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Decisions better made

Predictive Maintenance for Safety-critical systems with a Digital Diagnostic Twin

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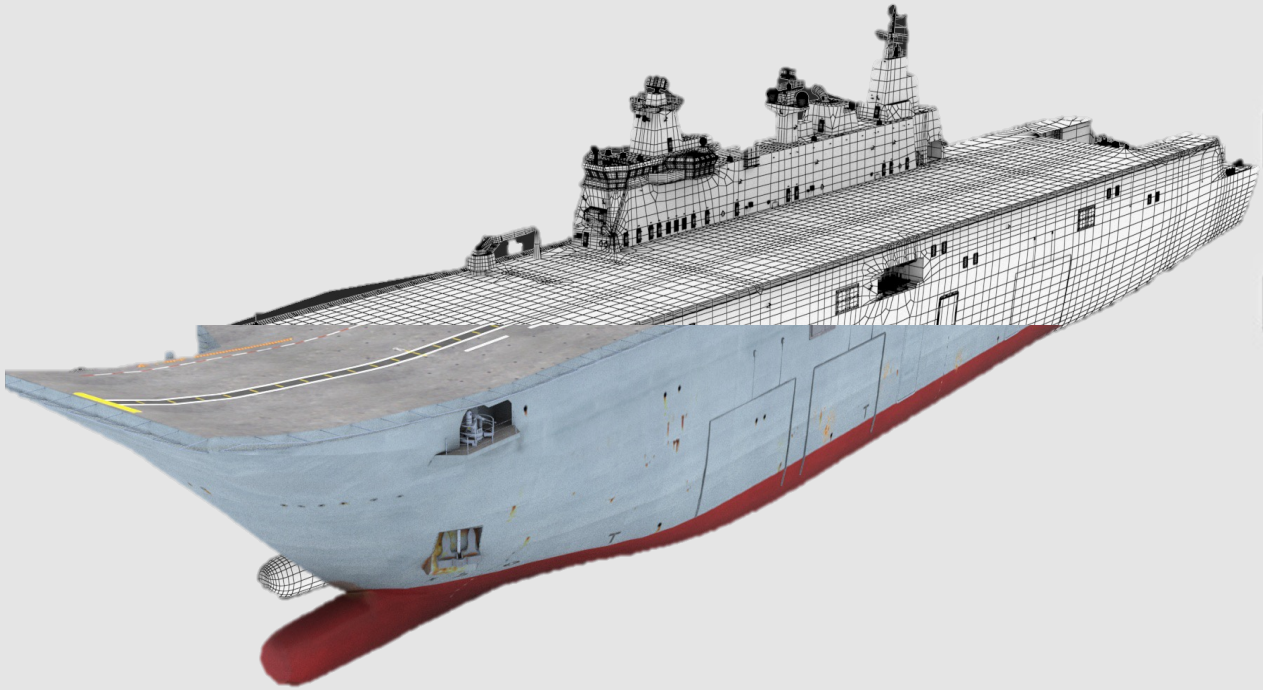
Introduction



- Predictive Maintenance (PdM) is a goal of RAMS, and requires accurate FDI
- New technologies such as Machine learning and Internet of Things have opened pathways towards PdM
- However, due to rushed adoption of this technology and rapid advancements in hardware, there are some misplaced expectations
- Safety critical systems cannot tolerate system failures to 'learn'
- This paper showcases Syndrome Diagnostics, a novel approach to FDI that leverages Digital RAMS Twins to incorporate domain understanding

Failure Identification & Isolation

"Remember – PdM is not a data science problem, it's an an engineering problem"

CTO, Jacek Stecki

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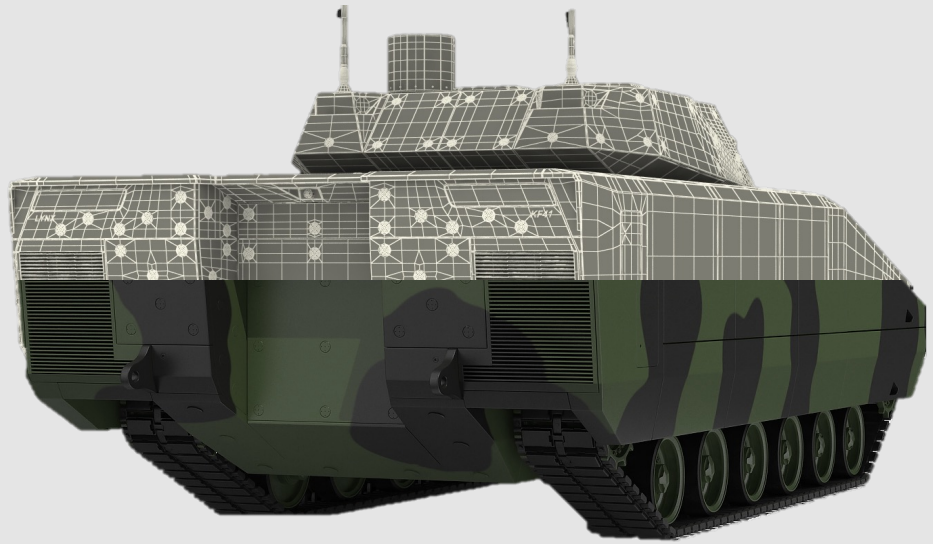
Data Science challenges with FDI



Data Science Challenges

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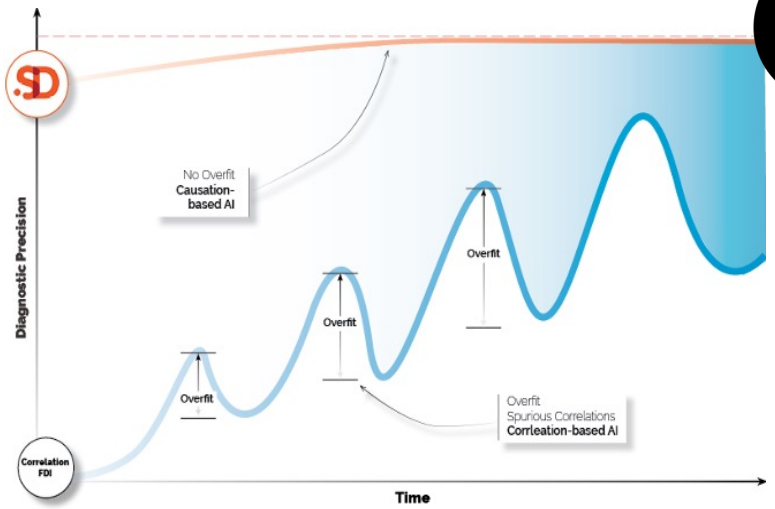
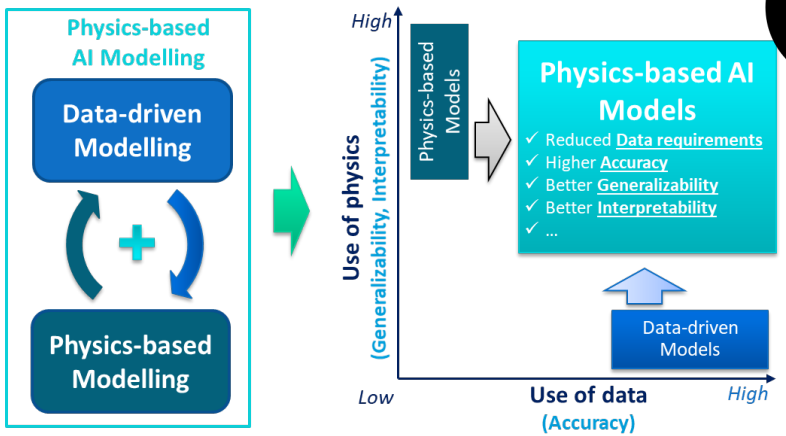
1 Overfit

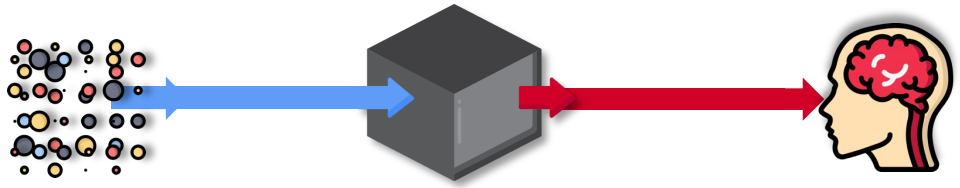


2 Determinism



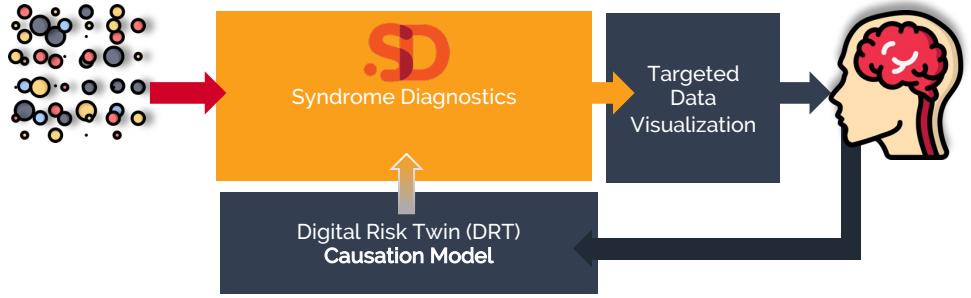
3 Traceability

Current solution



Why did the algorithm do that?
Can I trust the results?
How can I correct an error?

Next Generation solution



The domain expert can understand why
The domain expert can learn and correct errors
The domain expert can re-enact on demand

Comparison between explained and non-explained predictions

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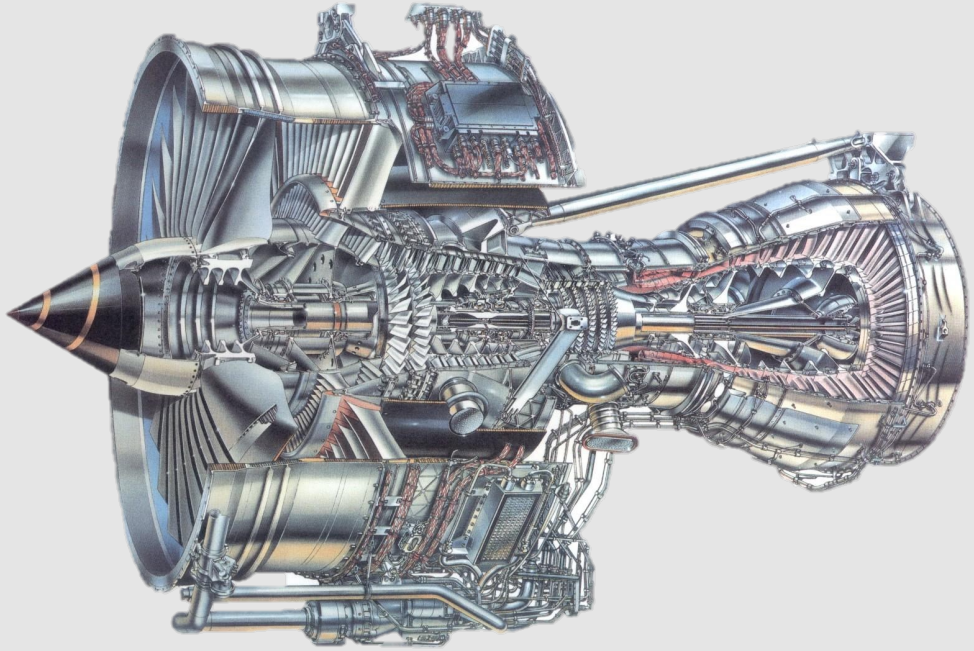
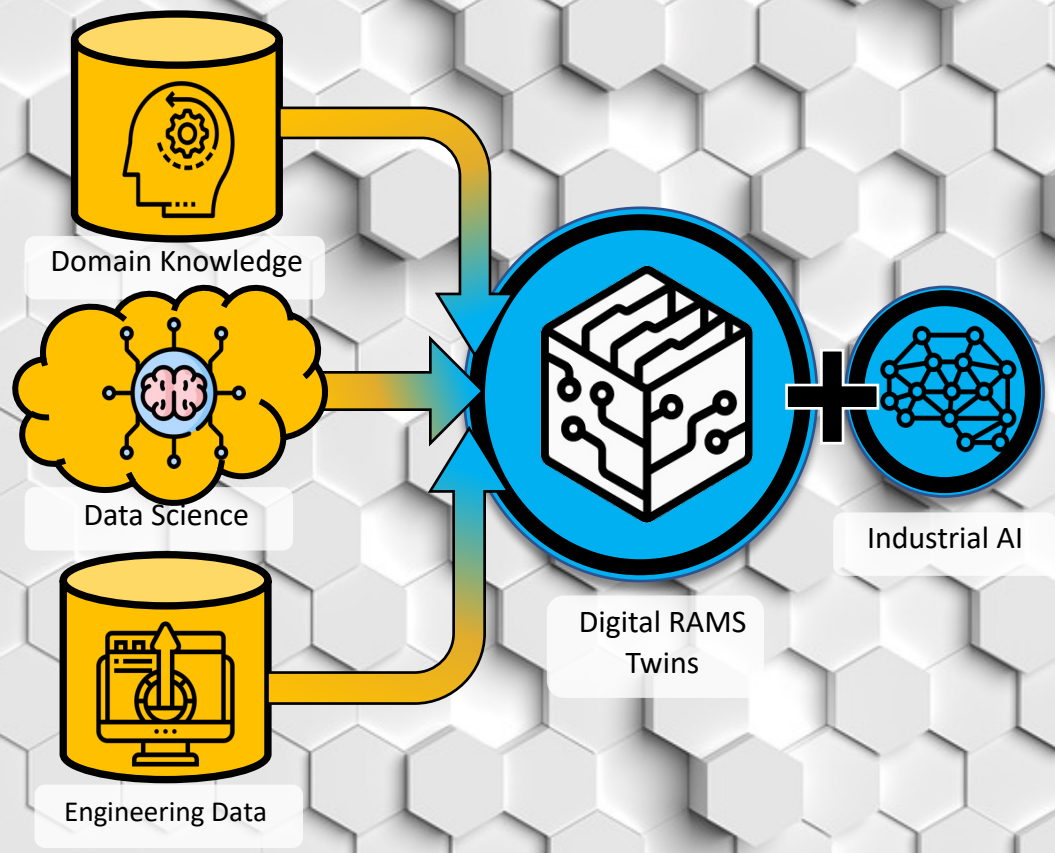
Syndrome Diagnostics & Digital Diagnostic Twin

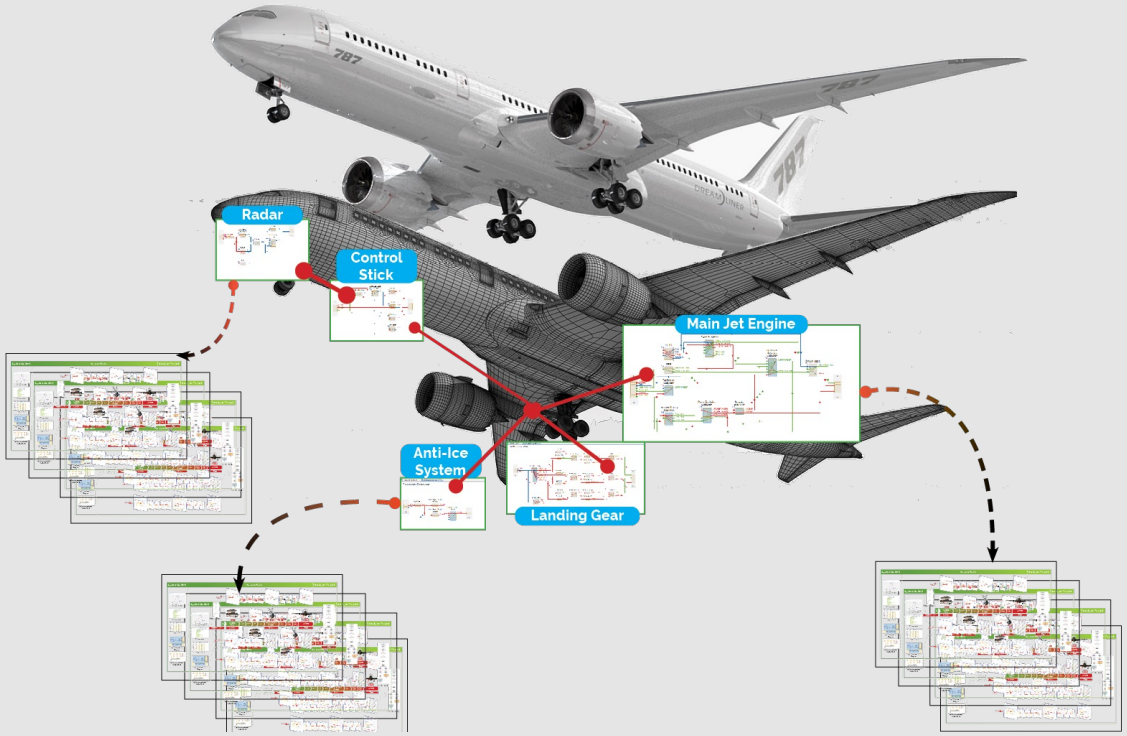


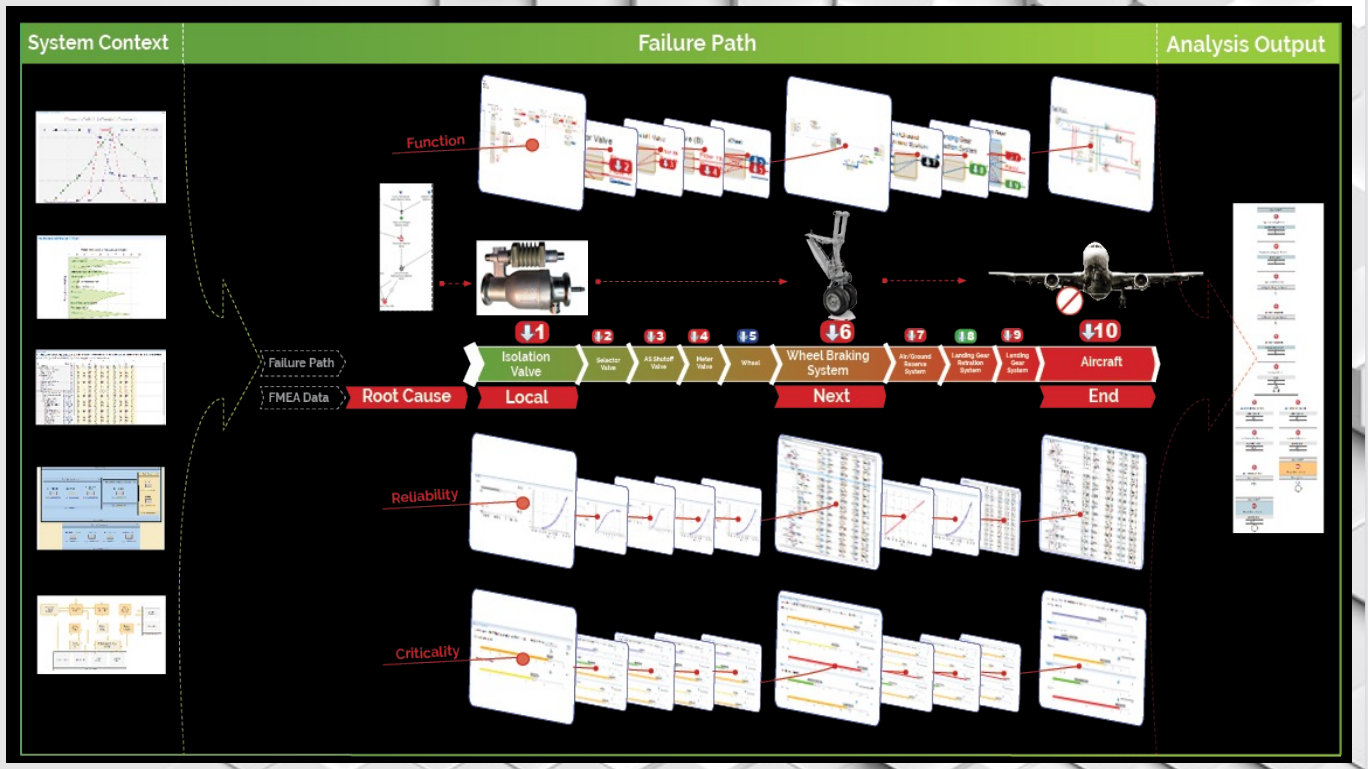
Digital Diagnostic Twin

- This digital twin contains all the information required for diagnostics
- Item information
  - Sensor mappings and parameters
  - Components and relationships
- Failure information
  - Functional failure details such as component, flow property and failure mode
  - Criticality of the failure
  - Narratives involved
  - Failure diagrams
  - Fault codes
- Trained algorithms



The Digital Risk Twin

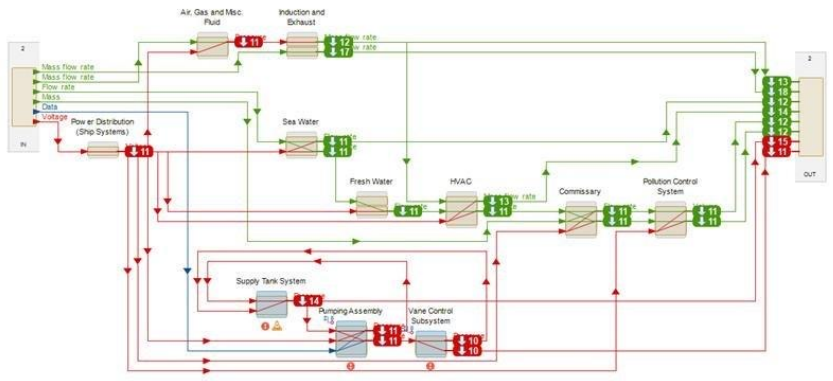




MADe
MAINTENANCE AWARE DESIGN

Syndrome Diagnostics

Asset

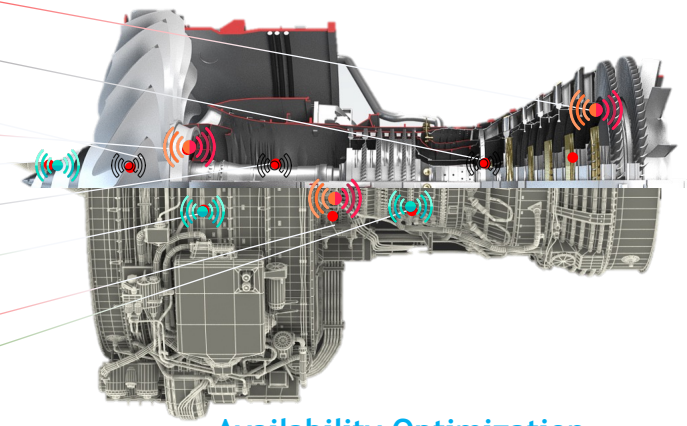


Digital Risk Twin

Model Outputs

1 2 3 4 5

System Outputs



Availability Optimization

AIF

MIF

Fault Isolation

Fault Detection

Health Condition

Residual Life

Operations

aFracas

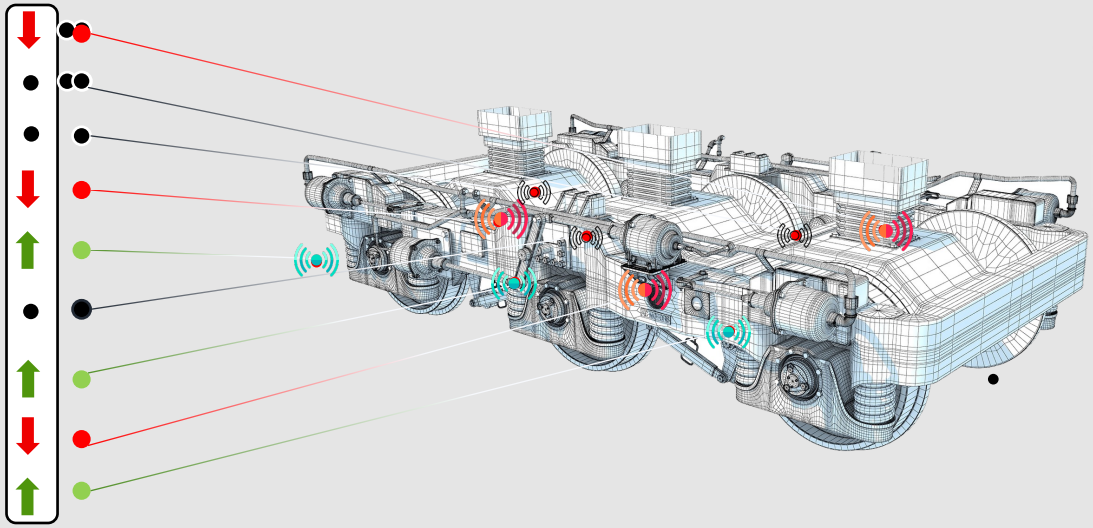
MMS

Model Updates

Asset Condition

Optimised Maintenance

Finding the needles…

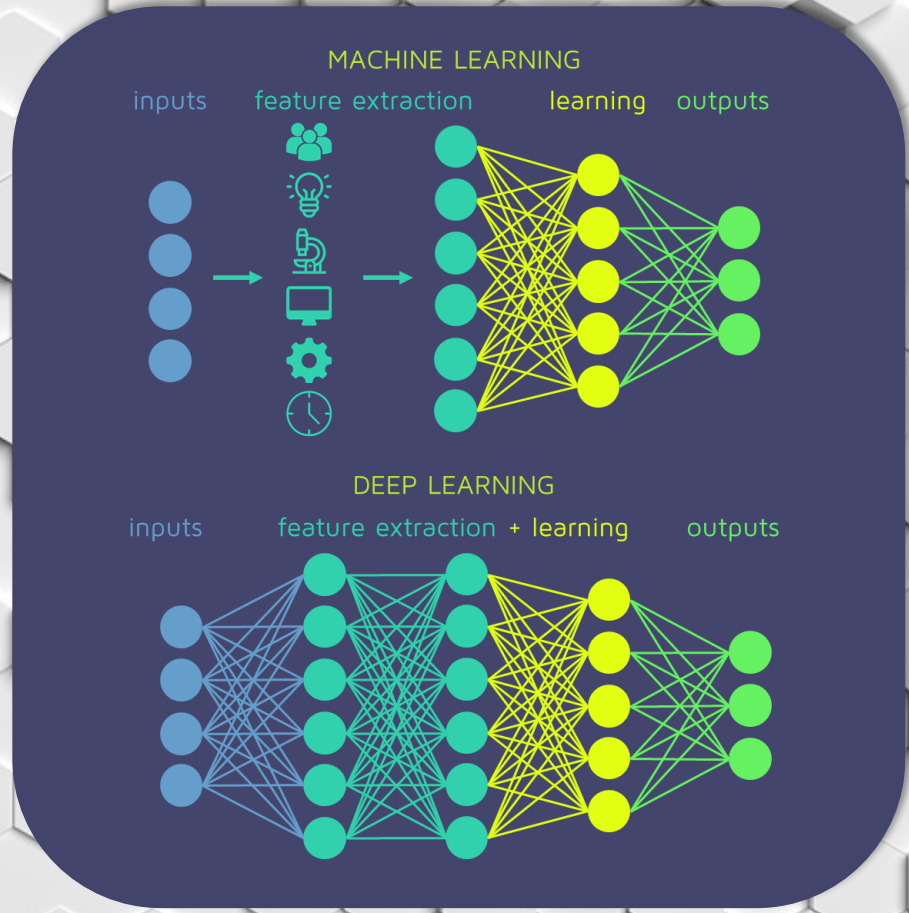


Finding the Needle

- The Digital Diagnostic Twin provides the domain knowledge required for FDI, effectively a digital Subject Matter Expert (SME)
- This provides advantages:
  - **Integrity**: due to a consistent and single source of truth for domain knowledge, the final predictions can be tracked to one location
  - **Reliability**: lack of spurious correlation from pure correlation renders Syndrome Diagnostics a trusted tool
  - **Rich Domain Knowledge**: multiple contributions and entry fields ensure that all the required information is available for reference
  - **Minimal User Interpretation**: since all the domain knowledge is already captured prior to inference, the user can simply be served information rather than be queried for more

Machine / Deep Learning Preprocessing & Feature Engineering

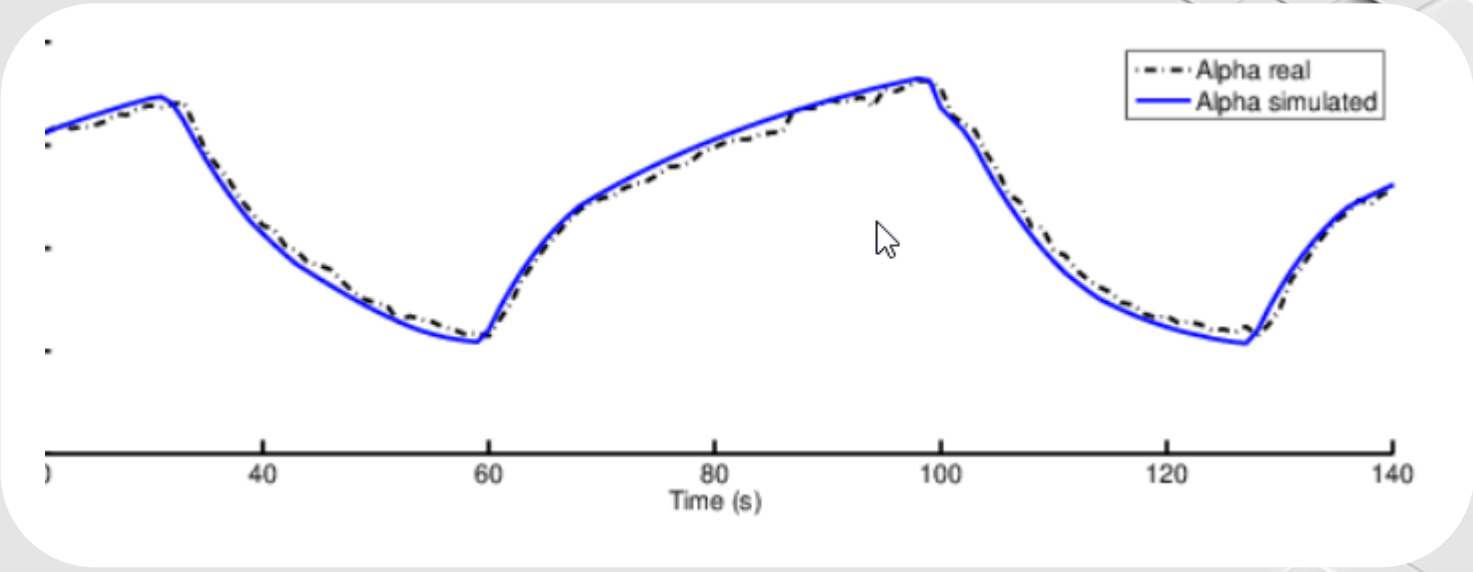
- Preprocessing
  - Reduce noise
  - Resample timestamps
  - Rearrange ‘broken’ messages
  - Normalize and scale data
- Feature engineering
  - Extract a useful subset or transform to a different domain space (time to frequency for example)
  - Reduce data size



Machine / Deep Learning:

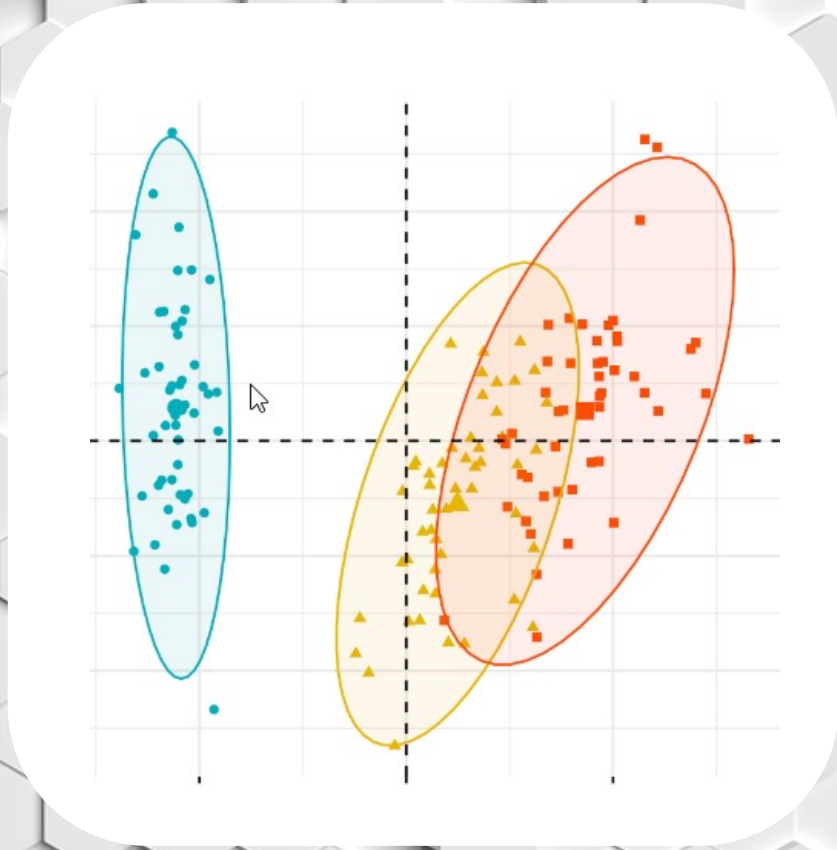
Reference Generation

- Easier to compare measured signals to a reference or nominal signal
- Use of Recurrent Neural Networks and Regression methods to generate reference data from signal



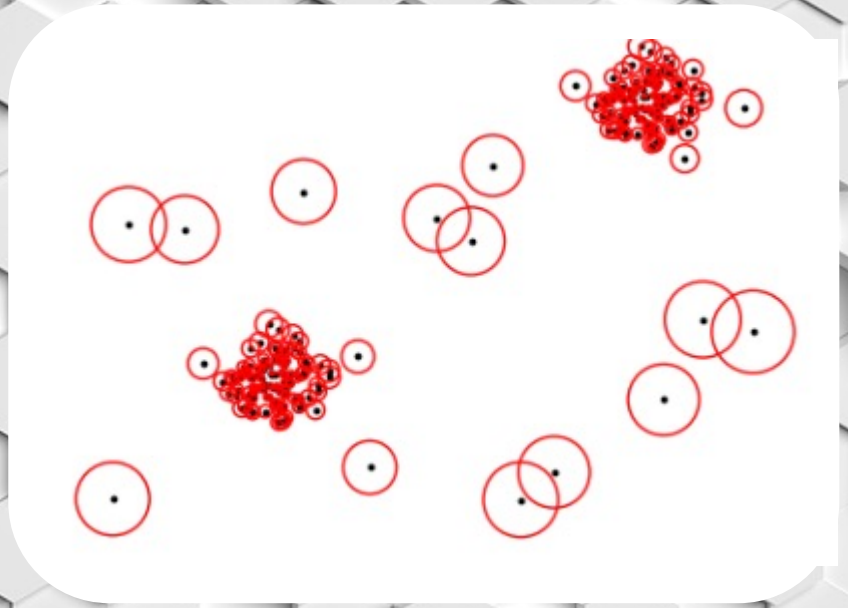
Machine/Deep Learning:
Determining Operating Modes

- Most machines these days operate different functions and thus will have varying operating modes
- Each mode will have its own 'native' failures and anomalies as well as nominal states
- The high-dimensional structural behaviour of the data is exploited to determine unique patterns of different modes.
- K-Means clustering is one of several techniques that used by SD for this task



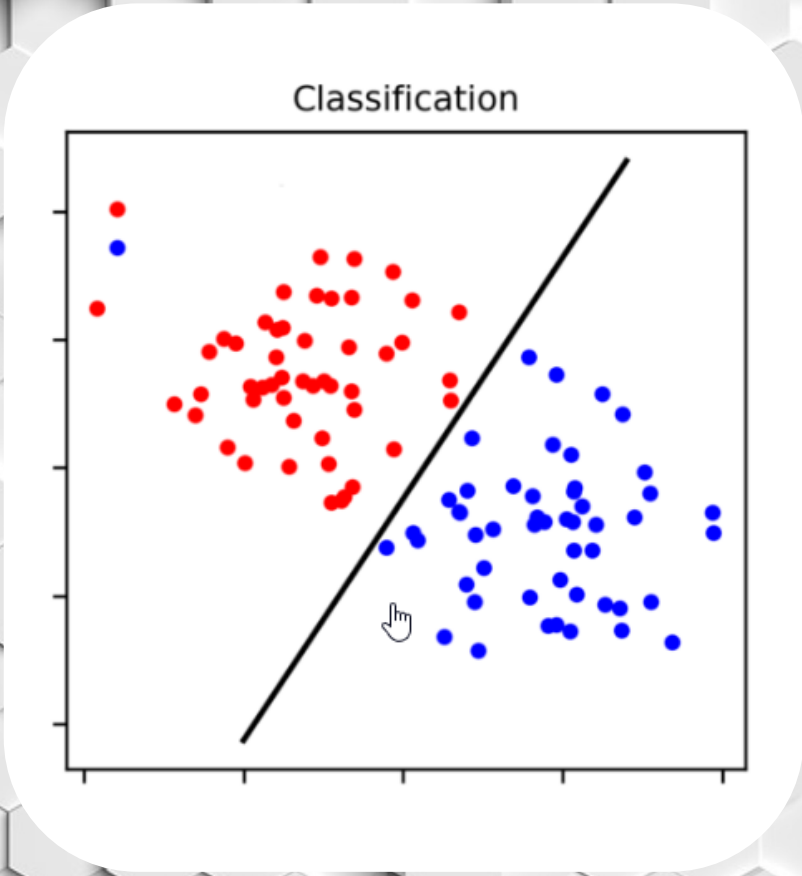
Machine/Deep learning:
Novelty Detection

- A quick analysis can be made prior to more complicated calculations to ‘weed out’ healthy readings
- Detection of odd behaviour, outliers or novelties makes it easier to only analyse possible failures or anomalies (processing efficiency)
- Boundary methods are common for this use-case such as an One Class Support Vector Machine (OCSVM)



Machine/Deep learning:
Symptom classification

- Failures and anomalies result in a deviation from the nominal state of a flow between components in a system
- These fall into labels of higher, lower or same as the nominal behaviour and thus is a classification problem
- Methods such as Gradient Boosting make suitable candidates for this task



Conclusion

- Syndrome Diagnostics is a novel approach, combining advances in hardware, software with the knowledge acquired from expert sources
- It is coupled with MADe to provide a Digital Risk Twin of the captured domain knowledge to provide in-depth information of the system and its failures
- Various stages of analysis is done using machine and deep learning to process large amounts of data efficiently to provide Causation-based AI.

End