LEONARDO

Leonardo Electronics

A Novel Predictive Maintenance Methodology for improving Defence Logistics Processes

SAS-165 Research Symposium on «Assessing the Implications of Emerging Technologies for Military Logistics»

Center for Higher Defense Studies Rome, Italy

06-07 July 2022

Authors : L. Monorchio, A. Garritano, E. Luciani, L. Ciolli, M. Santini

Electronics

Helicopters

Aircraft

Cyber & Security

Space

Unmanned Systems

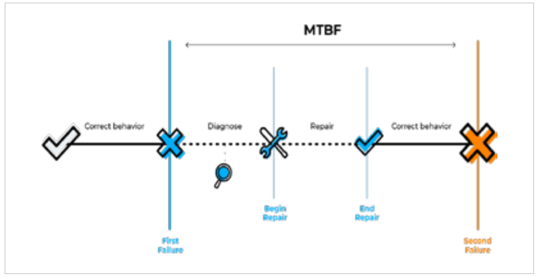
Aerostructures

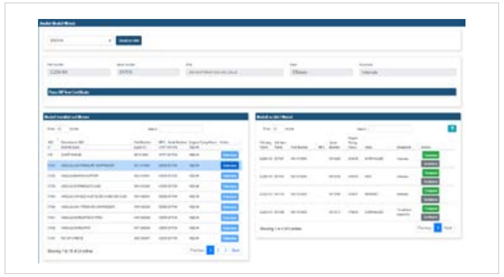
Machine Learning Solutions for New Maintenance Strategies

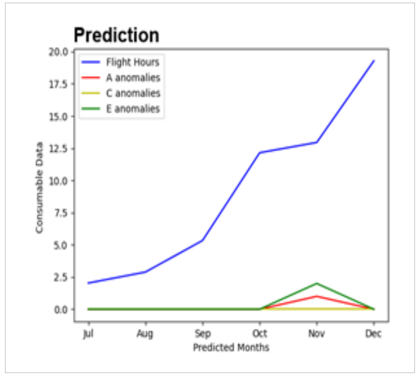
A novel **Predictive Maintenance Methodology** that uses **Machine Learning techniques** for improving military aircraft in-service logistics support processes

OBJECTIVES:

- To improve **Mean Time Between Failures** (MTBF);
- To increase **logistics KPI predictions reliability**,
- To reduce **maintenance support costs/working time**.







© 2022 Leonardo - Società per azioni

> Summary

> **Use Case 1: Smart Aircraft Anomalies Analysis**

> **Use Case 2: Aircraft Fleet Availability Improvement**

> **Use Case 3: Engine Test Stand (ETS) Optimization via Digital Twin**

© 2022 Leonardo - Società per azioni

Use Case 1: Smart Aircraft Anomalies Analysis

Objective: to support maintainers in solving newly raised anomalies using a **Natural Language Processing** (NLP) approach.








- Pilots and maintainers **record aircraft detected anomalies into the info-logistic system**,
- Their skills and the operative contexts in which they act are **highly heterogenous**,
- Useful information resides all over the **different types of meta data records** (structured and not, free text).

© 2022 Leonardo - Società per azioni

Natural Language Processing (NLP) approach

The proposed system provides the maintainer with a **list of past anomalies**, ranked by **similarity**, that helps him understand **how they have been solved** and find out which **spares** and **ground support equipment** have been used.

He can easily perform anomaly diagnosis, reducing the related MTTR (Mean Time To Repair).

NLP has been used to process information contained in *Incident* or *Health Reports* with the aim of understanding, at semantic level, the anomalies entered by the operator.

The final objective is to analyze, understand and generate human languages information, **just like humans do.**

© 2022 Leonardo - Società per azioni

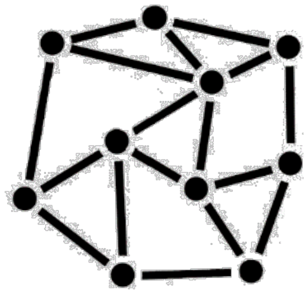
USE Network Easy-To-Read Architecture

UNIVERSAL SENTENCE ENCODER (USE)

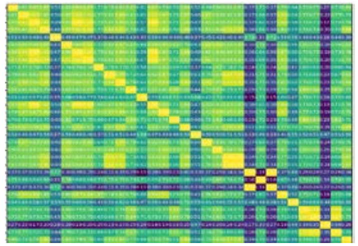
NEURAL NETWORK

INPUT DATA:
REAL DATA FROM IN-SERVICE
INFO-LOGISTICS SYSTEM

- Left Engine Bird Strike
- Debris Runaway Take-off
- Landing Gear Anomaly

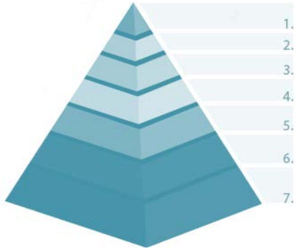


[0.3, 0.2, …]
[0.2, 0.1, …]
[0.9, 0.6, …]
...



SIMILARITY
MATRIX

SEMANTIC TEXT CLASSIFIER

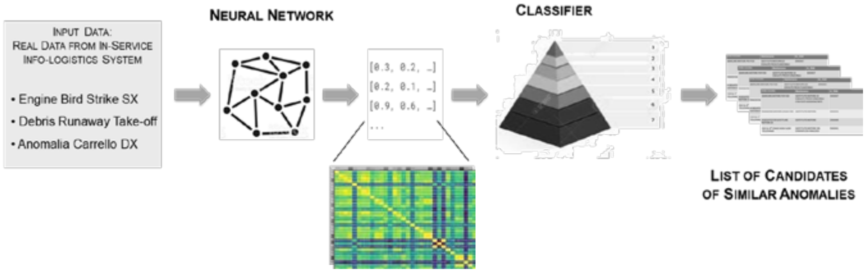


SIMILAR ANOMALIES
CANDIDATES LIST

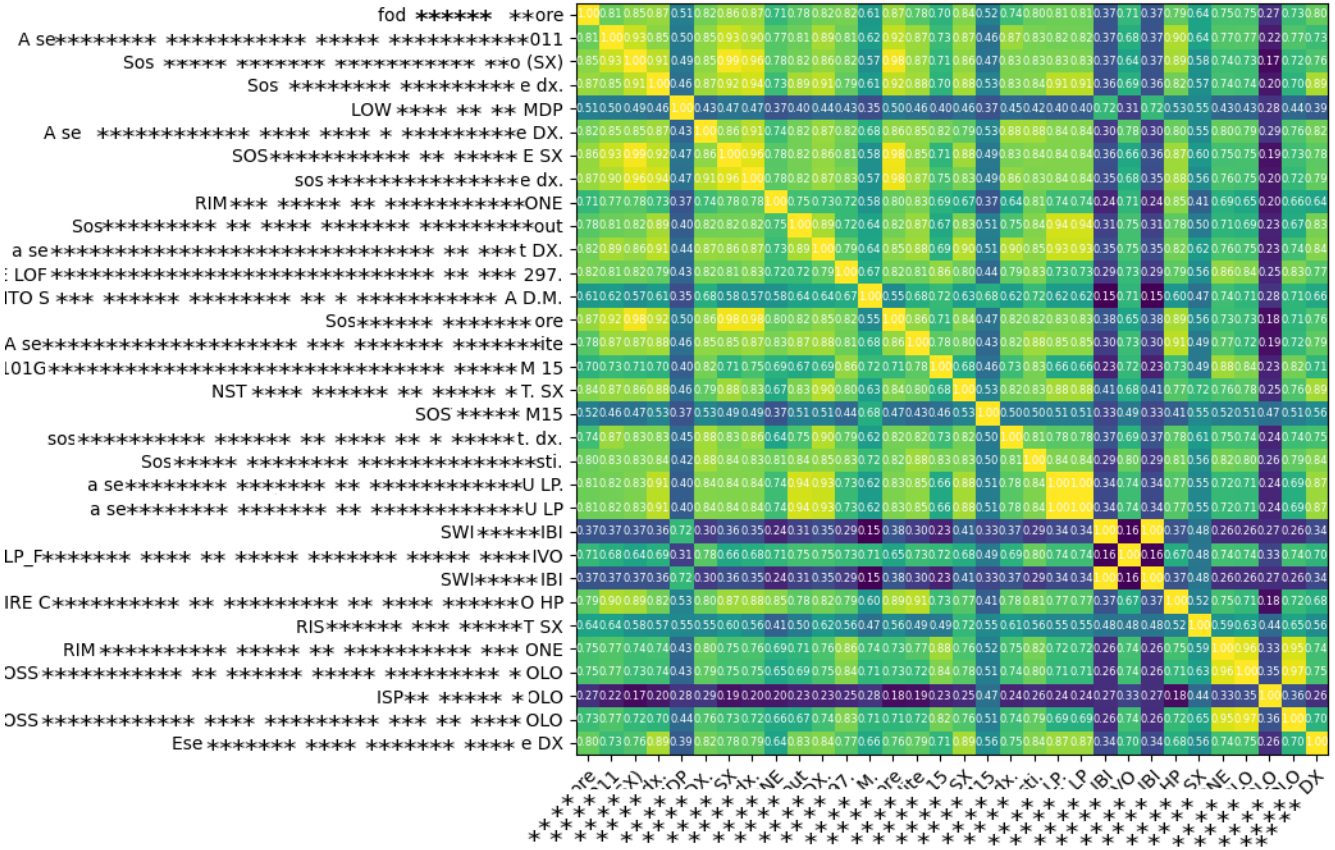
Support the Maintainer for solving the current anomaly

© 2022 Leonardo - Società per azioni

NLP: Semantic Text Similarity Approach

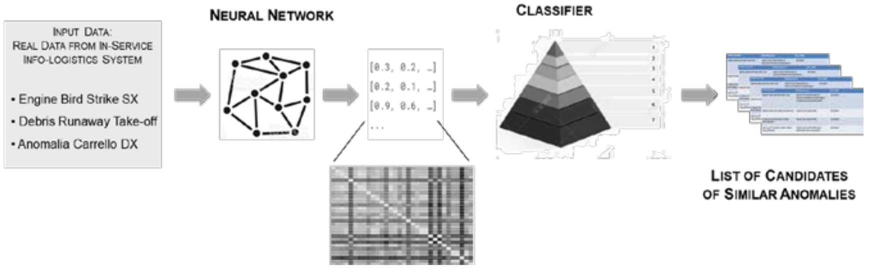


- Clusterization based on anomalies similarity matrix
- Main Diagonal: main correlation between past anomalies and current ones



© 2022 Leonardo - Società per azioni

Inference Examples



Oil Filter

Similarity Accuracy Level	Similar Anomalies	Maintenance	ID_TASK
1	REPLACE THE OIL FILTER ON R_ENGINE_OIL_FLTR_BLOCK	OIL FILTER CHANGED FOR ENG RIGHT WITH NEW OIL, OK	6XXXXX4
2	REPLACE THE OIL FILTER ON ENGINE LEFT.	DONE, OK	3XXXXX1
3	REPLACE THE OIL FILTER ON ENGINE LEFT.	DONE, OK	2XXXXX2
4	REPLACE THE OIL FILTER ON ENGINE LEFT.	DONE, OK	1XXXXX9

Bird Strike Event - Foreign Object Debris (FOD)

Similarity Accuracy Level	Similar Anomalies	Maintenance	ID_TASK
1	UNLOAD ENGINE - BIRD STRIKE EVENT	FOD CHECKING ON ENGINE S/N 1XXXXX2	3XXXXX7
2	UNDERSTAND FOD IMPACT	PERFORM ETS	3XXXXX3
3	FOUNDED BIRD STRIKE EVENT	ENGINE REPLACED	2XXXXX9
4	FOD ON 4° STAGE XXXX OUT-OF-TOLERANCE	Check ok, no further damages	5XXXXX1

© 2022 Leonardo - Società per azioni

Use Case 2: Aircraft Fleet Availability Improvement

Objective: To estimate the **aircrafts remaining flight time** in order to **improve aircraft fleet availability.**

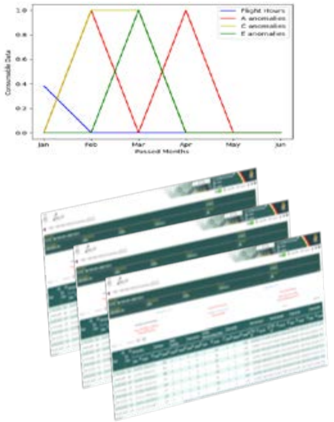
Knowing accurately when aircrafts will be available or not has great impact on maintenance organization processes and associated costs.

In this scenario, failure predictions play a decisive role when combined with in-service real data.

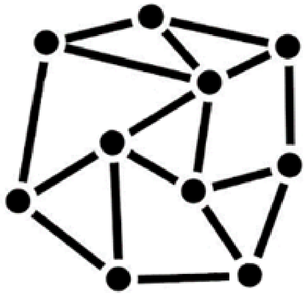
© 2022 Leonardo - Società per azioni

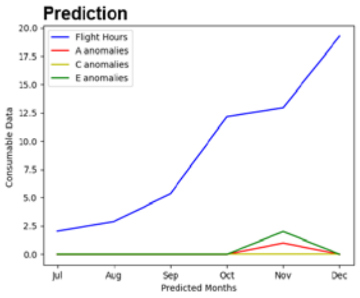
Robust Statistical Sensory Data (RSSD) Network for Aircraft Availability prediction

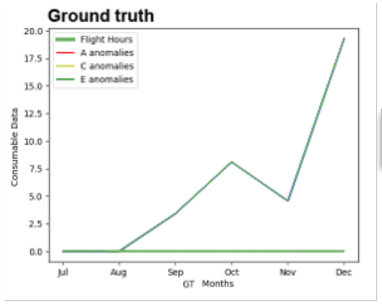
- A RSSD network has been developed and trained with **data fusion** approach.
- For a single aircraft (**Input**), the output (**Prediction**) is compared with the historical data stored into the legacy repository (**Ground truth**) to calculate the **improved potential aircraft availability**.



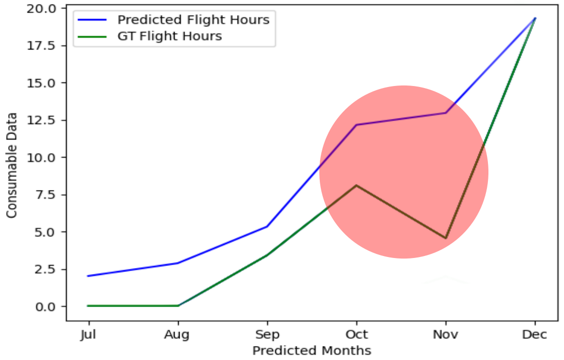
RSSD Network
ML Engine







Flight Hours: Predicted vs Ground



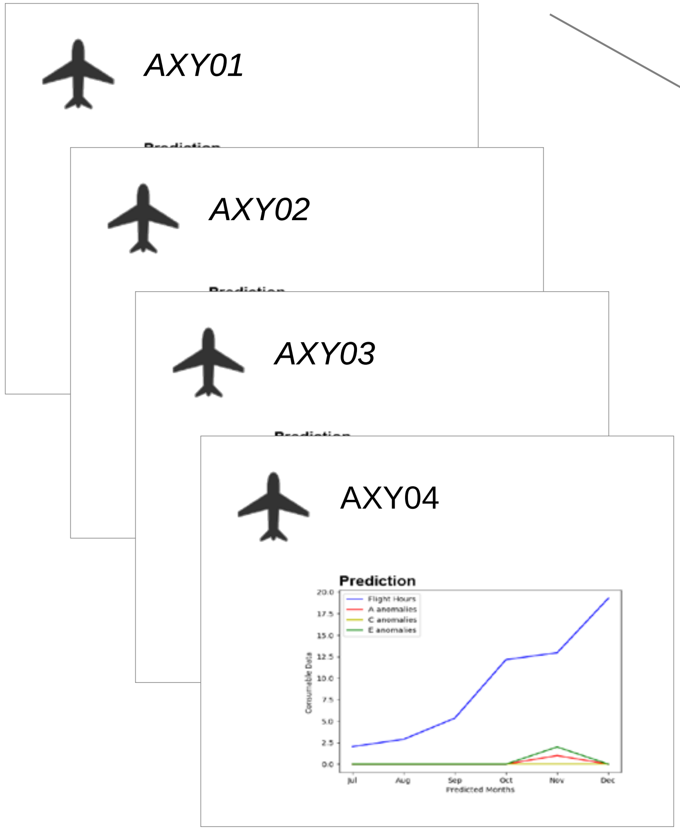
- Tail Number Mission data (landings, touch & go, maneuvers, etc ..)
- Mission & Sensor Right Engine Data (es: vibrometers)
- Mission & Sensor Left Engine Data

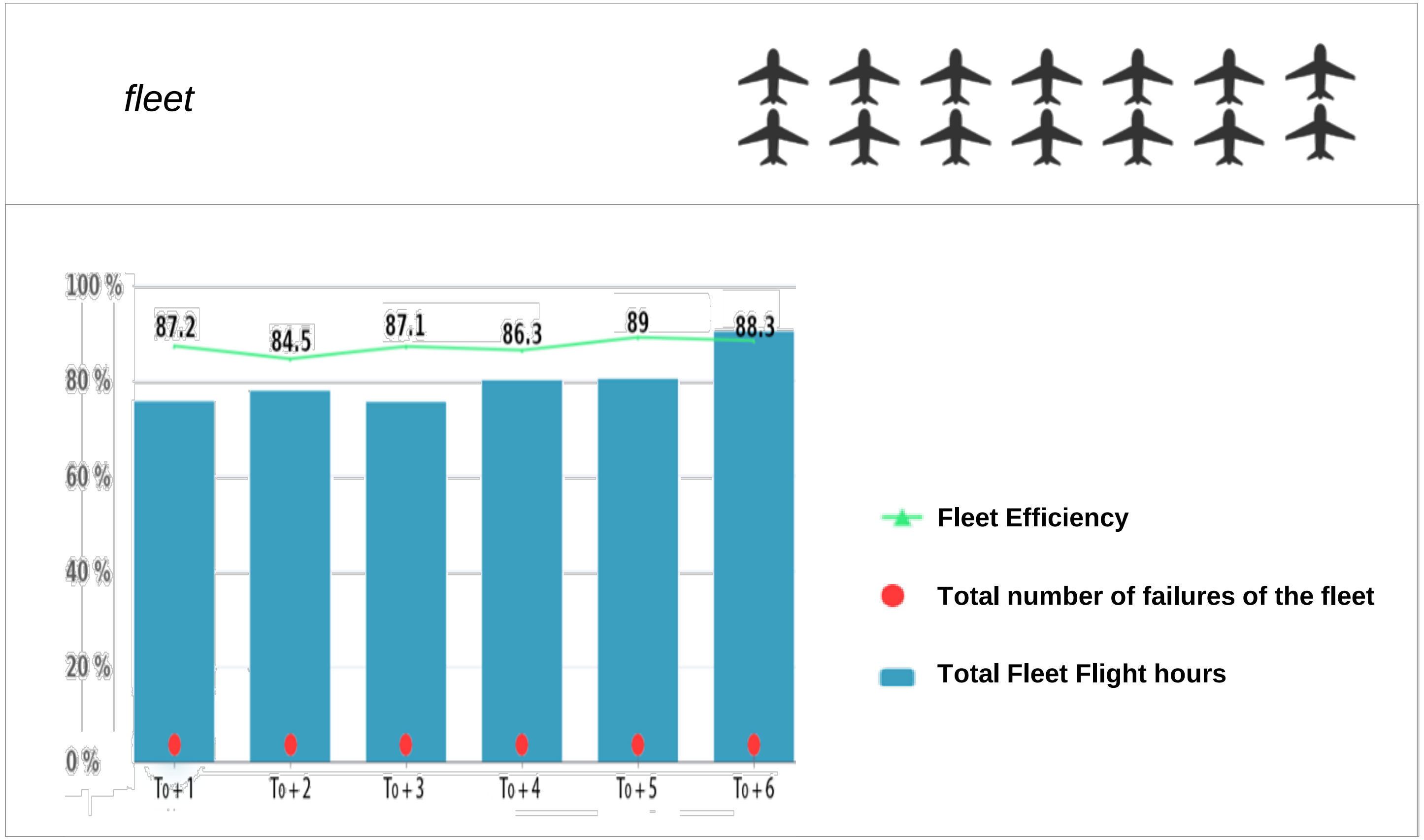
The similarity trend between the predicted data and the historical data confirms the correct accuracy of the Neural Network.

© 2022 Leonardo - Società per azioni

RSSD Fleet Flight Hours overtime Prediction

Single Tail Number

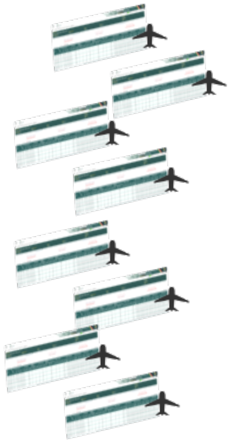




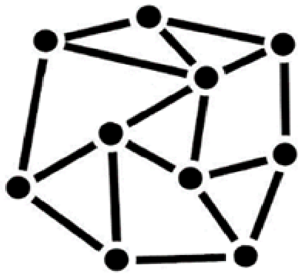
© 2022 Leonardo - Società per azioni

Robust Statistical-Sensory Data (RSSD) Neural Network

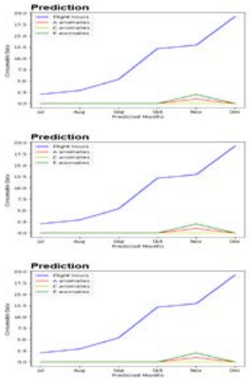
Exploiting **Data Fusion,** composed by statistical and sensorial data, to predict **Fleet availability** and **optimize Maintenance Schedule.**



- Tail Number Mission data
- Mission & Sensor Engine Data

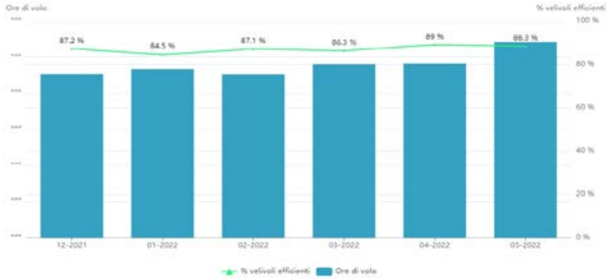


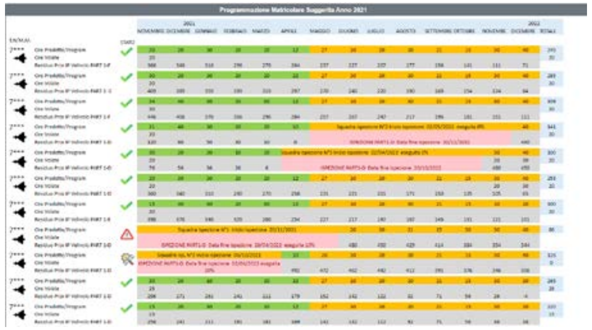
RSSD Network
ML Engine



Single TN Next 6 months
Availability prediction

Fleet Availability Index





Optimization Algorithm for readiness improvement

© 2022 Leonardo - Società per azioni

Use Case 3: Engine Test Stand (ETS) Optimization via Digital Twin

- ETS execution is the final process that **allows engines to pass the performance check** through rigorous tests.
- ETS are extremely **time-consuming and costly.**
- The objective is to **reduce the number of ETS** that a specific engine could be subjected to using Deep Learning approach on a simulation environment.

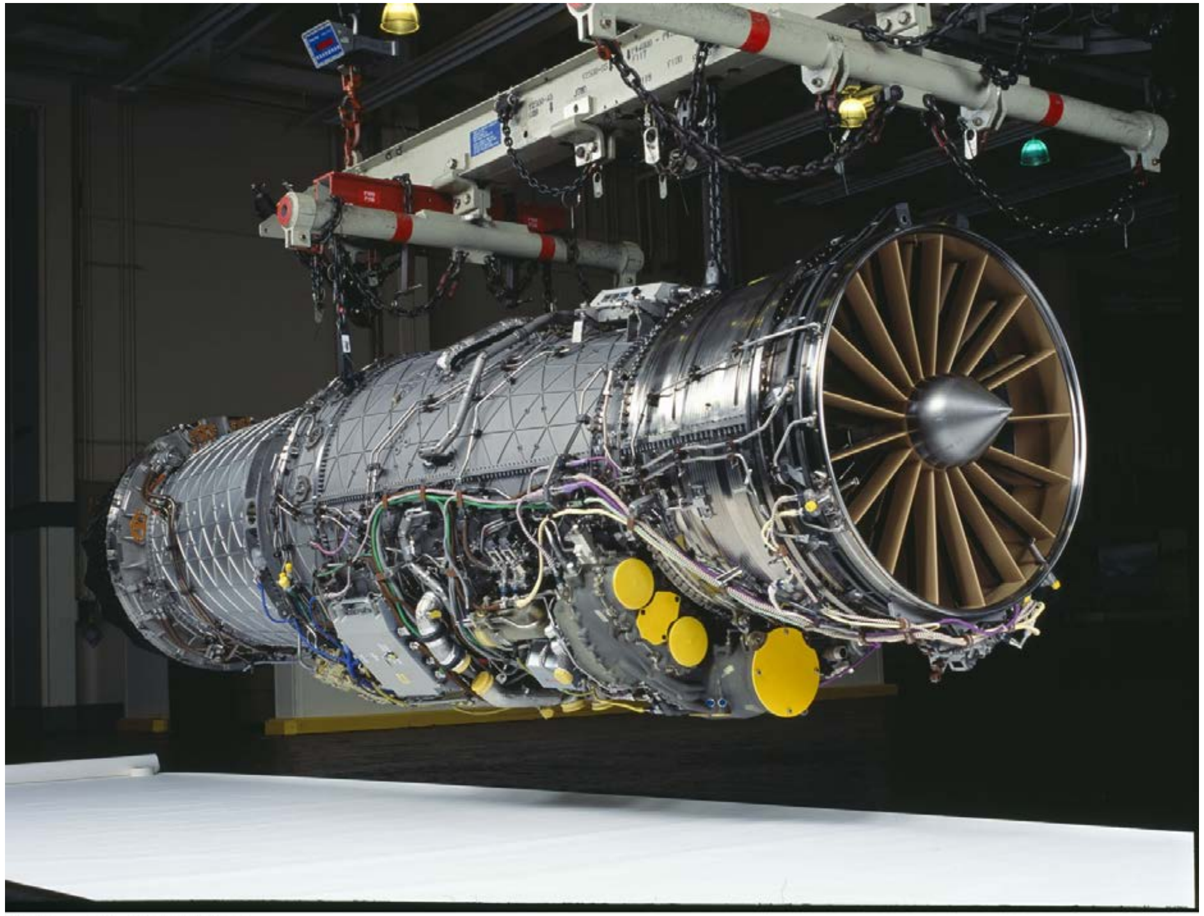


Photo credit: Pratt & Whitney

© 2022 Leonardo - Società per azioni

Digital Twin - Dashboard

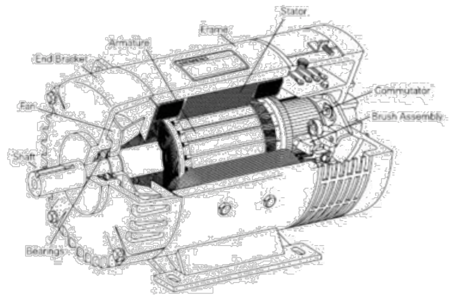
PLATFORM

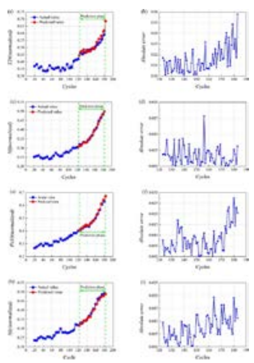
Big Data Module

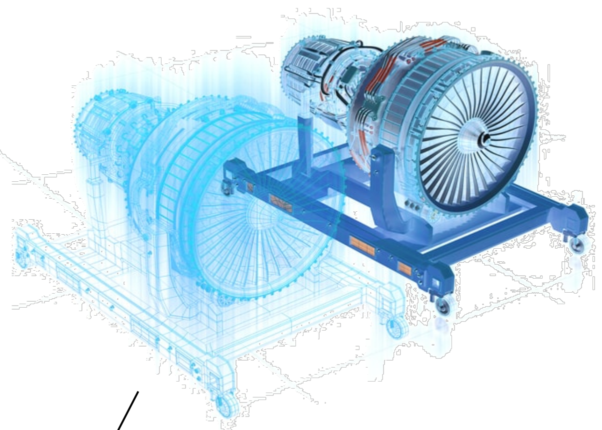
Data Lake Module

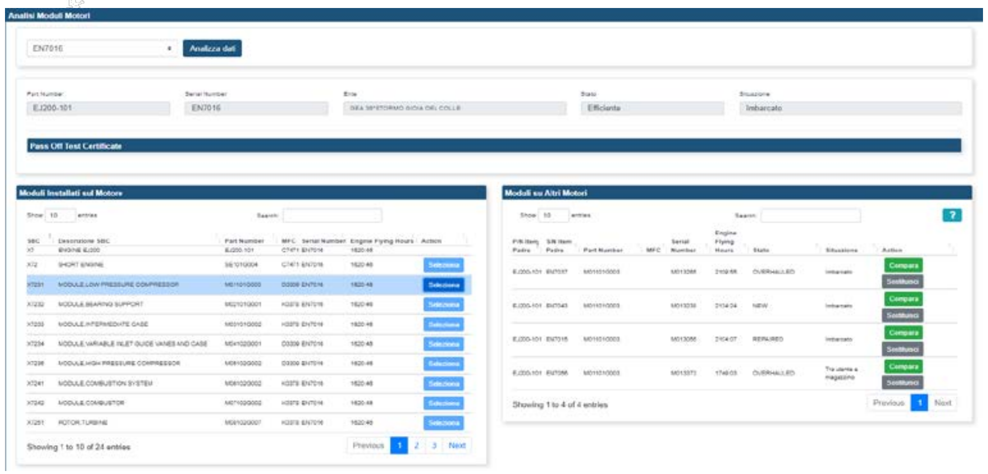
Neural Network Module

PHYSICAL ASSET









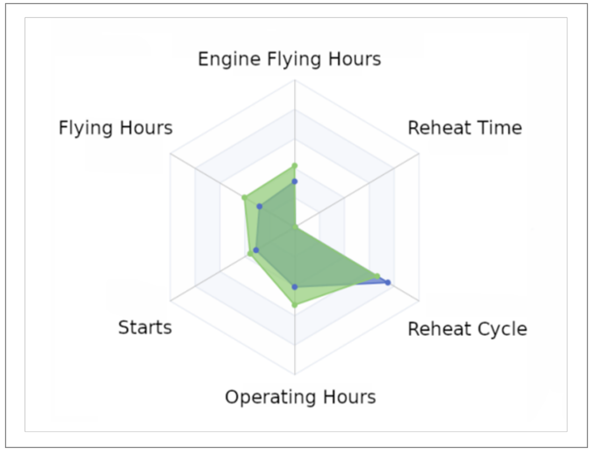
- Display all the simulated ETSs candidates that **improve real ETS pipelines**

- **KPI** of Engine Test Stand (ETS)

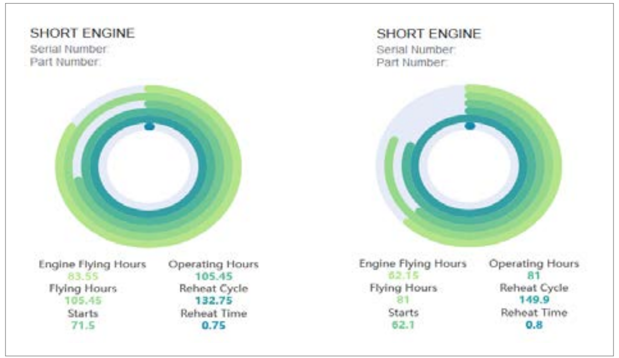
© 2022 Leonardo - Società per azioni

Digital Twin – ETS Simulations Comparison

The comparison between perfomances of 2 different asset configurations provides best ETS benchmark results.



Maintainer supervised asset configurations provides high flexibility of the proposed solution.



The operator chooses an engine parameters configuration setup depending on its maintenance impact.

© 2022 Leonardo - Società per azioni

Conclusion

The use cases have been developed in collaboration with Italian Air Force that provided the data. The results achieved by the **applications of ML methods on both statistical and sensorial data** have provided an insight of how to **maximise the aircraft operational availability** by

- **increasing the reliability of the prediction**
- **minimising the need for maintenance**
- **improving the total true-life cycle cost**

Future steps include the extension of the use cases and the definition of additional operational scenarios as further demonstration of the benefits that such applications can bring to military logistics.

© 2022 Leonardo - Società per azioni