

ENHAnCE Featuring Engineering

FINAL DISSEMINATION AND OUTREACH REPORT

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1. Introduction

The project ENHAnCE, which stands for European training Network in intelligent prognostics and Health mAnagement in Composite structurEs, is a Horizon 2020 Marie Skłodowska-Curie Actions Innovative Training Networks (H2020 MSCA ITN) program. ENHAnCE brings together a consortium of leading academic institutions, research centers, and industry partners across Europe, aiming to advance the field of prognostics and health management (PHM) for composite materials and structures. This interdisciplinary network is dedicated to developing innovative methodologies and technologies to predict the health and lifespan of composite structures, thereby enhancing their safety, reliability, and performance in various applications.

The present deliverable encapsulates the extensive dissemination and outreach activities conducted throughout the project's lifecycle. Dissemination and outreach are pivotal components of ENHAnCE, ensuring that the knowledge generated within the project reaches a broad audience, including the scientific community, industry stakeholders, policymakers, and the general public. By fostering a comprehensive dissemination strategy, ENHAnCE not only aims to share its research findings but also to stimulate dialogue, collaboration, and knowledge transfer within the realm of composite structures and PHM.

The following sections provide an in-depth overview of the strategies employed, the activities undertaken, and the outcomes achieved in the project dissemination and outreach efforts. This includes a detailed account of publications, conference presentations, workshops, training sessions, public engagement initiatives, and digital communication tools leveraged to maximize the project's impact and visibility. Through these endeavours, ENHAnCE has established itself as a pivotal player in the European research landscape, contributing to the advancement of intelligent PHM systems and supporting the EU's objectives of innovation, sustainability, and technological excellence.

In this deliverable, it is included:

- The initial Dissemination and Outreach Plan: This was the foundational strategy outlining the objectives, target audiences, and communication channels for disseminating project results.
- Open Meeting Points and Visits to Local Schools: Engagement activities designed to bring the project closer to the public, including open meetings and educational visits to schools to inspire the next generation of engineers and scientists.



- Attendance at Minisymposiums: Participation in specialized symposiums to present the project research findings and engage with other experts in the field.
- Thesis Contests and Showcases at Fairs such as JEC: Involvement in academic competitions and industry fairs to highlight our research outcomes and foster interaction with industry leaders and peers.
- Broadcasting of Press Releases and Videos: Use of media channels to disseminate information about the project's milestones and achievements to a wider audience.
- Technical Papers Submitted to Top Journals and Congresses: Publication of high-quality research papers in leading academic journals and presentations at prestigious international conferences.

The following sections provide detailed accounts of each of these activities, highlighting the project commitment to maximize impact and visibility. By sharing these research findings and engaging with diverse stakeholders, ENHAnCE has contributed significantly to the advancement of intelligent PHM systems.

2. Initial dissemination and outreach plan

A Dissemination and Outreach Plan was launched at the beginning of the project with the aim of the protection, dissemination and exploitation of the project results, which are conceived to be consistent and proportionate to the impact expected from the action. This plan initially included a website and media interfaces which were updated during the implementation of the project. The target group comprised both the researcher's training and the scientific community, fully in line with the purposes and nature of the Marie Skłodowska-Curie Actions programme.

2.1 Public engagement strategy

In order to achieve efficient communication with the target audiences and transmit the message of the project, adequate materials and infrastructure are set into place. The following sections summarize the different means and channels for communication and outreach of the project.

2.1.1 Project logo

The logo identifies the ENHAnCE's project, representing the transmission and reflection of a wave through a multi-layer picture of a composite layer. The waves refer to the signals that the ENHAnCE SHM sensors will produce. The color, chosen on grayscale, refers to the black and white (when fibers like glass are used) colours of composite materials.





ENHAnCE Featuring Engineering

Figure 1. Logo of ENHAnCE project

2.1.2 Website

The website is the core instrument of the project's communication achieving multiple objectives, not only sharing information within the project participants working as an operational platform but also offering a window to the general audience, deploying the main concepts related to the project along with links for the main social media (Twitter and Facebook) and contact via email.

The ENHAnCE website has been developed specifically for the project, with a public side fully accessible and a private part (intranet) only for beneficiaries and associated partners. It has been built to be adapted to work as a web application (App) so that every user can work with it as an App. The latter also applies to the internal intranet for ESRs and the rest of the consortium members, including a chat room, dropbox/drive space, and thematic/group forums, which can be operated within a smartphone and tablet environment.

The structure of the web comprises the following sections: *Home, The Project, Beneficiaries* & *Partners, ESRs, News*, and *Publications*, and can be easily accessible through the following link http://h2020-enhanceitn.eu/



Figure 2. ENHAnCE dedicated website (static view of the *Home* section)



The sections of the website are designed to present the following content, effectively disseminating the project knowledge to the public:

- Home: presents the web, with introductory in-motion images and links for the main social media (Twitter and Facebook), including contact via email with the coordination and the Project Manager. It also shows the most recent news related to the project, which includes links to events organized within the project or promotional actions that take place in external events, among others. Most recent announcements were posted in this section to be accessible from the main page and were also collected in the News section;
- The project: which includes a brief description of the project along with the challenges to be undertaken and the members of the Supervisory Board involved in the development of the project;
- Beneficiaries & partners: which shows key information regarding the beneficiaries and partners organizations (PO) involved in the project, including geographic information linked into an interactive map via Google Inc.;
- ESRs: Once recruited, the details of the 10 Early Stage Researchers (ESRs) are described on this page, showing a brief explanation of their PhD work;
- Management: The management structure of the project is outlined here, displaying the main decision groups and their committee leaders: the Supervisory Board-led by the Coordinator-, the Selection Committee-led by the Coordinator and the Equal Opportunity Officer-, the Research Committee-led by the Senior Tutor Mentor-, the Training and Tutoring Committee-led by the Senior Training Mentor along with the Industrial Co-Chair-, and the Administrator & Management Unit,-led by the Project Manager-. The leaders of the work packages constituting the work plan are also outlined here, along with the relationship between each work package and the ESR involved;
- News: Current news along with past announcements in the form of posts are announced through this channel and stored here. This section was updated every time a new event came across during the project's lifetime, being the most dynamic section of the web, including direct links to social media channels. The latest news were also presented on the main page Home;
- Publications: With 10 ESRs contributing in a productive environment, a significant amount of publications are expected. These publications were collected in this section, as a means of dissemination of the technical results of the project.



2.1.3 Social Media

To be connected to the general public and the scientific community, the project was linked to the main social media channels, such as Twitter (currently called X) and Facebook with the accounts: <u>*@ENHANCEITN1*</u> for both. Pictures of their profiles are given in the figures below.



Figure 3. ENHAnCE profiles in Facebook and Twitter (X)

In addition, a profile on LinkedIn was created to gather relevant people to the ENHAnCE project, where the ESRs can benefit from the project developments applied to their business paths and careers.

In addition to this, short videos showing the development of the project (ESRs in action, conferences and other events, short classes from the training weeks, etc.) will be uploaded on the ENHAnCE web and also on YouTube.

2.2 Communication activities

Communication was a key activity of the project as a means to give project visibility, inform and reach out to the general audience to show the benefits of the research. The Management and Administration Unit of the project, led by the Project Manager, was in charge of these tasks using dedicated means and targeting multiple audiences even beyond the project's own community (including the media and the public). Dedicated personnel from the University of Granada (UGR) Social Media unit will provide extra support with these tasks. Besides, all ENHAnCE participants contributed using the dedicated means along with their own resources.

Communication activities started at the beginning of the project with its presentation and the publication of the recruitment process on social media, reaching a specialised audience as well as potential candidates to occupy the ESR positions. They were planned strategically identifying clear objectives, and pursuing a creative and innovative way of communication, with all the beneficiaries involved in the outreach.



The following actions were taken in order to ensure that the developments are successfully communicated to the public:

- Communication skills were trained in the ESRs through specifically designed sessions and promoted at the Communication Days where the ESRs were invited to present their work to Consortium members, local authorities and industry partners. This way the ESRs were conscious of the importance of showing the role of the EU in promoting research at the top level and the funding impact on society, economy, environment and policy making.
- Boosting the social media channels (Twitter, Facebook, and LinkedIn) to contribute to the outreach of the news about ENHAnCE, being constantly updated with ESRs project progress, training events, visits, conference attendance, etc. This not only accelerated their research impact and aided their profile for being 'spotted' by potential future employers, but also increased the project visibility widely.
- Launching two open meeting points at each beneficiary doctoral school, training centres and HR departments, to seek cross-pollination not only among scientists and students but also with the public external to ENHAnCE.
- Engagement with primary and secondary schools in the respective countries of the participant's organisations, visiting local schools to deliver a presentation on what is behind modern predictive technologies, aircraft safety and wind-turbine engineering as well as to promote science and engineering careers, with special emphasis on women's careers on STEM. Each fellow showcased their research and communicated with the children about the merits of engineering education.
- Collaboration with the local H2020 communication project H2020-MSCA-NIGHT at the participating partners (like at UGR) contributing to exhibitions of general science and research projects to the general public. Other similar local initiatives such as Café Con Ciencia in Granada (Spain), were targeted and aimed at illustrating the impact of science on broader society.
- Organising ENHAnCE three-minute thesis contest among the ESRs and their respective Supervisors aiming at launching a 3-minute short movie about the context and motivation of their research.
- Arranging at least one showcase at the JEC Composite Conference (Paris), the biggest European commercial and industrial meeting around composite technology. The fellows will exhibit their work having a stand dedicated to illustrating the ENHAnCE technologies.



- Preparing press releases for distribution in the respective countries of the participating organisations and launching the ENHAnCE Web and App.
- ENHAnCE was aimed to participate in the two biggest European Airshows such as the Farnborough International and the Paris Air Show, where the fellows will exhibit their work in a stand dedicated to illustrating the ENHAnCE technologies.
- The ENHAnCE technological demonstrator was intended to be employed (also after the end of the project) during Open UCAS (Universities & Colleges Admissions Service in the UK) days and school visits at UNOTT along with accompanying information on modern aircraft safety. Demonstrators along with accompanying informative posters and presentations have proved particularly efficient for inspiring and excite the curiosity of visitors in the developed technologies.

2.3 Dissemination of the research results

At a scientific and technological level, the project results were disseminated through appropriate means, including open access to scientific publications and open access to research data - as ENHAnCE participates in the Open Research Data Pilot, whose implementation details are included in the Data Management Plan of the project. In order to achieve a successful dissemination of the project results, the following activities were planned:

- High-quality publications containing the essential scientific developments of ENHAnCE were intended to be published in peer-reviewed journals to effectively disseminate the research results. Top-ranked (according to their SNIP index) international journals are targeted. Granting green open access through free-access, online repositories and/or electronic libraries of the institutes that have co-authored the papers, like the UGR website depository (http://digibug.ugr.es) to all produced publications was also of significant importance for maximising their worldwide visibility and the chances of being identified by the future practitioners and future beneficiaries. Special emphasis was put on ENHAnCE's authors to disseminate their outcomes on scientific social networking sites like ResearchGate and Academia.edu to offer a free release of non-sensitive data to interested peers. It's important to note that any dissemination of results must indicate that it reflects only the author's view and that the Commission Agency is not responsible for any use that may be made of the information it contains.
- The public-facing ENHAnCE website included a public file depository where a full set of non-confidential measurements (Python/Matlab/GNU-Octave figure format) were uploaded



to be used as a benchmark by future researchers. Research progress reports were also be made available on the depository, adopting a 'green' open-access format.

- In addition, open-source codes including the computational methods developed in the project were published under the GNU General Public License.
- Communication of the results to the industrial and academic sectors was delivered through participation in high-calibre international conferences;
- The scientific and technological developments were communicated to targeted industrial and academic researchers through the ENHAnCE dedicated network-wide training schools arranged as Training Weeks, which were made available for the scientific community;
- Following the Open Research Data in Horizon 2020, a Data Management Plan was created for publishing a full set of non-confidential measurements of the SHM measurements on damaged composite structures, PHM results and laboratory simulations on damaged composite structures. Research progress reports were made available as a depository on the ENHAnCE website, adopting a 'green' open-access format;
- As required by Annex II of the Grant Agreement, the Coordinator ensures that all publications and presentations by members of the project consortium acknowledge the EU financial support received. This acknowledgement should specifically refer to the MSCA Innovative Training Networks (ITN) action, as well as the project number and acronym.

2.4 Exploitation of results and intellectual property

ENHAnCE adopted an exploitation strategy to maximize the valorisation of the achieved research and training outcomes, promoting their use for commercial purposes or in public policymaking. More precisely:

- It was highly anticipated that some of the ENHAnCE ESRs would be recruited by the beneficiaries after the end of their fellowship, therefore further developing their expertise acquired during ENHAnCE;
- Through exploiting the research outcomes, it was anticipated that beneficiaries and ESRs to strengthen long-term cooperation with other universities and non-academic partners, increase their worldwide research impact on the basis of the project findings and increase social awareness on acoustic emissions through the public engagement processes previously mentioned;
- The advances of ENHAnCE were boosted by all participants through the exchange of qualified personnel between universities, research centres, government agencies, and



companies, increasing their knowledge level and fostering intersectoral cooperation initiated within the network;

• The developed technology demonstrator was intended to provide a new vibroacoustic optimisation benchmark and attract the interest of worldwide researchers drawn from a variety of disciplines as well as end-user industries, all keen on implementing and testing their new concepts on the demonstrator.

Regarding Intellectual Property (IP), the work developed in ENHAnCE project is the result of the contribution of the whole consortium and as such, depending on the content, some usage rights need to be complied with. Specific Intellectual Property Rights (IPR) issues related to the exploitation of ENHAnCE are discussed in detail in the Grant Agreement. In particular:

- As beneficiaries of a MSCA-ITN (Marie Sklodowska Curie Action Innovative Training Network) grant, the participating organisations ensure that the project results are disseminated as swiftly as possible and that the dissemination activities are compatible with the protection of intellectual property of the associated partners involved.
- If required, ESRs hosted by an industrial partner might sign a non-disclosure agreement to allow facility usage while protecting design, procedures, and know-how owned by the organisation.

Beneficiaries that are universities or other public research organisations must take measures to implement the principles set out in the Code of Practice of the Commission Recommendation on the management of IPR in knowledge transfer activities¹ related to background and project results, ensuring that the ESR's are aware of this code.

3. Open meeting points and visits to local schools

Another communication and dissemination activity foreseen in the H2020 MSCA-ITN project ENHAnCE was to deploy open meeting points and visits to local schools to get public engagement. This action promotes the involvement of a large audience and brings knowledge on a particular topic to the general public.

Due to the circumstances that happened in 2020-21 (COVID), there was no possibility of launching any public activity because access to schools was restricted and the open meeting points

¹ Commission Recommendation C (2008) 1329 of 10.4.2008 on the management of intellectual property in knowledge transfer activities and the Code of Practice for universities and other public research institutions attached to this recommendation.



could not convoke larger audiences. Whenever it was possible, these activities were launched following these premises:

- These activities were performed by members of the Consortium to engage the general public about the ITN operations. Each Beneficiary must promote the project and its results by providing targeted information to multiple audiences in a strategic and effective manner.
- A range of face-to-face activities (e.g. school visits, lab "open days", public talks, science festivals) were planned to target multiple audiences.

The activities performed in the context of the open meeting points and the visits to local schools for the dissemination of the project results were as follows:

3.1 Open meeting points

3.1.1 British Science Week, March 2022

ESR7 Wen Wu presented his research during British Science Week in March 2022. The University of Nottingham and Nottingham Trent University hosted a popular science event called "Science in the Park," which served as a great open meeting point to showcase advancements. The event featured a range of fun and interactive science exhibits aimed at visitors of all ages. The cover of the Science exhibitor brochure is shown in the figure below.



Figure 4. Science exhibitor brochure



A poster was prepared to present the research topic in a detailed and logical manner, as shown in the figure. The title of the poster was "Digital World Signals Show Everything."



Figure 5. Poster for the open meeting point

The idea was to convey that we are living in a digital world where sensors are ubiquitous. Although many people may not understand how sensors work, their usage is quite familiar. Sensors are integral to various systems and equipment, often used to monitor conditions and performance. For instance, in this research, sensor signals are used to interpret the health of machinery like wind turbines and airplanes.

Additionally, an experimental demonstration featured an aluminum joint with defects monitored using Lamb waves. The joint, attached to four waveguide rectangles, had four piezoelectric sensors (PZTs) at the ends near the center. The leftmost PZT generated an input waveform, while the other PZTs received the reflected and scattered signals. The experimental setup, shown in Figure 8, included a Keysight 33512B arbitrary waveform generator for steady-state sinusoidal waveforms, and a DSOX2014A oscilloscope for digitizing signals at a 9.6 MHz sampling frequency, averaging 32 measurements to increase signal-to-noise ratio. A laptop remotely controlled the waveform generator and oscilloscope.





Figure 6. Set up of the experiment

The exhibition was engaging and impressive, attracting diverse visitors including children, adults, and engineering enthusiasts. This was the first time that the ESR was presenting research to the public, providing a unique experience compared to presenting to colleagues. It required using simple, relatable terms and examples. The interactive element, where attendees could change defect sizes (using blu-tack) and see the impact on signals, was particularly engaging.

Participating in this event improved the communication skills of the ESR and provided valuable feedback and new perspectives. The experience also highlighted the challenge of explaining complex research in an accessible manner, especially in a non-native language. The positive feedback from the public increased enthusiasm and passion for the research, and such events may inspire the next generation to engage in scientific activities.



Figure 7. Engaging with the public of all ages



3.1.2 European Researcher's nigth, September 2022 and 2023

In September 2022, the city of Granada's ENHAnCE team participated in the European Researchers Night, with the attendance of the ESR10 Ali Saleh, along with the Coordinator of the project Manuel Chiachío, Supervisor Juan Chiachío and Project Manager María Megía, showing to the general public the achievements of the project ENHAnCE so far.



Figure 8. European Researchers Night 2022: ESR 10 Ali Saleh with the Coordinator Manuel Chiachío explaining the project to the general public

During the European Researchers Night in September 2023, Juan Chiachio also contributed to a science podcast produced by the University of Granada, where he disseminated the project's findings and elaborated on the latest research advancements to the audience.







Figure 9. Supervisor Juan Chiachio participated in the University's radio podcast recording, alongside Coordinator Manuel Chiachio, explaining the project to school children.

3.1.3 Pint of Science nigth, May 2024

In May 2024, a dissemination event was held in a pub to informally showcase the digital twin technology related to the ENHAnCE project. The event was titled "DIGITAL TWINS FOR NATURAL TWINS," highlighting the fact that Manuel Chiachio (Coordinator of ENHAnCE) and Juan Chiachio (Supervisor of ENHAnCE) are natural twins. The event was a complete success, with a great turnout. Attendees did not hesitate to ask interesting questions, expanding their knowledge of this fascinating subject.





Figure 10. Pint of science diseemination's event

3.2 Visit of local school students

The ESR3 Amond Sarr Allouko was in charge of visiting a local school in Paris with l'Institut Polytechnique de Paris (ENSTA), leading an event for 75 students. The teenager's average age was 14 years and the challenge was to explain the use of mathematics in the current research to people who do not know the derivation of a linear function. The visit aims to show them that ordinary people can use mathematics. This exercise was interesting and helpful by forcing the researcher to use adequate words as much as possible in a few minutes. The event was scheduled as follows:

- 15 minutes of presentation
- 15 minutes of visit in the labs with posters presentation.

The presentation intended to explain the notion of acoustical waves in an easy way: from natural phenomena like the water waves, observed when a stone hits the surface of a lake, to the waves used by bats to find the location of food at night, the waves lie around us.

A numerical simulation of waves produced by a point source was presented. This simulation fitted with the stone hitting water surface. Since the ESR3 is working on the hybrid modal approach that uses elastic waves for the SHM of composite plates with finite element methods, ultrasonic acoustic techniques were introduced in aeronautics. That was the opportunity to talk about the ENHAnCE project and the various projects funded by the European Commission to train the next generation of worldwide experts in the PHM of composite materials.





Figure 11. ESR 3 Amond Sarr Allouko's presentation in a local school



4. Seminar, simposium, thesis contest and showcase

This section presents several activities related to the dissemination of the project results, consisting of the organization and development of a seminar, a congress symposium, the assistance of an international showcase and the celebration of a thesis contest. These activities are oriented toward improving the motivation, creativity and innovative potential of the researchers to enhance their careers and advance their research based on opportunities for acquisition and transfer of new knowledge.

6.1 Seminars

6.1.1 Aalto University

The Coordinator of ENHAnCE, Manuel Chiachío, travelled to Aalto University (Finland) from April 8th to 11th, 2024, as part of collaborative research under the Horizon Europe research framework, specifically associated with the ENHAnCE project. During this visit, he actively engaged in dissemination efforts by presenting an invited seminar titled: "Structural Digital Twin framework: a comprehensive overview of current technologies and future trends". A certificate of the seminar is attached in Appendix A1.



Figure 12. Seminar in Aalto University (Finland).

6.1.2 ESReDA

From May 29th to 31st, 2024, the University of Deusto in Spain hosted the 64th ESReDA (European Safety, Reliability & Data Association) seminar titled "Digital Maintenance in the Digital Twin Era." The seminar was sponsored by the H2020 ENHAnCE project, alongside BUILDCHAIN, an HORIZON Innovation Actions project with grant agreement ID: 101092052. Additional collaboration came from industrial technological entities including DeustoTech, Censolutions, and Ingeman.



ESReDA is an organization dedicated to the advancement of safety, reliability, and risk management. It aims to foster the exchange of knowledge and experience among professionals in these fields through seminars, workshops, and publications. ESReDA organizes technical working groups to develop new methods and tools, and collaborates with other organizations to promote best practices. Notable activities include the ESReDA seminars, which are platforms for presenting research and discussing advancements in safety and reliability.

Several members of the ENHAnCE project actively participated in this seminar. These included the Coordinator Manuel Chiachio, the Supervisor Juan Chiachio, and the Project Manager María Megía, as well as the ESR Wen Wu, who all delivered lectures and presented related topics.

The congress presented a valuable opportunity for members to showcase their research, engage with fellow professionals in the field, and contribute to discussions on safety, reliability, and data. More information can be found in the following link: <u>https://www.esreda.org/event/64th-esreda-seminar-may-30th-31st-2024-university-of-deusto-bilbao-spain-2/?instance_id=61</u> Besides, the full program of the seminar is attached in Appendix A2.



Figure 13. Various moments from the ESReDA seminar.



6.2 Symposium

A symposium was organized and chaired by the ENHAnCE Coordinator at the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2021) streamed from Athens, Greece, on June 2021 in conjunction with the 4th International Conference on Uncertainty Quantification in Computational Sciences and Engineering (UNCECOMP 2021) and the 14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control (EUROGEN 2021).

The title of the symposium was "Condition Based Maintenance and post-prognostics of composite structures: An ENHAnCE platform", number 22 of the symposiums celebrated at this venue. It aimed at providing a platform for idea exchange and knowledge dissemination through the latest developments in the field of condition-based maintenance and post-prognostics decision-making of complex composite structures. More information can be consulted at https://2021.compdyn.org/.

A presentation about "Reduction of Petri Net Maintenance Modelling Complexity Via Approximate Bayesian Computation" was carried out by one of the Early State Researchers, along with a paper "C20141- An Approximate Bayesian approach for complexity reduction of Petri Nets models". Certificates are included in the Annexes.

In addition to this, another article was published in the Proceedings of this Conference, with the title: "Particle filter-based hybrid damage prognosis considering bias", authored also by one of the Early Stage Researchers of ENHAnCE. This article can be accessed online through the link: <u>https://generalconferencefiles.s3.eu-west-1.amazonaws.com/compdyn_2021_proceedings_v1.pdf</u> Besides, certificates of the symposium is attached in Appendix A3.

6.3 Thesis contest

A thesis competition was run in March 2020 at CEA Saclay (Paris, France), a research centre from CEA List, for the ESRs in which they were asked to present their doctoral research in no longer than three minutes using a poster and/or no more than three overhead slides. This contest challenged their presentation skills and give them an opportunity to present their work to a general but technical audience – something that all researchers should be able to do if they are to communicate the importance of their work effectively.

There was a small judging committee composed of the Coordinator, the Tutor Mentor and several Supervisors who decided on which presentation was the best, based on the clarity, the quality of the science, and the level of technical understanding that the presenter demonstrates.



Presentations included details of the motivation for the research, the results achieved so far, the potential impact of the work, and what conclusions have been drawn to date. The quality was so high that finally, the result was a tie.



Figure 14. Thesis contest and presentations from the ESRs: Amond, Aravind and Thianzi





Figure 15. Thesis contest and presentations from the ESRs: Wen, Tasdiq and Morteza





Figure 16. Thesis contest and presentations from the ESRs: Ali and Juan

6.4 Showcase

The ESRs from ENHAnCe attended the JEC World showcase, the world's leading composites event which took place in Paris in March 2022. This showcase is dedicated to exhibiting the state of the art in composite materials, technologies and production processes, along with their applications sectors, with 1350 exhibitors, the presence of 112 countries, 250 speakers, 26 pavilions and more than 600 innovations presented.





Figure 17. Main features of the JEC showcase

At Paris Villepinte Parc des expositions, in hall 5 and hall 6, it took place the 2022 section, whose topic was about the sustainability of composites materials. During the event, all the composite materials actors worldwide were regrouped in one place. This was an opportunity for early-stage researchers to learn more about the process of composite materials, from the raw material producers to the final products. In order to have a structured stand visit, appointments for business meetings were requested. According to their position in the value chain, the aim of the meetings was to understand the whole process of composite materials. The JEC WORLD 2022 was an exciting event for the ESRs, an opportunity to learn nearest to the industrial companies about the composite manufacturing process.

ESR 1, Shankar Galiana

During the visit, different aspects of the ESR1 research has been discussed. The discussions have been focused on the research topics and spreading the ENHAnCE project through the assistant hosts. The Main discussed research topics were raw materials for transducer manufacturing, reinforcement orientation for the embedment composite, functionalized materials for the signal acquisition, testing characterization of the transducer properties, transducer implementation possibilities to the host structures, and possible final structure applications of the transducer networks.



Figure 18. TFP Tech stitched reinforcement



Regarding raw materials for the transducer manufacturing, thermoplastic composite reinforcement suppliers (Hexcel, Victrex, Toray, and Mitsubishi Chemical) has been visited to discuss the suitability of E-glass reinforcement to be embedded in high-performance thermoplastic. Also, the available different formulations of the LM-PAEK and how they can be supplied, either in separated glass mats and the LM-PAEK films for its pre-processing, in consolidated reinforced pre-preg lamina, or in additive manufacturing spools.

For the reinforcement orientation of the embedment materials, some discussions have been held with stitching machine suppliers (TFP Tech) to check the feasibility to directly stick the glass reinforcement in the proper shape in a thermoplastic lamina for its post-process. From the multifunctional perspective, some possible solutions for the rheological response of thermoplastic embedment composite and interface were discussed and discarded (3M), but some possible solutions where arise when discussing about small demonstrators of embedded printed circuits in thermoplastic material (EU-RECAT).



Figure 19. EURECAT embedded circuit

A new testing methodology was shown by one of the host assistants (IMCE), where when hitting a coupon plate and acquiring the vibration signal with an accelerometer, by reverse engineering using FEA, the material mechanical properties are computed. This test can also be made at different temperatures. Finally, there were several demonstrators of composite structures such as cars, tanks, or structure parts. Some meetings have been held regarding it to understand its structural loads state as the main problems that they face such as in the hydrogen tanks (Voith).





Figure 20. Voith Hydrogen tank

Moreover, over a technology demonstrator on welding thermoplastic composites, different welding integration strategies of the transducers were discussed (Fokker).

ESR 2, Aravind Balaji

The main focus with respect to the research of ESR is to develop a framework where the Acousto-Ultrasonicbased Structural Health Monitoring (AU-SHM) system becomes an integral part of manufacturing process of smart composites structures, relying on data obtained from multiphysical models and finally to predict it'slifespan. ESR2 primarily conduct my research at a private applied research center, Cenaero ASBL, Belgium in collaboration with Politecnico di Milano, Italy. Cenaero ASBL, with the presence of Senior Researchengineer and Polymer Composite Technologies leader, Mr. David Dumas was involved in the event to share innovative simulation solutions for high performace composites within the fields of aeronautical design, space-crafts and manufacturing processes and to promote projects namely ENHANCE ITN-MCSA, Horizon Europe DIDEAROT and WINGS.

The integral focus of research on ESR2 lies in the prediction of manufacturing defects in the form of residual stresses arising from the curing of composites structures. The state-of-the-art methodology to predict such manufacturing defects is the Finite Element visco-elastic constitutive models. At Hexagon booth in the event, ESR2 made a connection with one of the business development managers, Mr. Nicloas Jalbertwith the domain of Machine Learning solutions. The interaction was focused on the implementation on one of Hexagon's machine learning tools (ODYSSEE suite) for exploitation of new material data and in decision-making/analysis of manufacturing process effects on composites parts/prototypes.

With respect to the state-of-the-art FE visco-elastic constitutive models, numerical convergence issues with respect to the contact between the mould and the composites parts are quite



common. Comprehensive interactions were made with the RD development senior manager of Dassault Systemes, Dr. Huidi Ji with respect to the numerical tool, Abaqus CAE on how such issues could be migrated with solutions such as mesh adaption etc., especially in the areas close to the outer skin of the composites parts. In addition to this, ESR2 had interesting discussions on the recent innovative solutions on different applications with the Mechanical Industry Process Consult and Management Senior Director, Mr. Daniel Pyzak. One such innovative solutions is the wing-sail structure used for sailing, refer to the following figure.



Figure 21. Wing-sail structure, from Dassault Systemes

ESR 2's research focuses on integrating residual stresses into a damage mechanics simulation tool to optimize sensor placement for delamination detection and predict remaining useful life. Various models such as Linear Elastic Fracture Mechanics and Cohesive Zone Modeling, including Thick Level Set, Lipshitz Regularization, and Phase Field, are utilized to predict damage in composites, particularly delamination, and assess load-carrying capacity loss. Expert discussions at Altair informed a detailed exploration of these models. Experimental validation across different delamination modes is needed to verify their efficacy.

Several extensive interactions were made with organizations such as Grasse Zur Ingenieurgesellschaft mbH (with Dr. Fabian Grasse), Metravib (with Mr.Brice Taillet) and ZwickRoell GmbH Co. KG (with Dr. Hannes Körber) on the experimental set-up of composite coupons with embedded AU-SHM systems for mode I, mode II and mixed-mode cases and the chal-



lenges involved and such possible collaborations are possible in the near future with respect to composite testing. In addition to the above mentioned technical interactions, ESR2 participated in a few JEC conferences on the topics namely: "Rethinking Composite Materials Manufacturing: The Path to Sustainable Production", 'Simulation: The Key to Sustainable Product Development" byAltair, "New Hybrid Process Through Additive Manufacturing For Increasing Performances in Structural Composite Parts by9T Labs, 'FutureComposites: Combining Accessible Design, Scalable Simulation Reliable Manufacture" by Dassault Sys-temes, refer to the following figure, 'Using Sensors to Improve Sustainability in Composites Manufacturing, Design and Life Cycle 'by Composites World and 'Innovative 4.0 Training Dedicated to the Transformation Processes of Thermoset and Thermoplastic Composites" by Composites Academy.



Figure 22. JEC conference session

ESR 3, Amond Allouko

Since ESR3 topic is about a hybrid modal approach for the SHM of composite materials, using elastic guided waves and finite elements, this event allows knowing more about the monitoring development used in the industry for composite materials up to date. The event was organized in both hall 5 and hall 6. In the hall 5, the companies can be set in the following categories: Natural fibers companies, Carbon Fiber manufacturing companies, Machinery companies, and Monitoring companies.



Some exciting innovations were presented there like the "The augmented wood" from the company WOODOO. By chemical treatments of the wood, the wood is used as a screen to diffuse images. This wood can be used in luxury cars or planes to give more interactions compared to classical wood. The machinery companies present the latest version of their products. We attended some demonstrations about ATL (Automated tap layer) and AFL (Automated Fiber Placement) for composite piece manufacturing. We assisted during training week 3 in Madrid with similar demonstrations. The monitoring companies were generally focused either on the use of ultrasound (Bulk Waves) for defect determination or on determining the elastic properties of materials. We were impressed by the product of the company IMCE, by smashing a sample of the composite plate, they can find the elastic properties in efficient and quick post-treatments. The carbon fiber manufacturing companies present the products they can make according to the specifications of their clients. They can also sell the raw bobbin of carbon fibers.



Figure 23. mTorres full composite fuselage demonstrator

Hall 6 was dedicated to innovative products that can be performed with composite materials. Most of the companies' products are for aeronautic usage. The following figure shows a full fuselage demonstrators of the company mTorres. The challenge is to solve the electric conductivity problems encountered up to now in the plane fuselage full composite manufacturing.



Figure 24. PROFACTOR's process scan



The ESRs appreciated pretty much the NDT scan laser of the company PROFACTOR. This technology can monitor the fiber orientations during the layup process of composite material. It can be combined with ATL or AFL in order to get real-time monitoring during the process. The operator can then stop the process to correct the mistake layer by layer to have a final perfect product. This photo was taken in front of an aircraft frame in a composite material that is a collaboration between DLR and TuDelft. By the lightweight concept crucial in aeronautics, they designed a damping process based on composite springs. The following pictures show some interesting automotive projects presented during the event.



Figure 25. ESRs and car body in composites



5. Report on international press releases and documentary

Communication is a key activity of ENHAnCE as a means to give project visibility, inform and reach out to society, showing the benefits of the research. With this objective in mind, using the dedicated means and targeting multiple audiences even beyond the project's own community (including the media and the public), press releases and TV documentaries have been produced being planned strategically, pursuing a creative and innovative way of communication with all the beneficiaries involved in the outreach.

5.1. Press releases

During the action, a variety of press releases about the ENHAnCE ITN project have been published in generalistic and academic communication media presenting the project and its benefits to society. The following lines indicate the main ones in chronological order (including their permanent links, when available).

Press release at IDEAL newspaper (Spain)

The following illustrates the digital and print version of the release, dated on 24th of September, 2019. <u>https://www.ideal.es/miugr/liderara-proyecto-europeo-20190924113630-nt.html</u>

La UGR liderará un proyecto europeo para crear estructuras ultraligeras inteligentes aplicables en aviones y aerogeneradores

El proyecto ENHAnCE ha sido financiado con 2,67 millones de euros, y en el participan 9 instituciones europeas



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La Universidad de Granada (UGR) ha conseguido por primera vez la coordinación de un proyecto europeo tipo ITN (International Training Network) del programa H2020, denominado ENHANCE, cuyo objetivo es el desarrollo de tecnología para la creación de estructuras ultraligeras La Universidad de Granada (UGR) ha conseguido por primera vez la coordinación de un proyecto europeo tipo ITN (International Training Network) del programa H2020, denominado ENHANCE, cuyo objetivo es el desarrollo de tecnologia para la creación de estructuras ultraligeras inteligentes. Estas estructuras tendrán capacidad de autodiagnóstico y pronostico en forma de sistemas ciber-físicos, y son aplicables a estructuras aeroespaciales, palas de aerogeneradores, así como a otras estructuras de ingenieria civil como puentes, torres, etc.

El consorcio europeo de investigación ENHAnCE estará liderado por el profesor de la UGR Manuel Chiachio Ruano, y formado por 9 instituciones científicas y tecnológicas del máximo prestigio: Universidad de Granada (España), Agencia Espacial Alemana (Alemania), Universidad de Nottingham (Inglaterra), Universidad de Strathclyde (Escocia), Politécnico de Milán (Inalia), Universidad Tecnológica de Delft (Países Bajos), CEA-Tech Institute (Francia), Centro Belga de la Investigación Aeronáutica, Cenaero (Bélgica), Fundación para la Investigación, Desarrollo y Aplicación de los materiales compuestos, FIDAMC (España).

Además, habrá 8 instituciones repartidas entre Europa y América que actúan como colaboradoras, cuya participación en el proyecto será de forma activa mediante procedimientos, laboratorios, etc.: Sociedad Nacional Belga de Construcción Aeroespacial, SONACA (Bélgica), Instituto Tecnológico de la Fuerza Aérea Polaca, ITWL (Polonia), Ramboli, Inc. (Inglaterra), Universidad Tecnológica Clausthal (Alemania), Universidad de Brasilia (Brasil), Oritia & Boreas S.L (España).

Figure 26. Press Release at IDEAL newspaper, 24/9/2019



Press release at Canal UGR (University of Granada, Spain)

The following links indicate the digital version of the releases:

https://canal.ugr.es/noticia/la-ugr-liderara-un-proyecto-europeo-para-la-creacion-de-estructurasultraligeras-inteligentes-aplicables-en-aviones-y-aerogeneradores/

https://fundaciondescubre.es/noticias/la-universidad-de-granada-liderara-un-proyecto-europeo-paracrear-de-estructuras-ultraligeras-inteligentes-aplicables-en-aviones-y-aerogeneradores/



Figure 27. Press Release at Canal UGR media, 24/9/2019, 1 de 2





Figure 28. Press Release at Canal UGR media, 24/9/2019, 2 de 2

Press release at IDEAL newspaper (Spain)

predecir essenarios de comportaniento futuro de sistentas), con ponentes procedentes de ostatos muyo el Palo Alto Busearch Center o la NASA, entre

etras institutiones.

The following illustrates the digital and print version of the release, dated on 15th of April 2021. https://www.ideal.es/miugr/mayores-expertos-mundo-20210415185232nt.html?ref=https%3A%2F%2Fwww.google.com%2F



Figure 29. Press Release at IDEAL newspaper, 15/4/2021



5.2. TV video-documentary

A TV documentary has been broadcasted in a short format to be distributed through the ENHAnCE website and on at least one regional Spanish TV with whom agreements are already established. It is aimed to explain the project with meaningful images and explanations from the principal actors: the researchers, Coordinator, Supervisors and Project Manager. The same documentary has already been published on a number of ENHAnCE social media with the aim of popularising the developments among the non-expert public. The link to the documental video can be appraoched here: <u>https://youtu.be/ul9uC_JfFAc</u>



Figure 30. Image from the ENHAnCE project video documentary at https://youtu.be/ul9uC_JfFAc

In addition to this, for the presentation of the technical background of the researchers along with their thoughts about the project, main goals and plans for their future careers, individual videos were filmed for every researcher and included on the ENHAnCE website. Video of every ESR presentation in: <u>https://h2020-enhanceitn.eu/esrs/</u>



Figure 31. Image from the individual videos of every researcher at https://h2020-enhanceitn.eu/esrs/



In order to deep inside the project, a message from the Coordinator has been also included, with a clear and comprehensive exposition of the meaning, scope, and goals pursued by the project from the author. Message from the Coordinator: <u>https://youtu.be/DGPOqDuJUTE</u>





To this filming action done with the help of professional journalists, a budget was allocated for its importance in giving the correct and careful messages to the audience, and for having the complete rights of communication widely and openly during and beyond the project. The Supervisory Board agreed that that measure was even more beneficial than producing one or more TV realeses, where the control of contents and dissemination is limited.

6. Papers submitted to top journals and popular websites

In this section, the collection of papers submitted to top journals and popular websites is provided. This collection represents a culmination of rigorous research, innovative thinking, and collaborative efforts undertaken by the ESRs, supported by Supervisors, partners and collaborators. The papers that have been submitted to esteemed academic journals and prominent online platforms, with a diversity of topics covered, ranging from self-adaptive optimized maintenance policies to physics-informed neural networks for prognostic or numerical simulation-aided particle filter-based damage prognosis using Lamb waves. Each paper represents a unique contribution to the advancement of knowledge within its domain, offering novel insights, methodologies, and perspectives that contribute to the broader academic discourse.



The papers included in this document are organized based on the main author, who is an ESR, as well as by their respective topics. Additionally, they are distinguished by whether they have been submitted to journals or presented at conferences.

Papers submitted to journals undergo a rigorous peer-review process, where they are evaluated by experts in the field for their originality, significance, methodology, and contribution to the existing body of knowledge, being accessible to researchers worldwide.

On the other hand, papers presented at congresses or conferences are drawn in the form of conference proceedings. While they undergo some level of review by the conference organizers, the evaluation process is generally less extensive compared to journal submissions. Presenting at congresses provides researchers with an opportunity to share their findings with colleagues, receive feedback, and engage in discussions with fellow scholars, practitioners, and policymakers. The papers submitted to journals are also extensively featured on their popular websites, ensuring wide accessibility and reaching a broad audience.

At the time of composing this document, a total of 35 articles have been gathered. These articles cover a wide array of topics and reflect the collaborative endeavours of the research team. At this standpoint, it is important to note that the publication policy established by the Supervisory Board, by proposition of the Coordinator Prof. Manuel Chiachío, is to publish only in top and recognized journals, and following the highest standards of research integrity and assessment, as per the San Francisco Declaration on Research Assessment, along with the Open Science requirements.

6.1 Articles submitted to journals

Peer-reviewed publication ensures that research undergoes rigorous scrutiny by experts in the field, validating its credibility, accuracy, and significance. This process helps maintain the quality and integrity of academic work.

6.1.1 ESR 2 Aravind Balaji

RESEARCH TOPIC: Virtual Laboratory for Modelling and Optimisation of Manufacturing of Composites Structures with embedded structural health monitoring systems.

HOST INSTITUTION: Centre National de Recherches Aérospatiales (Cenaero)

ARTICLES SUBMITTED TO JOURNALS:

Prediction of shape distortions in thermosetting composite parts using neural network interfaced visco-elastic constitutive model

AUTHORS: Balaji A., Sbarufatti C., Dumas D., Parmentier P., Pierard O., Cadini, F. JOURNAL: Journal of Composite Materials, 00219983241235855. (2024)



LINK: https://journals.sagepub.com/doi/full/10.1177/00219983241235855

SUMMARY OF MAIN OUTCOMES: A non-parametric neural network model has been developed using characterization tests under various thermal loading conditions. The neural network-enhanced constitutive model outperforms the standard cure kinetics-interfaced constitutive model in accurately predicting distortions for the Z-shaped case study.

Particle filter-based prognostics for composite curing process

AUTHORS: Balaji, A. Dumas, D. Pierard, O., Sbarufatti, C.,Cadini, F. JOURNAL: Polymer Composites. Wiley. (2024)

LINK: https://4spepublications.onlinelibrary.wiley.com/doi/10.1002/pc.28677

SUMMARY OF MAIN OUTCOMES: Process-induced deformation (PID) arises in thermoset parts due to internal residual stress developed from their anisotropic properties, resulting in distortions. While passive numerical manufacturing control exists, active manufacturing control is crucial for enhancing the manufacturing process. The work focuses on diagnosing the polymerization reaction, known as the curing process, to consider the influence of uncertainties in thermal loading conditions on the behavior of cure kinetics. This is achieved using a Particle Filter approach, wherein a posterior distribution of cure evolution is recursively approximated based on observed measurements from characterization tests. The algorithm is designed to simultaneously perform the diagnosis and prognosis of the Degree of Cure and PID. This approach adopts the augmented cure formulation to address various scenarios with uncertainties in thermal loading conditions. It offers the advantage of providing comparable PID predictions with minimal computational costs. C-shaped thermoset parts made of epoxy/carbon fibers with varying thicknesses are cured using the Manufacturing Recommended Curing Cycle, and the predictions with the developed algorithm are validated against experimental measures. Upon validation, the converged prognosis capability of the Particle Filter model is employed to assess the impact of thermal loading uncertainty on cure profiles, which, in turn, affects the final PIDs outcome.

6.1.2 ESR 3 Amond Sarr Allouko

RESEARCH TOPIC: Computing Platform Based on Novel High-Order Numerical Methods for Smart FRP Composite Structures with Embedded AU-SHM sensors.

HOST INSTITUTION: Atomic Energy and Alternative Energies Commission - Laboratory for Integration of Systems and Technologie (CEA List) ARTICLES SUBMITTED TO JOURNALS:



Optimal computation of integrals in the Half-Space Matching method for modal simulation of SHM/NDE in 3D elastic plate

AUTHORS: A. Allouko, A.-S. Bonnet-Ben Dhia, A. Lh'emery, V. Baronian

JOURNAL: The Journal of Physics: Conference Series. (2024)

LINK: https://hal.science/hal-04599319v1

SUMMARY OF MAIN OUTCOMES: The Half-Space Matching (HSM) method has been established for the development of a model that hybridizes local finite element (FE) computations for GW scattering by a flaw. Integral formulae appear in the HSM method. A method is proposed to reduce by a factor of 10 the time to get a good accuracy of these integrals.

6.1.3 ESR 4 Tasdeeq Sofi

RESEARCH TOPIC: Novel procedure for designing, manufacturing and assembling smart composite wind turbine blades with embedded AU-SHM sensors.

HOST INSTITUTION: Foundation for Research, Development and Application of Composite Materials (FIDAMC)

ARTICLES SUBMITTED TO JOURNALS:

An Efficient Procedure for Bonding Piezoelectric Transducers to Thermoplastic Composite Structures for SHM Application and Its Durability in Aeronautical Environmental Conditions

AUTHORS: Sofi, T., Gude, M.R., Wierach, P., Martin, I., Lorenzo, E.

JOURNAL: Sensors 23, 4784. (2023)

LINK: https://www.mdpi.com/1424-8220/23/10/4784

SUMMARY OF MAIN OUTCOMES: The article introduces a novel approach to bonding sensors to aircraft structures using thermoplastic films, offering an easily installable, reparable, and more reliable method. It highlights the limitations of the current method, which involves bonding transducers to composite structures using epoxy adhesives. These shortcomings include difficulties in reparability, weldability, longer curing cycles, and shorter shelf life. Through testing in standard aeronautical environmental conditions, the proposed method demonstrates superior performance compared to bonding with epoxy adhesives.



6.1.4 ESR 5 Morteza Moradi

RESEARCH TOPIC: Prognostic signatures based on data-fusion techniques from Lamb-wave and acoustic emission in real-world FRP laminates subjected to random fatigue damage. HOST INSTITUTION: Delft University of Technology (TU Delft)

ARTICLES SUBMITTED TO JOURNALS:

Intelligent health indicator construction for prognostics of composite structures utilizing a semi-supervised deep neural network and SHM data.

AUTHORS: Moradi, M., Broer, A., Chiachío, J., Benedictus, R., Loutas, T. H., & Zarouchas, D. JOURNAL: Engineering Applications of Artificial Intelligence, 117, 105502. (2023).

LINK: https://www.sciencedirect.com/science/article/pii/S0952197622004924

SUMMARY OF MAIN OUTCOMES: The research focuses on the development of an intelligent Health Index (HI) utilizing acoustic emission data obtained from composite panels. It employs a semi-supervised learning approach, implicitly integrating prognostic criteria into the model construction process. Through the application of a Bayesian optimization algorithm, the study identifies optimal network architectures for enhanced performance. Results indicate a significant 77.3 percent improvement in HI quality based on prognostic criteria. Additionally, the study verifies the approach's generalization capabilities through leave-one-out cross-validation. Overall, the research demonstrates promising advancements in HI construction using acoustic emission data and semi-supervised learning techniques.

A Novel machine learning model to design historical-independent health indicators for composite structures.

AUTHORS: Moradi, M., Gul, F. C., & Zarouchas, D.

JOURNAL: Composites Part B: Engineering, 111328. (2024).

LINK: https://www.sciencedirect.com/science/article/pii/S1359836824001392

SUMMARY OF MAIN OUTCOMES: The proposed approach relies solely on current guided wave (GW) data, eliminating the need for historical information. It offers flexibility in accommodating various GW sensor configurations and setups. Validation studies conducted on T-single stiffener CFRP panels subjected to compression-fatigue loading and dogbone CFRP specimens under tension-fatigue loading demonstrate high performance, with success rates reaching up to 93% and 81%, respectively. Overall, the methodology showcases promising adaptability and effectiveness in structural health monitoring applications.



6.1.5 ESR 6 Tianzhi Li

RESEARCH TOPIC: Development of super-fast Bayesian algorithms for real-time prognostics in composite structures using structural health monitoring.

HOST INSTITUTION: Politecnico di Milano (POLIMI)

ARTICLES SUBMITTED TO JOURNALS:

Particle filter-based hybrid damage prognosis considering measurement bias.

AUTHORS: Li, T., Sbarufatti, C., Cadini, F., Chen, J., & Yuan, S.

JOURNAL: Structural Control and Health Monitoring, 29(4), e2914. (2022).

LINK: https://onlinelibrary.wiley.com/doi/full/10.1002/stc.2914

SUMMARY OF MAIN OUTCOMES: This paper proposed a new bias-based prognostic model that can take measurement uncertainties into consideration, which has been demonstrated by fatigue crack prognostic studies.

Numerical simulation-aided particle filter-based damage prognosis using Lamb waves.

AUTHORS: Li, T., Lomazzi, L., Cadini, F., Sbarufatti, C., Chen, J., Yuan, S.

JOURNAL: Mechanical Systems and Signal Processing, 178, 109326. (2022).

LINK: https://www.sciencedirect.com/science/article/pii/S0888327022004630

SUMMARY OF MAIN OUTCOMES: By combining numerical simulation and bias-based prognostic model, this paper has proposed a novel Lamb wave-based prognostic framework.

SUMMARY AND CONCLUSION: Lamb wave-based damage prognosis methods typically require a data-driven measurement equation to describe the relationship between the damage state and some properly chosen damage-sensitive features of Lamb waves. The formulation of such a model generally requires sufficiently experimental or in-field datasets collected during the run-to-failure process, which, however, may not be available due to some causes like the high costs.

By combining a numerical simulation-aided damage quantification method with a damage prognosis framework accounting for the unavoidable measurement bias, this work has proposed a new particle filter-based damage prognosis framework, which only requires numerically simulated Lamb waves for building the measurement equation. The proposed framework has three advantages, i.e.,

• The costs and efforts in conducting run-to-failure tests and collecting experimental or in-field data for model formulation can be avoided.

• The numerical database developed in this work only consists of nine Lamb wave propagation simulations, each of which requires a few computation efforts, i.e., about four minutes on an AMD Ryzen 9 3950X 16-Core Processor.



• The proposed method is robust, as validated by the results from the five specimens because it takes the uncertainties from both the damage evolution and measurement models into account by online updating their parameters.

In a more realistic application scenario, where tens of or hundreds of sensors are installed for monitoring, the measurement vector in this method can be high-dimensional and most of the measurements far away from the damage can be damage-insensitive, which should possibly lead to an inaccurate and time-consuming prognosis. In order to deal with this problem, one may refer to a proper measurement partitioning strategy by online selecting limited-amount damage-sensitive measurements for estimation.

Particle filter-based delamination shape prediction in composites subjected to fatigue loading.

AUTHORS: Li, T., Cadini, F., Chiachío, M., Chiachío, J., Sbarufatti, C. JOURNAL: Structural Health Monitoring, 22(3), 1844-1862. (2023) LINK: <u>https://journals.sagepub.com/doi/abs/10.1177/14759217221116041?journalCode=shma</u> SUMMARY OF MAIN OUTCOMES: This paper has elaborated that the delamination shape in composites can be predicted and then proposed a new delamination shape prediction method.

Particle filter-based damage prognosis by online feature fusion and selection.

AUTHORS: Li, T., Chen, J., Yuan, S., Cadini, F., Sbarufatti, C. JOURNAL: Mechanical Systems and Signal Processing, 203, 110713. (2023). LINK: <u>https://www.sciencedirect.com/science/article/pii/S0888327023006210</u> SUMMARY OF MAIN OUTCOMES: Given the usage of the statistical feature can have a significant effect on prognostic performance, this paper has proposed a new online feature fusion and selection method within a particle filter-based prognostic framework.

Multiple local particle filter for high-dimensional system identification.

AUTHORS: Li, T., Sbarufatti, C., Cadini, F.

JOURNAL: Mechanical Systems and Signal Processing, 209, 111060. (2024).

LINK: https://www.sciencedirect.com/science/article/pii/S0888327023009688

SUMMARY OF MAIN OUTCOMES: This paper has proposed a new particle filter method that can offer the possibility of beating the curse of dimensionality, which has been validated by the numerical simulation of bounce wen frame structure and the experimental study of fatigue crack prognostic.



Particle filter-based fatigue damage prognosis by fusing multiple degradation models. AUTHORS: Li, T., Chen, J., Yuan, S., Zarouchas, D., Sbarufatti, C., Cadini, F. JOURNAL: Structural Health Monitoring, 14759217231216697. (2024). LINK: https://journals.sagepub.com/doi/full/10.1177/14759217231216697?casa_token=BgauJcW9dwAA

AAAA%3AfHlJ1WNbWAQXGGNrC4s4ywixK_6Pm2r0c7HjPj24u9htirKh1vuz8kh6CE449n650Q Ye088exMPJ-Q

SUMMARY OF MAIN OUTCOMES: Given the usage of the degradation model can have a significant effect on prognostic performance, this paper has proposed a new online model fusion method within a particle filter-based prognostic framework.

6.1.6 ESR 7 Javier Contreras

RESEARCH TOPIC: Development of a System-Level Post-Prognostics Reasoner for FRP turbine blades using on-board SHM.

HOST INSTITUTION: University of Strahclyde, Glasgow, U.K.

ARTICLES SUBMITTED TO JOURNALS:

A cross-sectoral review of the current and potential maintenance strategies for composite

structures.

AUTHORS: Contreras Lopez, J., Chiachío, J., Saleh, A., Chiachío, M., Kolios, A.

JOURNAL: SN Applied Sciences 4, 180. (2022)

LINK: https://link.springer.com/article/10.1007/s42452-022-05063-3

SUMMARY OF MAIN OUTCOMES: A review of the current state of O&M for safety-critical structures. Limitations in the use of composites and advanced maintenance methods in 4 different sectors (Civil, Aerospace, Wind and Naval) are derived.

Risk-based maintenance strategy selection for wind turbine composite blades.

AUTHORS: Lopez, J. C., Kolios, A.

JOURNAL: Energy Reports, 8, 5541-5561. (2022).

LINK: https://www.sciencedirect.com/science/article/pii/S2352484722007922

SUMMARY OF MAIN OUTCOMES: A criticality ranking of the different failure modes of a wind turbine blade including a framework to select maintenance strategies for these. A review of the suitability of SHM for the failure modes identified is also provided.



A wind turbine blade leading edge rain erosion computational framework.

AUTHORS: López, J. C., Kolios, A., Wang, L., Chiachio, M.

JOURNAL: Renewable Energy, 203, 131-141. (2023).

LINK: https://www.sciencedirect.com/science/article/pii/S0960148122018353

SUMMARY OF MAIN OUTCOMES: A computational framework to evaluate wind tubine blade leading edge erosion effect on annual energy production and quantify the effect of weather uncertainty. AEP reduction is estimated to be in the range 1.25-1.75% for the case study.

Reliability-based leading edge erosion maintenance strategy selection framework.

AUTHORS: Lopez, J. C., Kolios, A., Wang, L., Chiachio, M., Dimitrov, N.

JOURNAL: Applied Energy, 358, 122612. (2024).

LINK: https://www.sciencedirect.com/science/article/pii/S0306261923019761

SUMMARY OF MAIN OUTCOMES: A framework to evaluate and select calendar-based maintenance strategies for leading-edge erosion failures. This framework provides a practical tool for O&M practitioners to design a baseline strategy for this failure mode.

6.1.7 ESR 8 Wen Wu

RESEARCH TOPIC: Modelling risk of failure using guided wave propagation and interaction with damage in complex composite structures.

HOST INSTITUTION: University of Nottingham, U.K.

ARTICLES SUBMITTED TO JOURNALS:

Guided waves-based damage identification in plates through an inverse Bayesian process.

AUTHORS: Wu, W., Malik, M. K., Cantero-Chinchilla, S., Lawrie, T., Yan, W. J., Tanner, G., ... & Chronopoulos, D.

JOURNAL: Ultrasonics, 125, 106773. (2022).

LINK: https://www.sciencedirect.com/science/article/pii/S0041624X22000816?via%3Dihub

SUMMARY OF MAIN OUTCOMES: A Bayesian inference framework for damage identification of plate structures with spherical symmetry is presented where a guided waves interaction model is used based on a semi-analytical approach.



Damage Quantification and Identification in Structural Joints through Ultrasonic Guided Wave-Based Features and an Inverse Bayesian Scheme

AUTHORS: Wen Wu, Sergio Cantero-Chinchilla, Wang-ji Yan, Manuel Chiachío Ruano, Rasa Remenyte-Prescott, Dimitiros Chronopoulos

JOURNAL: Sensors, 23(8), 4160. (2023).

LINK: https://www.mdpi.com/1424-8220/23/8/4160

SUMMARY OF MAIN OUTCOMES: A Bayesian inference framework is presented to identify the size of the circular hole in joints using frequency domain damage features.

6.1.8 ESR 9 Juan Fernández

RESEARCH TOPIC: Paradigm-Shift Research for System-Level Real-Time Prognostics of Cyber-Physical Assets using Deep Learning approaches.

HOST INSTITUTION: University of Granada, Spain.

ARTICLES SUBMITTED TO JOURNALS:

Uncertainty quantification in Neural Networks by Approximate Bayesian Computation: Application to fatigue in composite materials.

AUTHORS: Juan Fernández, Manuel Chiachío, Juan Chiachío, Rafael Muñoz, Francisco Herrera JOURNAL: Engineering Applications of Artificial Intelligence. (2022).

LINK: https://www.sciencedirect.com/science/article/pii/S0952197621003596?via%3Dihub

SUMMARY OF MAIN OUTCOMES: Development of a new training algorithm for artificial neural networks based on Bayesian methods. This is a gradient-free algorithm, that provides more flexibility and quantifies the uncertainty in the predictions in a realistic manner.

Physics-guided Bayesian neural networks by ABC-SS: Application to reinforced concrete.

AUTHORS: Juan fernández, Juan Chiachío, Manuel Chiachío, Jose Barros, Matteo Corbetta JOURNAL: Engineering Applications of Artificial Intelligence. (2023).

LINK: https://www.sciencedirect.com/science/article/pii/S0952197622007801

SUMMARY OF MAIN OUTCOMES: Development of a new hybrid algorithm that combines feedforward artificial neural networks with physics-based models, and their application to structural assets. This algorithm is trained with Bayesian methods so that the uncertainty in the predictions is quantified.



Physics-guided recurrent neural network trained with approximate Bayesian computation: A case study on structural response prognostics.

AUTHORS: Fernández, J., Chiachío, J., Barros, J., Chiachío, M., & Kulkarni, C. S.

JOURNAL: Reliability Engineering & System Safety, 243, 109822. (2024).

LINK: https://www.sciencedirect.com/science/article/pii/S0951832023007366

SUMMARY OF MAIN OUTCOMES: A new hybrid recurrent neural network combined with physicsbased models for prognostics. This new methodology improves multi-step ahead forecasting, including the quantification of the uncertainty.

Training of physics-informed Bayesian neural networks with ABC-SS for prognostic of Li-ion batteries.

AUTHORS: Fernández, J., Corbetta, M., Kulkarni, C. S., Chiachío, J., & Chiachío, M.

JOURNAL: Computers in Industry, 155, 104058. (2024).

LINK: https://www.sciencedirect.com/science/article/pii/S0166361523002087

SUMMARY OF MAIN OUTCOMES: A new training method for physics-informed recurrent neural networks based on Bayesian methods. This new algorithm accounts for the uncertainty in both the data and the physics-based models, providing useful information for the decision-making process.

6.1.9 ESR 10 Ali Saleh

RESEARCH TOPIC: Development of a prognostics-based self-adaptive Expert System for smart Composite Structures.

HOST INSTITUTION: University of Granada, Spain.

ARTICLES SUBMITTED TO JOURNALS:

Reduction of Petri net maintenance modelling complexity via approximate Bayesian computation.

AUTHORS: M. Chiachío, A. Saleh, S. Naybour, J. Chiachío, J. Andrews.

JOURNAL: Reliability Engineering & System Safety 222 108365. (2022)

LINK: https://www.sciencedirect.com/science/article/pii/S0951832022000436

SUMMARY OF MAIN OUTCOMES: Proposing a method to reduce the complexity of Petri nets by using the Approximate Bayesian Computation, which results in reduced computational cost.



Self-adaptative optimized maintenance of offshore wind turbines by intelligent Petri nets AUTHORS: Ali Saleh, Manuel Chiachío Ruano, Juan Fernández Salas, Athanasios Kolios JOURNAL: Reliability Engineering & System Safety, 231, 109013. (2023). LINK: <u>https://www.sciencedirect.com/science/article/pii/S0951832022006287?via%3Dihub</u> SUMMARY OF MAIN OUTCOMES: Optimized maintenance strategy for offshore wind turbines using Reinforcement learning and Petri nets.

Intelligent and adaptive asset management model for railway sections using the ipn method.

AUTHORS: D. Prescott, R. Remenyte, M. Chiachio, A. Saleh. JOURNAL: Reliability Engineering & System Safety 241 109687. (2024) LINK: <u>https://www.sciencedirect.com/science/article/abs/pii/S0951832023006014</u> SUMMARY OF MAIN OUTCOMES: Modeling the degradation of vertical geometry profile and ballast in railways while proposing an optimized maintenance strategy.

6.2 Articles submitted to international conferences

Presenting at prestigious conferences enhances a researcher's reputation within their academic community. It establishes them as an expert in their field and opens up opportunities for collaboration, funding, and career advancement. In the following section, a detailed list of the articles presented at congresses by the ESRs will provided.

6.2.1 ESR 1 Shankar Galiana

RESEARCH TOPIC: Reliable sensor networks for Structural Health Monitoring systems in highly loaded composite structures.

HOST INSTITUTION: German Aerospace Center (DLR)

ARTICLES SUBMITTED TO CONGRESSES:

Acousto-ultrasonic composite transducers integration into thermoplastic composite structures via ultrasonic welding

AUTHORS: Galiana, S., Moradi, M., Wierach, P., Zarouchas, D.

CONGRESS: 10th ECCOMAS Thematic Conference on Smart Structures and Materials 956-965, (2023), Patras, Greece.

LINK: https://elib.dlr.de/201886/



6.2.2 ESR 4 Tasdeeq Sofi

RESEARCH TOPIC: Novel procedure for designing, manufacturing and assembling smart composite wind turbine blades with embedded AU-SHM sensors.

HOST INSTITUTION: Foundation for Research, Development and Application of Composite Materials (FIDAMC)

ARTICLES SUBMITTED TO CONGRESSES:

Novel Procedure of Integrating Transducers to Thermoplastic Composite Structures by Induction Heating for SHM

AUTHORS: Sofi, T., Gude, M., Garcia, J., Wierach.

CONGRESS: In proceedings of the 10th ECCOMAS Thematic Conference on Smart Structures and Materials, Patras, Greece, 3-5 July 2023; pp. 1291-1302.

LINK: https://elib.dlr.de/201883/

6.2.3 ESR 5 Morteza Moradi

RESEARCH TOPIC: Prognostic signatures based on data-fusion techniques from Lamb-wave and acoustic emission in real-world FRP laminates subjected to random fatigue damage.

HOST INSTITUTION: Delft University of Technology (TU Delft)

ARTICLES SUBMITTED TO CONGRESSES:

Intelligent Health Indicators Based on Semi-supervised Learning Utilizing Acoustic Emission Data

AUTHORS: Moradi, M., Broer, A., Chiachío, J., Benedictus, R., & Zarouchas, D.

CONGRESS: In European Workshop on Structural Health Monitoring (pp. 419-428). Cham: Springer International Publishing. (2022, June), Palermo, Italy.

LINK: https://link.springer.com/chapter/10.1007/978-3-031-07322-9_43

Interpretable neural network with limited weights for constructing simple and explainable HI using SHM data

AUTHORS: Moradi, M., Komninos, P., Benedictus, R., & Zarouchas, D.

CONGRESS: In Annual Conference of the PHM Society (Vol. 14, No. 1). (2022, October), Nashville, USA

LINK: https://papers.phmsociety.org/index.php/phmconf/article/view/3185



Developing health indicators for composite structures based on a two-stage semisupervised machine learning model using acoustic emission data.

AUTHORS: Moradi, M., Chiachío, J., & Zarouchas, D.

CONGRESS: In Proceedings of the 10th ECCOMAS Thematic Conference on Smart Structures and Materials (Vol. 10). (2023, July), Patras, Greece.

LINK:<u>https://repository.tudelft.nl/islandora/object/uuid%3Ad3912853-0178-40ba-9735-</u> <u>d3699107c9cf</u>

6.2.4 ESR 8 Wen Wu

RESEARCH TOPIC: Modelling risk of failure using guided wave propagation and interaction with damage in complex composite structures.

HOST INSTITUTION: University of Nottingham, U.K.

ARTICLES SUBMITTED TO CONGRESSES:

Asset management modelling approach integrating structural health monitoring data for composite components of wind turbine blades

AUTHORS: Wen Wu, Ali Saleh, Rasa Remenyte-Prescott CONGRESS: 32nd European Safety and Reliability Conference. (2022), Dublin, Ireland LINK: <u>https://www.researchgate.net/publication/363267167</u>

6.2.5 ESR 9 Juan Fernández

RESEARCH TOPIC: Paradigm-Shift Research for System-Level Real-Time Prognostics of Cyber-Physical Assets using Deep Learning approaches. HOST INSTITUTION: University of Granada, Spain. ARTICLES SUBMITTED TO CONGRESSES:

Probabilistic safety assessment in composite materials using BNN by ABC-SS. AUTHORS: Juan Fernández, Juan Chiachío, Manuel Chiachío, Ali Saleh CONGRESS: Annual Conference of the PHM Society, (2022), Nashville, USA LINK: <u>https://papers.phmsociety.org/index.php/phmconf/article/view/32754</u>

6.2.6 ESR 10 Ali Saleh

RESEARCH TOPIC: Development of a prognostics-based self-adaptive Expert System for smart Composite Structures.

HOST INSTITUTION: University of Granada, Spain.



ARTICLES SUBMITTED TO CONGRESSES:

An assessment of different reinforcement learning methods for creating a decision support system based on the Petri net model.

AUTHORS: Ali Saleh, Manuel Chiachío.

CONGRESS: Annual Conference of the PHM Society, (2002), Nashville, USA

LINK: https://papers.phmsociety.org/index.php/phmconf/article/view/3240

Optimized Petri net model for condition-based maintenance of a turbine blade.

AUTHORS: A. Saleh, M. Chiachio, J. Chiachio.

CONGRESS: World Congress on Engineering Asset Management, Springer, pp. 657-664. (2022).

LINK: https://link.springer.com/chapter/10.1007/978-3-031-25448-2_61 Seville, Spain.

An optimized asset management petri net model for railway sections.

AUTHORS: D. Prescott, R. Remenyte, M. Chiachio, A. Saleh.

CONGRESS: Materials Research Proceedings 27 (2023). The 9th Asia-Pacific Workshop on SHM, Cairns, Queensland, Australia.

LINK: https://www.mrforum.com/product/9781644902455-37/



Appendixes



A1. Certificate of the Seminar in Aalto University





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To whom it may concern,

This document certifies that Dr. Manuel Chiachio visited Aalto University during the 8th to 11th of April, 2024 for collaborative research within the Horizon Europe research framework.

During this stay, he presented an invited seminar titled: "Structural Digital Twin framework: a holistic view of current technologies and future trends".

Should you require further information, please do not hesitate to contact me at the following address.

18th April 2024 Espoo, Finland

Heid: John Heidi Salonen Professor, Head of Department Department of Civil Engineering, School of Engineering, Aalto university Email: heidi.salonen@aalto.fi



A2. Programme of the Seminar ESReDA





64th ESReDA Seminar

digital maintenace in

the digital twin era.







doctoral workshop on digital twin. 30th 31th may 29th 30th 31th

may

with the collaboration of

DeustoTech censolutions Singeman

EVENT LOCATION Universidad de Deusto Bilbas (Spain)





PROGRAMME

	Day 1 29th May	Day 2 30th May	Day 3 31th May
Doctoral Workshop	Workshop Sessions	 Workshop Sessions Gala Dinner 	Workshop Sessions
64th ESReDA Seminar	ESReDA BoD meeting	Seminar Sessions ESReDA GA meeting Gala Dinner	Seminar Sessions



Doctoral Workshop Agenda

ACADEMIC LECTURERS

Prof. Hermann Matthies (Technical University of Braunschweig, Germany) Prof. Noemi Friedman (Institute for Computer Science and Control, SZTAKI, Hungary) Prof. Andras Benczur (Institute for Computer Science and Control, SZTAKI, Hungary) Prof. Anna Kucerova (Czech Technical University, Prague) Prof. Manuel Chiachio (University of Granada, Spain) Prof. Juan Chiachio (University of Granada, Spain) Ing. Francisco Carmona (Quantia S.L., Spain)

TECHNICAL PROGRAMME

May 29th			
Start	End	Agenda item	Duration
08.30:00	09:00:00	Welcome to the participants and COFFEE	00:30:00
09:00:00	10:00:00	Introduction to Digital Twinning Prof. Hermann Matthies (TU Braunschweig, Germany)	01:00:00
10:00:00	10:30:00	BREAK	00.30.00
10:30:00	11:45:00	Introduction to Inverse Problems and their Probabilistic Treatment 1 Prof. Hermann Matthies (TU Braunschweig, Germany)	01:15:00
11:45:00	12.00:00	COFFEE BREAK	00:15:00
12:00:00	13:15:00	Introduction to Inverse Problems and their Probabilistic Treatment 2 Prof. Hermann Matthies (TU Braunschweig, Germany)	01:15:00
13:15:00	14:30:00	COOKTAILLUNCH	01:15:00
14:30:00	15:45:00	Predictive/Proxi modeling, explainability of models 1 Prof. Anna Kucerova (CTU Prague)	01:15:00
15:45:00	16:00:00	COFFEE BREAK	00:15:00
16:00:00	17:15:00	Predictive/Proxi modeling, explainability of models 2 Prof. Andras Benczur (SZTAR), Hungary)	01:15:0



		May 30th	
Start	End	Agenda Item	Duration
08:30:00	09:30:00	Predictive/proxi modeling, explainability of models 3 Prof. Andras Benczur (SZTAK), Hungary)	01.00:00
09:30:00	10:15:00	PLENARY TALX: Digital Twin aiding more effective Digital Maintenance Diego López de Ipiña_DEUSTOTECH	00.45.00
10:15:00	11:15:00	Proxi modeling for stochastic systems 1 Prof. Hermann Matthies (TU Braunschweig, Germany)	01.00.00
11:15:00	11:30:00	COFFEE BREAK	00:15:00
11:30:00	13:00:00	Proxi modeling for stochastic systems 2 Dr. Noemi Friedman (SZTAR), Hungary)	01.90.00
13:00:00	14:00:00	COOLTAIL LUNCH	01:00:00
14:00:00	14:45:00	PLENARY TALX: PLENARY TALK: Digital transformation in maintenance and asset management. Guidelines for organizations. Prof. Adolfo Crespo_UNVERSIDAD DE SEVILLA	00.45.00
14:45:00	15:30:00	Bayesian model updating and filtering and computational techniques 1 Prof. Juan Chiachio (University of Granada, Spain)	01:15:00
15:30:00	15:45:00	COFFEE BREAK	00:15:00
15:45:00	17:00:00	Bayesian model updating and filtering and computational techniques 1 Prof. Manuel Chiachio (University of Granada, Spain)	01:15:00

		May 31st	
Start	End	Agenda item	Duration
09:00:00	09:15:00	Welcome to the participants and COFFEE	00-15:00
09:15:00	10:00:00	PLENARY TALK: BIM technologies and digital twinning 1 Ing. Francisco Carmona (QuantiA S.L., Spain)	00:45:00
10:00:00	10:45:00	PLENARY TALK: Identifying the Future Skills Requirements of the Digital Maintenance era Felix Bayon_SIDENOR	00:45:00
10:45:00	11:45:00	BIM technologies and digital twinning 2 Ing. Francisco Carmona (QuantiA S.L., Spain) & Prof. Manuel Chiachio (University of Granada, Spain)	01:00:00
11:45:00	12:00:00	COFFEE BREAK	00:15:00
12:00:00	13:30:00	Educative examples of the whole framework, summary Dr. Noemi Friedman (SZTAKI, Hungary)	01:30:00
13:10:00	13:40:00	Wrapping Up: Key Takeaways and Roundtable Discussion Prof. Adoifo Crespo, Prof. Hermann G. Matthies, Diego López de Ipiña, Ibón Iribarren	00:30:00
13:40:00	15:00:00	LUNCH	01-20:00



64th ESReDA Seminar Agenda

DAY 1. WEDNESDAY 29 May

Start	End	Agenda Item	
16:30	18:00	ESReDA Board of Director meeting	

Day 2. Thursday 30 May

Start	End	Agenda Item
9:00	9:30	Welcome to the participants and COFFEE
9:30	10:15	PLENARY TALK: Digital Twin aiding more effective Digital Maintenance Diego López de Ipiña_DEUSTOTECH
10:15	11:15	Al for the application of maitenance techniques
10:15	10:30	Artificial Intelligence as a driver for Prescriptive Maintenance: Limitations Joaquín Ordieres_UNIVERSIDAD POLITÉCNICA DE MADRID
10:30	10:45	Al-Powered Models: Catalysts for Digital Twin Advancements in Industry 4.0 Maria Megia_UNIVERSIDAD DE GRANADA
10:45	11:00	A Review of Hybrid Prognostics Applications for Power & Energy Systems Joxe I. Aizpurua_MONDRAGON UNIBERTSITATEA
11:15	11:45	COFFEE BREAK
11:45	13:00	IoT and DT
11:45	12:00	An innovative IoT device designed to enhance teaching performance through the application of digital twin technology Diego Casado_DEUSTOTECH
12:00	12:15	Edge-Based AI for Online Health Monitoring of Critical Water Desalination Pumps: Aingura IIoT Applications in the Digital Twin Era David Cruz AINGURA



12:15	12:30	Self-powered instrumentation systems for IoT and Maintenance Jorge Marcos Acevedo_UNIVERSIDAD DE VIGO
12:30	12:45	Recalibration of Digital Twins via Mobile Agents Sascha Peitzsch_ FRAUNHOFER SIRIOS
13:00	14:00	COCKTAIL LUNCH
14:00	14:45	PLENARY TALK: PLENARY TALK: Digital transformation in maintenance and asset management. Guidelines for organizations. Adolfo Crespo_UNVERSIDAD DE SEVILLA
14:45	15:45	DT Modelling and Simulation techniques I
14:45	15:00	A Petri net-based Digital Twin development for managing wind turbine blade maintenance Wen Wu_UNIVERSITY OF NOTTINGHAM
15:00	15:15	"Towards Precision in Railway Corrugation Estimation: Employing CNN-1D Networks and Fractal Dimensions" Massoud Haghbin_UNIVERSIDAD DE GRANADA
15:15	15:30	Basic architecture for digital twin implementation for power electronics application José López_CEN SOLUTIONS, Juan Gómez_UNIVERSIDAD DE SEVILLA
15:45	16:00	COFFEE BREAK
16:00	17:00	DT Modelling and Simulation techniques II
16:00	16:15	Simulation on reliability analysis of linear consecutive K-out-of-n systems for Weibull parameter estimation with incomplete failure data Daniel Gaspar TECNICO DE LISBOA
16:15	16:30	Smart factory maintenance: building a predictive model of pathogen transmission during the food fabrication process Sébastien Delmotte_MAD-Enviroment
16:30	16:45	Digital Twin-Assisted Predictive Maintenance (DT-PdM) Framework for Complex Systems: Preliminary Research through a Pilot Study Huxiao Shi Politecnico di Torino
16:45	17:00	Bases for Ontology of Digital Twin of Maintenance Process. A Railway Application Mauricio Rodríguez_UNIVERSIDAD DE SEVILLA
17:00	18:30	45 th ESReDA General Assembly
20:30	- 2	Gala Dinner



64th ESReDA Seminar

Start	End	Agenda Item
9:00	9:30	Welcome to the participants and COFFEE
9:30	10:15	PLENARY TALK: Identifying the Future Skills Requirements of the Digital Maintenance era Felix Bayon_SIDENOR
10:15	11:15	Lines of value for DT and DM development: human centered and servitization
10:15	10:30	Vulnerabilities in the human factor-digital technology relationship in the railway system Sever Paul_AGIFER
10:30	10:45	The consideration of the Human-Machine Interface in the Safety Management System of the process industry Romulado Marrazzo_VAL-RTEC
10:45	11:00	DFMAS Project: IoT and DT application for evolution of services with low level of digitalization Antonio Sánchez_UNIVERSIDAD DE SEVILLA
11:15	11:45	COFFEE BREAK
11:45	12:15	PLENARY TALK Service: the red pill. How to make industrial service a reality Ibon Iribarren_TIMEPACK
12:15	13:10	Digitalization for sustainability and management
12:15	12:30	Digital Twin technology in Civil Engineering: research vision from the ENHANCE and BUILDCHAIN European projects Manuel Chiachío_UNIVERSIDAD DE GRANADA
12:15	12:30	Sustainable maintenance and digital twin technology: a test case for evaluating integration potentialities Maria Grazia Gnoni_UNIVERSITY OF SALENTO
12:30	12:45	Impact of digitization on physical asset management Javier Serra_ENAGAS

Day 3. Friday 31 May

13:10	13:40	Wrapping Up: Key Takeaways and Roundtable Discussion
13:40	14:55	COCKTAIL LUNCH
•		Free visit to the Guggenheim Museum Bilbao (Limited number of invitations. To attend, registration will be open during the seminar until all available invitations are filled.)



A3. Cetificates of the symposium COMPDYN



1. Symposium certificate





2. Certificate of a paper presentation

Ссомая	European Community on Computational Methods in Applied Sciences
COMPDVN 2021	
8 th International Conference on Computational Methods in Structural Dynamics and Farthquak	e Engineering
28-30 June 2021, Athens, Greece	c engineering
An IACM Special Interest Conference	e-mail: info@compdyn.org jurt: http://2021.compdyn.org
Certificate	of Presentation
This is to certify that Mr Ali Saleh prese BAYESIAN APPROACH FOR COMPLEXIT International Conference on Computat Earthquake Engineering (COMPDYN 202 June 2021 in conjunction with the 4 th Quantification in Computational Science the 14 th International Conference on E Design, Optimization and Control (EURC	nted the paper "C20141 - AN APPROXIMATE Y REDUCTION OF PETRI NET MODELS" at 8 th tional Methods in Structural Dynamics and 21) streamed from Athens, Greece, on 28-30 th International Conference on Uncertainty ses and Engineering (UNCECOMP 2021) and Evolutionary and Deterministic Methods for OGEN 2021).
Sincerely,	
Manolis Papadrakakis On behalf of COMPDYN 2021 Organizers	5