# Structural Health Sensing & Monitoring

**Advanced Material department**
Raquel Travieso Puente, PhD
*raquel.travieso@aimen.es*


***11th June 2019***

- SHM

- Fiber Optic Sensors (FOS) & DC-dielectric sensors towards manufacturing and SHM of composites

- SHM
  - Definition
  - Past Catastrophic Failures
  - SHM Applications
  - SHM Advantages
  - SHM Steps

- Fiber Optic Sensors (FOS) & DC-dielectric towards manufacturing and SHM (NERO project)

# SHM - Definition

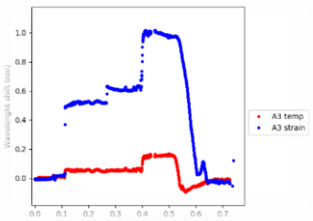
*S*tructural *H*ealth *M*onitoring (*SHM*)

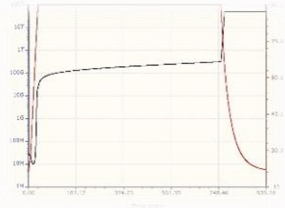
the process of implementing a damage detection that can affect the system's performance and characterization strategy for engineering structures.

System

Sensors

Signal



Analysis

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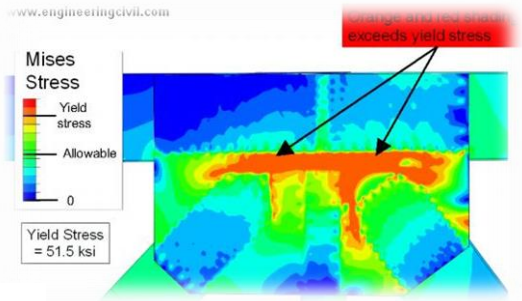
# SHM – Past Catastrophic Failures

Sampoong department store collapse due to overload (Seoul, South Korea, 1955)
502 killed people
937 injured




I-35 bridge collapse (Minneapolis, US, 2007)
Need of repair – failure of gusset
13 killed
+145 seriously injured

Chevron Oil Explosion (Richmond, California, 2013)
Old pipe - Crude oil leaking
+15000 residents needed medical attention

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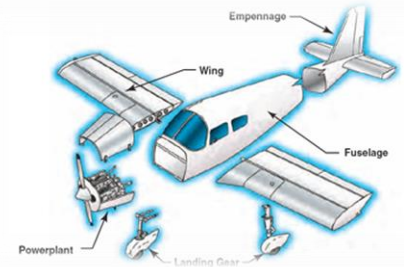
# SHM - Applications

- **Civil engineering**
  - Buildings
  - Bridges
  - Dams
  - Tunnels
  - Mining



- **Chemical installations**
  - Piping
  - Tanks

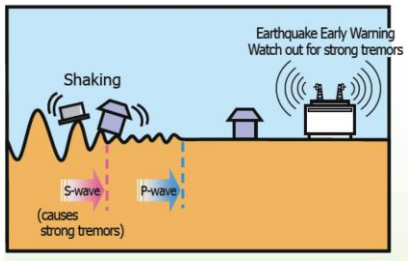

- **Aerospace**
  - Civil and military airplanes
  - Space craft
  - Helicopters




- **Energy**
  - Oil&gas installations and pipelines
  - Wind turbines
  - Nuclear plants
  - Tidal wave generators

- **Transportation**
  - Automotive
  - Trains
  - Ships/boats

- **Geophysics**
  - Soil mechanics
  - Volcanoes
  - Earthquakes

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# SHM - Advantages

- ✓ **Sensoring damage** due to: strain, rotation, temperature, corrosion, leakage, etc.

- ✓ **Manufacturing control**:
  - curing control
  - defect control
  - reduce rejection

- ✓ **In service control**:
  - detecting damage in early stage to enable proactive responses
  - replacing schedule-driven maintenance with condition-based maintenance
  - timely warning of impending failures

- ✓ Increase structures **lifetime**

- ✓ **Time** and **cost effective**

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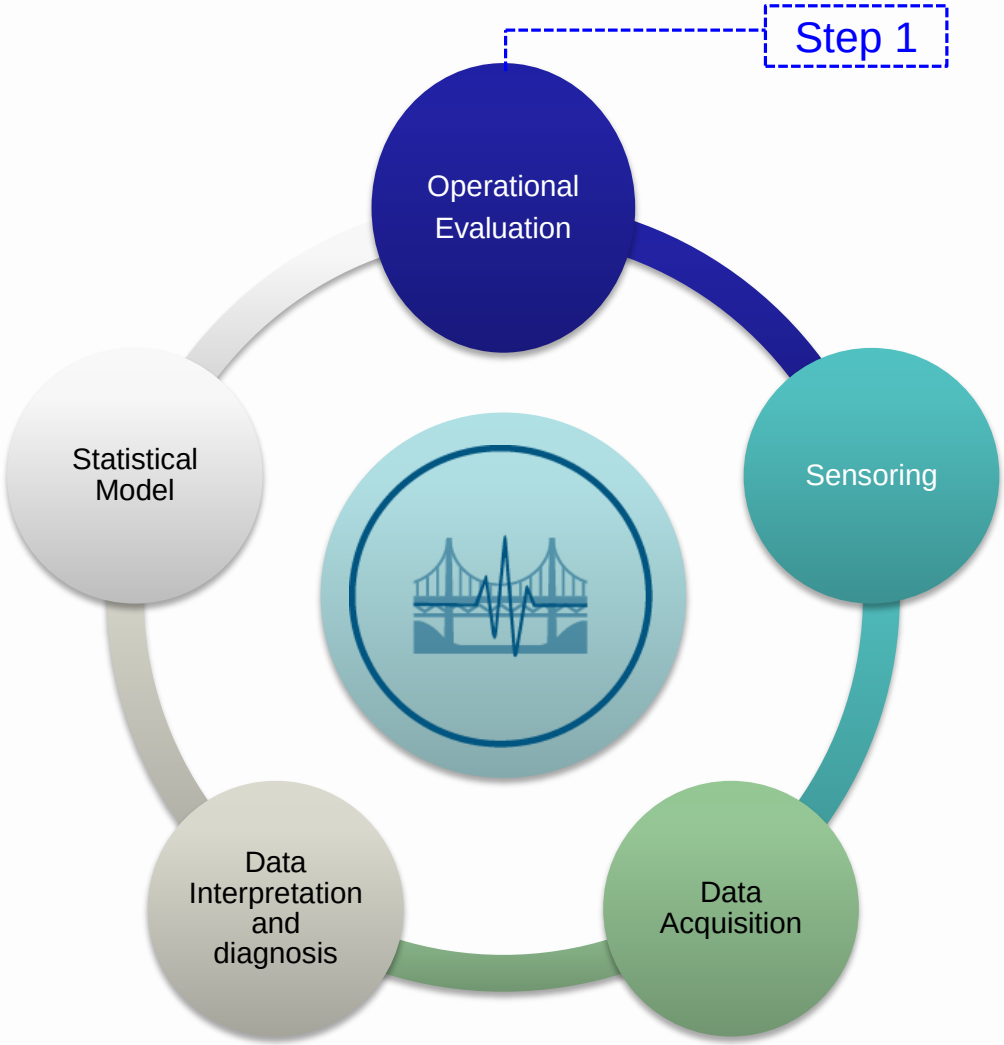
# SHM - Steps

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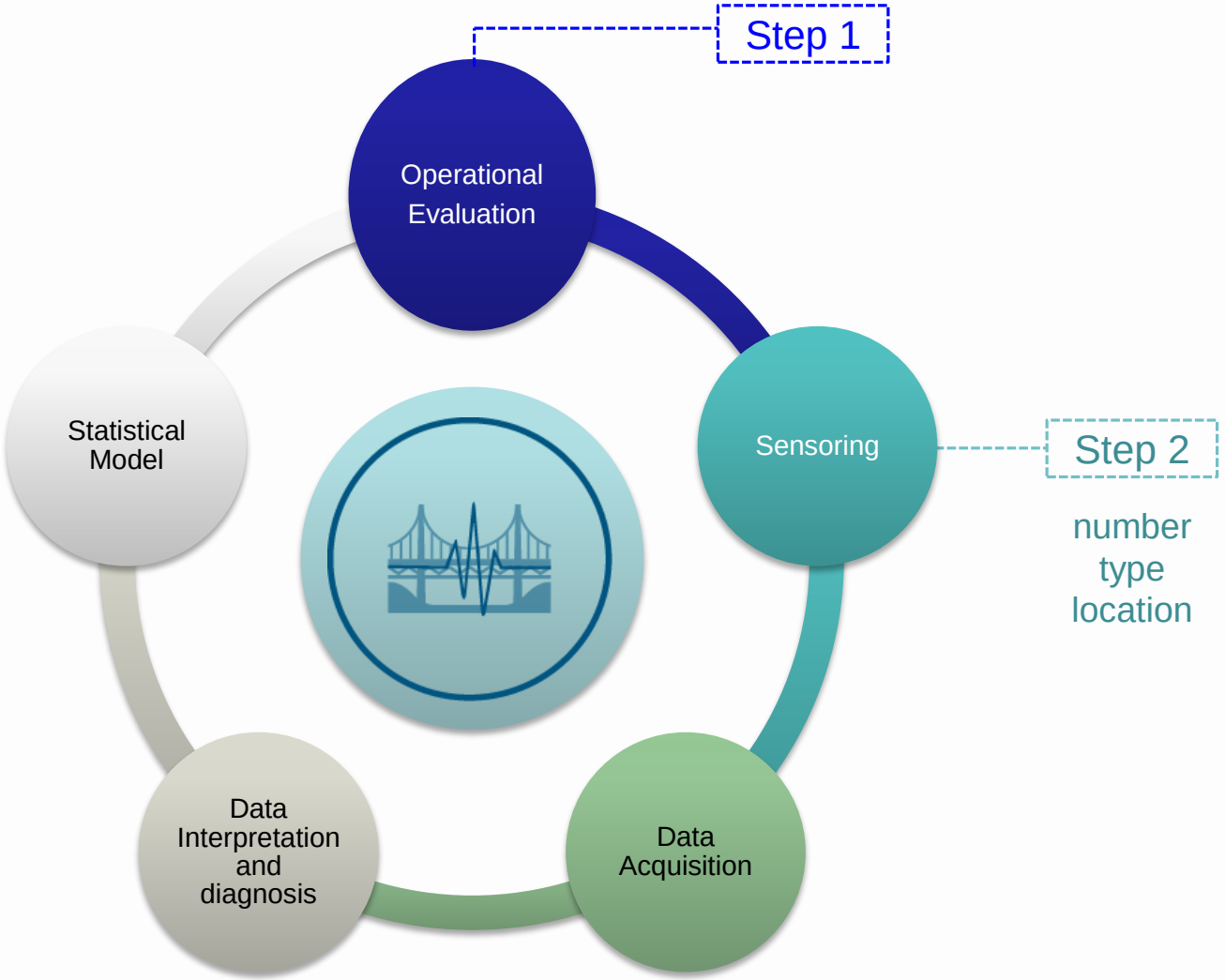


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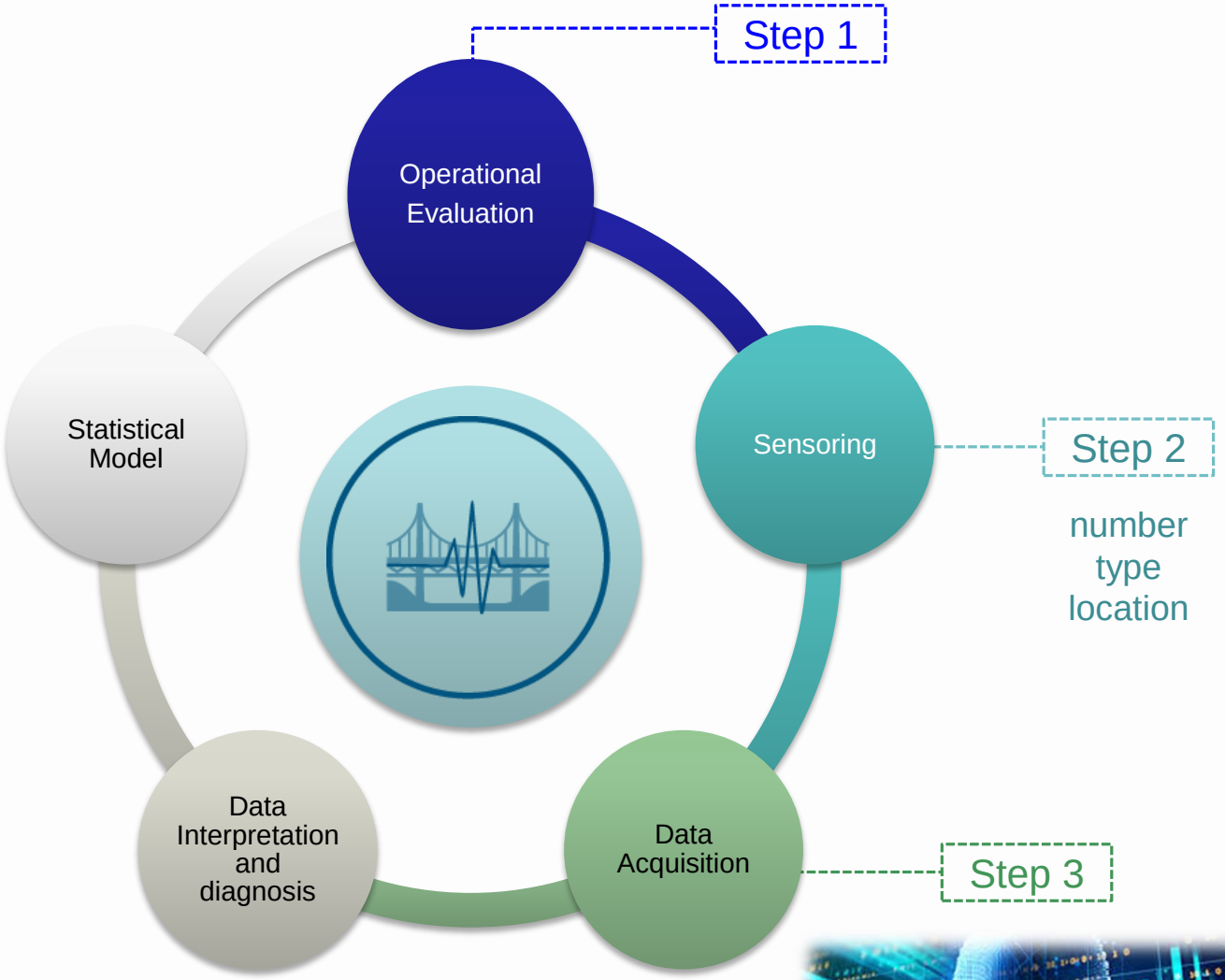


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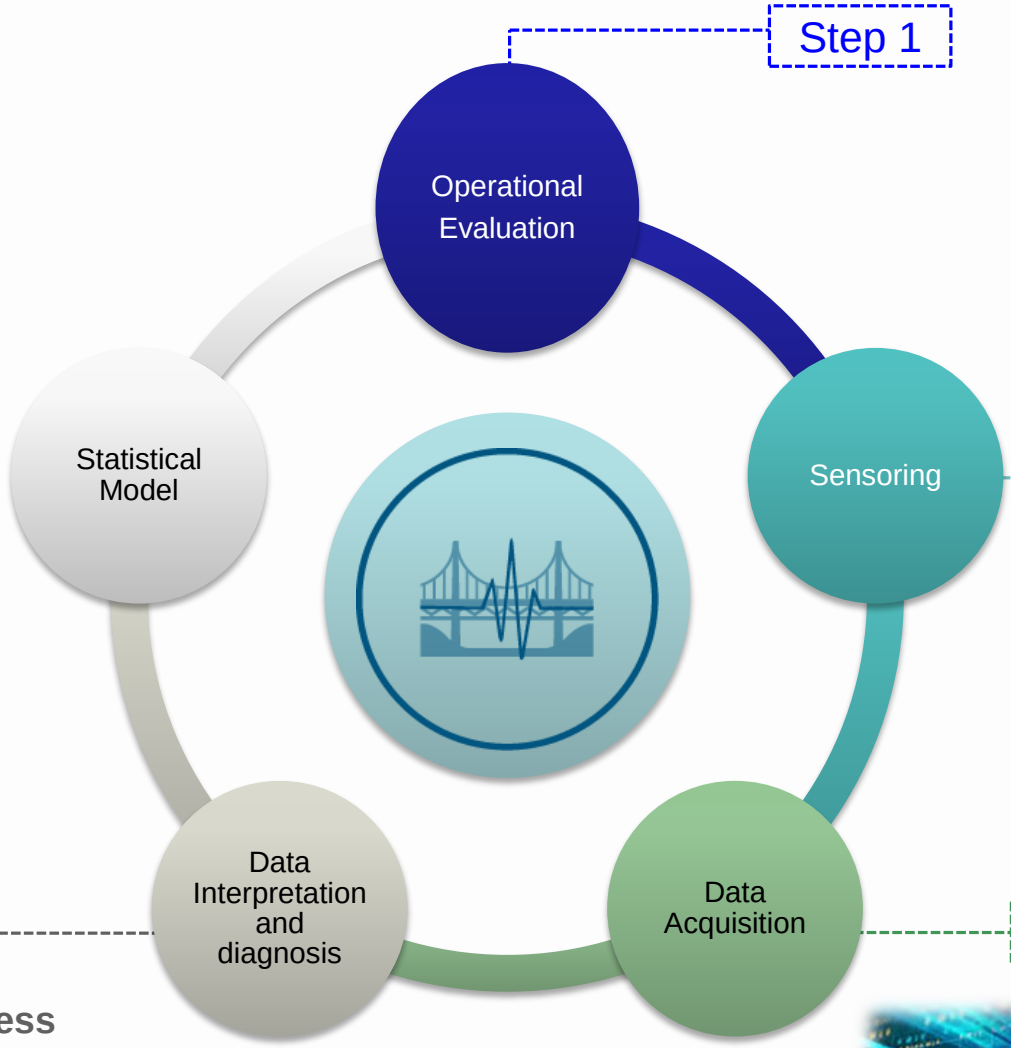


**teaching process**
convert sensor data
to damage information

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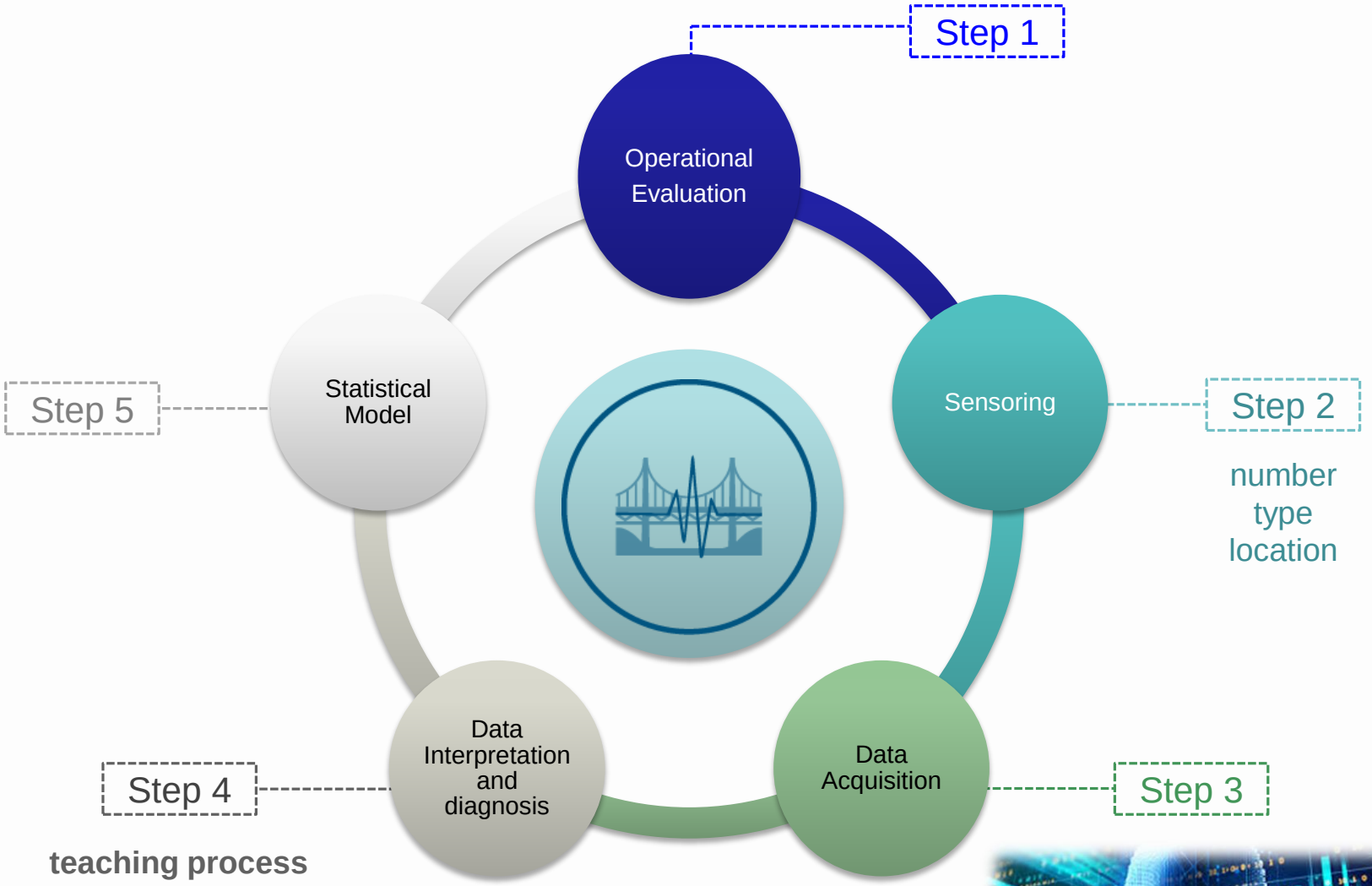


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- Fiber Optic Sensors (FOS) & DC-dielectric sensors towards manufacturing and SHM of composites
  - Aim
  - Technologies & Materials
  - Technology A: DC-Dielectric sensors

  - Technology B: Fiber Optic Sensors (FOS)
  - Real case at Galventus

galventus · CASTRO · Astimar Astilleros Triñones Dominguez S.L. · Fiberglas · tecdesoft 25 años · aimen CENTRO TECNOLÓGICO

# ADVANCED MONITORING SYSTEMS DEVELOPMENT FOR MANUFACTURING PROCESSING AND SERVICING OF COMPOSITES BASED ON NON-INVASIVE EMBEDDED SENSORS

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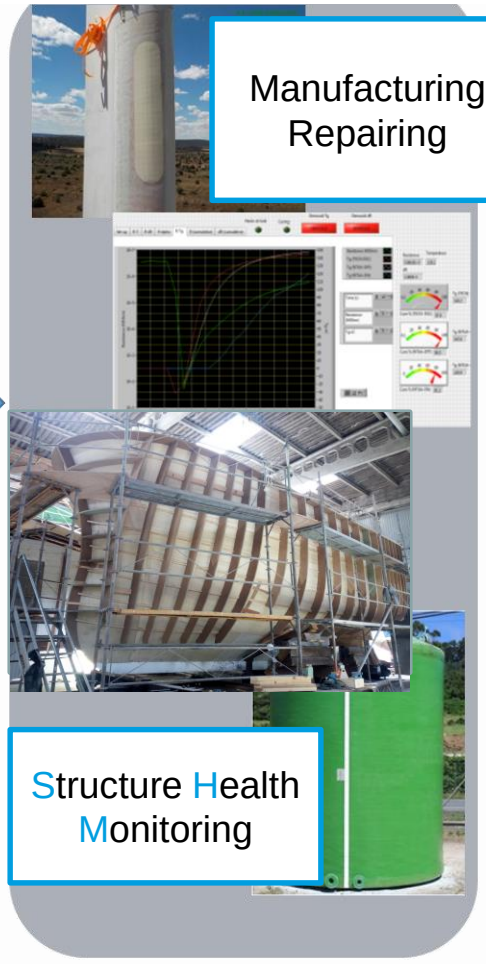
# Aim of the project

## SECTORS INVOLVED


## TECHNOLOGICAL DEVELOPMENT


## USE-CASES

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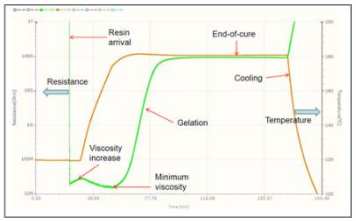
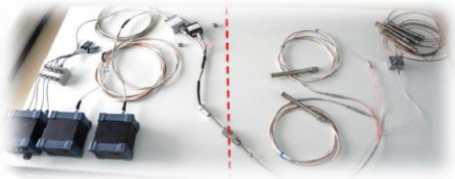
# Aim of the project

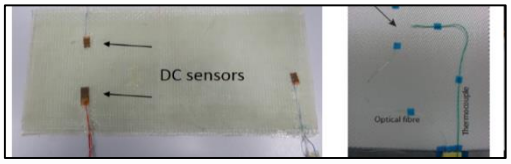
CUTTING-EDGE CONTROL SYSTEMS

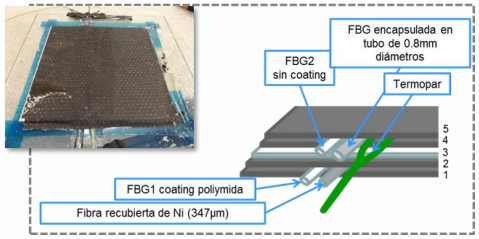
- Greater control in curing process
- New leaking detection

- Ensuring product quality
- Reducing rejection rates in production
- Minimizing manufacturing time

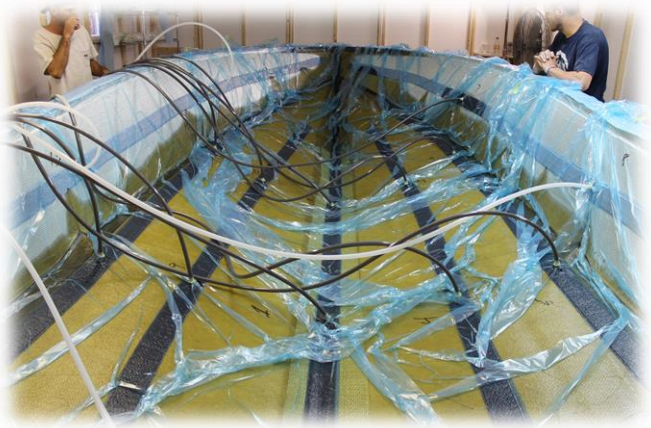





Validation of technology in materials and structures employed by each user



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# Technologies & Materials

## Advanced Materials

Thermoset & thermoplastic composites

Process out of autoclave

Monitoring manufacturing of composites

## Robotic & Control

Photonic sensors

Smart manufacturing – Machine Learning

Manufacturing process control

Structural Health Monitoring (SHM)

### Technology A

### DC-DIELECTRIC SENSORS

Resin flow and cure evolution

Monitoring based on ion mobility or dielectric measurement

Invasive

% curing degree signal

TEACH

### Technology B

### FIBER OPTIC SENSORS (FOS)

Fiber Bragg Grating (FBG) – localized

Distributed - continuous

Non-invasive

Unknown signal

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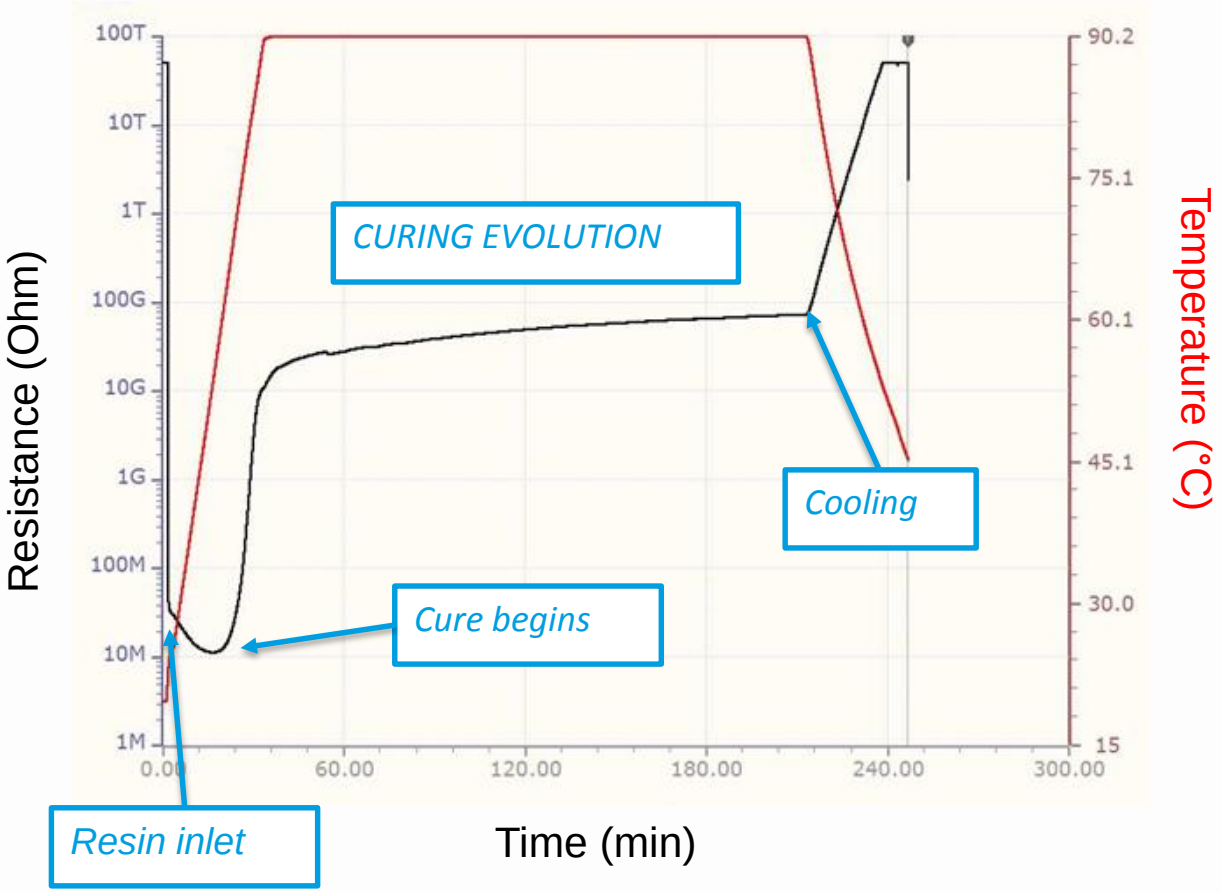
# Technology A – DC-Dielectric sensors

## Monitoring Manufacturing
## Resin flow and cure evolution
## based on ion mobility or dielectric measurement

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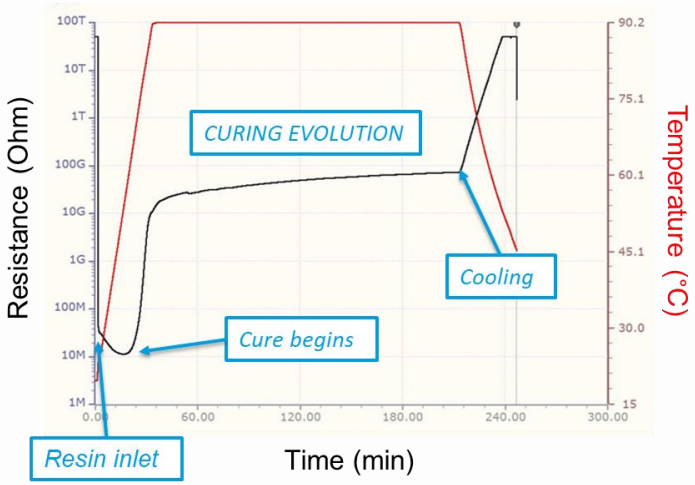


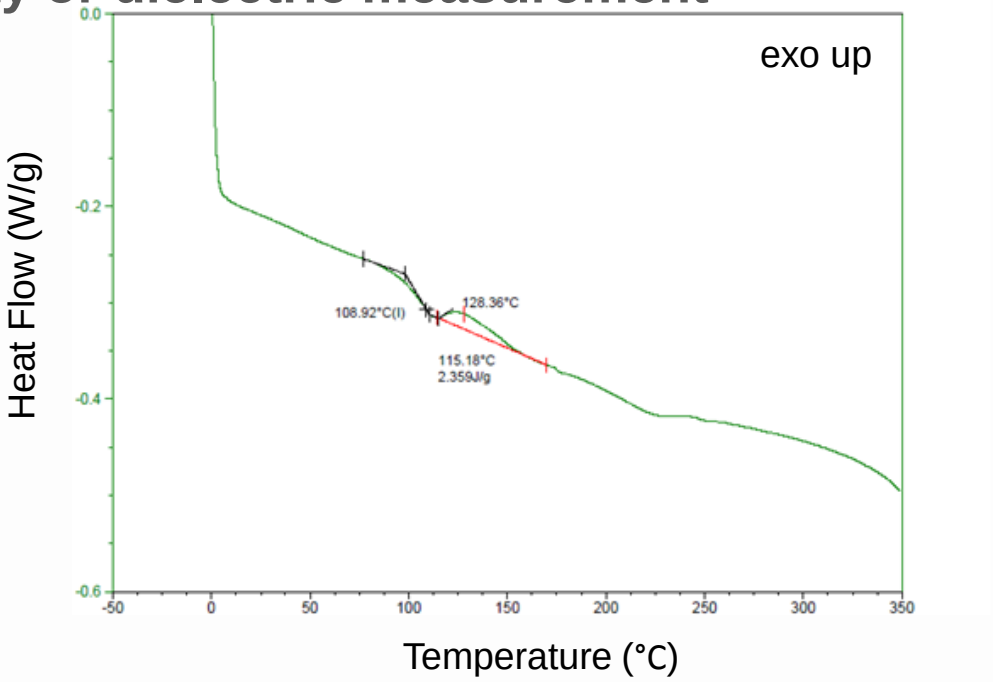


$$\alpha = \frac{H_T - H_r}{H_T} \times 100$$

α (%): curing degree
$H_R$: heat reaction
$H_T$: heat 100% cure

**curing degree** = (307.3-2.4) / 307.3 = **99 %**

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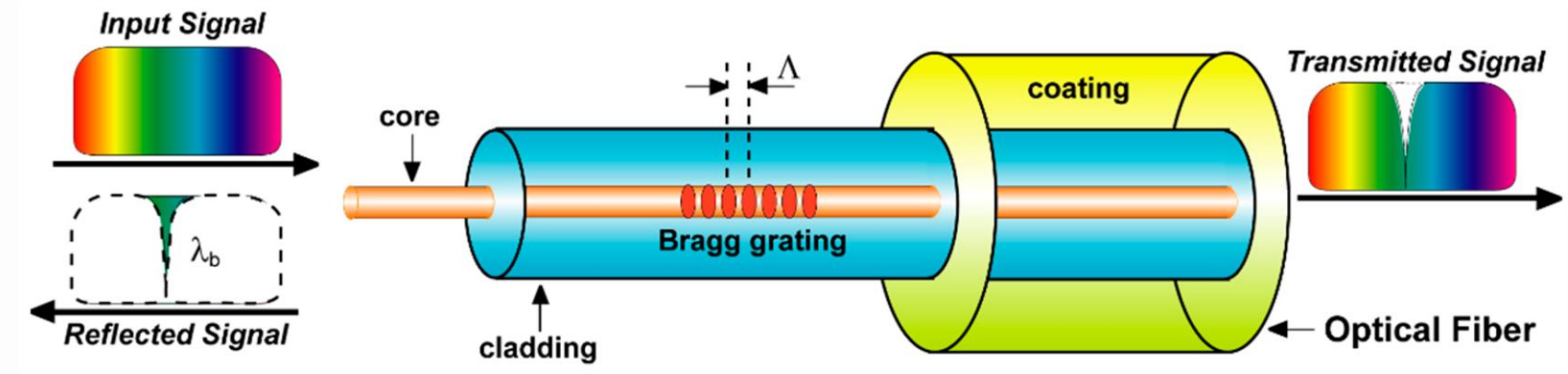
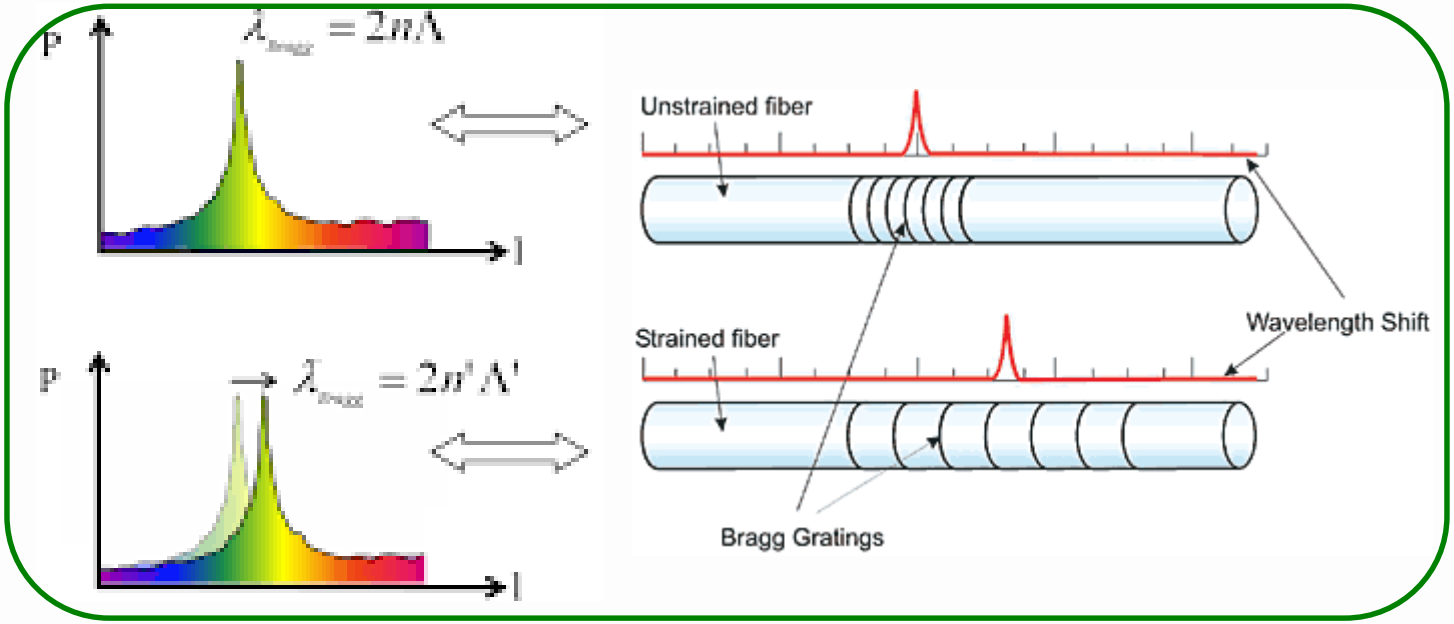
# Technology B - FOS - Fiber Bragg Grating (FBG)

In SHM, most commonly used Fiber Optic Sensors (**FOS**) is Fiber Bragg Grating (**FBG**) sensors, with Multiplexing capacity



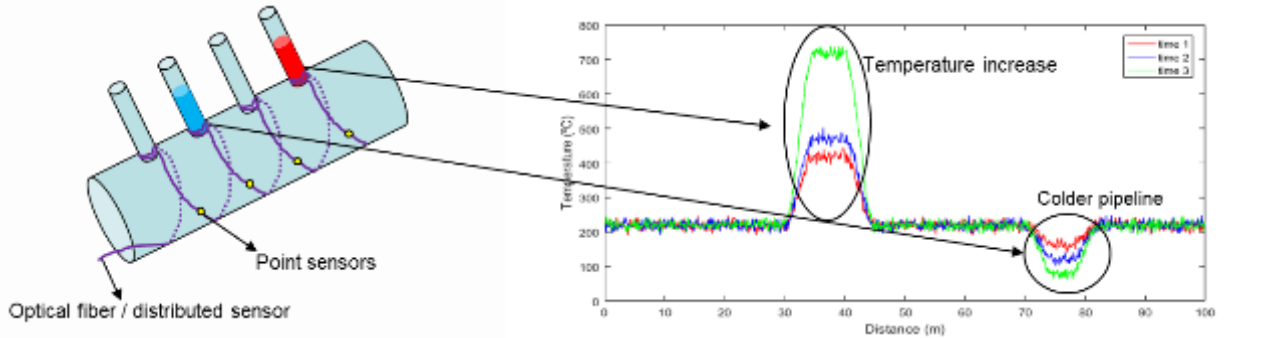
# Technology B - Fiber Optic Sensors (FOS)

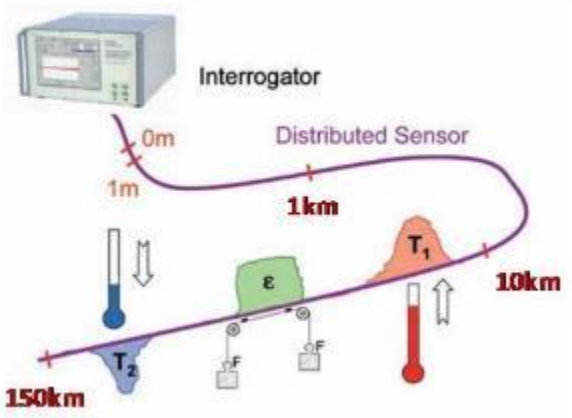
## Fiber optic point sensors interrogator development (FBG)

- ✓ High resolution and accurate measurements in localized locations (**critical points**)

## Fiber optic distributed sensors interrogator development (Brillouin or Rayleigh)

- ✓ Distributed (continuous) measurements along distance



# Technology B - Fiber Optic Sensors (FOS)

## Advantages:

- ✓ Small size 125µm of diameter
- ✓ Light weight
- ✓ Passive: immune to electric and electromagnetic fields
- ✓ Easy integration into a wide variety of structures and materials, including composite materials, with little interference due to their small size and cylindrical geometry
- ✓ Resistant to harsh environments and high temperatures (<1000ºC)
- ✓ High sensitivity and resolution
- ✓ Multiplexing capability to form sensing networks
- ✓ Remote sensing capability
- ✓ Single ended remote operation over several km
- ✓ Can monitor a wide range of physical and chemical parameters: **temperature, strain, humidity, pressure, pH, acoustic emissions, vibrations,** etc.

## Disadvantages:

- ✓ NOT mature technology
- ✓ Fragile
- ✓ Necessary to know its fundaments

**I+D+i Oportunity**

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17:30-19:00 (12th June )
visit to Galventus - reparation of wind turbine blades

**LEADING EDGE REPARATION by Hand lay-up manual process**

- ✓ Study of the damage
- ✓ Surface treatment

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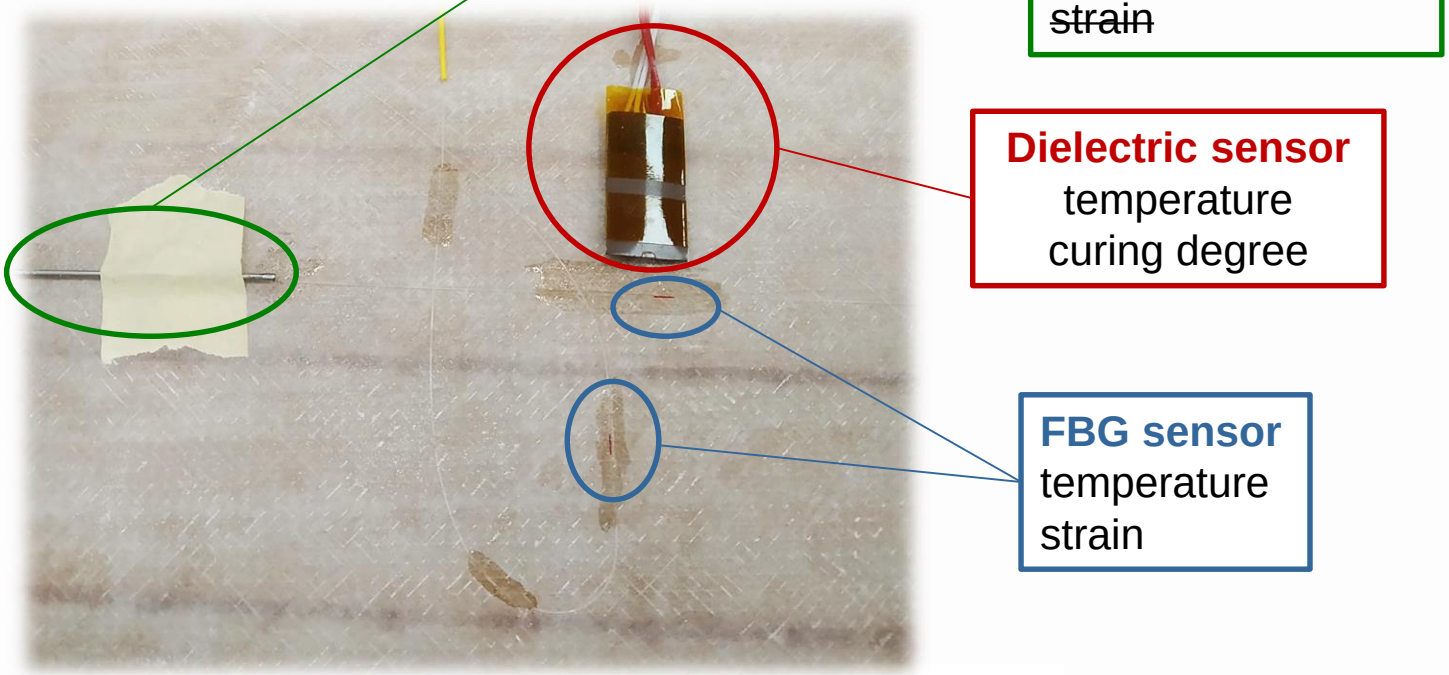


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## LEADING EDGE REPARATION by HAND LAY-UP manual process

- ✓ Study of the damage
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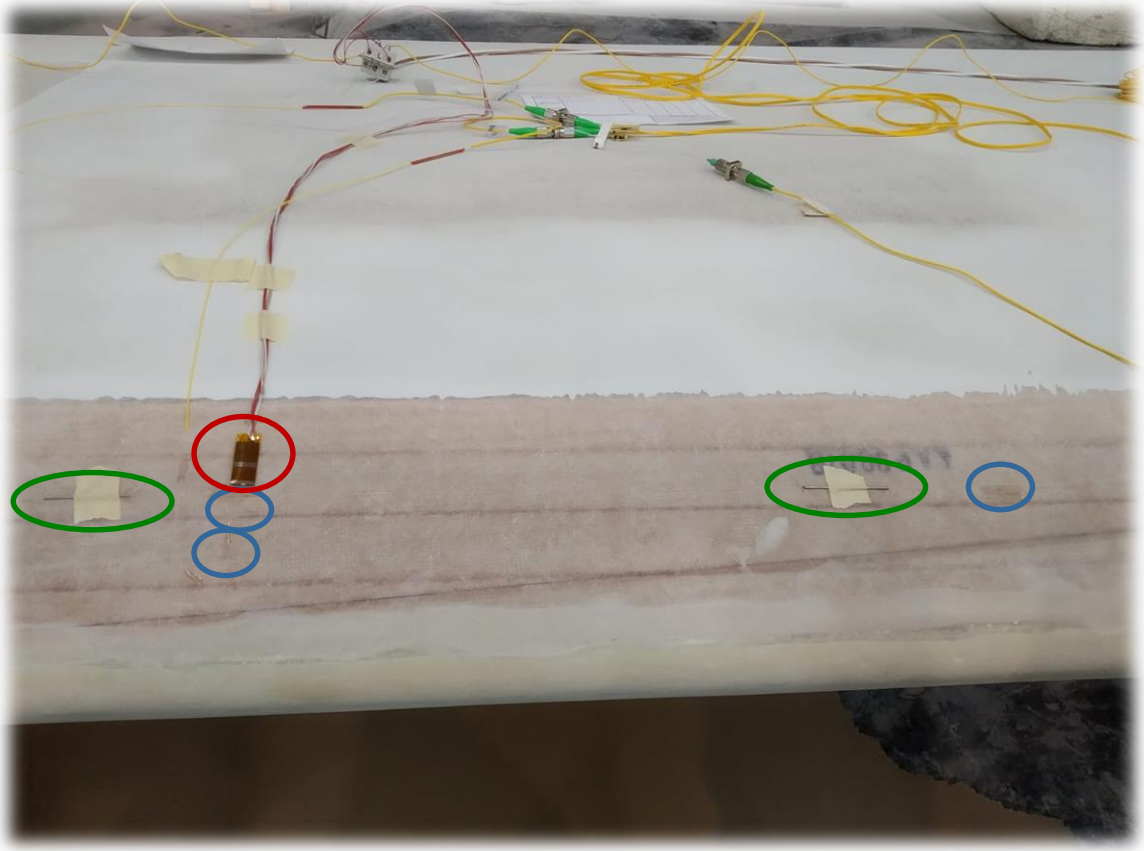
**FBG sensor**
**steel protection**
temperature
~~strain~~

**Dielectric sensor**
temperature
curing degree

**FBG sensor**
temperature
strain



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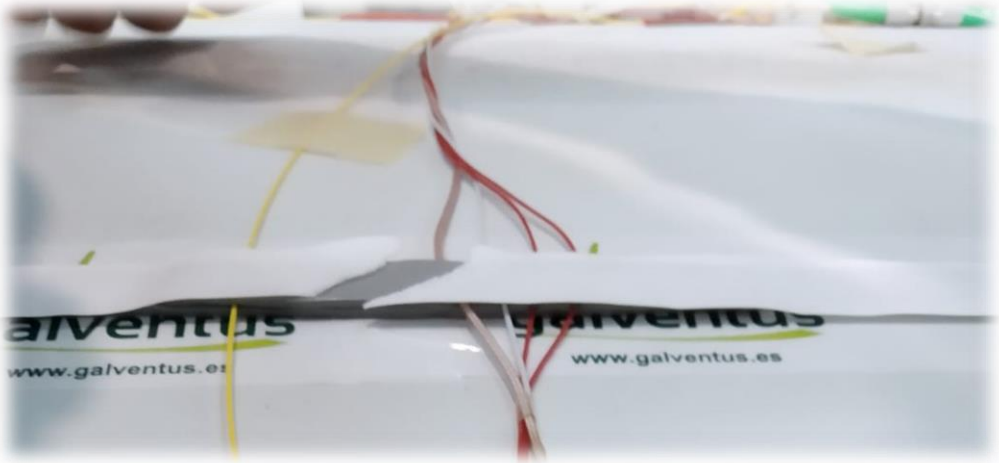
**LEADING EDGE REPARATION by HAND LAY-UP manual process**

- ✓ Study of the damage
- ✓ Surface treatment
- ✓ Sensor set-up
- ✓ Double sided tape to limit the zone to be repaired

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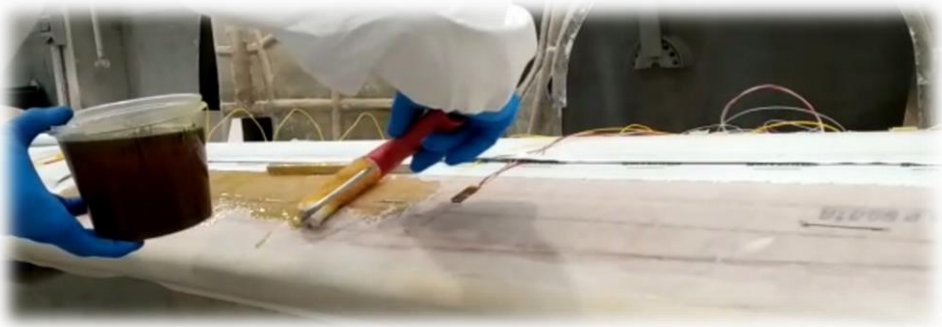
- ✓ Resin + catalyst
- ✓ Reinforcement: glass fiber



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- ✓ Sensor set-up
- ✓ Double sided tape
- ✓ Resin + catalyst
- ✓ Reinforcement: glass fiber
- ✓ Second layer of FBG sensors

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- ✓ Resin + catalyst
- ✓ Reinforcement: glass fiber
- ✓ ……

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- ✓ Second layer of FBG sensors
- ✓ Resin + catalyst
- ✓ Reinforcement: glass fiber
- ✓ ……..
- ✓ Bleeding blanket
- ✓ Peel ply

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- ✓ Peel ply
- ✓ Absorption blanket

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- ✓ Resin + catalyst
- ✓ Reinforcement: glass fiber
- ✓ …..
- ✓ Bleeding blanket
- ✓ Peel ply
- ✓ Absorption blanket
- ✓ Plastic bag > vacuum

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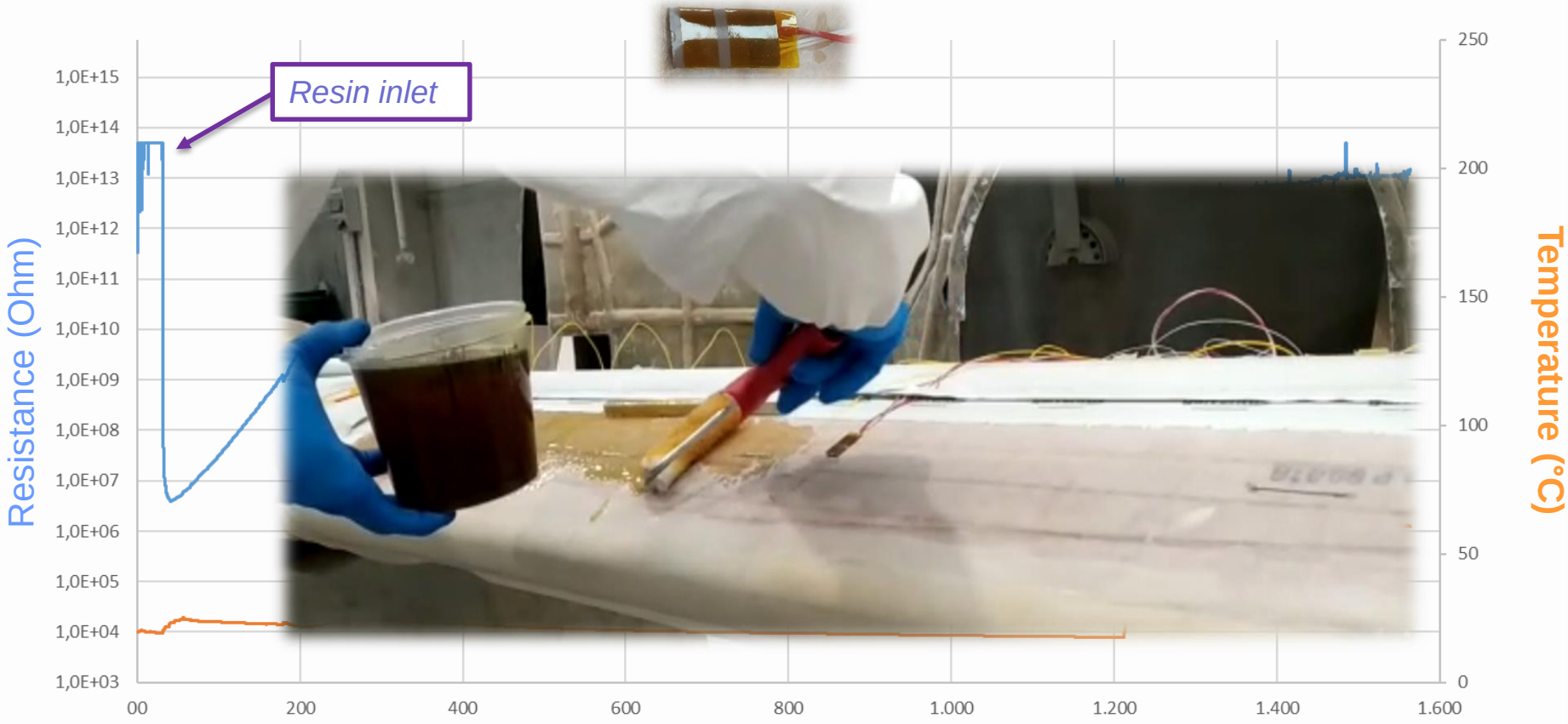


raquel.travieso@aimen.es

17:30-19:00 (12th June )
visit to Galventus - reparation of wind turbine blades

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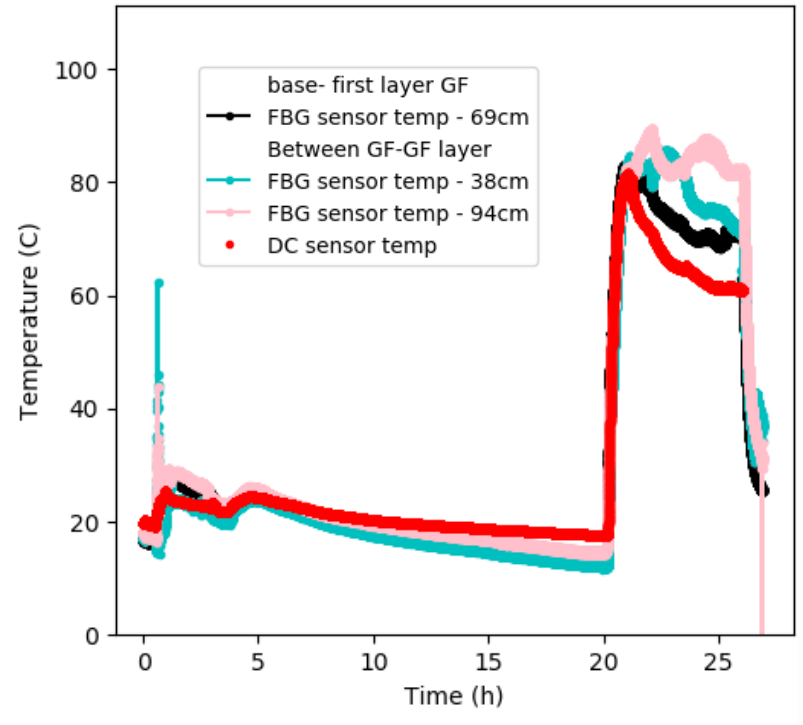


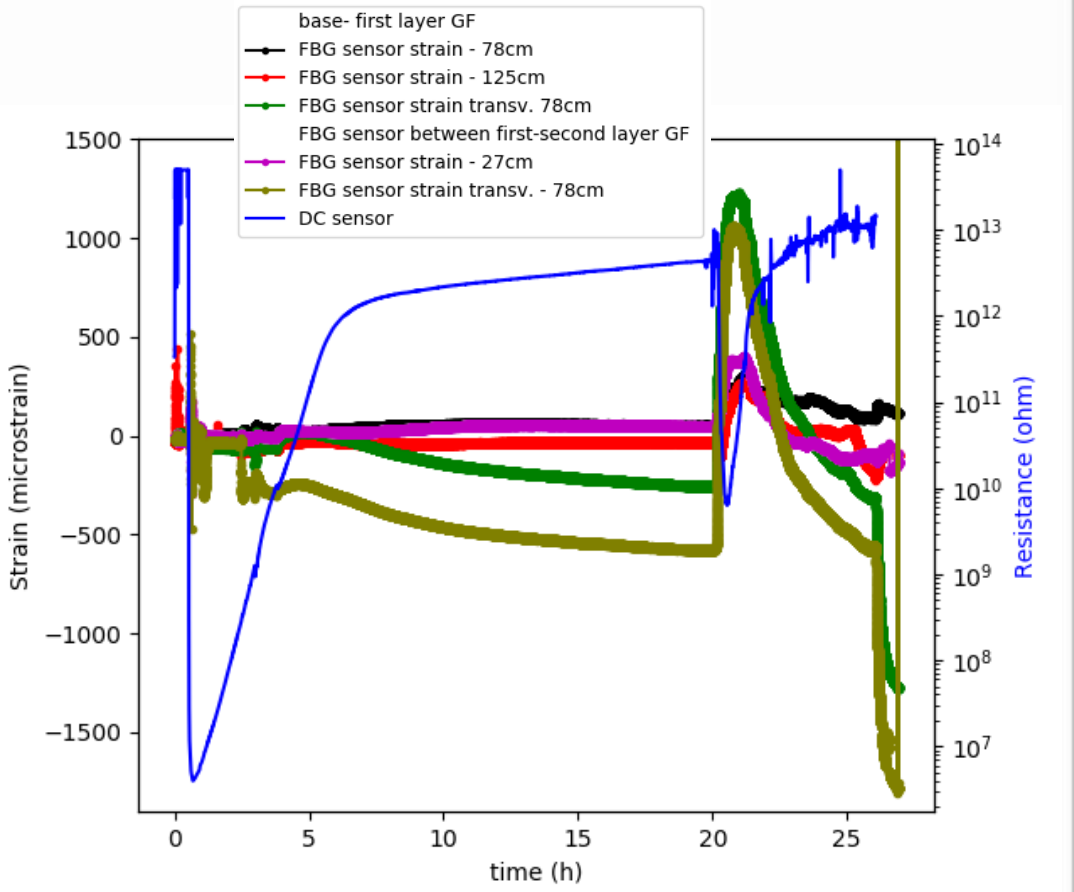


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# Monitoring manufacturing process

Astrimar
Asteleiros Triñanes Domínguez S.L

Tracking the flow of resin infusion is easy, just look for the dark areas to see the progress.

Manufacturing control by monitoring the full process

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# SHM Take home

**Fiber Optic Sensors (FOS)** ✚ **DC-Dielectric sensors** 〓

- ✓ Teaching process from DC to FOS
- ✓ Control of manufacturing process:
  - Vacuum level
  - Resin inlet
  - Wetting of the layers
  - Resine curing degree
  - Defect control
  - Reduce rejection

- ✓ Embedded sensors for in service monitoring (SHM):
  - Detecting damage in early stage (corrosion, strain, leakage, etc.)
  - Replace Schedule-driven maintenance with condition-based maintenance
  - Timely warning of impending failures

- ✓ Lifetime control
- ✓ Improves safety
- ✓ Time and cost effective

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Edificio 103, Planta 2
ES 48170 ZAMUIDO - Vizcaya
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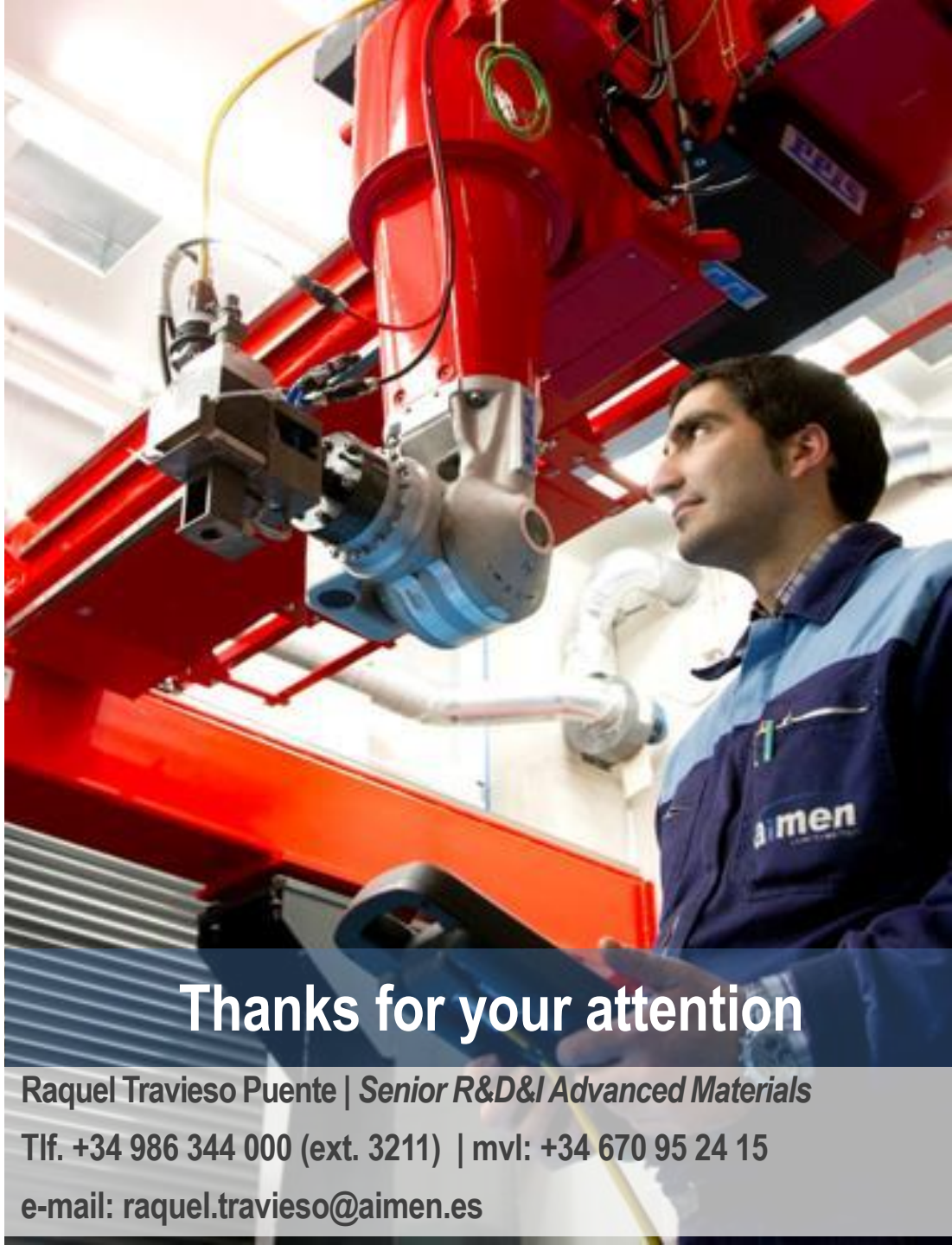


# Thanks for your attention


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