continue the search for good candidates. The RC is kept informed at all times when new eligible candidates appear. The RC makes an official complaint in case the Code of Conduct for the Recruitment of Researchers is breached. The involved supervisor is then expected to find another candidate. Recruitment problems are also, if still needed, discussed during the first ETERNITY Network Wide Events (M7, M12) in order to deliver specific action plans to target specific networks relevant for the vacant ESR positions.
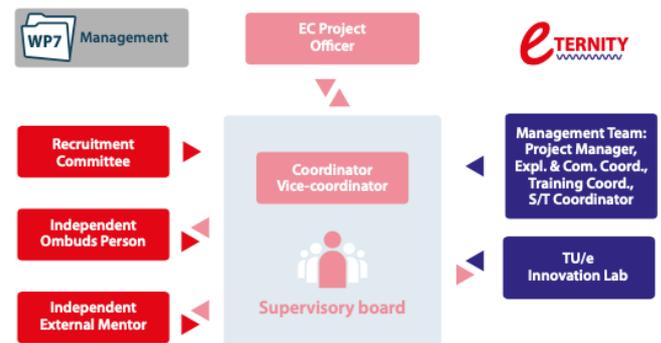

Figure 3: ETERNITY Project Management Structure

Recruitment Committee = This committee involves the General Coordinator, the Vice-Coordinator and at least one representative per Beneficiary. Its goal is to oversee the recruitment of the 14 ESRs during the collective recruitment event.