



# USES<sup>2</sup> Industry Days#2

## Work Package (WP) introduction

14<sup>th</sup> April 2026





# WP1: Innovative sensor technologies

5 DCs



Prof Antonio Fernando Lopez

Universidad Politécnica de Madrid



# Objectives

**Improve connections and energy efficiency of embedded sensors thanks to new mechanical wave sensing solutions**

(**Bottleneck#1**) the sensor networks (e.g. cables, connectors) connecting them to acquisition devices

(**Bottleneck#2**), existing autonomous sensors powered by batteries and/or energy harvesting technologies do not last long enough for widespread adoption



# Objectives

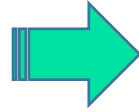
Develop new and innovative **hardware platforms** to be **embedded** into materials of interest (composite, polymers, concrete, soil) and overcome current bottlenecks, such low size & low power at high frequencies with high accuracy interrogator units for FBG sensors:

- **Photonic Integrated Circuits (PIC)** of low losses and highly integrated architecture.
- **Dispersive Bragg Spectrometer (DBS)**, to interrogate hundreds of measurements at a sampling frequency of several hundredskHz.
- **Wireless capabilities** will also be developed by taking into account:
  - The **high amount of data** to be efficiently processed (high frequencies, numerous sensors).
  - The capacity of systems to be fully autonomous (**inductive coupling for energy harvesting** of piezoelectric actuators and sensors).



# Presentation & objectives

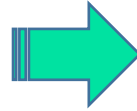
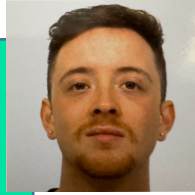
DC01 Shaojie Xu



Design and development of photonic integrated circuits for optical fibre sensing interrogation



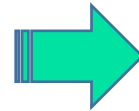
DC02 Giovanni Vacirca



High speed/High capacity distributed FBG sensing for SHM applications



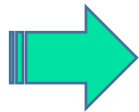
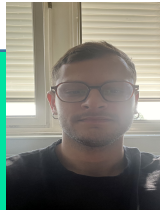
DC03 Jasmien Hassanien



Efficient sensor data acquisition via compressed sensing for autonomous sensor applications



DC04 Marios Kaminiotis



Embedded self-powered sensor devices for passive monitoring of composite components



DC11 Nalin Kamath



Embedded wireless sensor devices for monitoring composite components

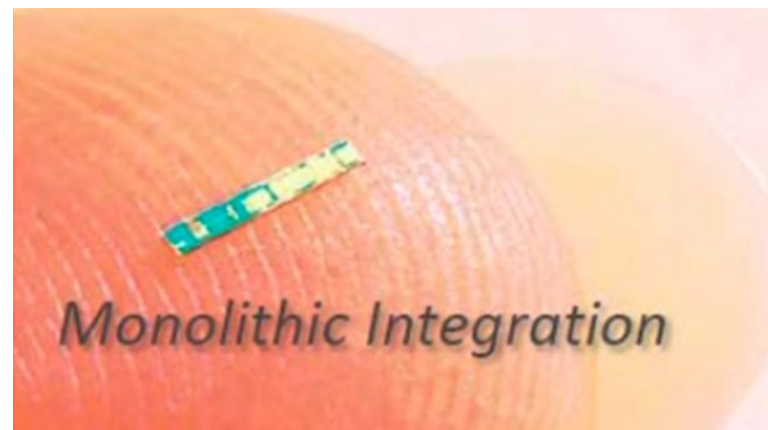
# DC01 - Design and development of photonic integrated circuits for optical fiber sensing interrogation

DC01 Shaojie Xu



## Objective

Develop a Photonic Integrated Circuit (PIC) architecture capable of measuring at high frequencies ( $>200$  kHz- 1 MHz) and high accuracy (less than 1pm) solid waves in different structures with embedded FBG sensors using an hybrid silicon photonics with nonlinear crystals or through use of a spectrometer developed with an Arrayed Waveguide Grating.

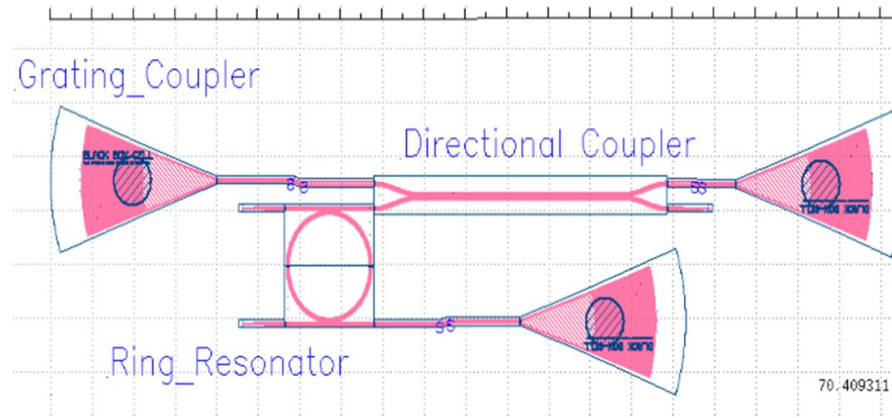
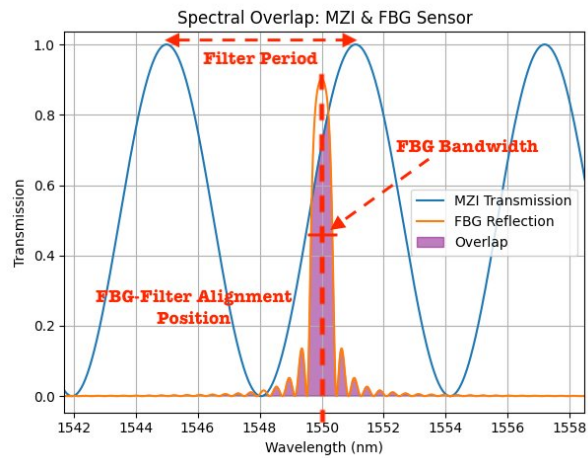


# What has been done so far

DC01 Shaojie Xu



Full design and optimization of photonic optical circuit using Mach Zehnder interferometers in transmission



# What is next

Manufacturing, characterization and integration of PIC interrogator

# DC02 - High speed/High capacity distributed FBG sensing for SHM applications

DC02 Giovanni Vacirca



## Objective

- FBG acoustic sensing is limited by the capacity (WDM-based) or by the scan rate (OFDR-based), although Tomography with acoustic techniques requires high capacity and high scan rate with the aim to improve quality of image reconstruction
- Dispersive Bragg Spectrometry is emerging as a powerful monitoring approach to overcome these limitations. The underlying principle is to use a high repetition rate (40 MHz to 100 MHz) ps/fs, pulsed laser associated with a highly dispersive optical media providing a Bragg-to-time delay conversion and High Bandwidth Oscilloscope (HBO, 30-40 GHz). Data are sampled at the repetition rate of the laser (i.e. every 10 ns at 100 MHz, or an equivalent space resolution of 50  $\mu\text{m}$  for a 5,000 m/s wave velocity)



## DC03 - Efficient sensor data acquisition via compressed sensing for autonomous sensor applications

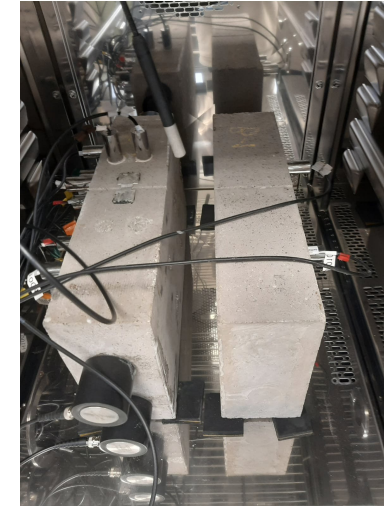
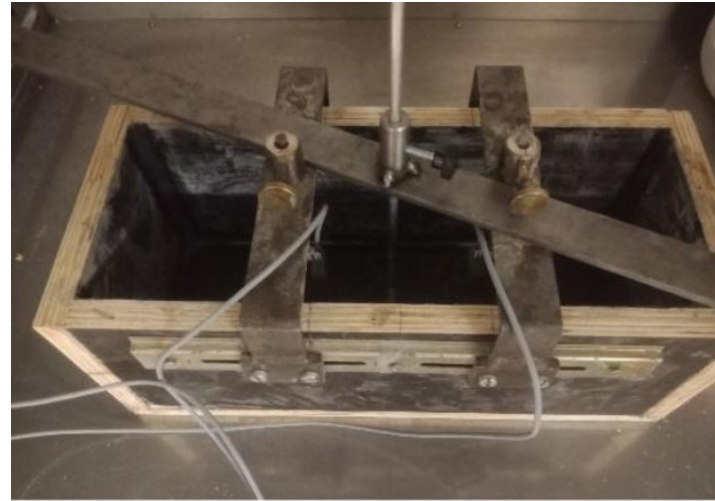
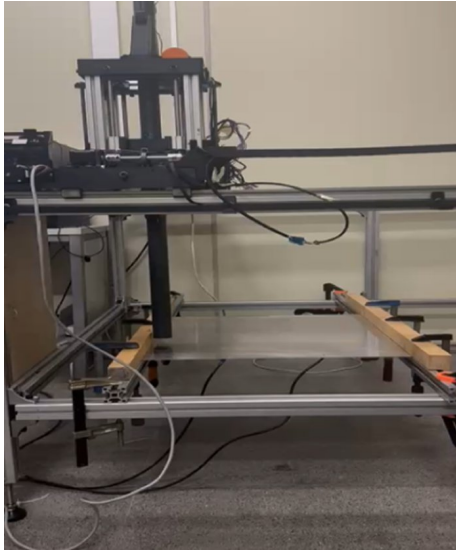
### Objective

- Generic data reduction approaches like Compressed Sensing (CS) might provide a suitable approach to deliver reusable architectures. The solution is based on the fact that prior knowledge on the signals is often available in monitoring applications, due to the repetitive nature of acoustic/ultrasonic measurement.
- Through tight interaction with the corresponding partners, a thorough comprehension of the relevant sensor modalities should be established so that a clear understanding of relevant and irrelevant parts of the measurement signals is achieved.
- This process follows three basic steps:
  - Software-based data reduction (post acquisition)
  - On board data reduction close to the sensor (e.g. FPGA-based)
  - On-chip data reduction (via suitable custom electronic design)



# What has been done so far

Apply the Compressed Sensing methodology to different USES2 scenarios



# What is next

Optimize and continue applying Compress Sensing Methodology

# DC04: Embedded self-powered sensor devices for passive monitoring of composite components

DC04 Marios Kaminiotis



## Objective

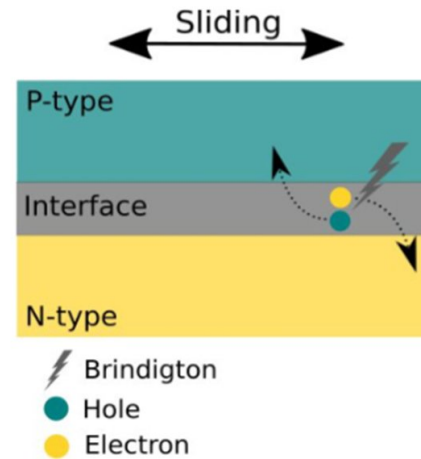
- Explore how electronic system may be optimised to maximize energy harvesting using embedded piezoelectric sensors used for passive imaging in a range of materials, from carbon and glass composites to concrete and difference sources of vibrations (spectrum, energy);
- Embed optimised sensors into several experimental structures with project partners;
- Explore how the sensor measurement performance may be improved through the use of signal processing expertise within the consortia
- Investigate synergies with the other techniques developed in USES<sup>2</sup>

# What has been done so far

DC04 Marios Kaminiotis



Study the triboelectric energy harvester in low frequency environment and its potential as power source i



# What is next

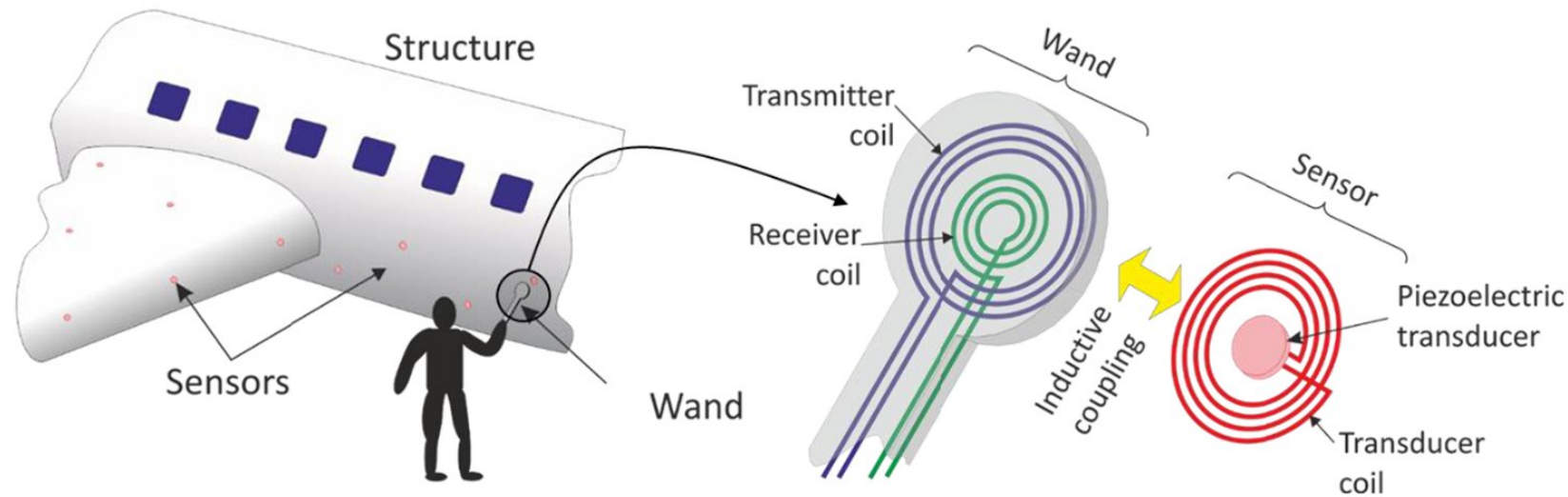
Optimize to apply it as power source of a wireless sensor node

# DC11 - Embedded wireless sensor devices for monitoring composite components



## Objective

- Explore how embedded wireless sensors in a range of materials, from carbon and glass composites to concrete and explore sensor measurement performance

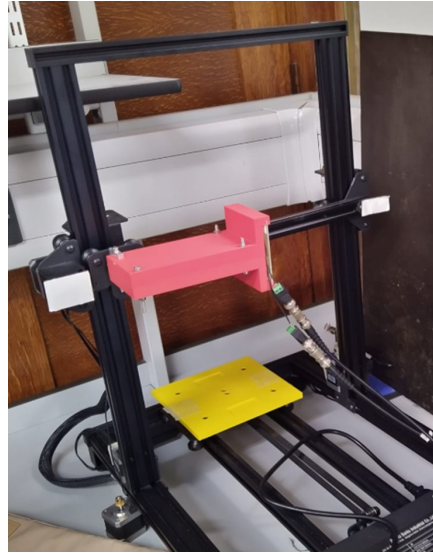


# What has been done so far

DC11 Nalin Kamath



Experimental characterization of WAND probe and transducer characterization for guided waves



## What is next

Optimizing the profile of the transducer and minimize the structural impact of embedding WAND transducers in composites



# WP2: Advanced imaging using mechanical waves



**Dr Ernst Niederleithinger**  
Federal Institute for Materials Research  
and Testing



**Dr Alessandro Brovelli**  
Isamgeo



3 DCs

# Objectives

Enhance the detection, localisation and quantification of undetectable damage thanks to advanced imagery methods rendering undetectable damages visible

*Why develop new advanced mechanical wave imaging methods?*

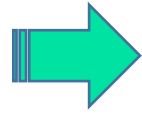
Already lots of methods for imaging available in NDT and geophysics (and other methods for translating NDT/geophysical parameters to engineering parameters), but

**Bottleneck#3:** Methods are mostly limited to simple geometries, yielding in some instances an insufficient resolution (and some other limitations)

**Bottleneck#4:** Some types of damage (like closed cracks, delamination or bonding imperfections) remain undetectable

# WP2 Doctoral candidates

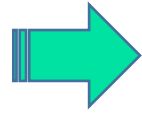
DC05 Alina Suchkova



Joint processing and inversion of active and passive ultrasonic data



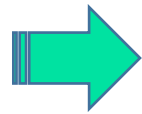
DC06 Olga Nesterova



Densely distributed sensor networks for seismic wave detection in complex environments for civil engineering applications



DC07 Shilan Shaabani



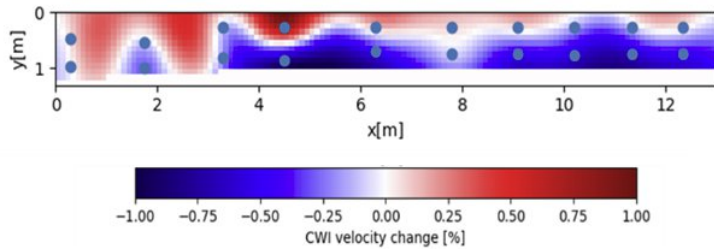
Nonlinear Coda Wave Interferometry imaging (NCWII) with active and passive pumps



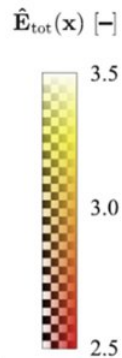
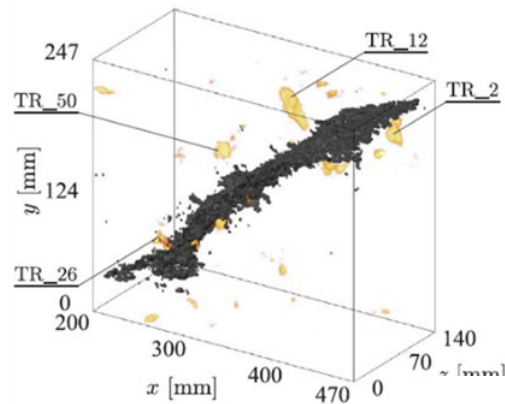
# DC05 – Alina Suchkova @BAM

- **Overall goal:** combining (active and passive) innovative, full wave-equation-based technologies within a single framework to allow for the **acoustic imaging** of the interior of engineered objects for **quality assurance, inspection and monitoring**
- combine the most advanced acoustic tools from NDT and Geophysics into one framework:
  - Full Waveform Inversion (**FWI**) of active data for derive parameter distribution
  - Coda Wave Interferometry (**CWI**) to monitor parameter changes
  - Time reversal (**TR**) for AE to follow crack generation an propagation
  - Reverse Time Migration (**RTM**) to check for internal features in high resolution
- Use the same simulation framework for all to provide model update to each other
- Use the same hardware for several methods (at least for embedded transducers)

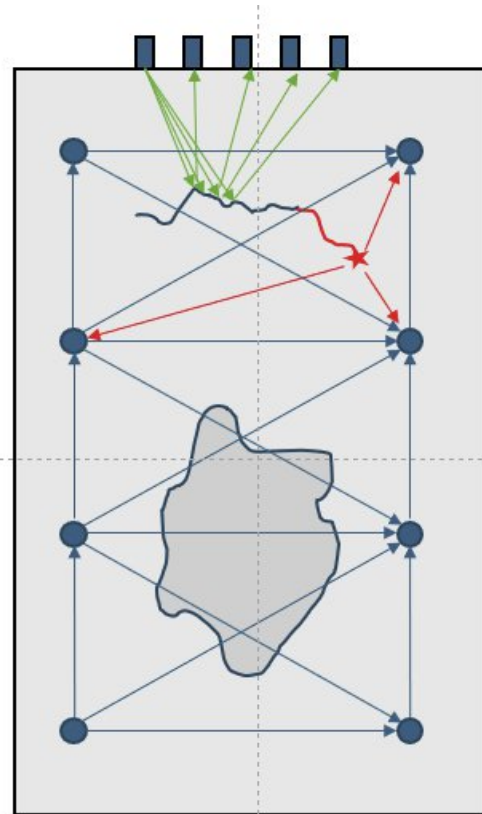
# Status of the work and next steps



Epple et. al., NDT-CE 2022



Localizing active cracking by AE/TR  
Kocur et al., Ultrasonics 2016



## Work done so far:

- Development of tailored data processing workflows
- Completed synthetic FWI tests on ultrasonic datasets

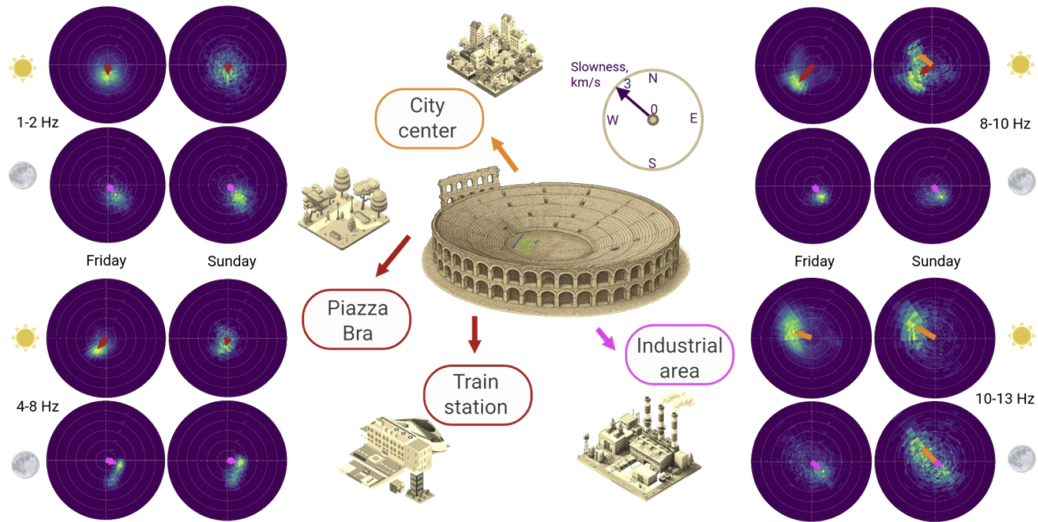
## Coming soon...

- Processing of real (experimental) ultrasonic data

# DC06 – Olga Nesterova @ISAMGEO

- **Overall goal:** develop, test and validate monitoring tools based on seismic surface waves and particularly on the use of passive seismic sources (noise) for the **assessment of natural risks and detailed characterization of the shallow subsurface**, particularly in urban areas.
- This effort will lead to determining **detailed shallow subsurface structures**
  - of shear wave velocity
  - local seismic amplification, assessment of Peak Ground Acceleration
  - anthropogenic underground structures
- Integrate heterogeneous sensors (DAS, MEMS, velocimeters) in densely distributed networks for monitoring ambient noise in urban environments
- The main challenge lies in the capability to deploy dense networks and manage large datasets in order to retrieve spatially dense information in terms of both shallow subsoil characteristics and local seismic source localisation.

# Status of the work and next steps

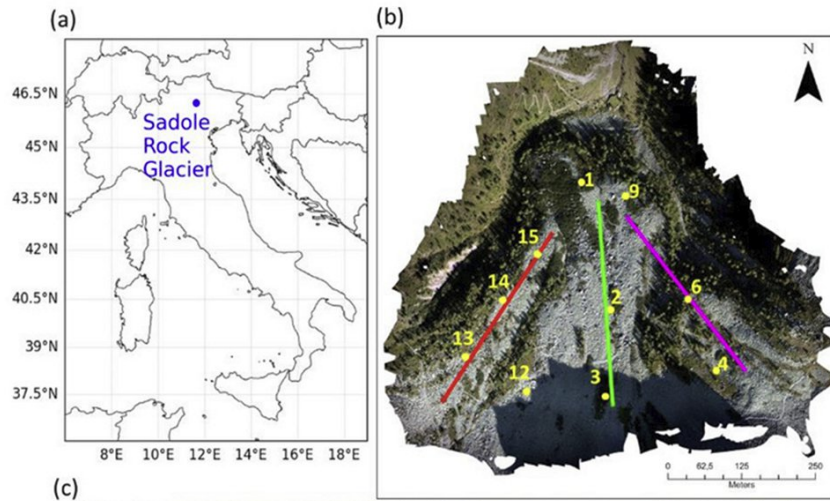


## Work done so far:

- Determination of the spatial and temporal distribution of seismic noise sources
- Identification and characterization of the generated wavefield.
- Reconstruction of S-wave velocity ( $V_s$ ) models
- Development of tailored data processing workflows

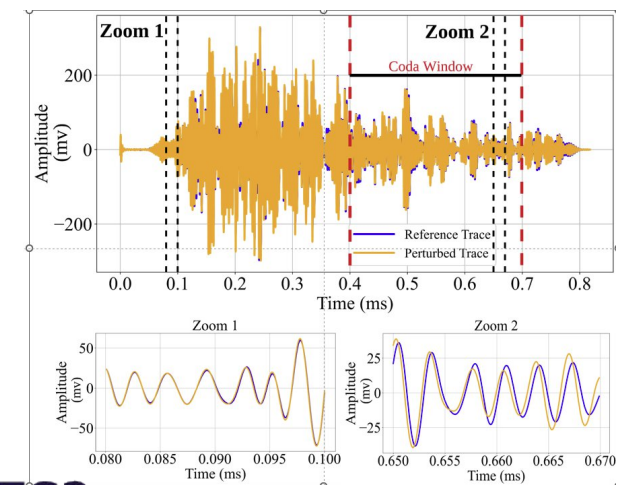
## Coming soon...

- Characterization of complex subsurface structures
- Monitor soil/subsoil dynamics and seasonal variability



# DC07 – Shilan Shaabani @Univ EIFFEL

## Nonlinear Coda Wave Interferometry (NCWI)



### Technical limitations & challenges

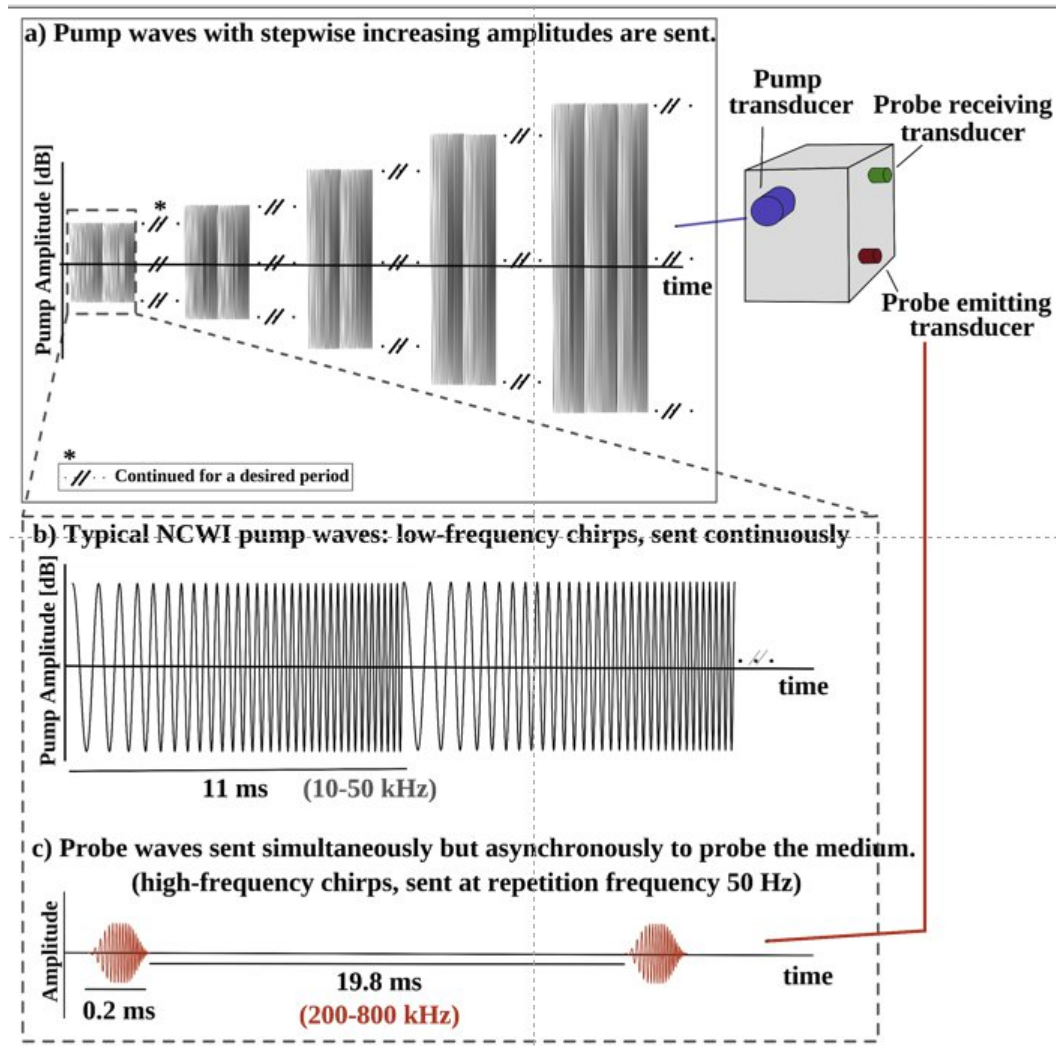
- Quantitative information
- On site applications
- Experimental set-up (optimisation, energy ↔ source: pump/coda,...)
- Environmental bias: temperature, water saturation,...
- Sensors

### Project for USES2

- Imaging: Can we map quantitative information?
- Embed transducers for coda waves?
- Can ambient noise replace the pump?

***"Is it possible to use in-service loading, such as traffic, as passive pump excitation for NCWI-based on-site measurements?"***

# Status of the work and next steps



## Work done so far:

- Assessment of pump parameters (duration, amplitude) on NCWI results
- Noise-based pumping successfully demonstrated in the lab
- Field measurements conducted at the Cheviré bridge: traffic can act as passive pump

## Coming soon...

- Identify reliable damage indicators from field data
- Conduct simplified lab experiments to better understand and reduce complexity.



# WP3: Smart and robust structures and materials



3 DCs

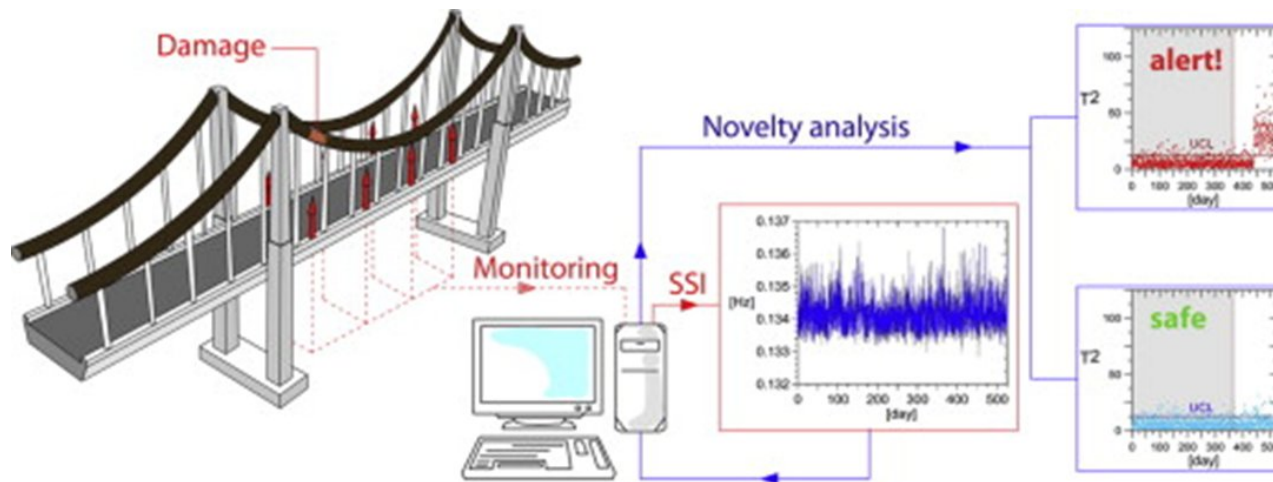
Prof Arnaud Deraemaeker

Université Libre de Bruxelles

**ULB**

# Objectives

To add robustness to automated monitoring systems based on embedded transducers in order to **transition from laboratory applications to field monitoring**, to overcome potential **sensor failure** as well as the high sensitivity of the measured indicators to **environmental and operational variations**, which are responsible for false alarms (not due to damage).



[Comanducci et al., 2025]

Why test new monitoring concepts against in situ conditions?

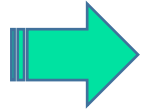
One of the main maturity blockers in diagnostic SHM systems used in common practice is the **lack of robustness**

-Environmental and operational conditions (**Bottleneck#5**)

-Sensor failure, drift, etc... (**Bottleneck#6**)

# Presentation & objectives

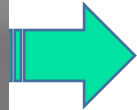
DC08 Jitendra Sharma  
Kumar



Filtering of environmental effects for ultrasonic based monitoring using embedded piezoelectric transducers

ULB

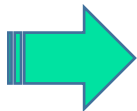
DC09 Luigi Trezza



Study on environmental and operational conditions for SHM systems



DC10 Damiano Gianotti



Sensor data fusion and analysis for reliable premature detection of degradation in full-scale assets



# DC08 - Filtering of environmental effects for ultrasonic based monitoring using embedded piezoelectric transducers

DC08 Jitendra Sharma  
Kumar



## Objective

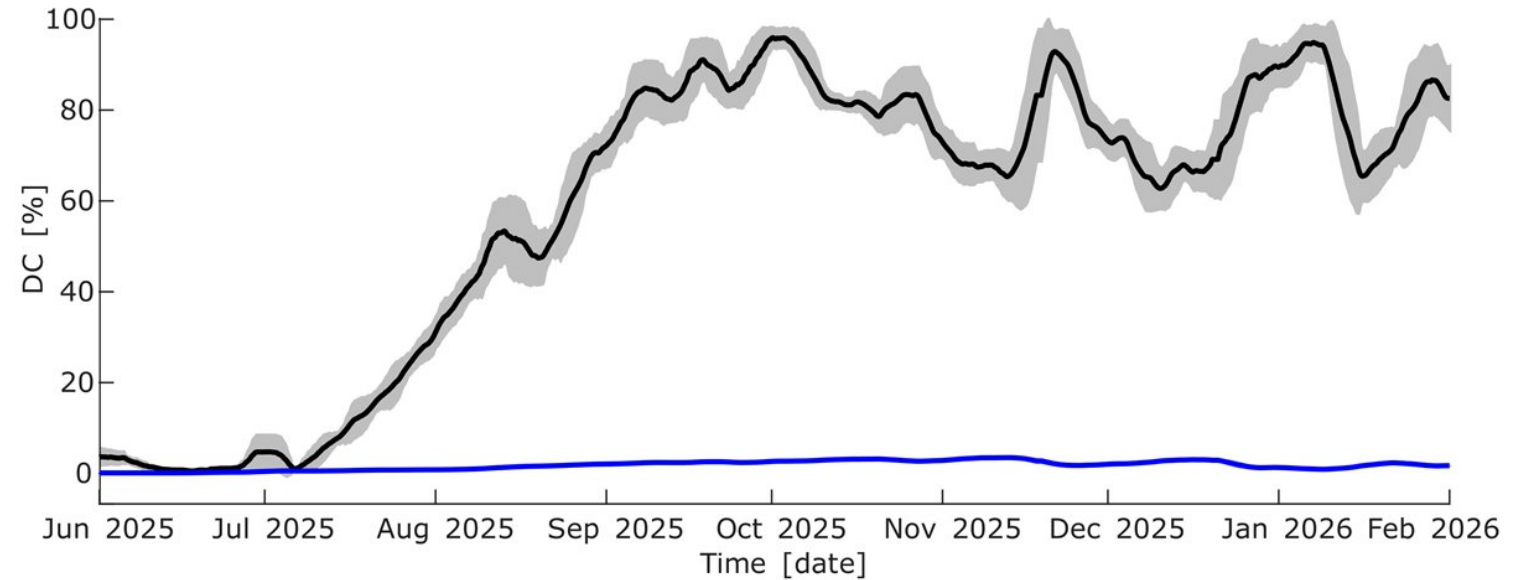
- To develop innovative methods to filter out EOC effects and enhance damage monitoring systems robustness to changing environmental and/or operational conditions by means of:
  - (1) studying **new damage indicators** that are less sensitive to environmental and/or operational changes by (i) improvement of our existing techniques using linear ultrasonics, and (ii) investigation into nonlinear ultrasonic indicators; and
  - (2) using **statistical approaches** to identify a subspace of variations from the aforementioned data and develop techniques to detect changes outside of this subspace. The robustness and efficiency of the proposed techniques will be **tested on the continuously monitored data from the Rogier Tunnel** throughout the project

# What has been done so far

DC08 Jitendra Sharma  
Kumar

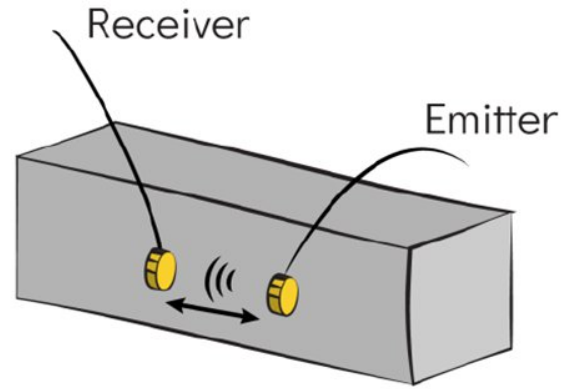


- Development of novel strategies to compensate for changes in ultrasonic signals due to **environmental conditions**
- Study of the effect of EOC on **embedded transducers dynamics** for applications in concrete structures



Evolution of damage indicator in Woluwé tunnel (Brussels)

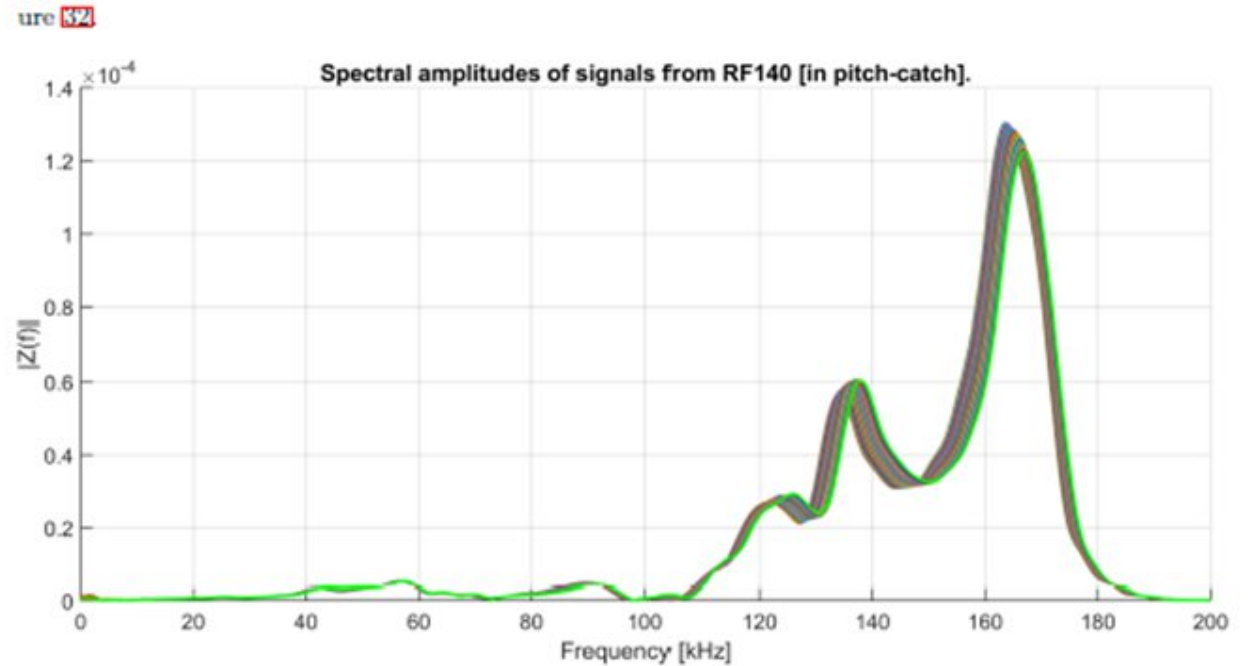
# What is next



DC08 Jitendra Sharma  
Kumar



- Development of enhanced compensation methods to take into account effects of **environmental conditions on embedded transducers dynamics**



Changing dynamics of embedded transducers



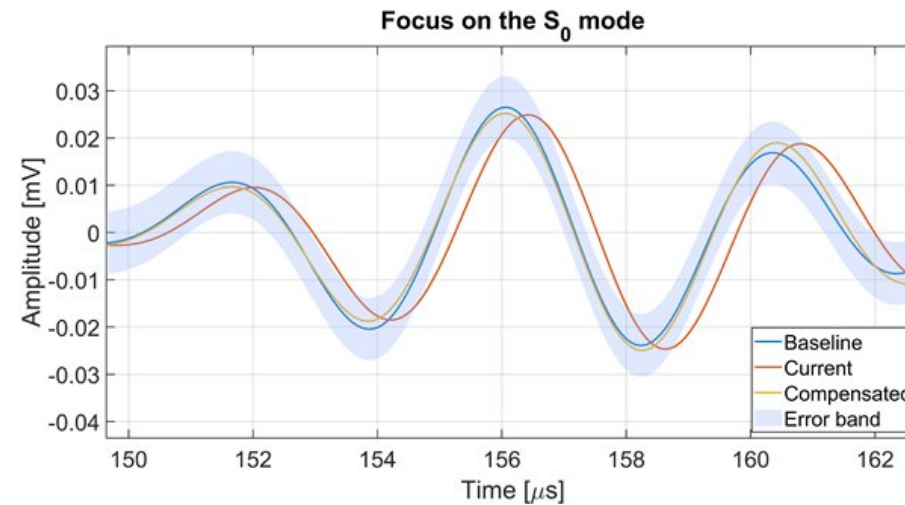
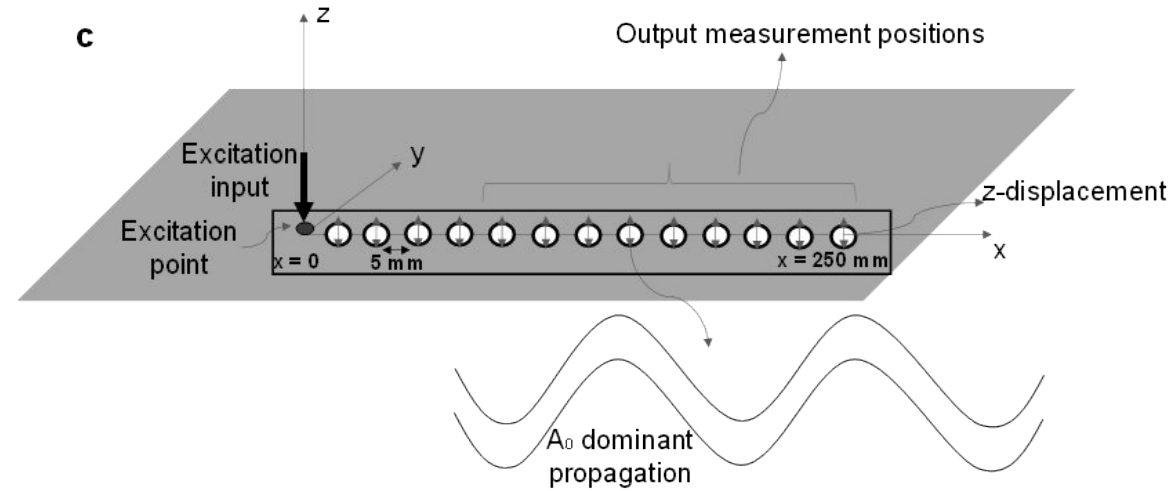
## Objective

- To develop a new methodology for Environmental and Operational Conditions (EOC) compensation in events and damage diagnostic SHM based on mechanical waves (passive and active) derived from the **exploitation of experimental data and data-driven models** (Artificial Neural Networks (ANN), plus advanced signal processing techniques) with additional support from FEM and analytical solutions.
- This development will support the reliable use of diagnostic SHM in actual applications, such as the **maintenance of in-service aircraft composite structures**.
- (a range of  $-70^{\circ}$  to  $50^{\circ}$  C for the temperature and from static to vibrations for the loads).

# What has been done so far



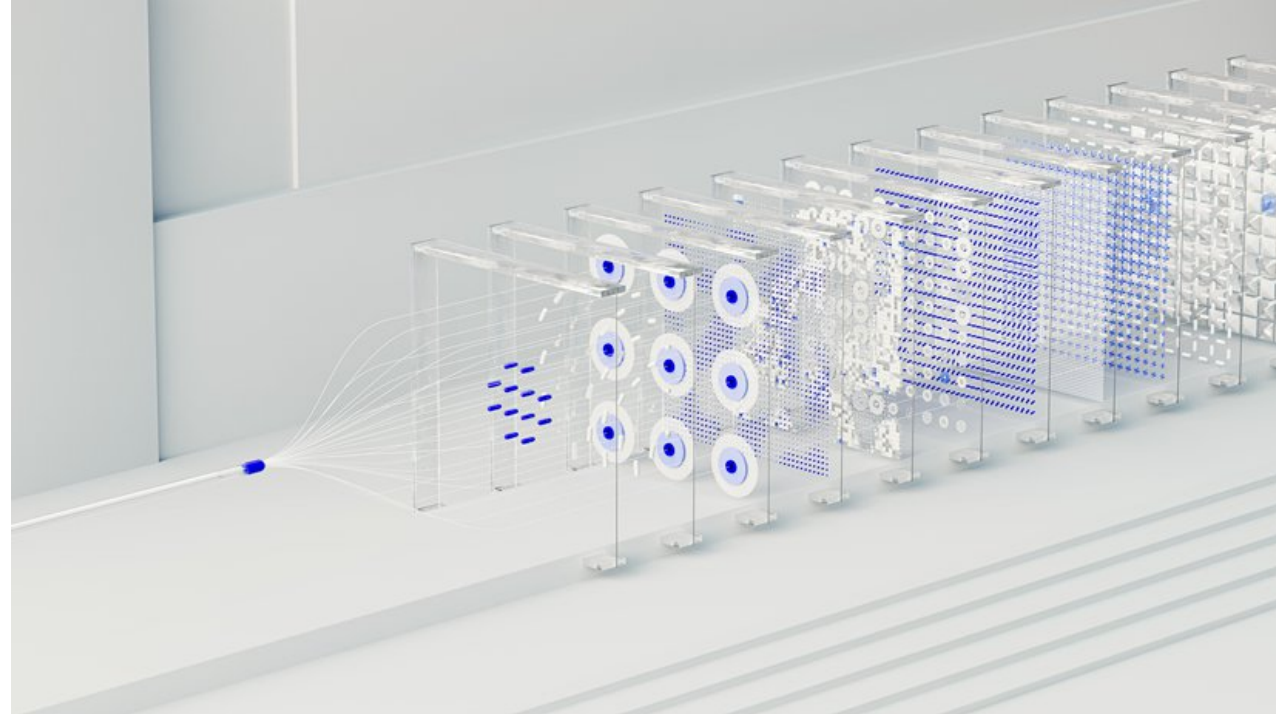
- An effective time stretching compensation strategy has been developed to **correct temperature-induced velocity variations** in guided elastic wave signals



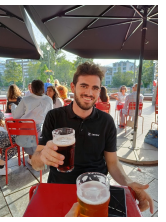
# What is next



- Future research will delve into the development of a method to reduce reliance on user-defined parameters (such as window selection), potentially involving the use of **deep learning techniques** to provide a more adaptable and automated compensation strategy.



Deep learning algorithms



## Objective

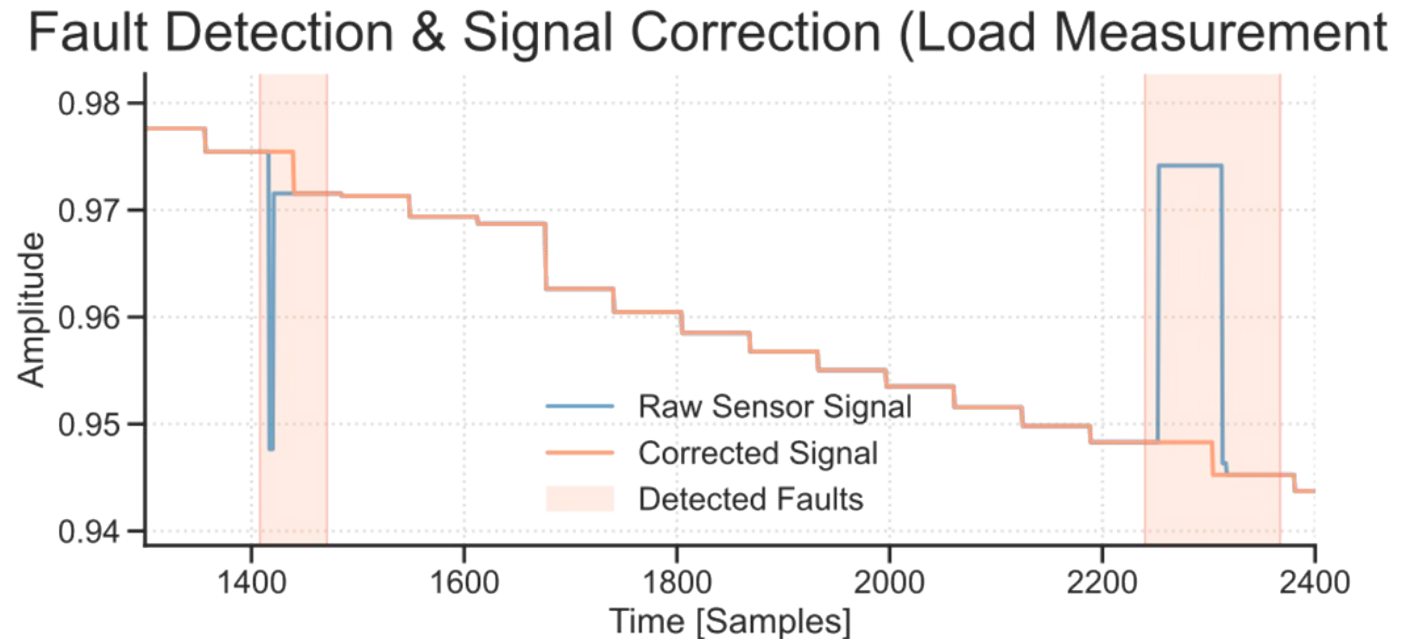
- To track automatically **data integrity and quality**.
- To generate a generic framework for monitoring the quality of data flows generated by **multiple types of sensors installed on civil assets** before being used for (advanced) analysis tasks.
- Algorithms will be developed and then combined with code based on physics, including background knowledge on the sensor type and the corresponding working principle, together with more black box (neural-network based) model approaches.

# What has been done so far

DC10 Damiano Gianotti

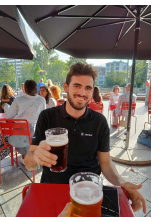


- Dissemination of work on experimental characterisation and Finite Element Method (FEM) simulations to assess the **reliability limits of optical fibre sensors** under high-strain gradients.
- Investigation of **sensor data error detection** and correction routines in aerospace context.



# What is next

DC10 Damiano Gianotti



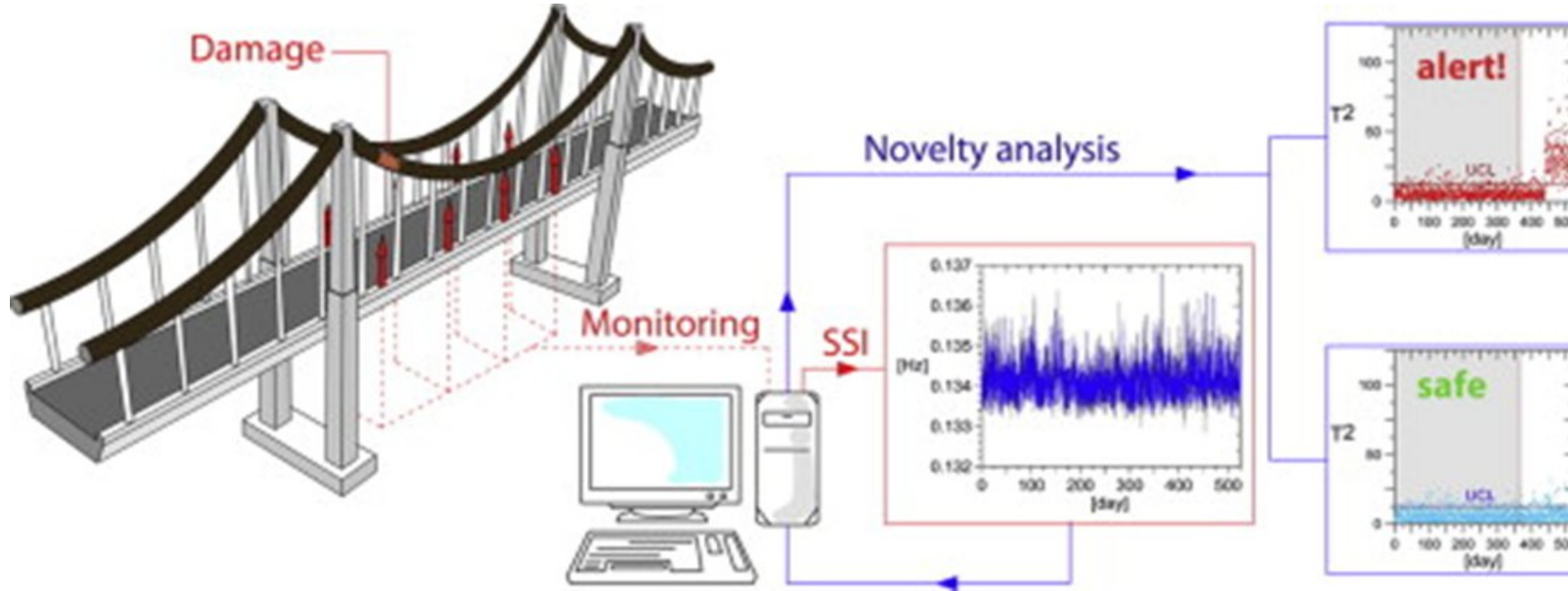
- Development of an unsupervised framework to automatically distinguish and classify **sensor faults** from actual **structural events**



Unsupervised classification

[<https://ai.thestempedia.com/>]

# Increase the reliability of embedded sensing solutions for a large panel of *in situ* materials and structures thanks to new viable data processing and monitoring methodologies



[Comanducci et al., 2025]

Towards robust and reliable  
Smart Structures and Systems.

# See you at the USES2 training school in Nantes, France, 25-29 May 2026



USES2 Industry Days#2

Project 101072599 — HORIZON-MSCA-2021-DN-01

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# Beneficiaries and partners

