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Instrumenting the Ocean

Data Capabilities of HarshLab

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Bilbo
27/05/2026

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1. Introduction

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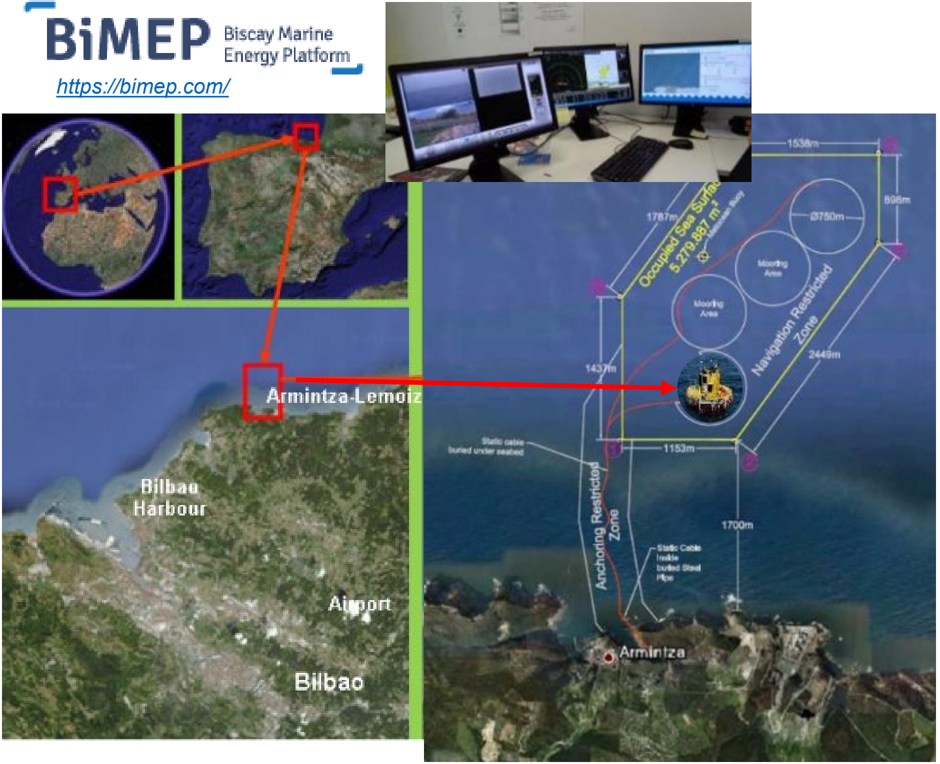
What is HarshLab and where is it located?

BiMEP Biscay Marine Energy Platform
https://bimep.com/



- **Floating laboratory,** moored at Bimep, Armintza (Bizkaia).
- At a depth of 65 meters and 1.6 nautical miles from the coast.
- BiMEP is an open-sea test area with grid connection for the demonstration and validation of ocean energy technologies.
- Fully equipped with subsea infrastructure for connection to the onshore grid::
  - **4 subsea cables 13.2 kV – 5 MW**
  - Controlled and monitored environment
  - **24/7 surveillance**
- Quick access from Armintza port (10 min)

What can be tested?

- **Testing** of **materials** and **components** in a real offshore environment: **atmospheric**, **splash**, **immersion**, **confined areas**, and **seabed**
- Testing of solutions for **protection** against **corrosion**, **fouling**, and **corrosion,** fatigue.
- Monitoring and **data acquisition** for AI-ML models for **O&M** and design. Example: Structural, mooring lines, and dynamic cable.
- **Monitoring** of **environmental** conditions and **marine fauna**
- **Training personnel** in offshore operations

https://harshlab.eu/

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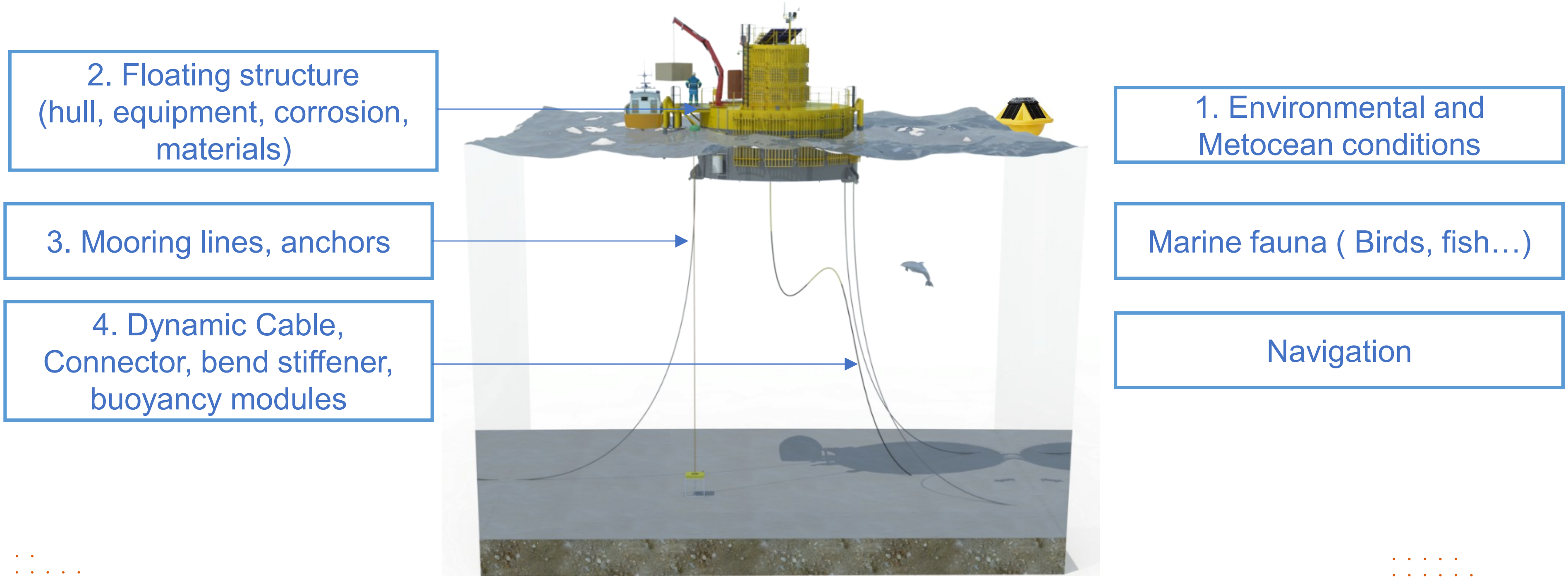
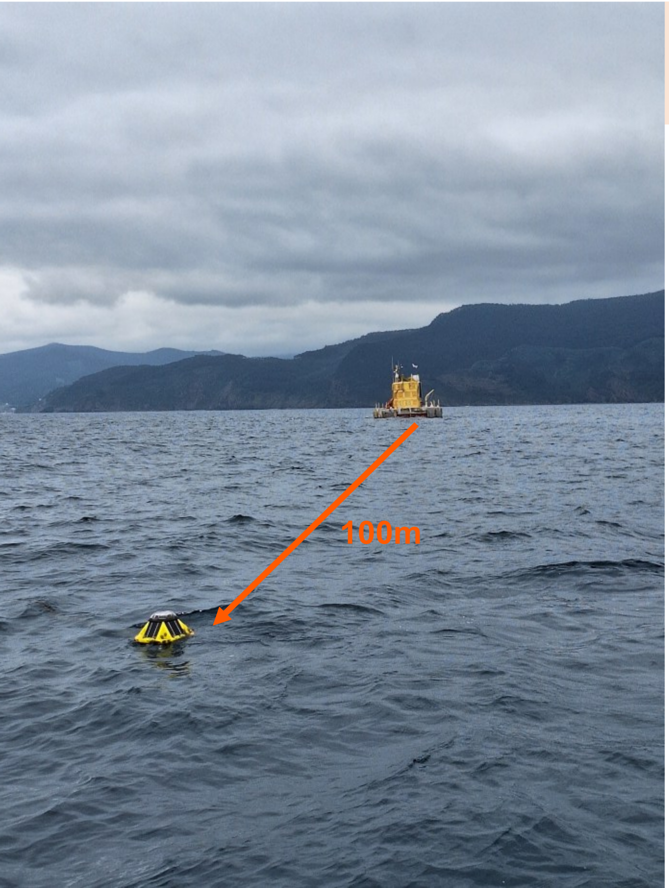
3. Sensors

What can be monitored in HarshLab?



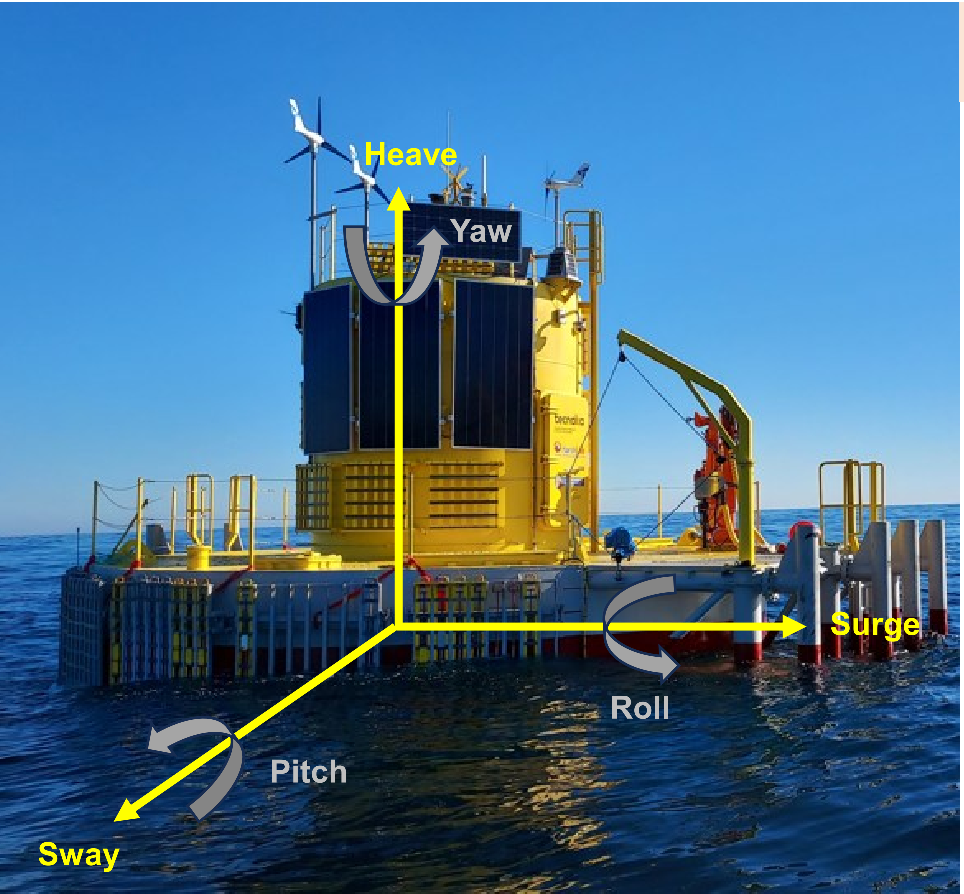
What are we monitoring in HarshLab?



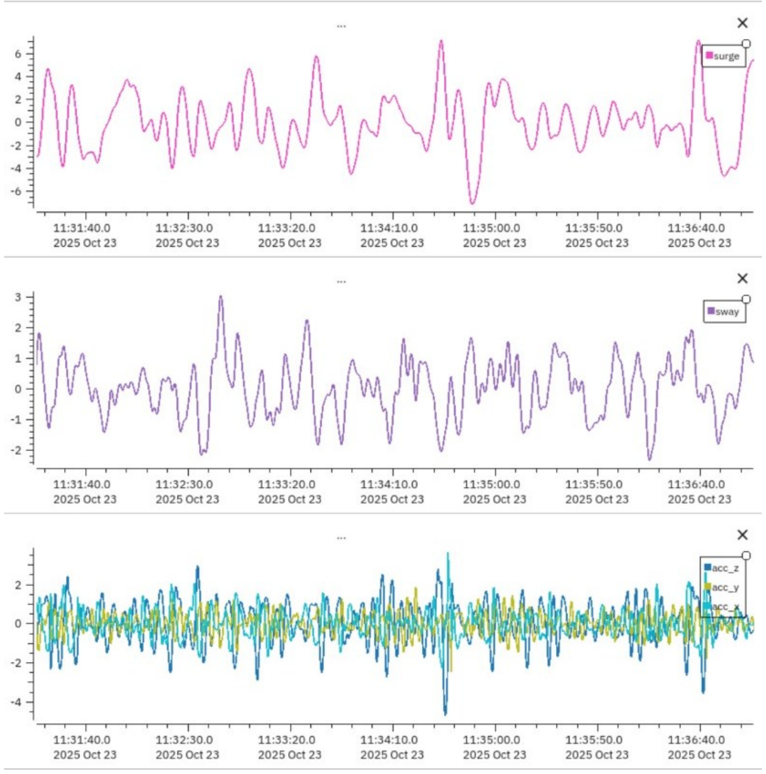
1. Metocean and environmental conditions: Spotter and weather station

- **Spotter Metocean buoy :** $H_s(m)$, $T_p(s)$, directional spectrum, air Pressure, Wind (speed and direction), Water temperature..
- **Meteorological data**: Air Temperature and pressure, Humidity, Wind (speed and direction),Rain rate, Solar radiation
- **Underwater environmental data:** Hydrophone for detection of marine fauna (future)
- **Underwater camera :** Fish detection

What are we monitoring in HarshLab?

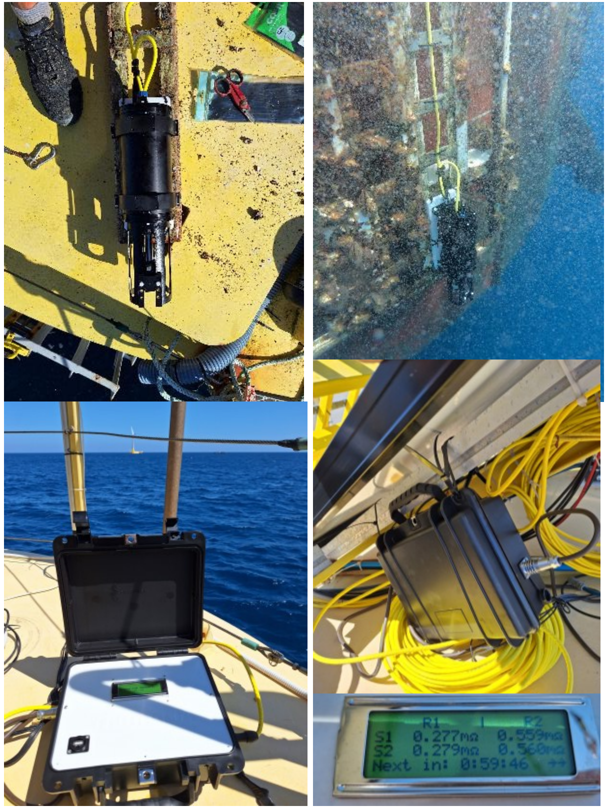


2. Floating Structure 6 Degrees of freedom (📡 GNSS , 🎯 IMU)



What are we monitoring in HarshLab?

2. Materials: Corrosion Sensor (joint development Vicinay–Tecnalia)



Determine the corrosion rate in structures submerged in the marine environment

Estimate the **remaining life** of the element

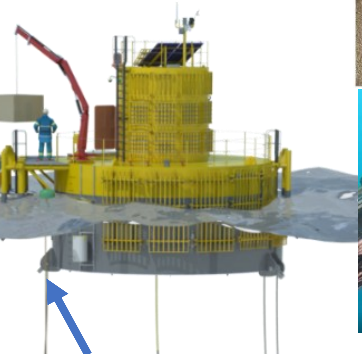
How does it work?

- An electric current is passed through a specimen made of the same material as the structure to be monitored.
- The electrical resistance of the specimen is measured.
- The variation in resistance indicates material loss due to corrosion.
- The corrosion progress in mm/year is calculated from that resistance difference.

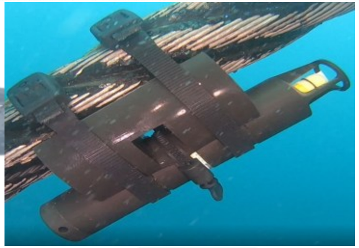
Current status: **TRL5 at HarshLab**, patent PC25-00866-148

What are we monitoring in HarshLab?

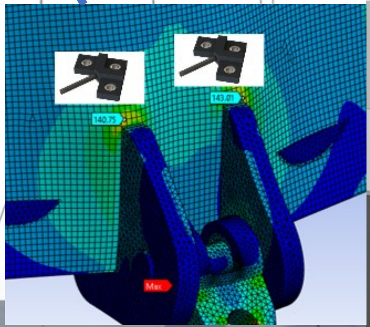
3. Mooring System: tensions

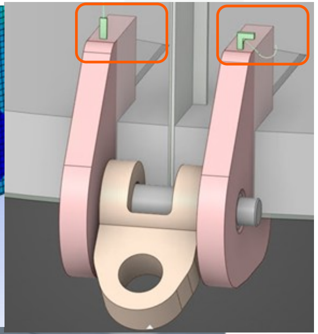


✅ **Strain Gauges (indirect measurement from the inside)**
12 strain gauges inside the hull (4 per mooring point) in areas of maximum mechanical stress..



✅ **Inclinometers for Mooring Lines + Receiver Hydrophone** (Tecnalia-CoreMarine – INTEGRIA project, Float&OM)





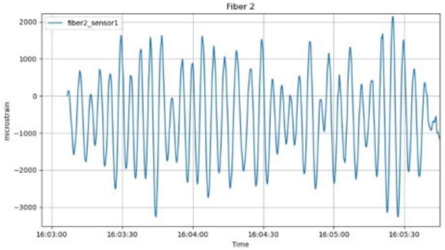
✅ **Strain Gauges (indirect measurement from the outside)**
2 strain gauges on top of each of the 3 padeyes, on the outside of the hull – **ONGOING – Gauges purchased, to be installed**

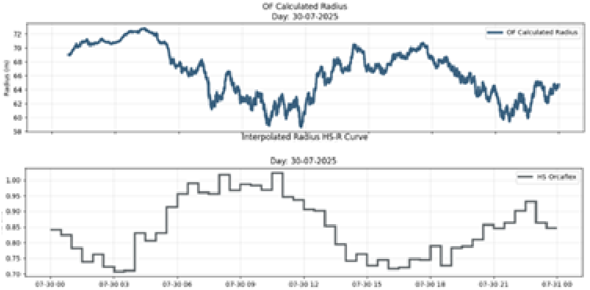
❌ Direct measurement strain gauge for mooring line tension

What are we monitoring in HarshLab?

4. Dynamic Cable: Tensions and curvatures

- ✅ **Bend Stiffener** – 4 strain gauges (curvature measurement)
- ✅ **Bend Stiffner** 4 fiber optic sensors for curvature measurement. Inalia development





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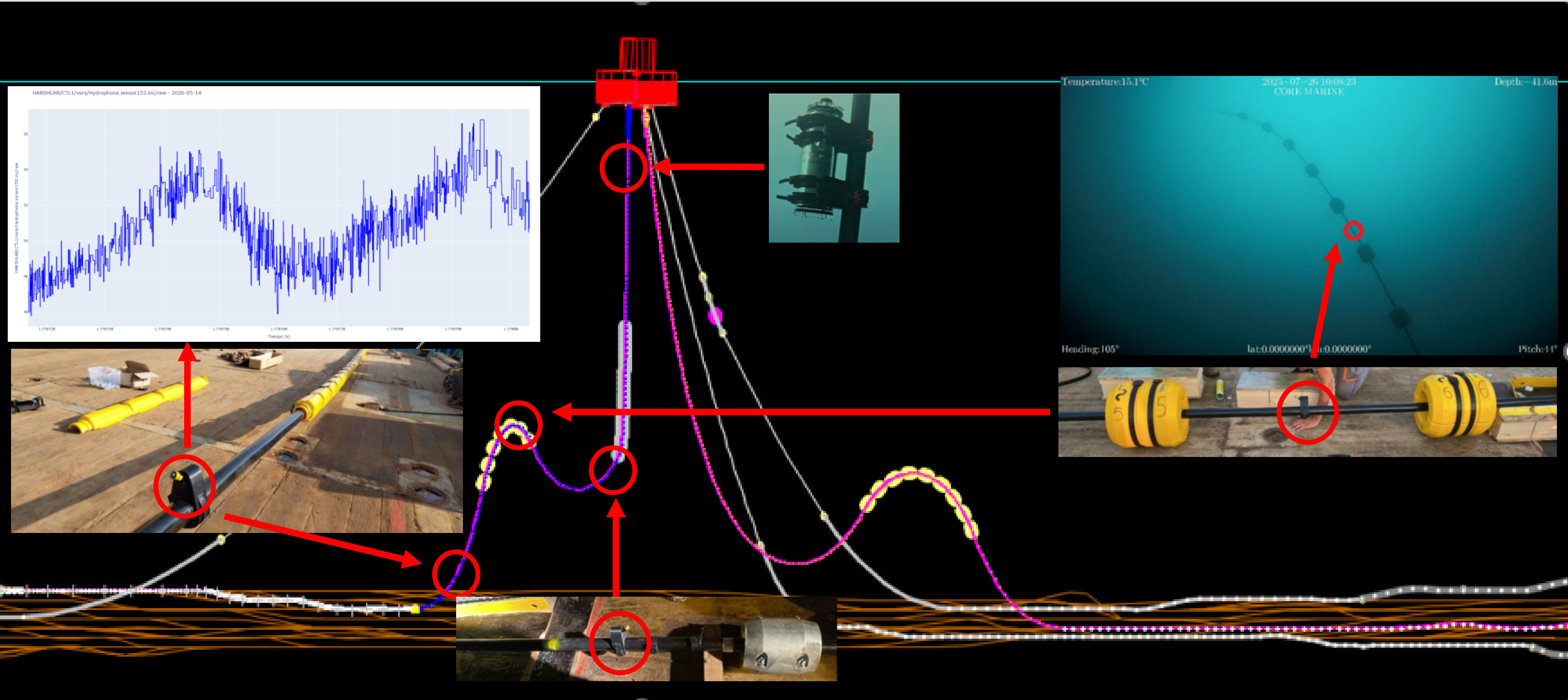
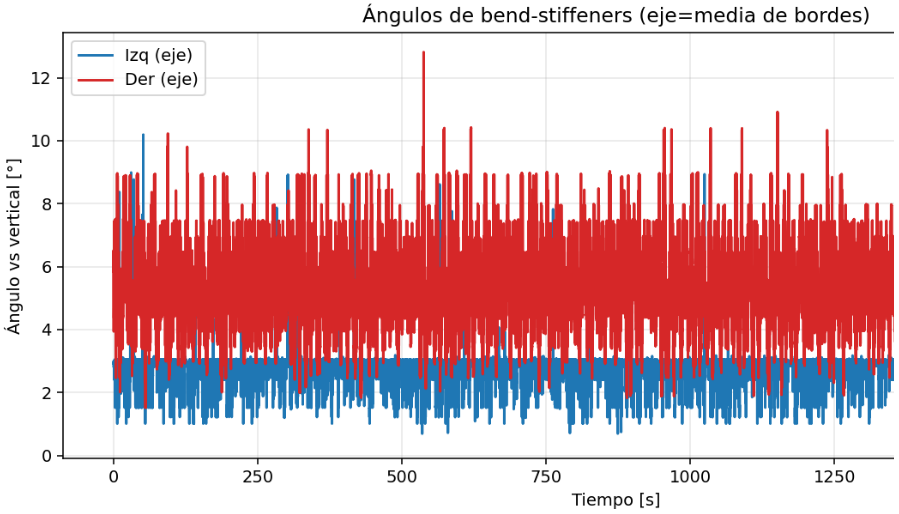
4. Dinamic cable: Inclinations at different points (CoreMarine –Tecnalia)



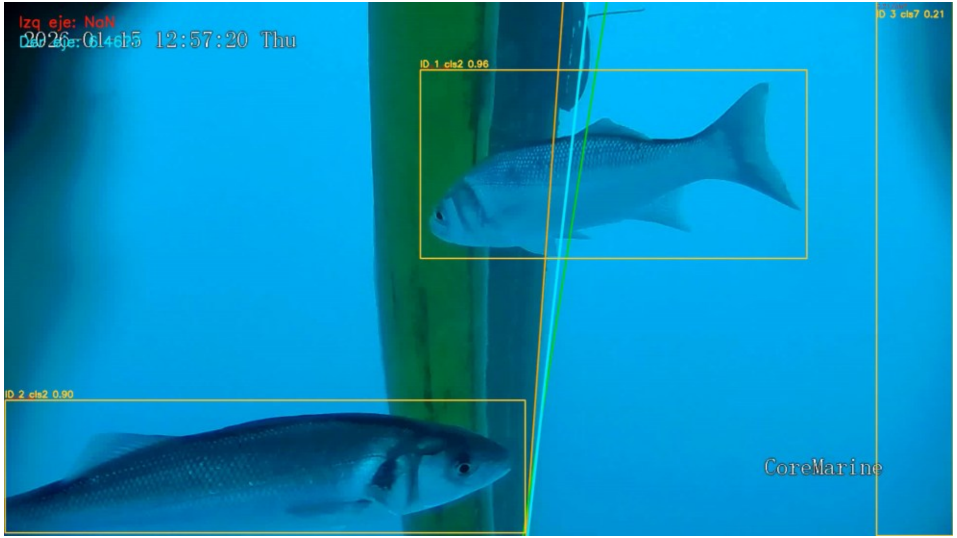
What are we monitoring in HarshLab?

4. Dynamic cable: Monitoring Bend Stiffener and fish with underwater camera

- ✅ Clasical Computer vision for angle measurement



- ✅ Fish detection Based on YOLOv8 trained model



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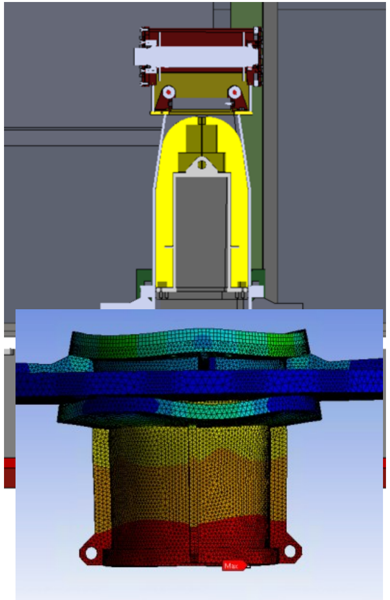
What are we monitoring in HarshLab?

4. Dynamic Cable–Ditrel Connector: Stresses

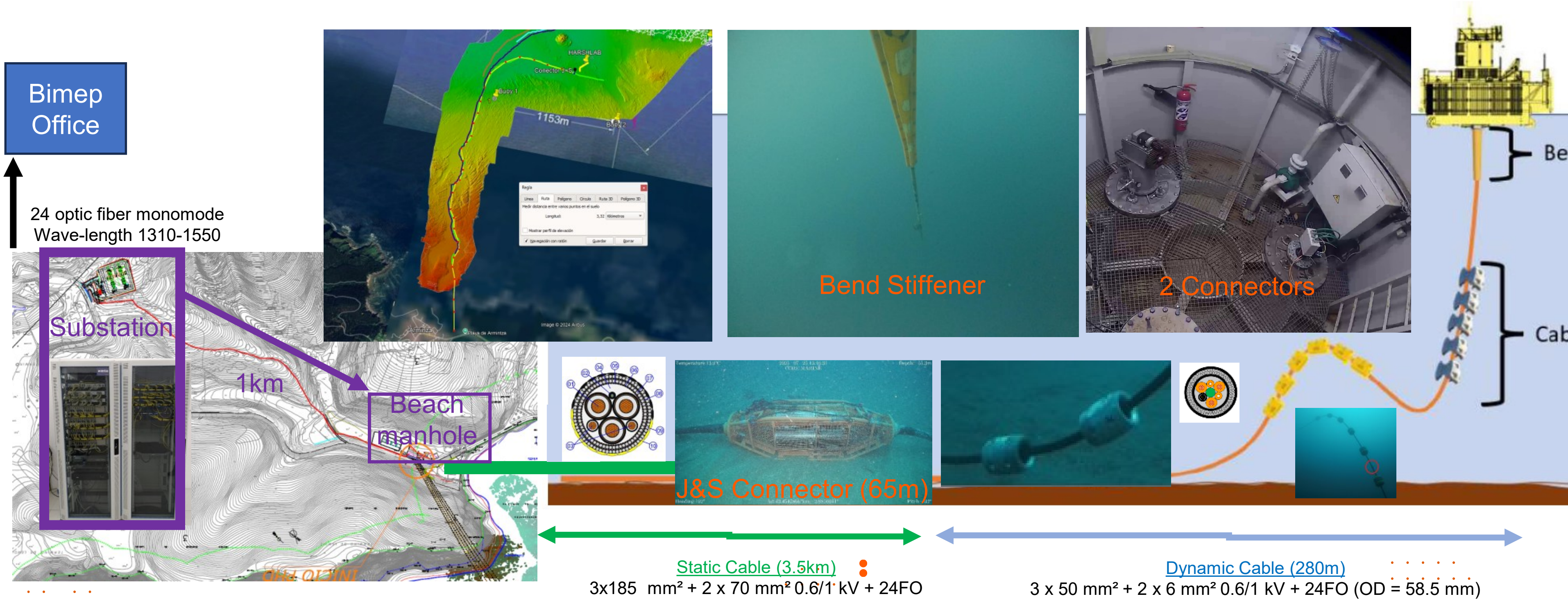
✅ **Strain gauges** installed on the **connector** for axial load measurement



What can be monitored in HarshLab?

4. Dynamic Cable: Possibility of monitoring the dynamic cable through fiber optics

- ✅ European project proposals submitted in February



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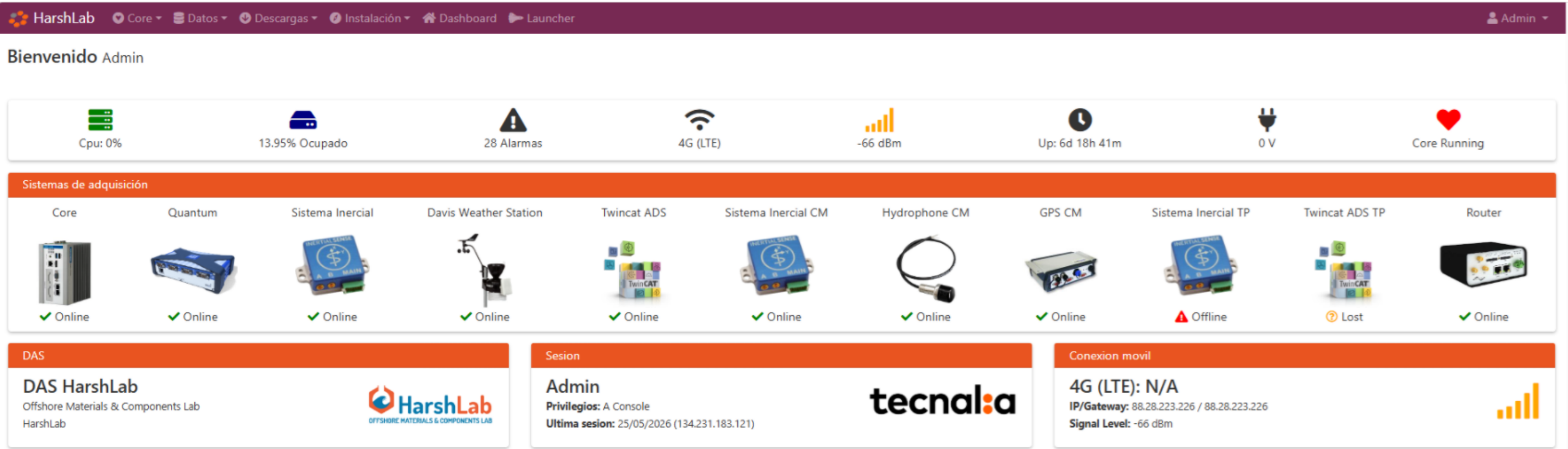
HarshLab as Data Source → DasWind



Datos en directo

Variables

Todo | System | Inertial | HBM | Twincat | Env | Meteo | Tracker | TP | Gauge | test

Mostrar: 50 lineas

Variable	Descripcion	Category	Value
Inertial.VarStatus	Estado de las variables de la IMU-GPS	Inertial	0 NOARG
Inertial.Euler.Yaw	Angulo de Euler YAW	Inertial	57.863058 deg
Inertial.Euler.Pitch	Angulo de Euler PITCH	Inertial	1.455314 deg
Inertial.Euler.Roll lineal	Angulo de Euler ROLL	Inertial	-5.546236 deg
Inertial.Acc.X	Aceleración en el eje Longitudinal de la Nacelle	Inertial	0.162 m/s2
Inertial.Acc.Y	Aceleración en el eje transversal de la Nacelle	Inertial	-0.65 m/s2
Inertial.Acc.Z	Aceleración en el eje Z de la Nacelle	Inertial	-9.743 m/s2
Inertial.Gyro.X	Angular Rate X axis	Inertial	-0.234913 deg/sec
Inertial.Gyro.Y	Angular Rate Y axis	Inertial	0.641713 deg/sec
Inertial.Gyro.Z	Angular Rate Z axis	Inertial	-0.085944 deg/sec
Inertial.Latitude	Latitude	Inertial	43.456283 deg
Inertial.Longitude	Longitude	Inertial	-2.884973 deg
Inertial.Altitude	Altitude	Inertial	53.556 m
TP.Inerti	J-GPS	TP/Inertial	0 NOARG
TP.Inerti	al de la Nacelle	TP/Inertial	0 m/s2
TP.Inerti	de la Nacelle	TP/Inertial	0 m/s2
TP.Inerti	:elle	TP/Inertial	0 m/s2
TP.Inerti		TP/Inertial	0 deg/sec
TP.Inerti		TP/Inertial	0 deg/sec
TP.Inerti		TP/Inertial	0 deg/sec

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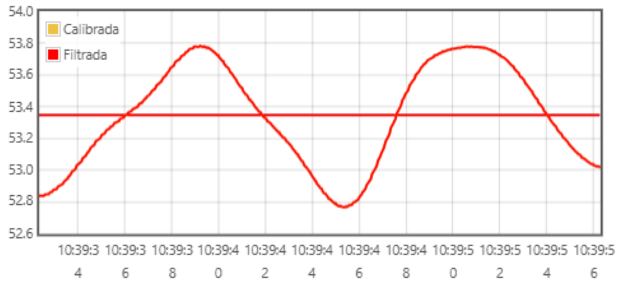
Variable: Inertial.Altitude double



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HarshLab Core Datos Descargas Instalación Dashboard Launcher

Datos en directo

Portal / Variables / Listado

Variables

Todo System Inertial HBM Twincat Env Meteo Tracker TP Gauge test

Mostrar: 50 lineas

Variable	Descripcion	Category	Value
Hbm.Signal1	Canal 1 Quantum	HBM	-2.074903 -
Hbm.Signal2	Canal 2 Quantum	HBM	-4.386075 -
Hbm.Signal3	Canal 3 Quantum	HBM	1999999973982208 -
Hbm.Signal4	Canal 4 Quantum	HBM	7999999895928832 -
Hbm.Signal5	Canal 5 Quantum	HBM	7999999895928832 mV/V

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HarshLab Core Datos Descargas Instalación Dashboard Launcher

Datos en directo

Portal / Variables / Listado

Variables

Todo System Inertial HBM Twincat Env Meteo Tracker TP Gauge test

Mostrar: 50 lineas

Variable	Descripcion	Category	Value
Meteo.Temperature lineal	Temperature	Meteo	21.4 C
Meteo.Humidity	Humidity	Meteo	79 %
Meteo.Pressure lineal	Barometric pressure	Meteo	1024.3 mbar
Meteo.AbsPressure lineal	Absolute barometric pressure	Meteo	1024.3 mbar
Meteo.WindSpeed	Wind speed	Meteo	16 kph
Meteo.WindDirection	Wind direction	Meteo	59 deg
Meteo.RainRate lineal	Rain rate	Meteo	0 mm/hour
Meteo.UVIndex	UV Index	Meteo	51 -
Meteo.SolarRadiation	Solar radiation	Meteo	610 W/m2

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HarshLab Core Datos Descargas Instalación Dashboard Launcher

Datos en directo

Portal / Variables / Listado

Variables

Todo System Inertial HBM Twincat Env Meteo Tracker TP Gauge test

Mostrar: 50 lineas

Variable	Descripcion	Category	Value
Tracker.Gps.alt	Altitud	Tracker	3.3188 m
Tracker.Gps.er_alt	Auto	Tracker	0.035 -
Tracker.Gps.er_lat	Auto	Tracker	0.015 -
Tracker.Gps.er_lon	Auto	Tracker	0.013 -
Tracker.Gps.fix	Adquisicion valida	Tracker	4 -
Tracker.Gps.hdp	Auto	Tracker	0.7 -
Tracker.Gps.lat	Latitud	Tracker	43.456276 deg
Tracker.Gps.lon	Latitud	Tracker	-2.885015 deg
Tracker.Gps.pdop	Auto	Tracker	1.4 -
Tracker.Gps.sats	Numero de satelites	Tracker	16 -
Tracker.Gps.vdop	Auto	Tracker	1.2 -
Tracker.Inertial.Euler.Yaw	Angulo de Euler YAW	Tracker	-136.7601 deg
Tracker.Inertial.Euler.Pitch	Angulo de Euler PITCH	Tracker	1.2887 deg
Tracker.Inertial.Euler.Roll	Angulo de Euler ROLL	Tracker	-0.508 deg
Tracker.Inertial.Acc.X	Aceleración en el eje Longitudinal de la Nacelle	Tracker	0.303 m/s2
Tracker.Inertial.Acc.Y	Aceleración en el eje transversal de la Nacelle	Tracker	0.1047 m/s2
Tracker.Inertial.Acc.Z	Aceleración en el eje Z de la Nacelle	Tracker	-9.7561 m/s2
Tracker.Inertial.Temperature	Temperature	Tracker	36.65 °C
Tracker.Inertial.Heave	Desplazamiento vertical respecto a posición media	Tracker	0.0347 m
Tracker.Inertial.HeaveRate	Velocidad vertical	Tracker	-0.0632 m/s
Tracker.Inertial.DelayedRate	Heave corregido	Tracker	-0.3858 m

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Hydrophone.line		Ultima linea NMEA	Tracker	0 --	2.0 s
Hydrophone.lines		auto	Tracker	36443 --	2.0 s
Hydrophone.sensor104.acc	⚠	Aceleración RMS	Tracker	43 m/s2	3m 34s
Hydrophone.sensor104.inc	⚠	Inclinación	Tracker	19 deg	3m 34s
Hydrophone.sensor105.acc	⚠	Aceleración RMS	Tracker	14 m/s2	7m 29s
Hydrophone.sensor105.prof	⚠	Profundidad	Tracker	10 m	7m 29s
Hydrophone.sensor106.acc	⚠	Aceleración RMS	Tracker	0 m/s2	
Hydrophone.sensor106.inc	⚠	Inclinación	Tracker	0 deg	
Hydrophone.sensor107.acc	⚠	Aceleración RMS	Tracker	0 m/s2	
Hydrophone.sensor107.prof	⚠	Profundidad	Tracker	0 m	
Hydrophone.sensor110.acc	⚠	Aceleración RMS	Tracker	40 m/s2	4m 54s
Hydrophone.sensor110.inc	⚠	Inclinación	Tracker	16 deg	4m 54s
Hydrophone.sensor111.acc	⚠	Aceleración RMS	Tracker	16 m/s2	8m 50s
Hydrophone.sensor111.prof	⚠	Profundidad	Tracker	7.5 m	8m 50s
Hydrophone.sensorTBR.noiseMean	⚠	Ruido medio	Tracker	9 --	4m 5s
Hydrophone.sensorTBR.noisePeak	⚠	Ruido pico	Tracker	15 --	4m 5s
Hydrophone.sensorTBR.temp	⚠	Temperatura	Tracker	23.200001 °C	4m 5s
Hydrophone.sensor153.inc		Inclinación	Tracker	47.9 deg	2.0 s
Hydrophone.sensor153.std		Desviación típica	Tracker	0 deg	2.0 s
Hydrophone.sensor154.inc	⚠	Inclinación	Tracker	0 deg	
Hydrophone.sensor154.std	⚠	Desviación típica	Tracker	0 deg	
Hydrophone.sensor155.inc		Inclinación	Tracker	52 deg	8.0 s
Hydrophone.sensor155.prof		Profundidad	Tracker	23 m	8.0 s

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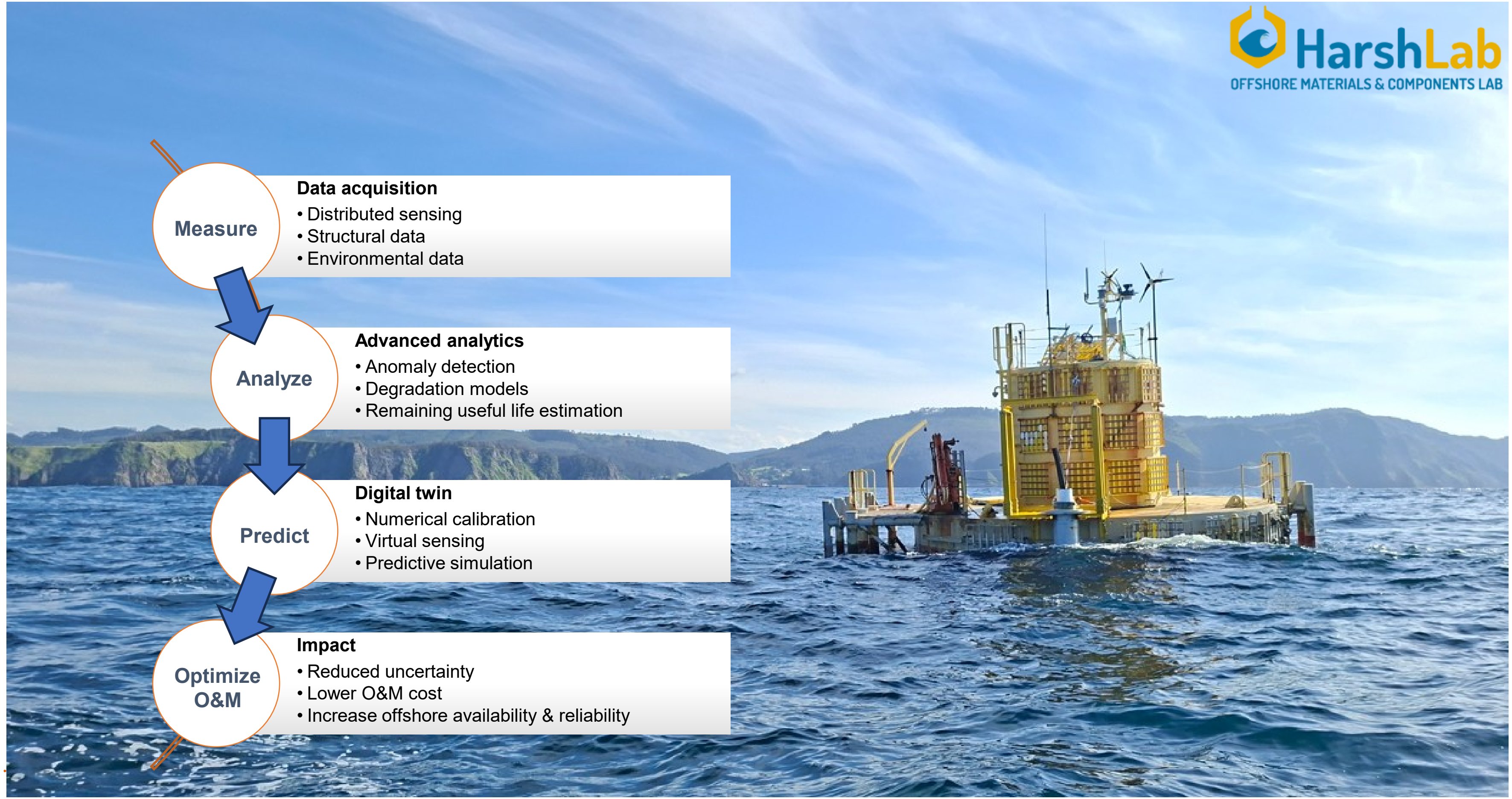
Why monitor offshore floating structures?



Measure

Data acquisition
- Distributed sensing
- Structural data
- Environmental data

Analyze

Advanced analytics
- Anomaly detection
- Degradation models
- Remaining useful life estimation

Predict

Digital twin
- Numerical calibration
- Virtual sensing
- Predictive simulation

Optimize O&M

Impact
- Reduced uncertainty
- Lower O&M cost
- Increase offshore availability & reliability

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4. Studies based on HarshLab data

RULET project

Motivation and project approach

STUDY A: 🔗 ASSESSMENT OF MOORING LINE DEGRADATION 🔗

STUDY B: 🔌 UMBILICAL CABLE DAMAGE MONITORING 🔌

EUSKO JAURLARITZA
GOBIERNO VASCO

Proyecto subvencionado por el Departamento de Industria, Transición Energética y Sostenibilidad del Gobierno Vasco (Programa ELKARTEK 2024)
Eusko Jaurlaritzaren Industria, Trantsizio Energetiko eta Jasangarritasun Sailak (ELKARTEK 2024 Programa) diruz lagundutako proiektua
Project funded by the Department of Industry, Energy Transition and Sustainability of the Basque Government (ELKARTEK 2024 Programme)

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RULFET

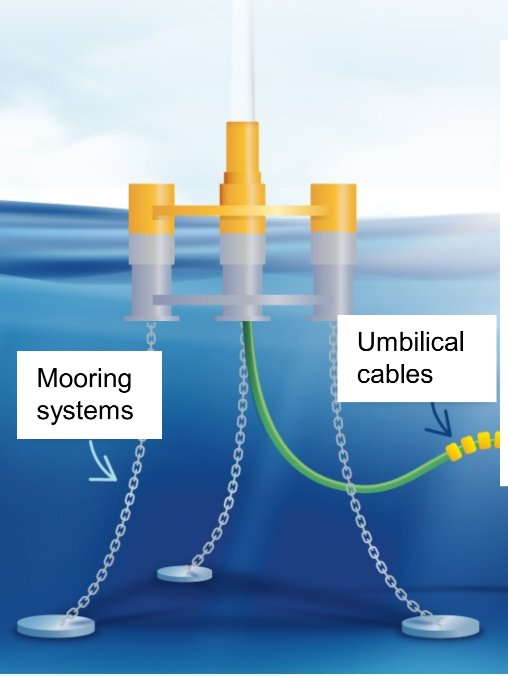
OBJECTIVE: Estimate the Remaining Useful Life of offshore mooring systems and dynamic cables

Efficient dataset generation strategies

- Acceleration of physical testing in the laboratory
- Failure data simulation

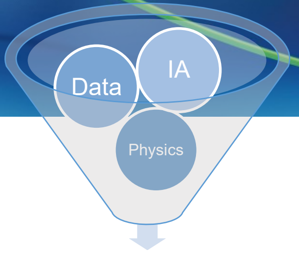
Decision-making tools for predictive maintenance

- Multi-objective optimisation
- Uncertainty management



AI-based condition monitoring of components

- Structural health diagnosis
- Degradation assessment
- Flexible and generalizable prediction models for other contexts



Motivation

Increasing unit power

Increasing structural loads

High access and maintenance costs

Energy production losses in case of failure

AI is promising - but DATA is essential

Decisions are economically driven → RELIABILITY is critical

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Eusko Jaurlaritza / Gobierno Vasco

Proyecto subvencionado por el Departamento de Industria, Transición Energética y Sostenibilidad del Gobierno Vasco (Programa ELKARTEK 2024)
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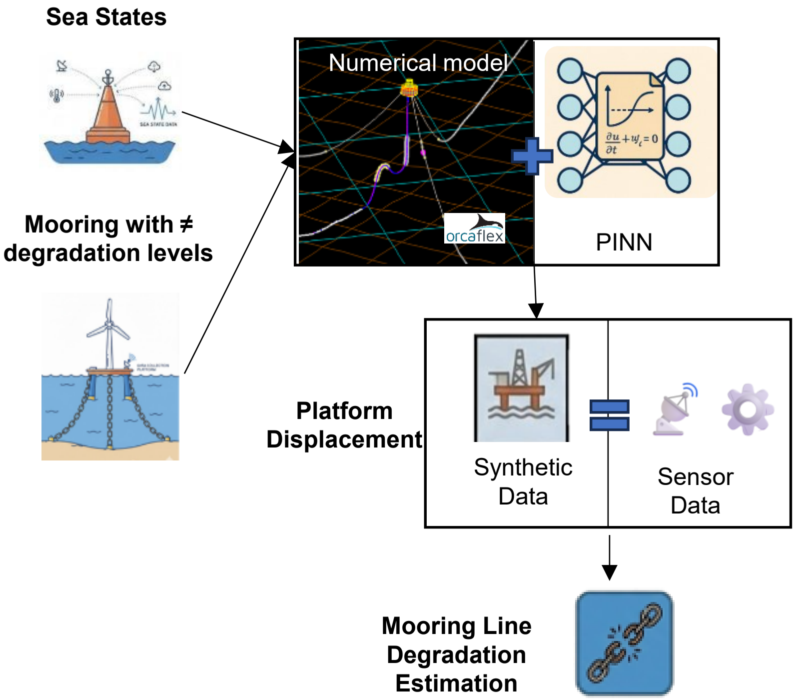
Project funded by the Department of Industry, Energy Transition and Sustainability of the Basque Government (ELKARTEK 2024 Programme)

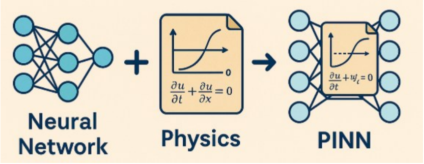
STUDY A: ASSESSMENT OF MOORING LINE DEGRADATION (I)

- **Objective:** To estimate corrosion based on variations in floater motions
- **Approach**: direct measurement of corrosion is challenging
  - numerical model → synthetic data generation
  - PINN trained across:
    - sea states and
    - degradation levels



¿¿Why Physics-Informed Neural Networks-PINNs??

- Combine physics and data
- Improving accuracy and consistency
- Less data required
- Better generalization
- Fast simulations



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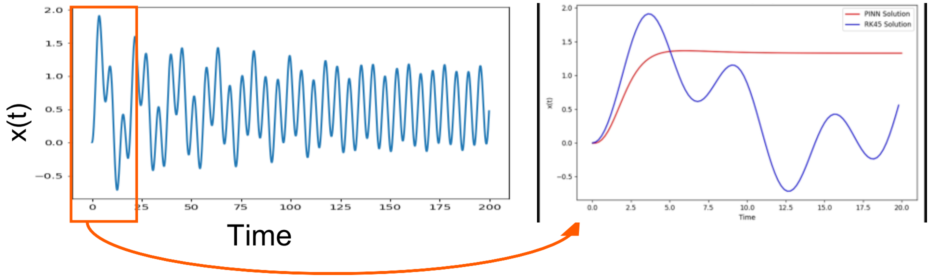
STUDY A: ASSESSMENT OF MOORING LINE DEGRADATION (II)

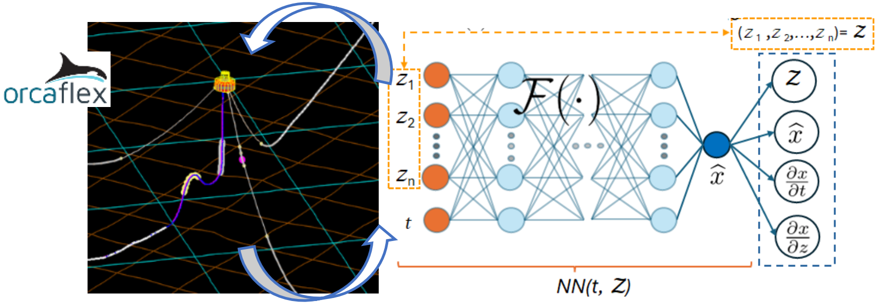
Training 1: simplified physics (single DOF – surge)

Real movement | **PINN aproximation of the motion**



PINNs learn the physics, not just the data and mimic the physics-based solver

Training 2: PINN connected to OrcaFlex (6 DOF)



Automatized simulation:
PINNs ↔ Numerical model

Key findings

- Limited impact of sea state on accuracy
- Degradation level drives prediction error
- Best performance at intermediate degradation levels

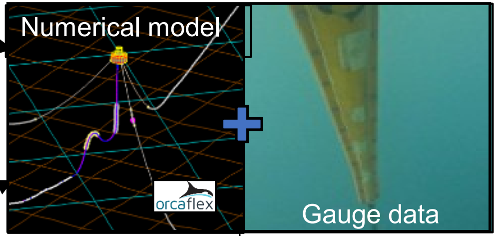
In moorings lines, what degrades matters more than the sea state

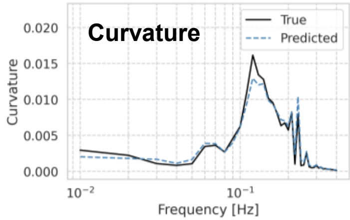
STUDY B: UMBILICAL CABLE DAMAGE MONITORING (I)

- **Objective:** To predict curvature PSD at a given location
- **Inputs:**
  - Metocean data (Hs, Tp, direction, currents)
  - Platform motion (6 DOF response spectra)
- **Output:** Curvature PSD → damage estimation
- **Approach:**
  - Machine learning surrogate model
  - Trained with synthetic and measured data

Sea States

Platform motion





Accumulated damage computation

120 sea states
Hs, Tp, dw

currents
5 velocities
1 direction

PSD of motions
Elevation
+
6 kinematic
DOFs

INPUT

600 OrcaFlex
simulations
Hs, Tp, dw

OUTPUT
PSD of curvature

80% train

20% test

ML models
- Linear, Ridge, Lasso regressions
- Random Forest
- ANNs (HB tuned)

VALIDATION

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STUDY B: 🔌 UMBILICAL CABLE DAMAGE MONITORING 🔌 (II)

Model	Curvature RMSE [m^{-1}]		Pearson correlation	
	mean	Std	mean	std
Linear regression	0.00239	0.0044	0.726	0.342
Ridge	🥇 **0.00098**	0.0014	0.859	0.239
Lasso	0.00104	0.0015	0.864	0.219
Random forest	0.00107	0.0019	🥇 **0.874**	0.221
ANN	0.00138	0.0018	0.757	0.321

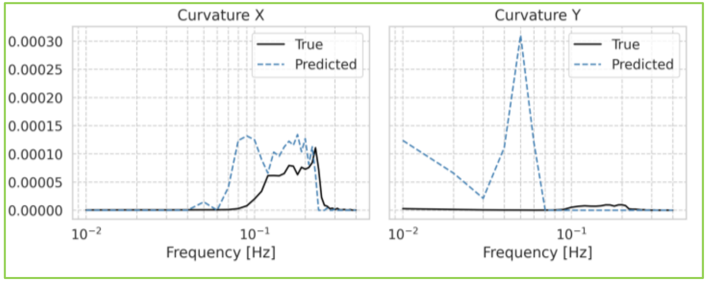
Model Results

- Regularized models (Ridge, Lasso) and RF - best performance
- Ridge - lowest RMSE
- Random Forest - highest Pearson correlation
- Linear Regression - underperformed, insufficient model flexibility
- ANNs likely suffered from limited training instances

Model Performance Across Conditions

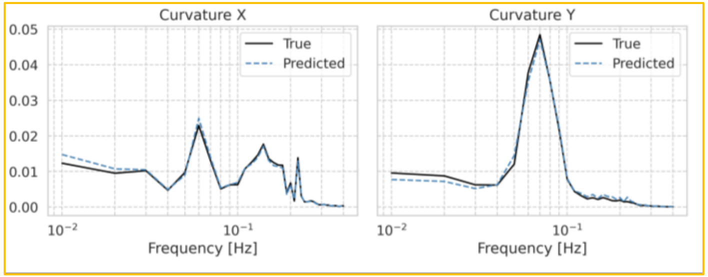
Hs = 0.25 m-Low energy

- Low absolute error
- High relative error
- Worse reconstruction



Hs = 6.75 m-High energy

- High absolute error
- Low relative error
- Better reconstruction



🔍 🔌 **Model accuracy depends on sea state energy, but model ranking remains consistent**

Combining **HarshLab data, physics-based models and AI** enables more reliable **degradation assessment** and RUL estimation for **offshore renewable systems.**

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Thank you very much for your attention

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Eskerrik asko!