ARTIFICIAL INTELLIGENCE FOR DATA-DRIVEN MAINTENANCE IN THE POWER GENERATION SECTOR:

Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin Constructed with Deep Learning Techniques

CÁTEDRA
APLICACIONES DE LA IA
AL MANTENIMIENTO
BASADO EN DATOS

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Data-Driven Maintenance (DDM)

The vision of DDM

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✓ On **July 24th, 2019** a new initiative was introduced at the **Endesa Open Space** to apply **Artificial Intelligence** aimed to the optimization of the power generation asset management by means of **Machine Learning algorithms**. This initiative called **Data-Driven Maintenance** is made up of two main pillars:

- Change the current Maintenance Culture towards a "**Digital minset applied to Maintenance**" through the development of Data-Driven Maintenance projects and training plant staff in machine learning techniques:

M B D MantEnimiento Basado en Datos

- Digitalization of the Ordinary Maintenance Management through a **Digital Platform** that would respond all the needs of the Plant Maintenance staff.

Plataforma GM_digital

Data-Driven Maintenance (DDM)

The dawn of AI

¿What is the purpose of AI?

"To proceed on the basis of the conjecture that every aspect of **learning or any other feature of intelligence** can be in principle be so precisely described that a **machine can be made to simulate it".**

¿What is the goal of AI?

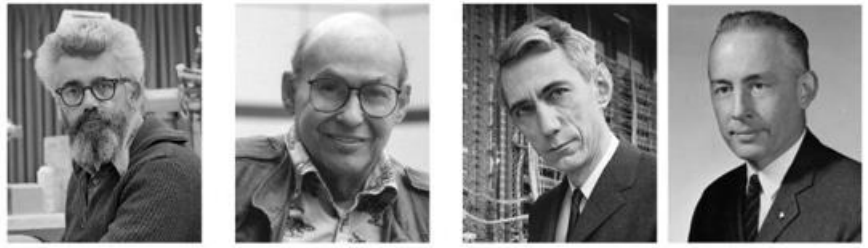
"The goal is to make **machines use language, develop abstractions and concepts, solve problems** usually reserved for people, and improve".

¿What is Prescriptive AI?

It is a type of Artificial Intelligence that is designed **to provide recommendation, solution, or actions** to optimize a specific process or outcome. It usually uses **machine learning algorithms** and other advanced technologies to analyze large datasets and **generate recommendations based on the data.**

¿What is Generative AI?

It is a type of Artificial Intelligence that can **create original content—such as text**, images, video, audio or software code—in response to a user's prompt or request.

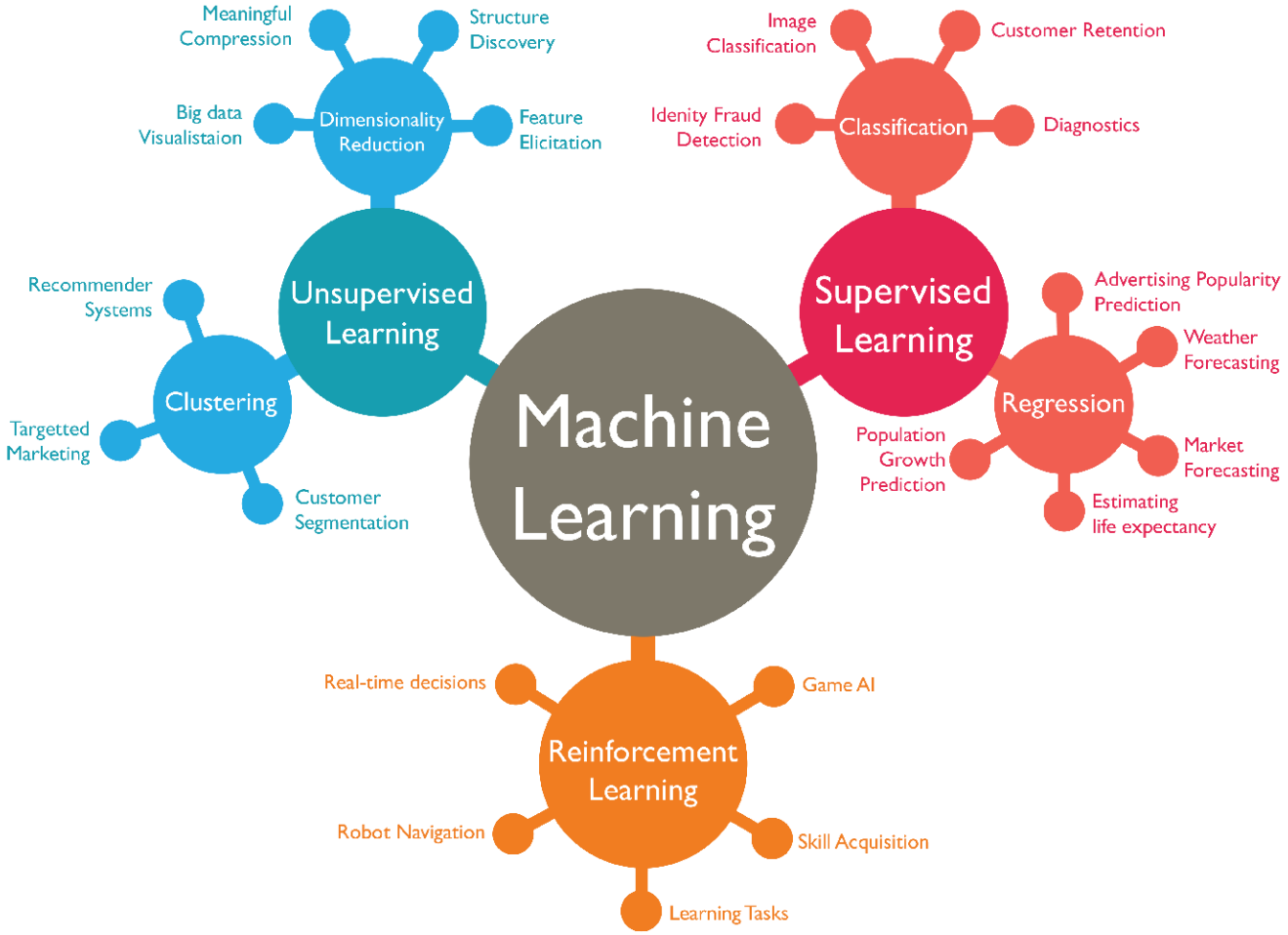


John MacCarthy | Marvin Minsky | Claude Shannon | Nathaniel Rochester

Campus of the Dartmuth College (EEUU). Summer workshop August 31rst 1956

Data-Driven Maintenance (DDM)

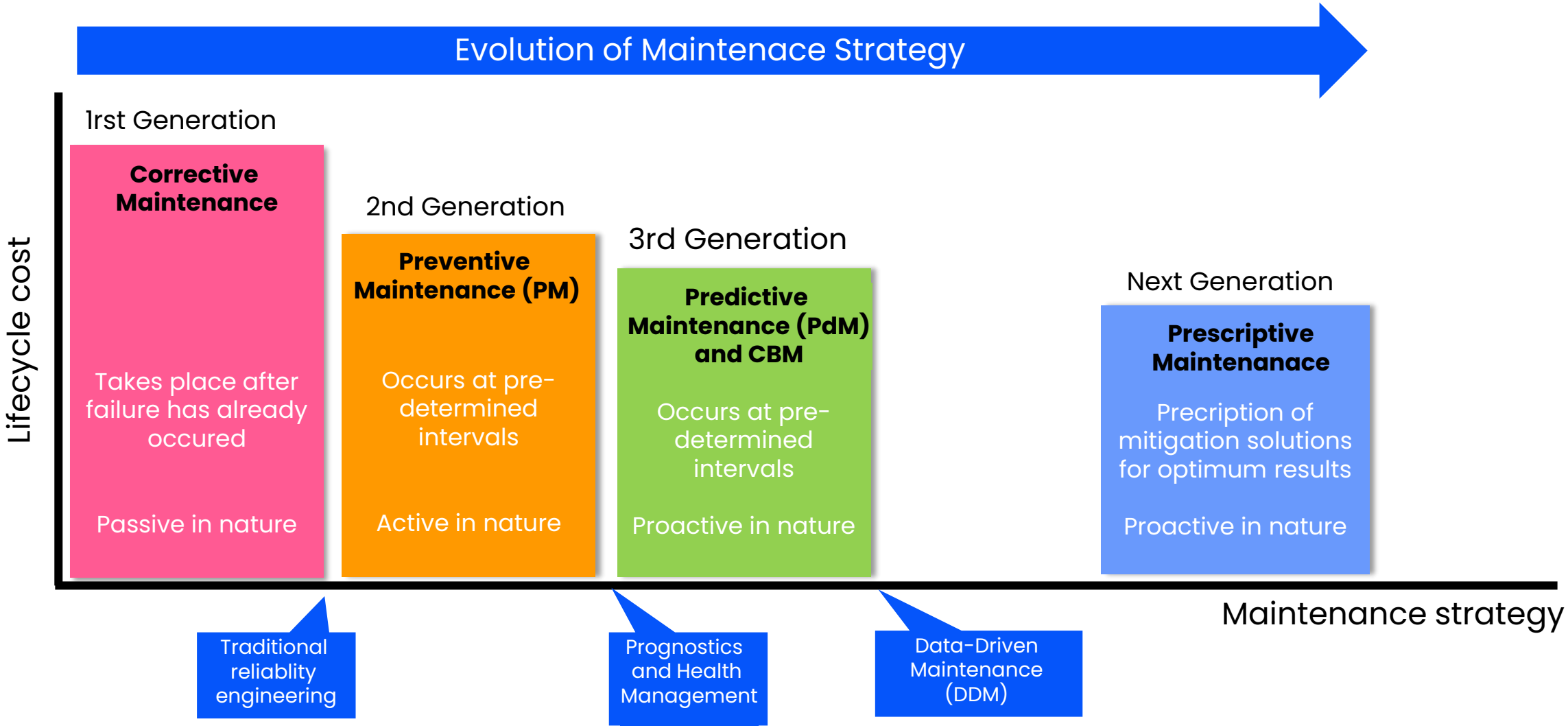
Machine Learning



Source: Machine Learning Types #2. Supervised Learning | by Rajesh Khadka | Towards Data Science

Data-Driven Maintenance (DDM)

Maintenance strategy



Data-Driven Maintenance (DDM)

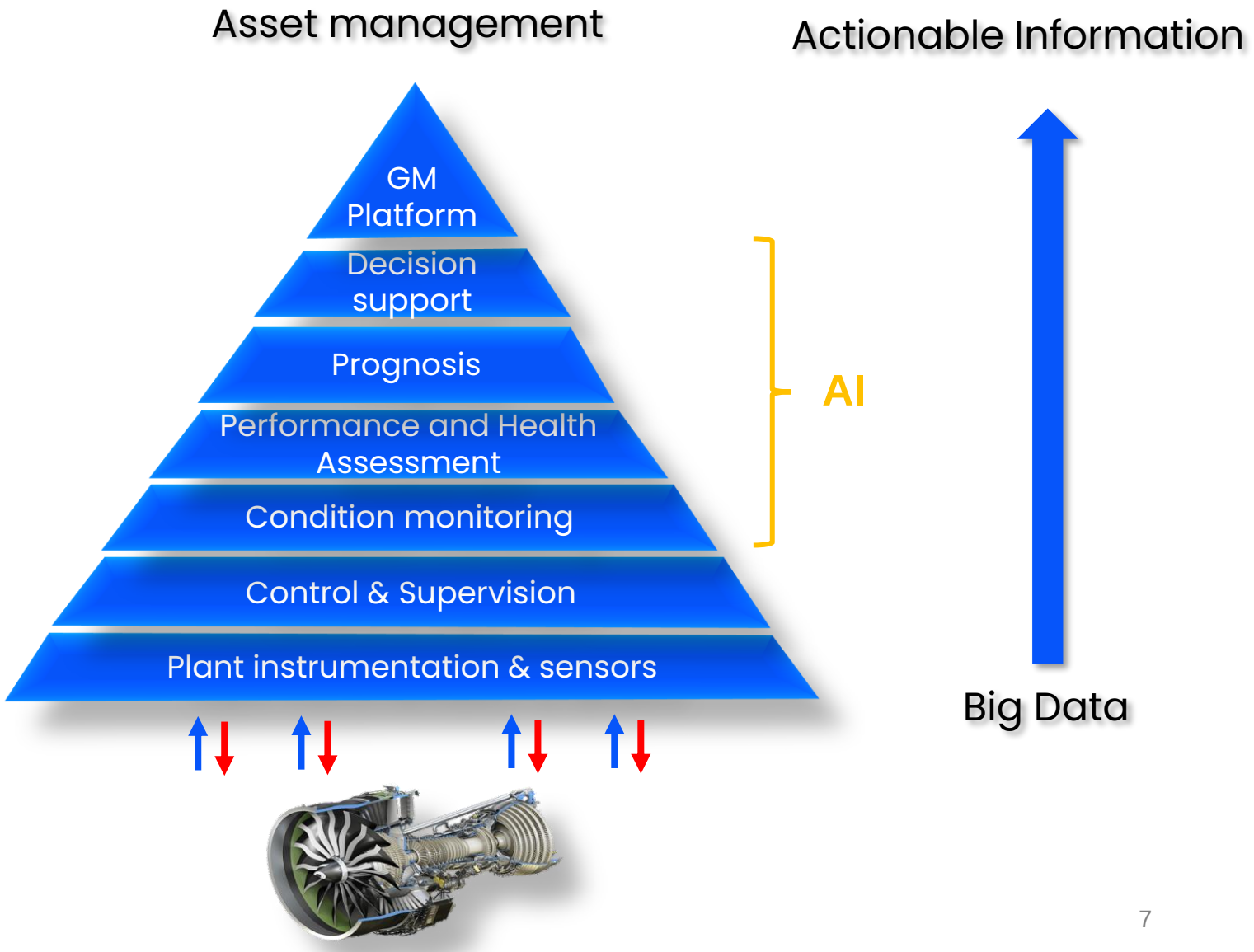
Types of Data Analysis

Precriptive analysis: answers the question, "what should be do about it?

Predictive analysis: answers the question, "what might happen in the future?

Diagnostic analysis: answers the question "why did it happen?"

Descriptive analysis: answers the question, "what happened?"



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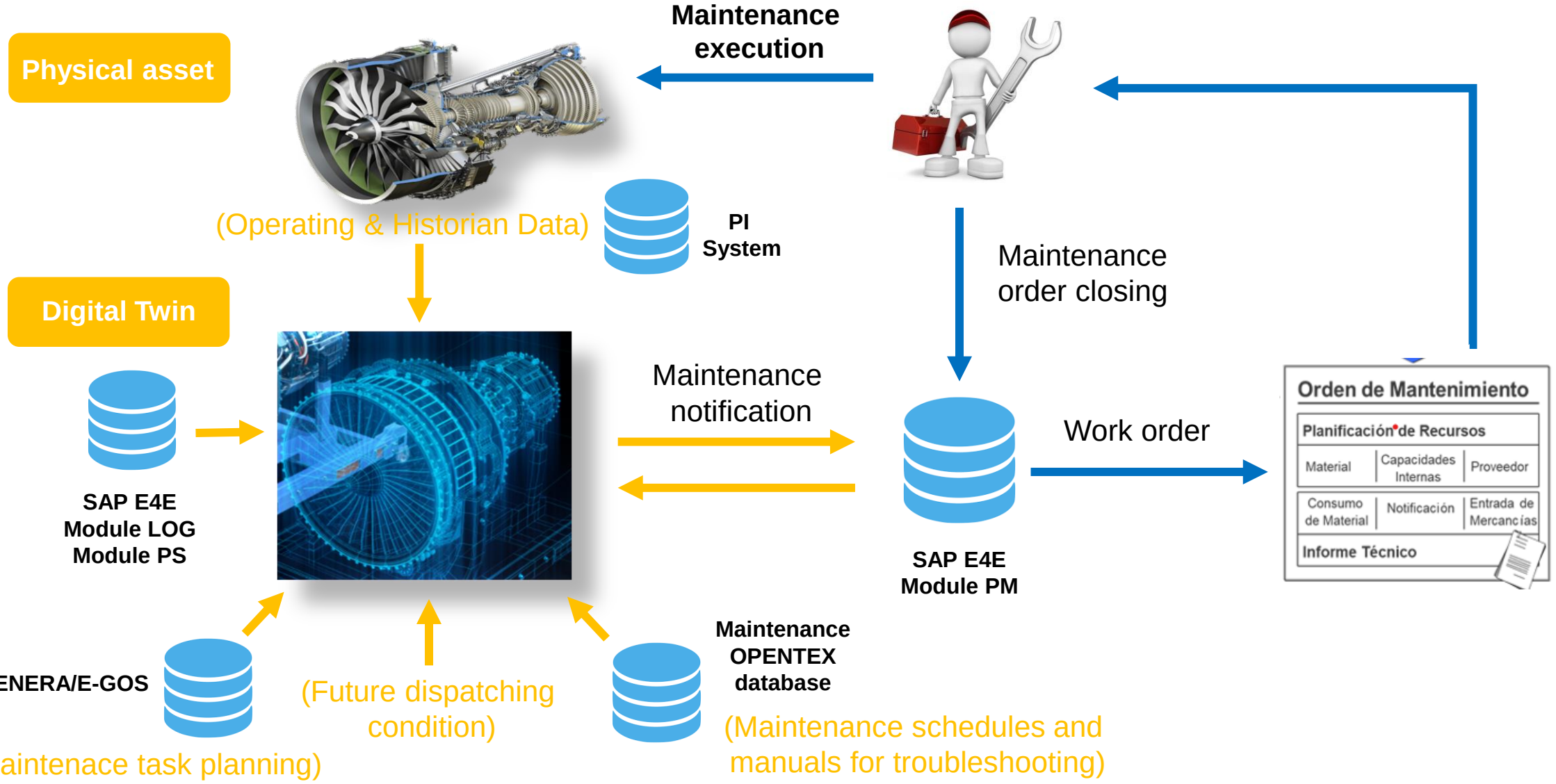
Data-Driven Maintenance process

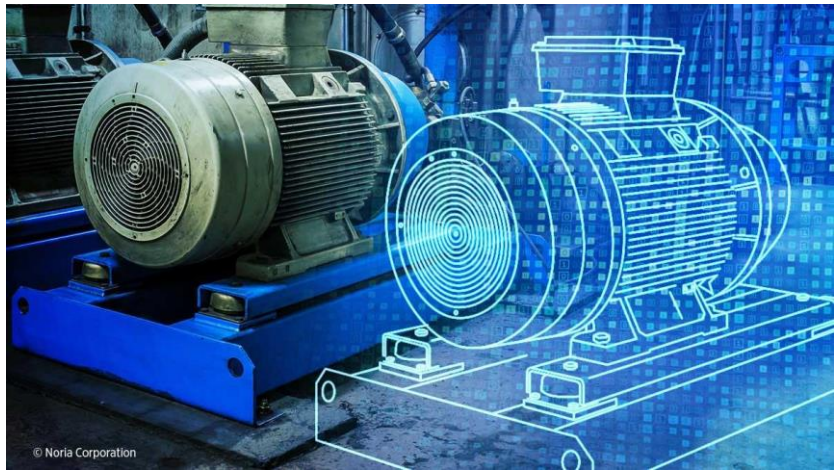


Data-Driven Maintenance (DDM)

Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

Global Maintenace Twin: GMTwin

- Maintenance management of the circulating water pumps (CWP) of a Combined Cycle Power Plant at Granadilla (Tenerife, Spain).
- Two Virtual Digital Twin developed to emulate the normal behaviour of the CWPs in the absence of malfunctions.
- Early anomly detection module of the CWP failure modes.
- Risk assessment (Time to Failure and Severity).
- Maintenance resource planning.
- Generative AI designed to provide recommendation, solution, or actions to optimize the operation and maintenance of the CCWs.



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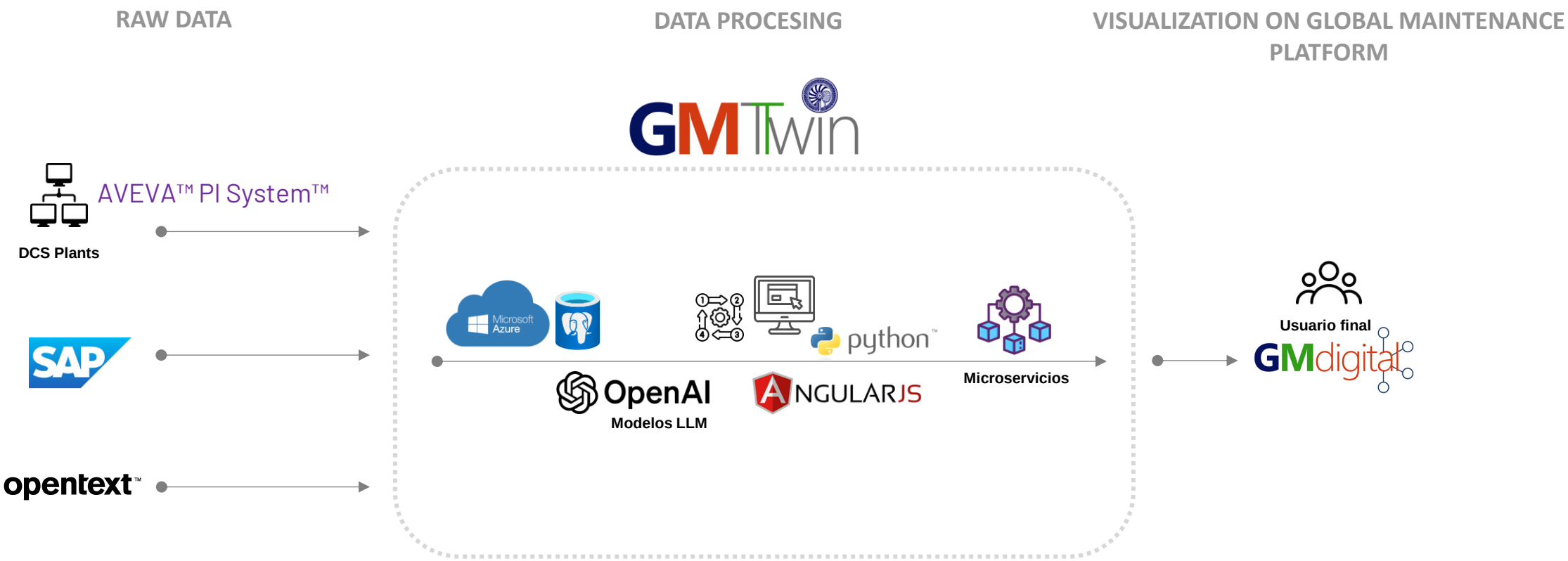

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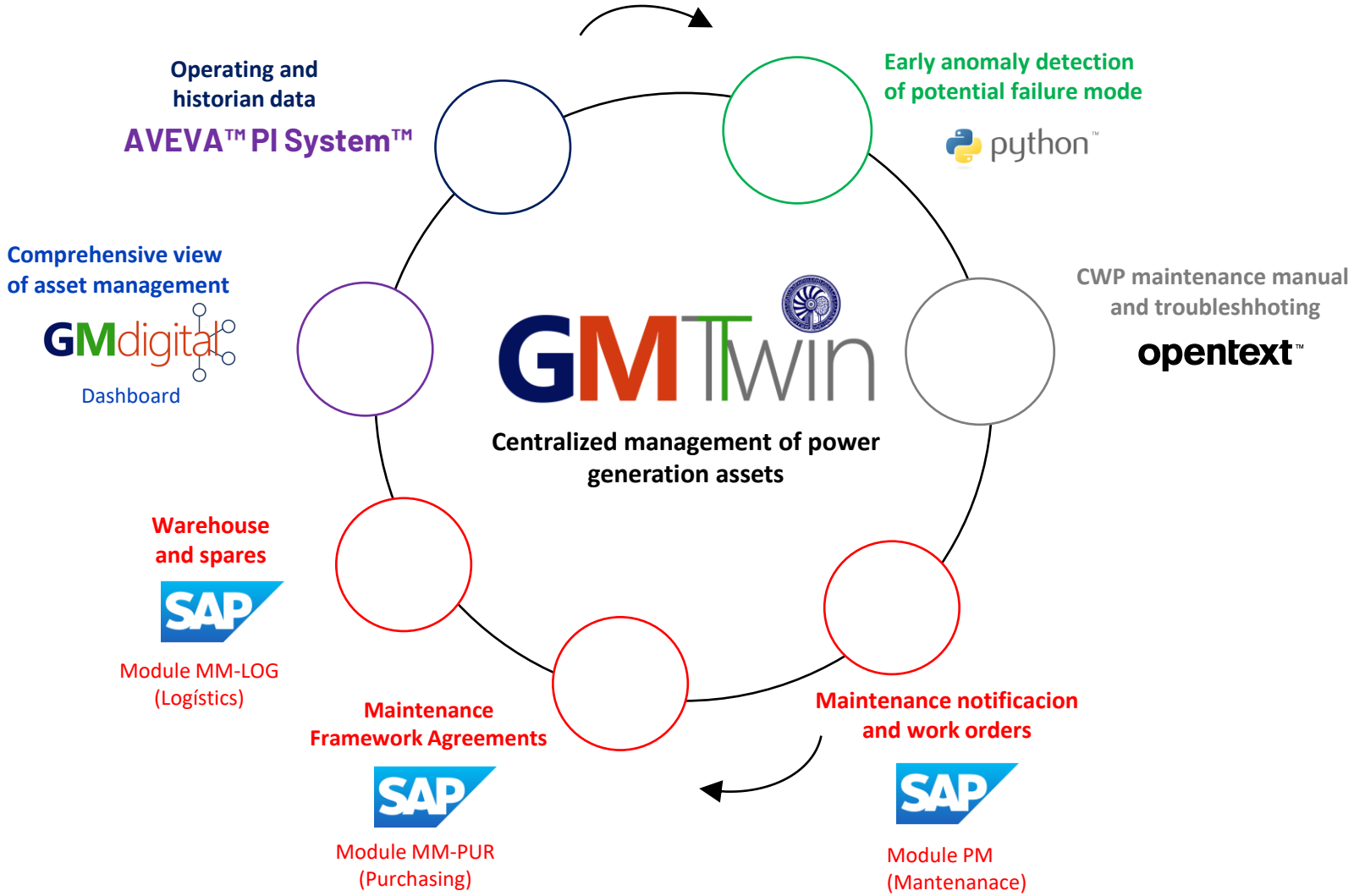

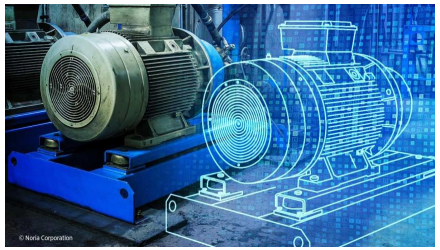

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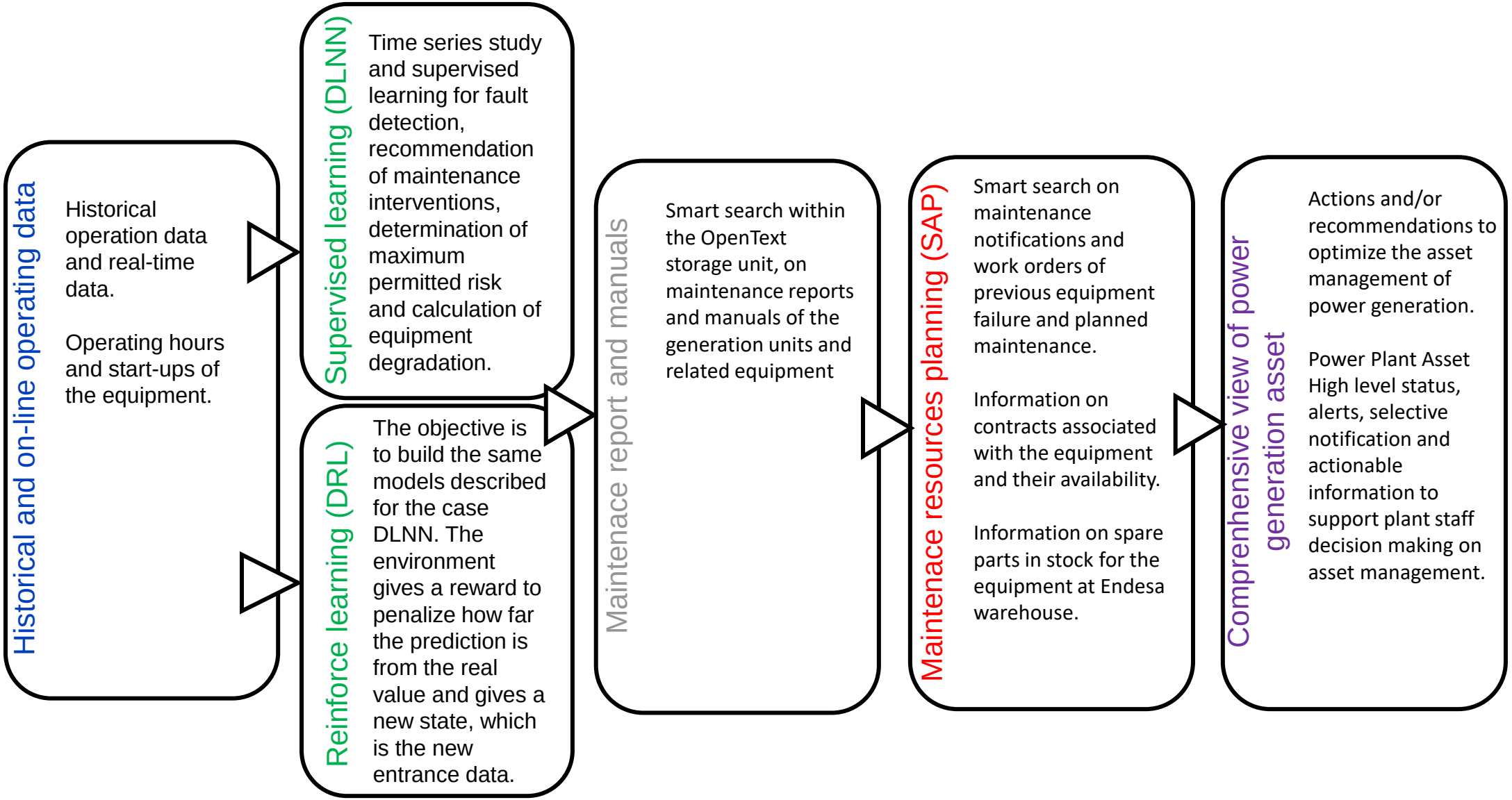

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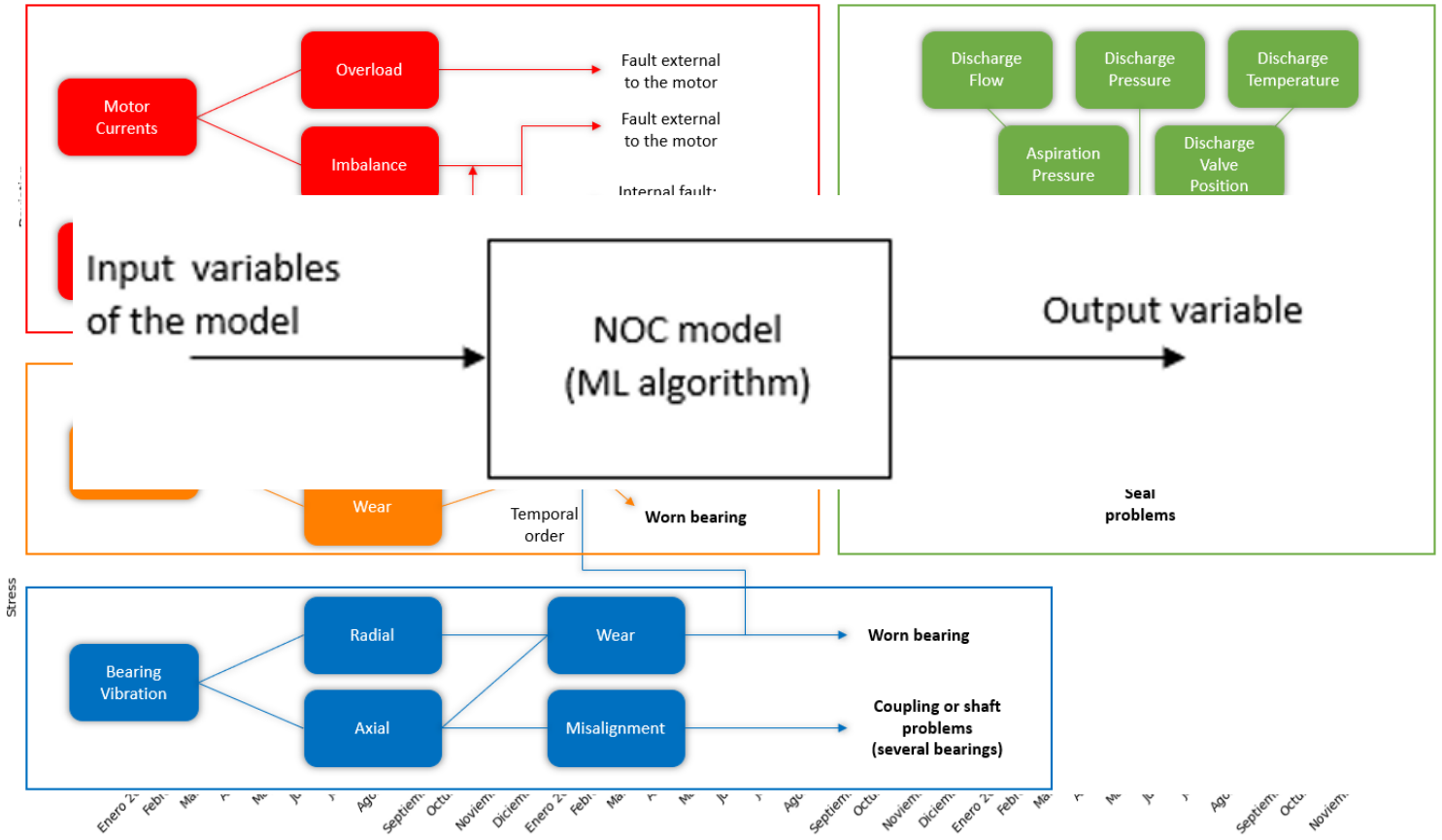
Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

- Failure Mode, Effects and Analysis (FMEA).
- Normal Behaviour Model based on Deep Learning Neural Networks (DLNN) and Deep Reinforce Learning (DRL).
- Monitoring of main parameters under actual working conditions.
- Assessment of the risk of failure.



Anomaly Detection of a Cooling Water Pump of a Power Plant Based on its Virtual Digital Twin Constructed with Deep Learning Techniques | PHM Society European Conference

Data-Driven Maintenance (DDM)

Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

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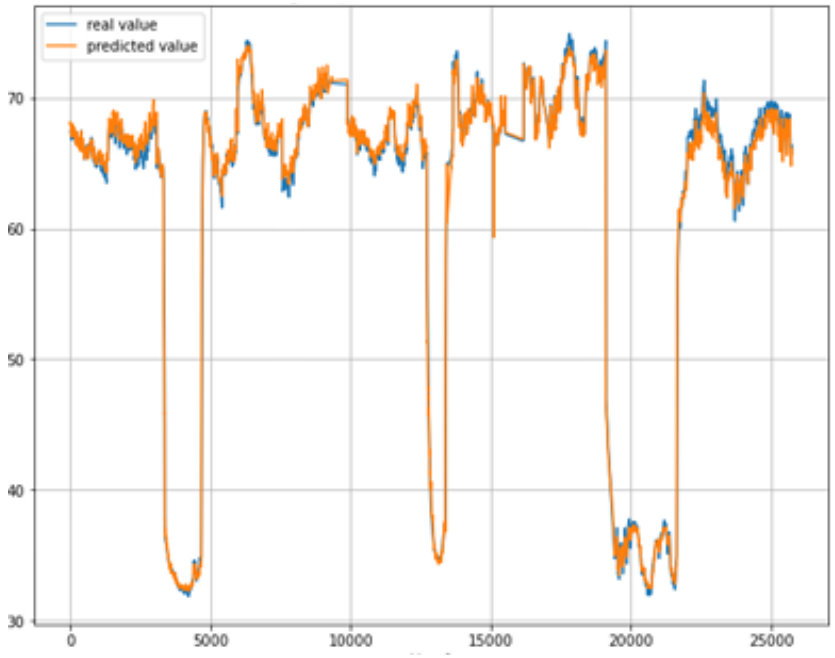
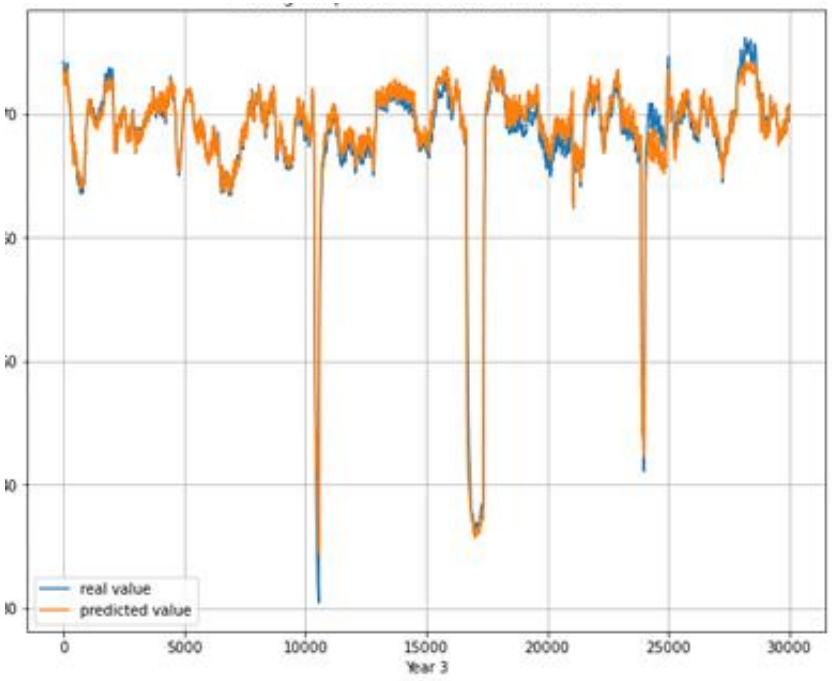
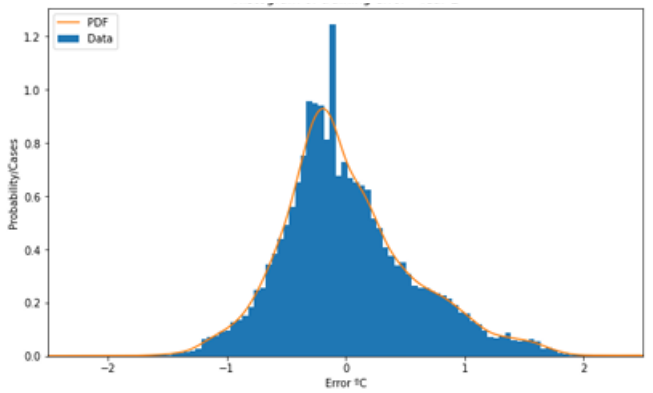
Actual and predicted values for the bearing temperature using Year 1 data as training data.



Actual and predicted values for the bearing temperature of the dataset Year 3 not used in training



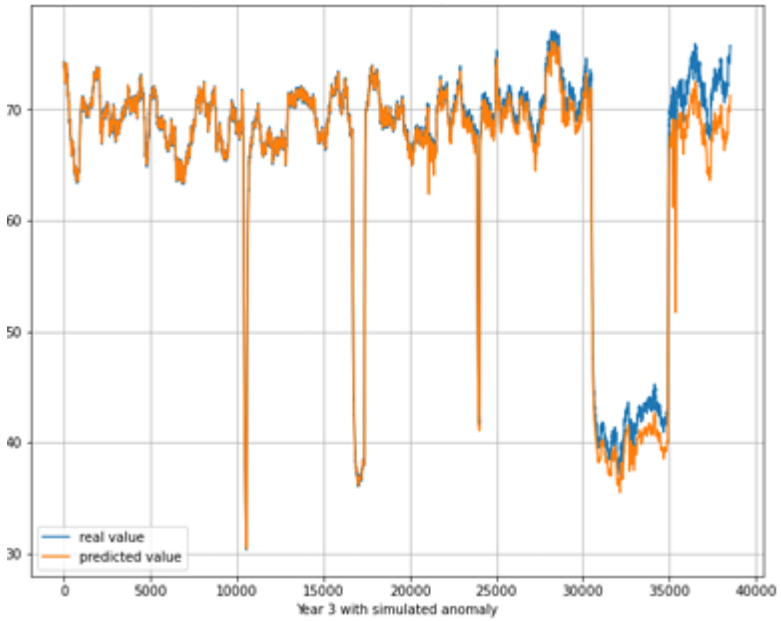
Error observed between actuak and predicted values for the bearing temperature using Year 1 data



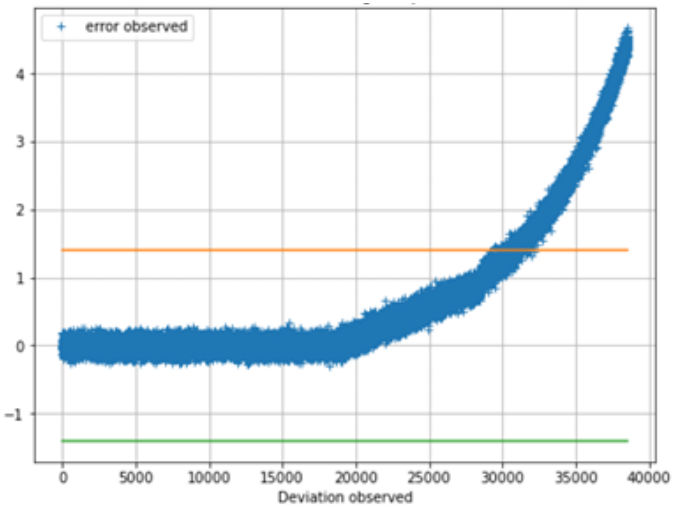
Data-Driven Maintenance (DDM)

Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

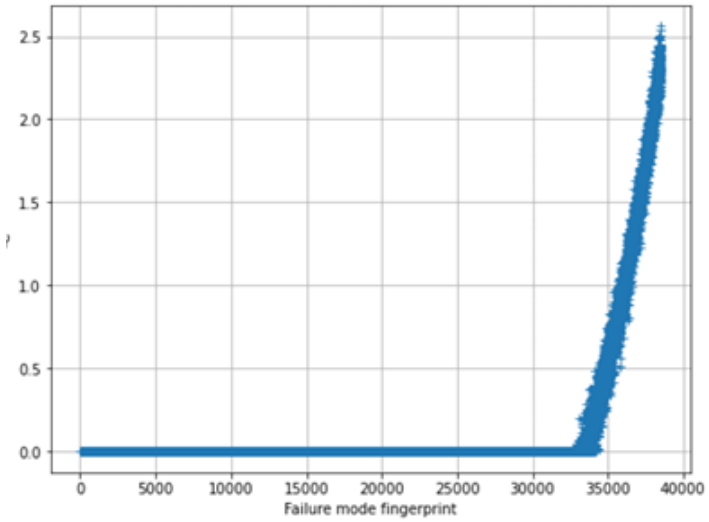
Actual and predicted values by the DLNN digital twin. An anomaly is detected at the end of the period



Error inside and outside



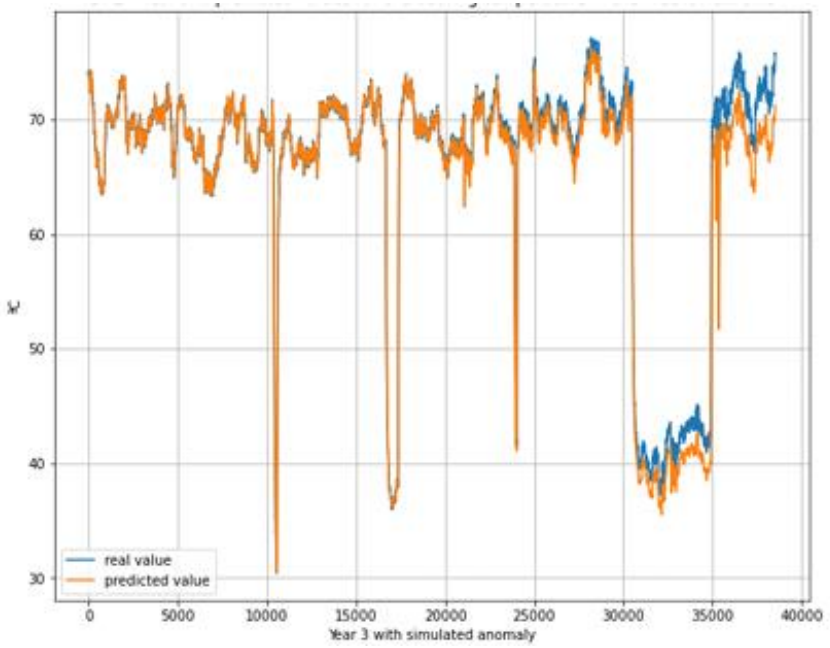
DLNN – Risk of Failure



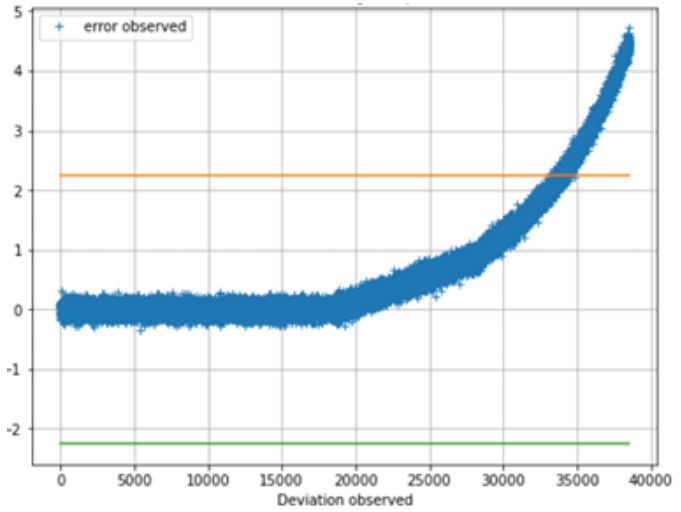
Data-Driven Maintenance (DDM)

Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

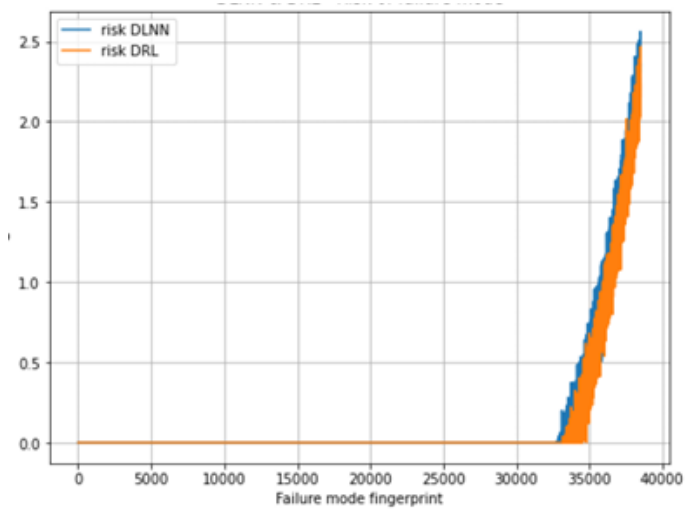
Actual and predicted values by the DRL digital twin.
An anomaly is detected at the end of the period



Error inside and outside



DLNN and DRL – Risk of Failure



Data-Driven Maintenance (DDM)

Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

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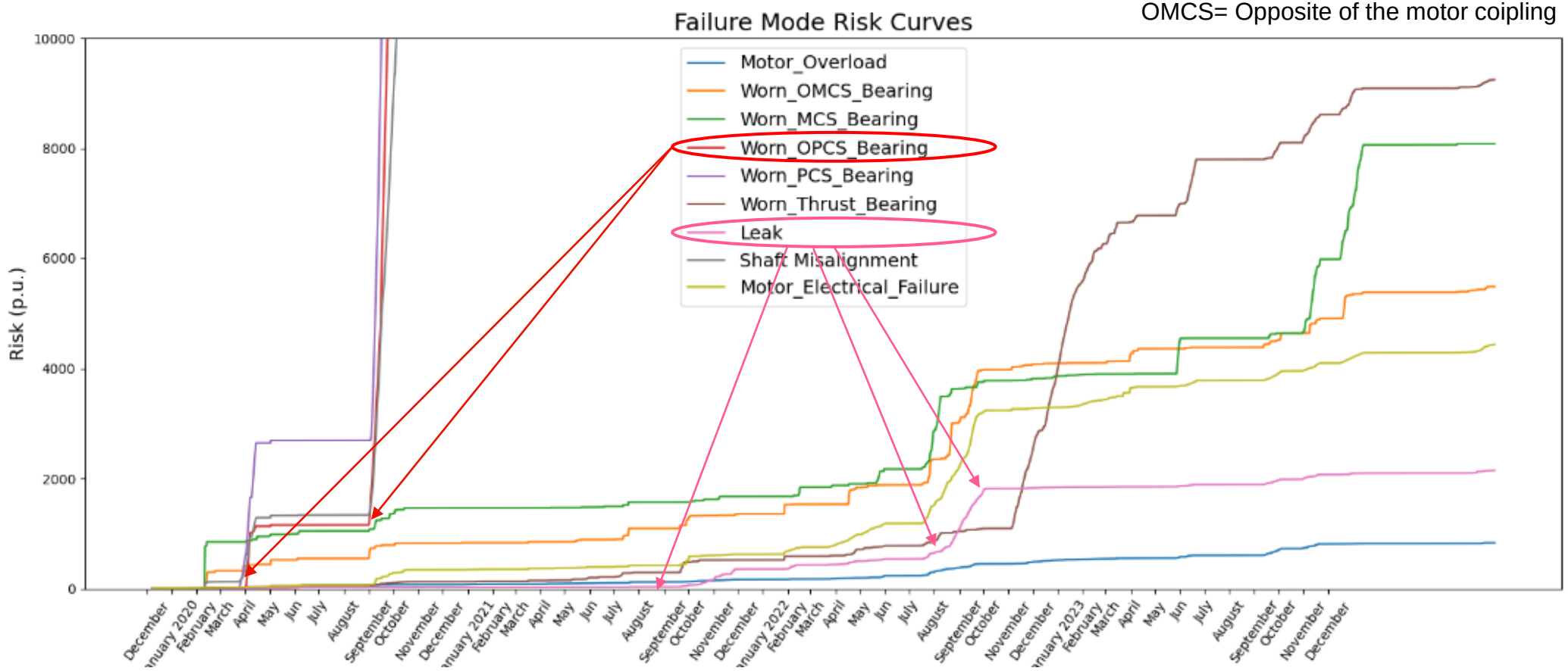
OPCS= Opposite of the coupling pump
PCS= Pump coupling side
MCS= motor coupling side
OMCS= Opposite of the motor coipling



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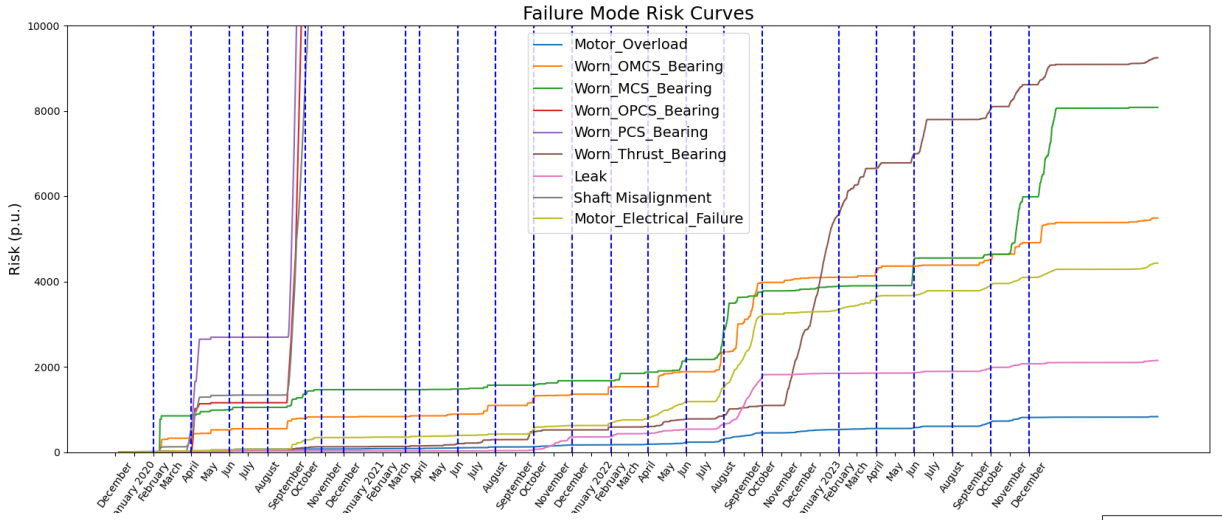
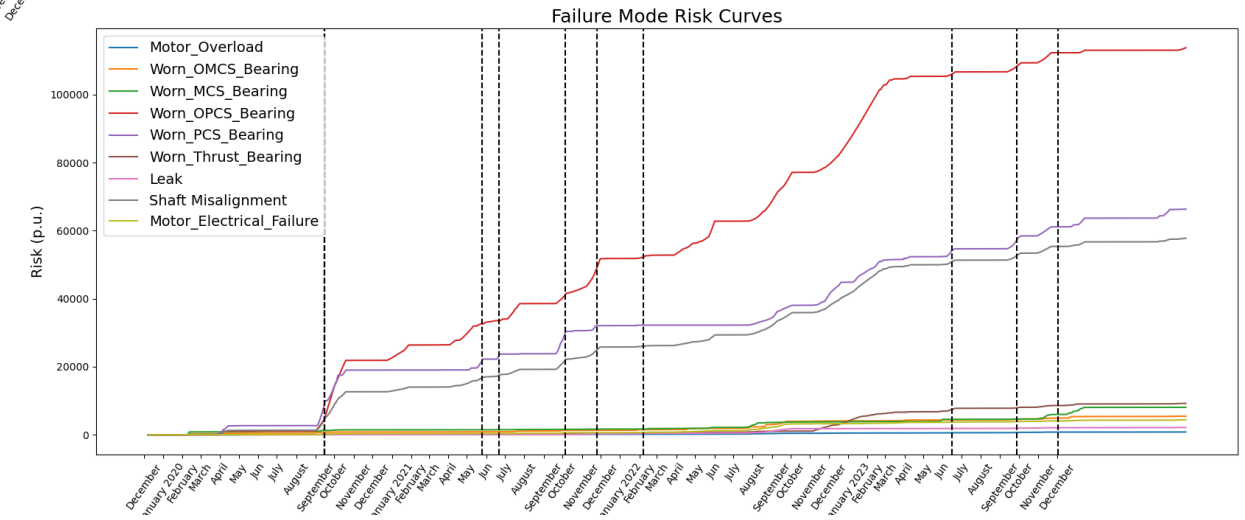
Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin



Preventive Maintenance Actions



Corrective Maintenance Actions

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GMTwin dashboard

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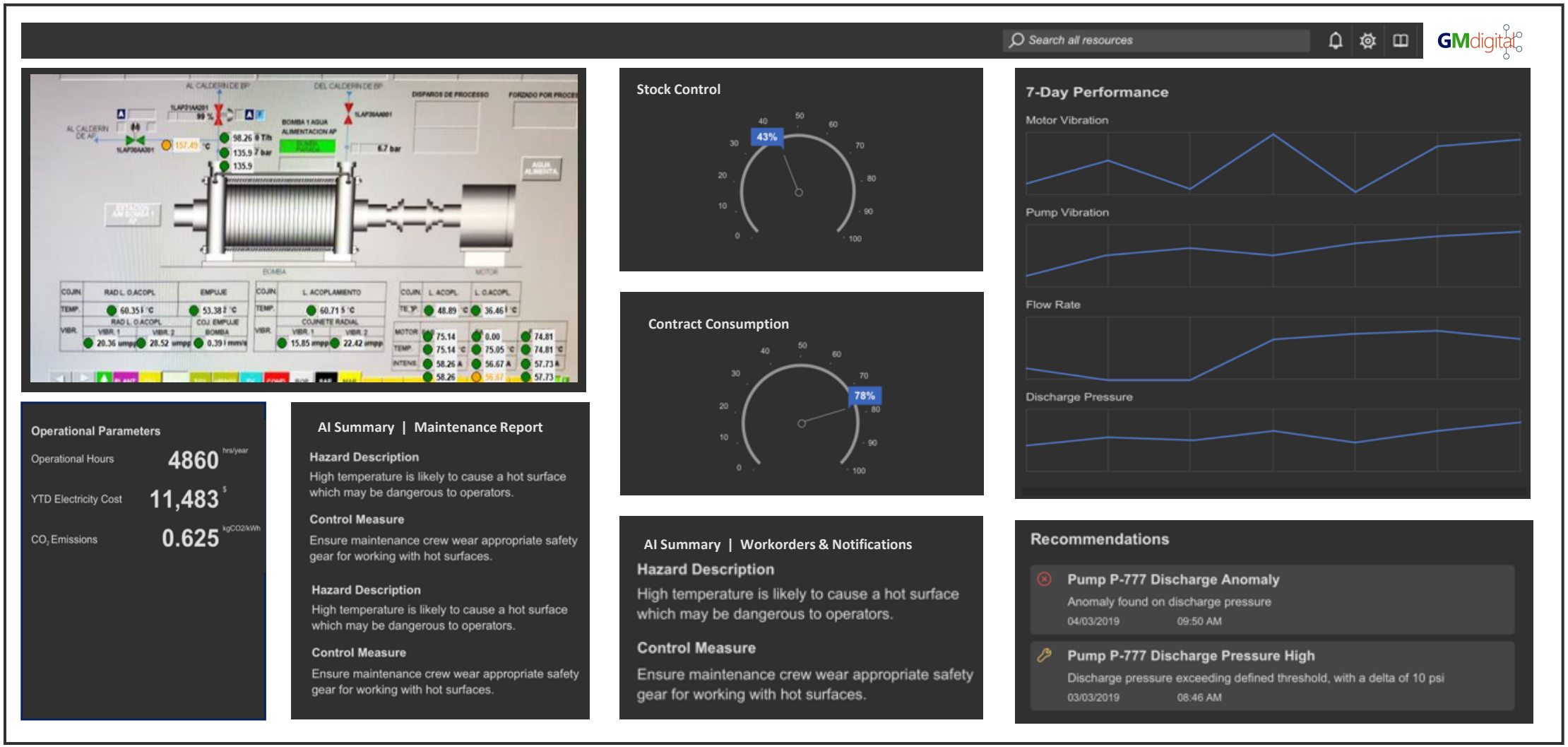
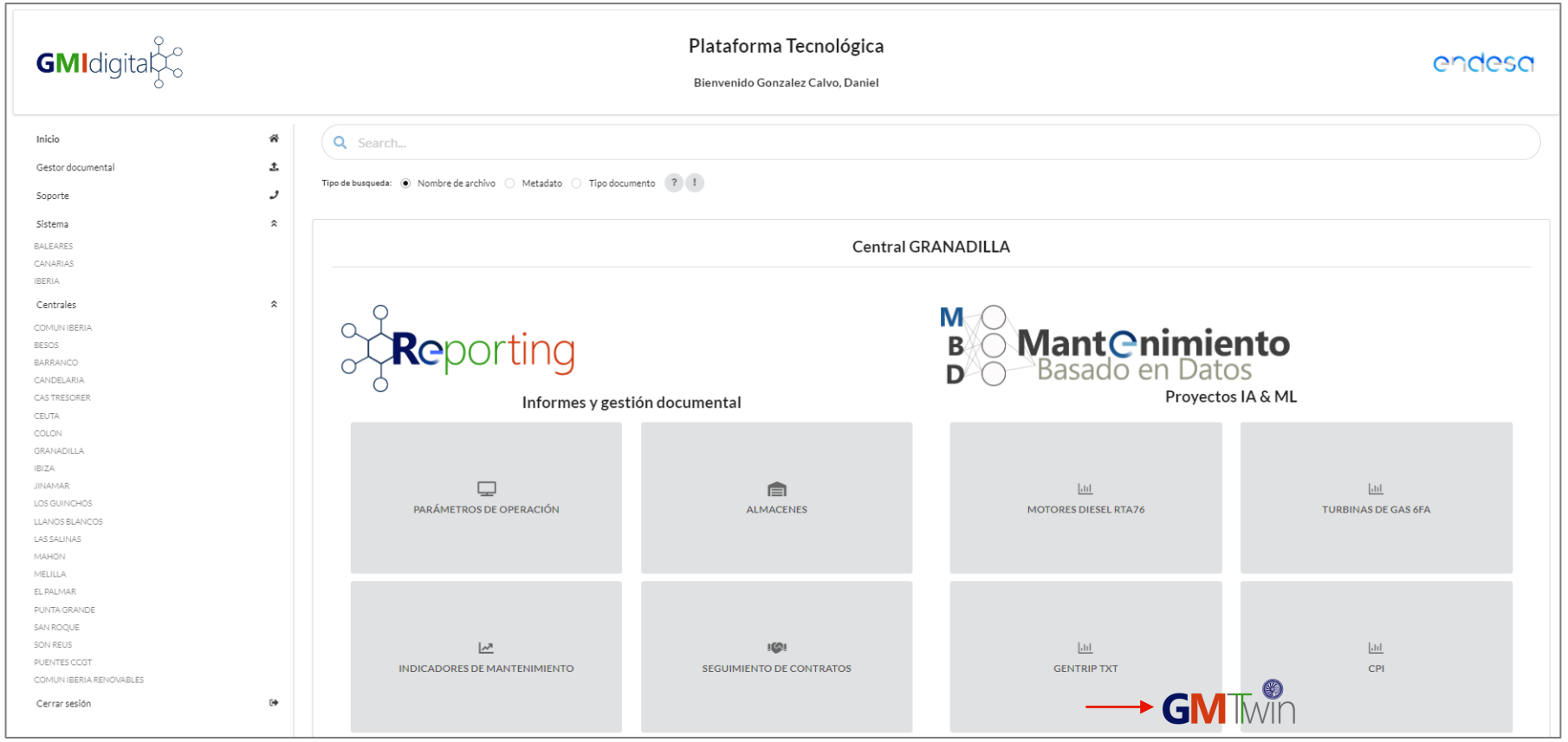


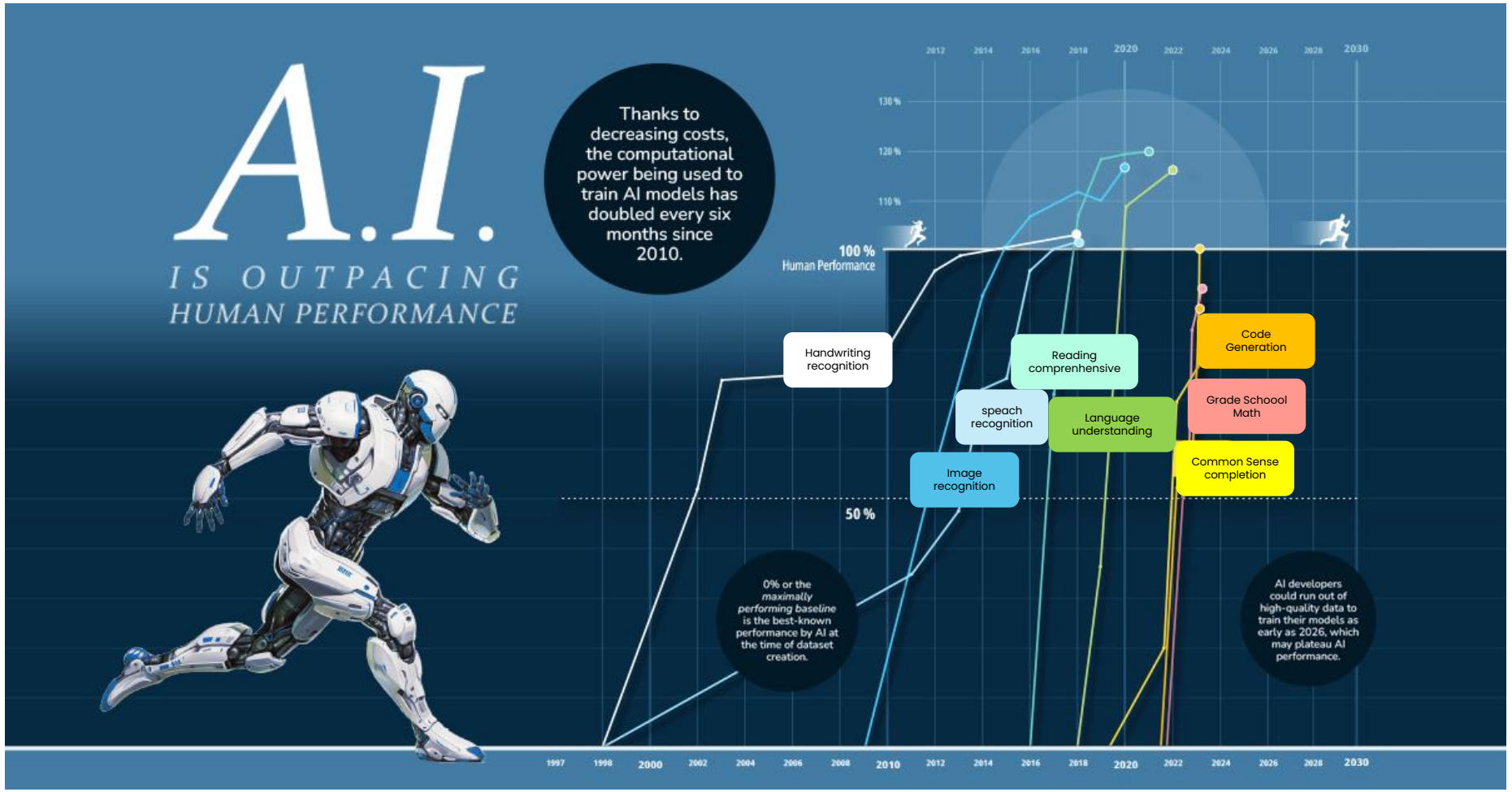
Data-Driven Maintenance (DDM)

Global Maintenance digital platform GMd



Mantenimiento Basado en Datos

AI versus humans - who does it better?



Aplications of Data-Driven Maintenance

Data-Driven Maintenance

Applications of DDM

MBD Mantenimiento Basado en Datos

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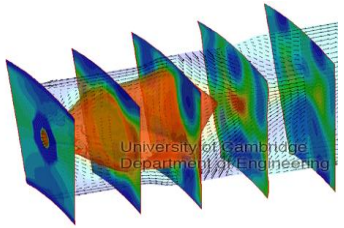
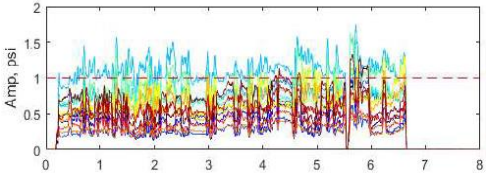
1.- Combustion diagnostic algorithm

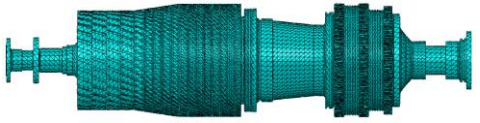
Anomaly detection of combustión dynamics (DLN combustors)

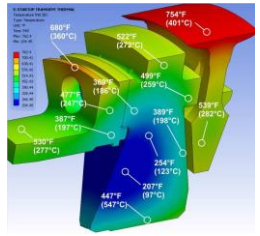


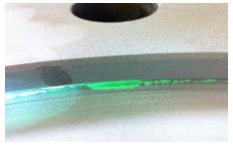


2.- 6B GT rotor replacement based on condition by means of a Digital Twin

Digital twin of the thermal-stress behaviour of a 6B gas turbine rotor components.

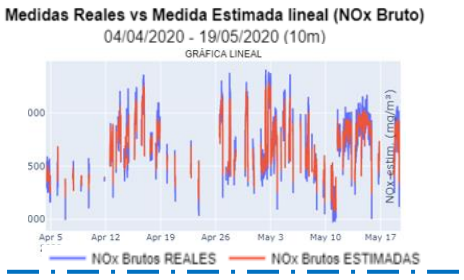






3.- Failure pattern analysis in diesel engines

Failure pattern analysis and prediction environmental events of RTA76 diesel engines.



4.- Exhaust Temperature Analysis of 6FA Gas Turbines

Anomaly detection of combustión issues by means of thee xhaust temperatura evolution

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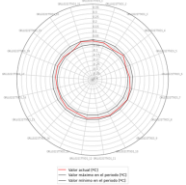

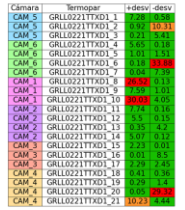

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Applications of DDM

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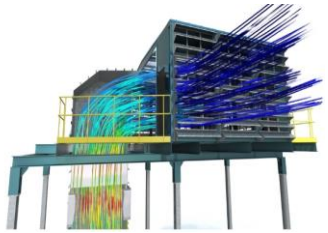
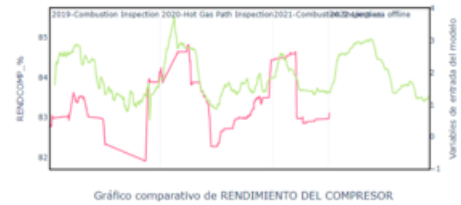
5.- Optimisation of compressor performance in 6FA Gas Turbines

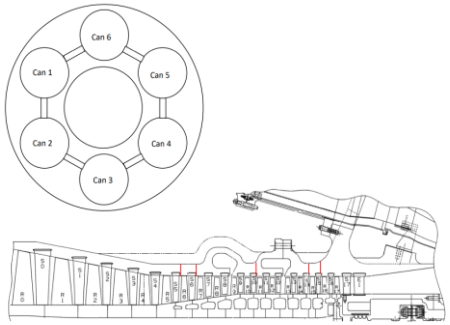
Digital Twin of the 6FA gas turbine compressor for their efficiency optimization and off-line water washing interval definition.





6.- Definition of maintenance intervals according to the actual dispatch of the 6FA gas turbine

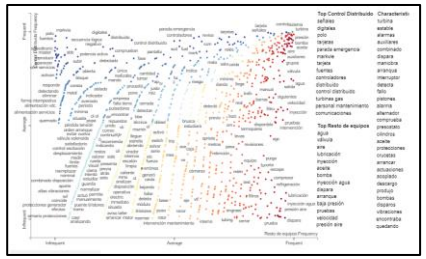
Proprietary algorithm for calculating the hours and starts for the 6FA Gas Turbines maintenance definition based not only on the operating hours and starts, but also on the dispatch load

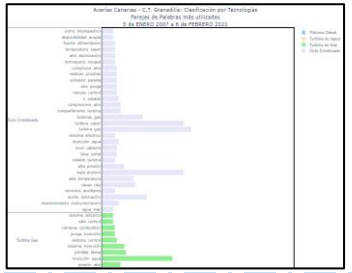


Optimización de intervalos entre revisiones

7.- Natural Language Processing (NLP) and Maintenance Management.

Transformation of natural language into formal language, which computers can process for maintenance management purpose.





8.- Digital Maintenance Platform

Web platform for digitalization of the regular maintenance management.

Plataforma GMIdigital