Why PHM Is Not Just A Data Science Problem?

PHM Technology
Decisions better made

- Issues
- Digital Twin Solution
- PHM of the future

Our Platforms:

MADe
MAINTENANCE AWARE DESIGN

MODe
MAINTENANCE OPTIMIZED DIAGNOSTICS

November 2022

SIEMENS

Overview

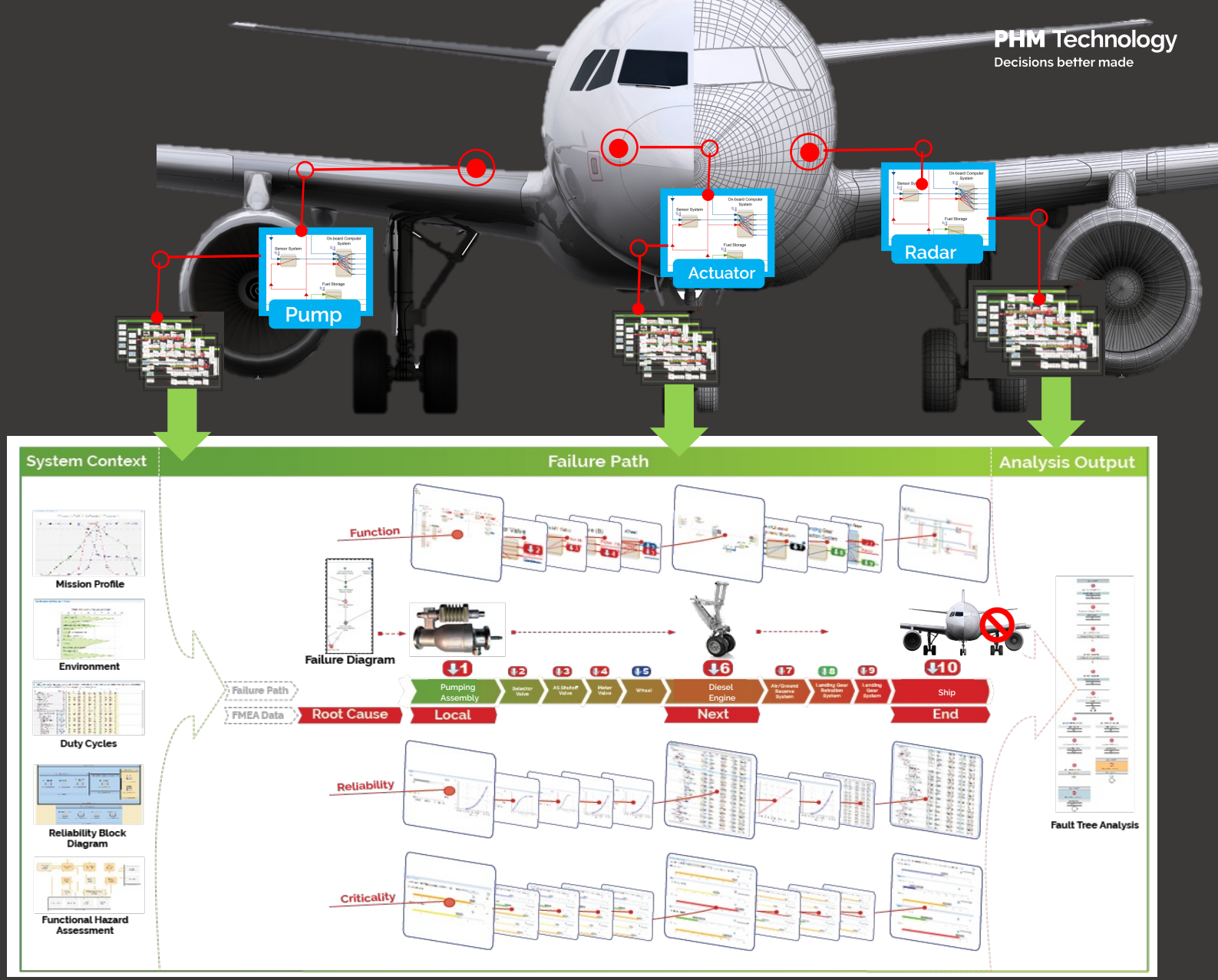
- Issues with Data Science only approach
- Digital Twin Approach Vs Data Science only approach
- Digital Twin solution - High Level
- Digital Risk Twin
- The rationale for the Digital Twin approach
- Advantages of Digital Twin solution
- MADe Platform: Live Demonstration
- Syndrome Diagnostics Overview
- Syndrome Diagnostics Video
- Closing the loop
- Conclusion

Digital Risk Twin

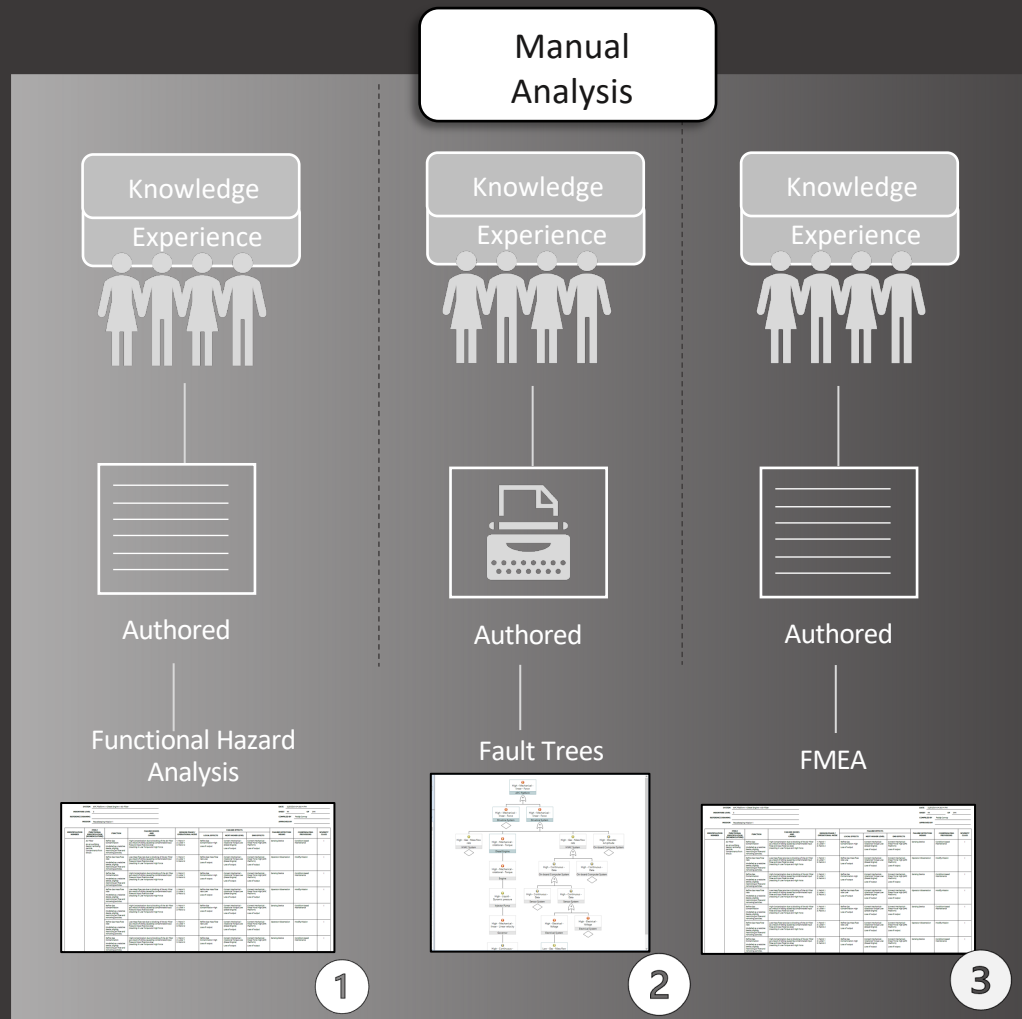
The Digital Risk Twin (DRT) uses a simulation model of a system to identify & analyse potential failures / hazards & their impacts.

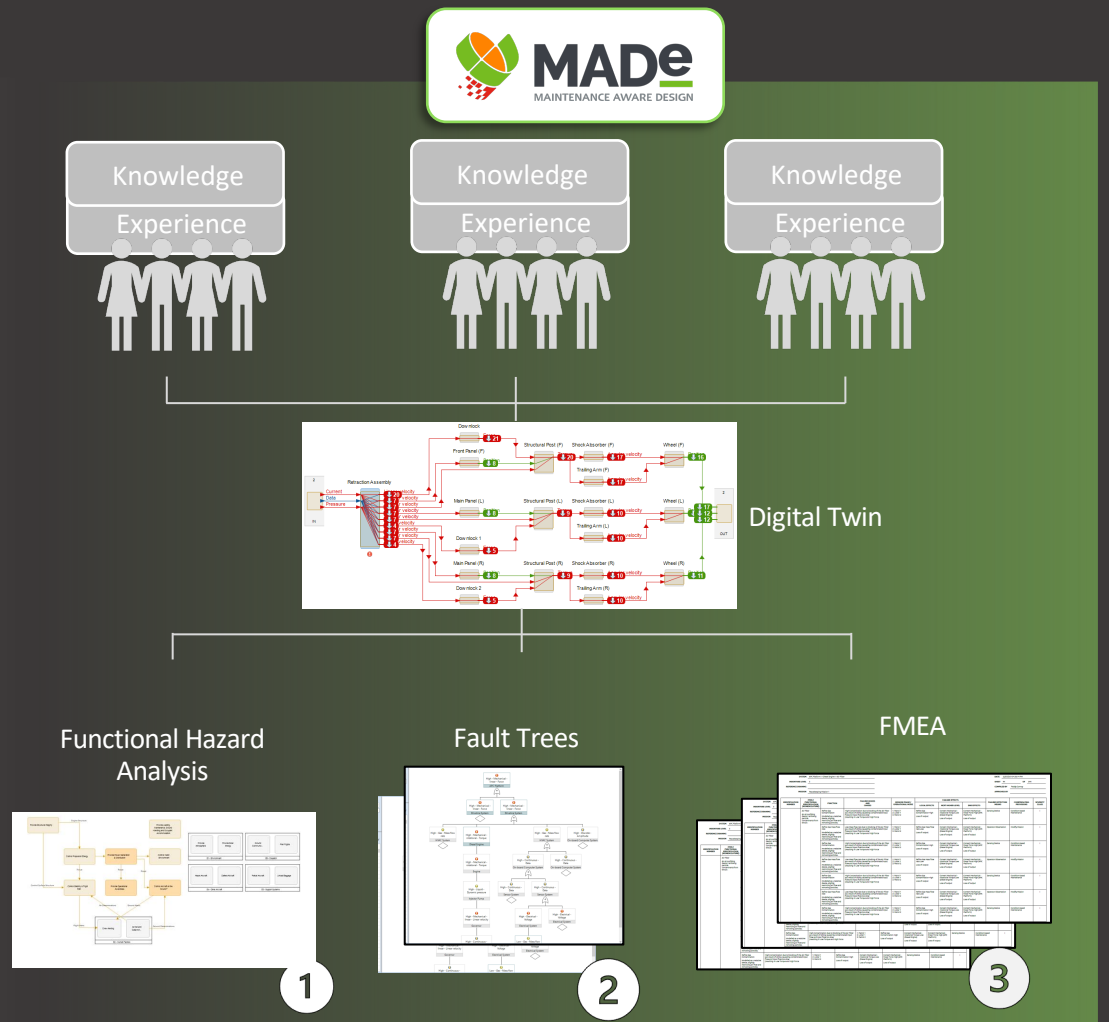
Each potential risk is based on the system configuration (concept / design) , context (environment, use case, etc.), cost and impact.

- Model-based RAMS Analyses
- Model-based Diagnostic Design
- Digitization of Domain Knowledge
- Digital Diagnostic Twin

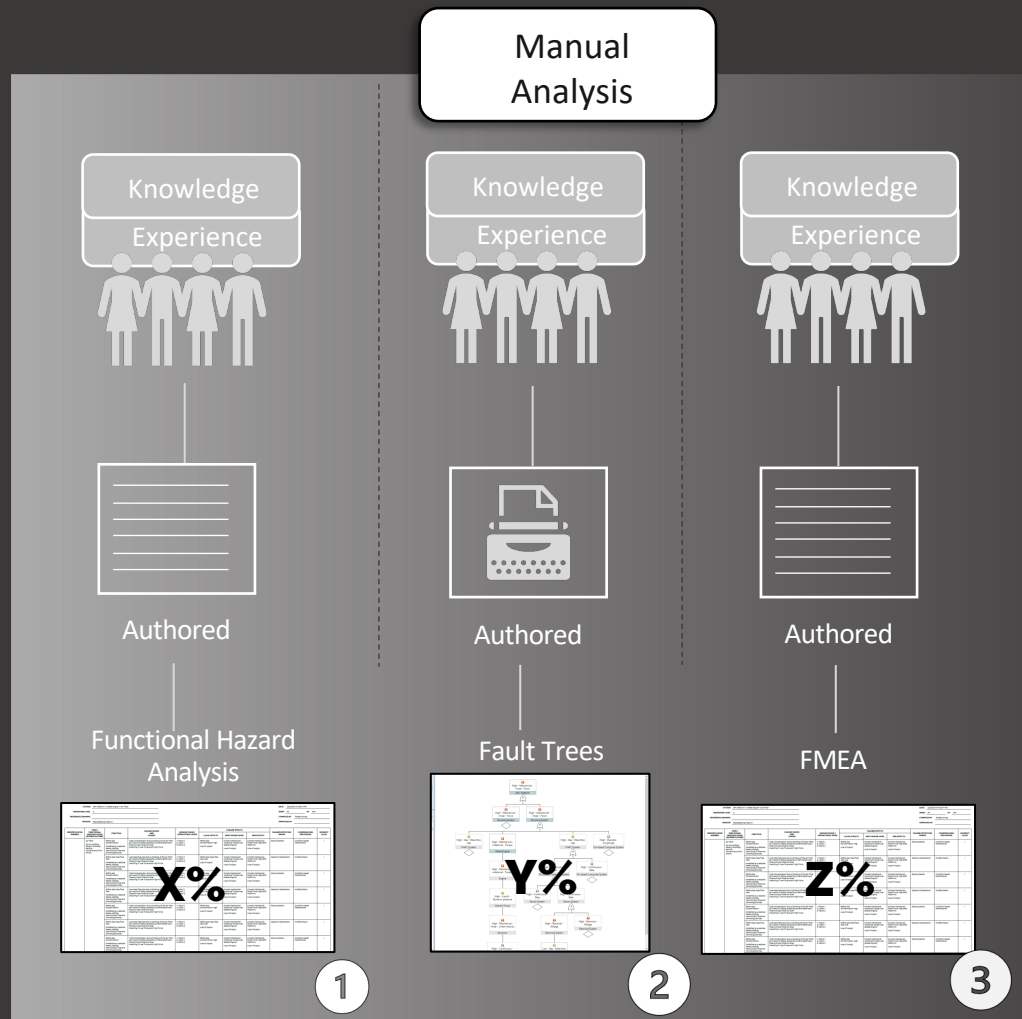


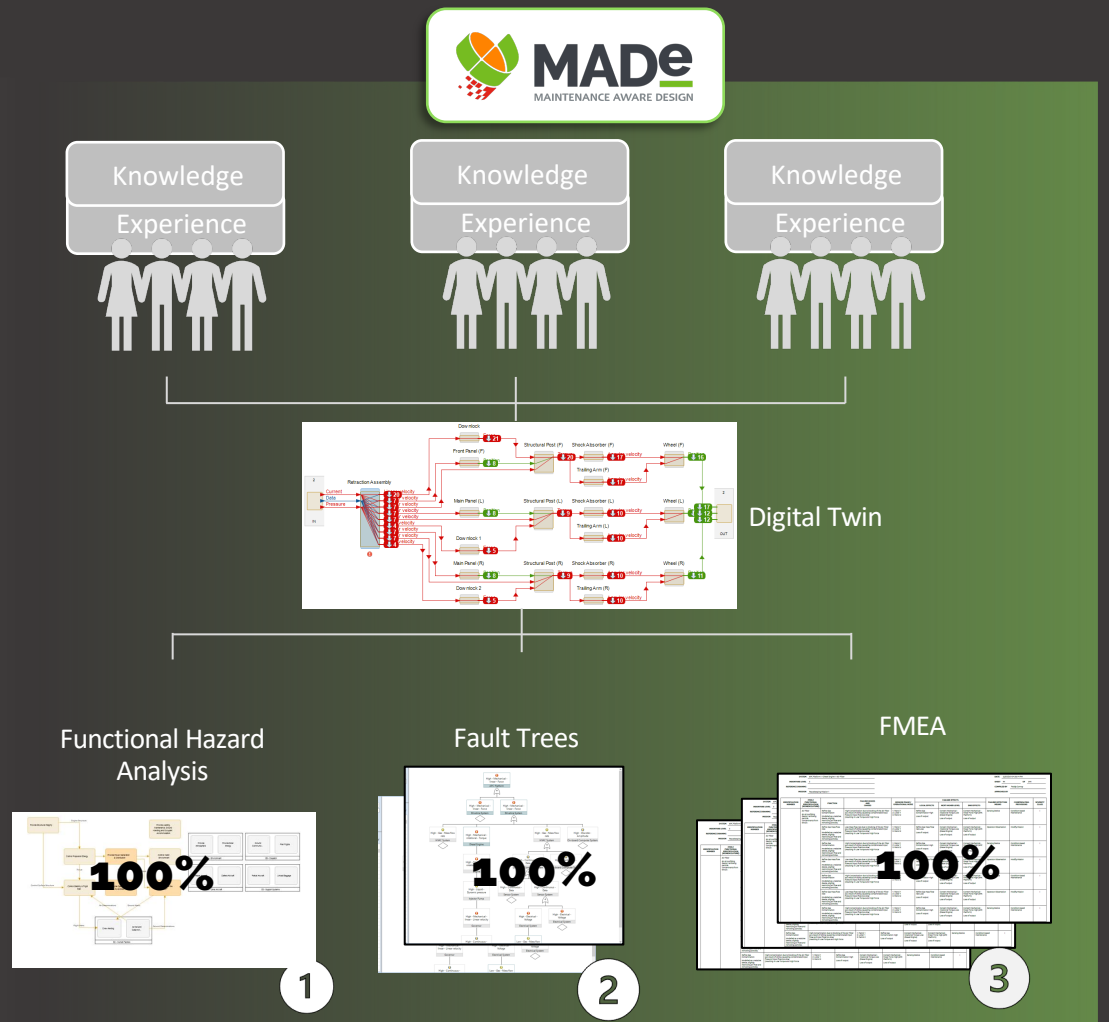
The rationale for the Digital Twin approach





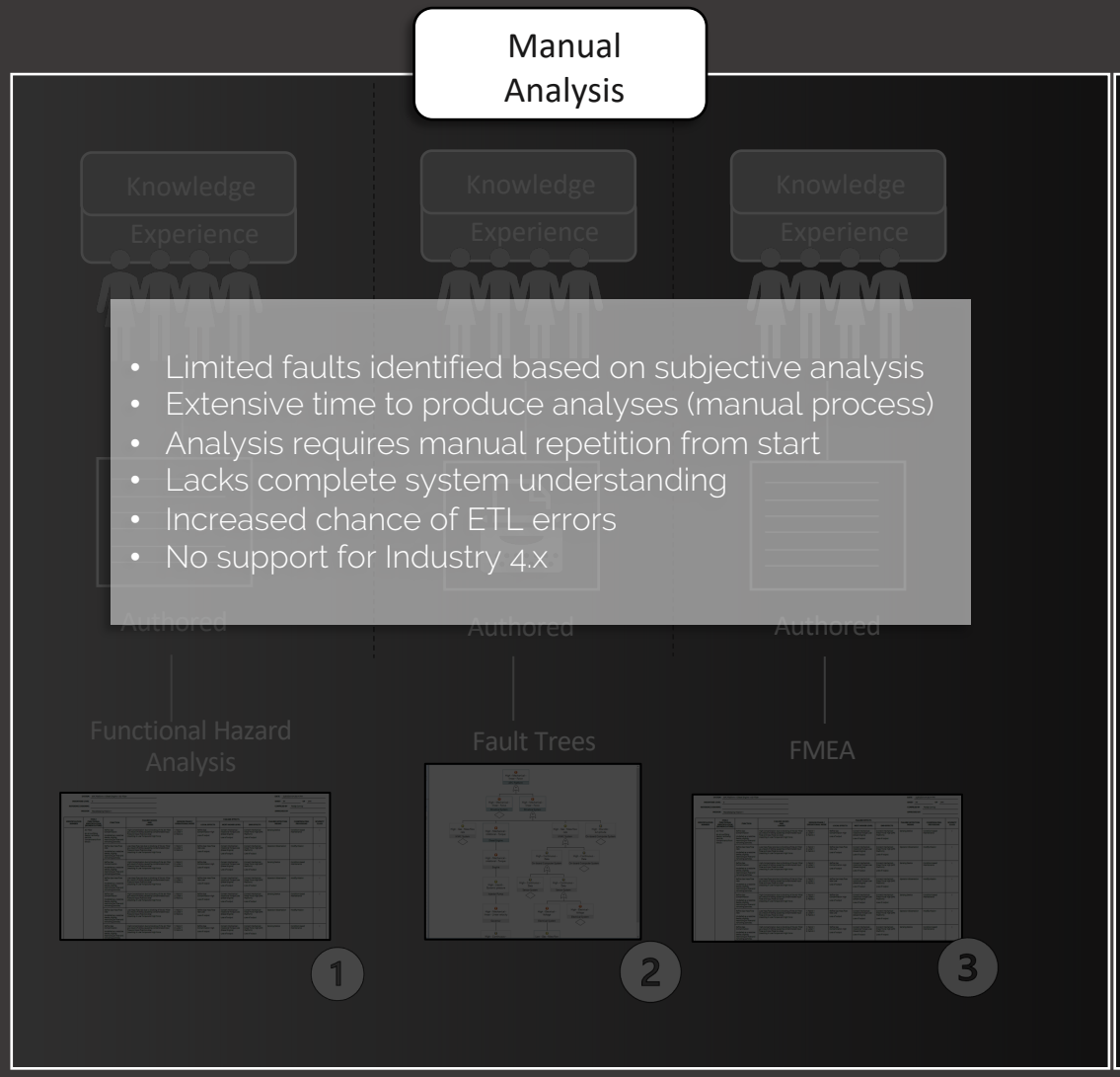
The rationale for the Digital Twin approach





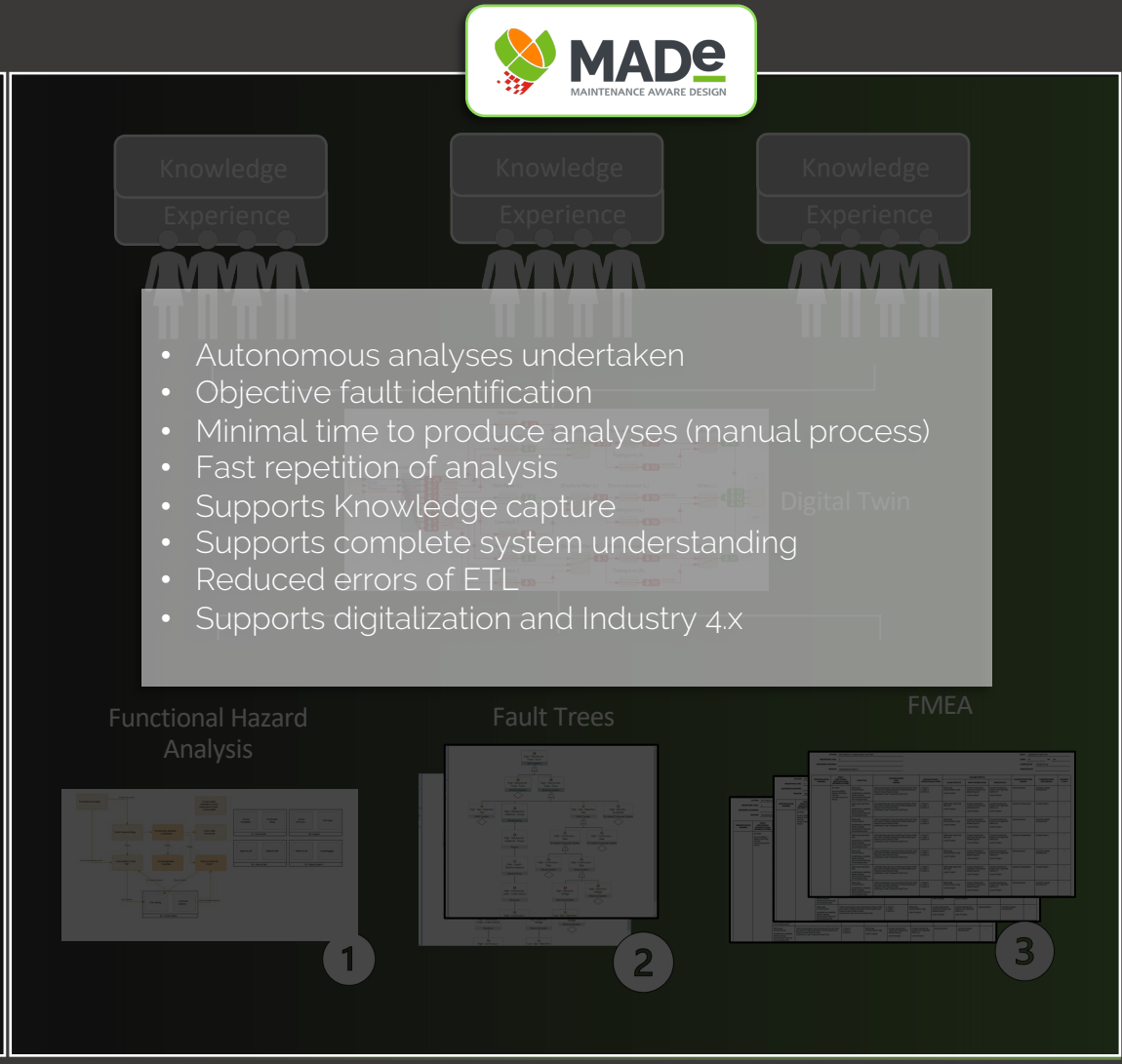
The rationale for the Digital Twin approach

Manual Analysis



- Limited faults identified based on subjective analysis
- Extensive time to produce analyses (manual process)
- Analysis requires manual repetition from start
- Lacks complete system understanding
- Increased chance of ETL errors
- No support for Industry 4.x

MADe – Maintenance Aware Design



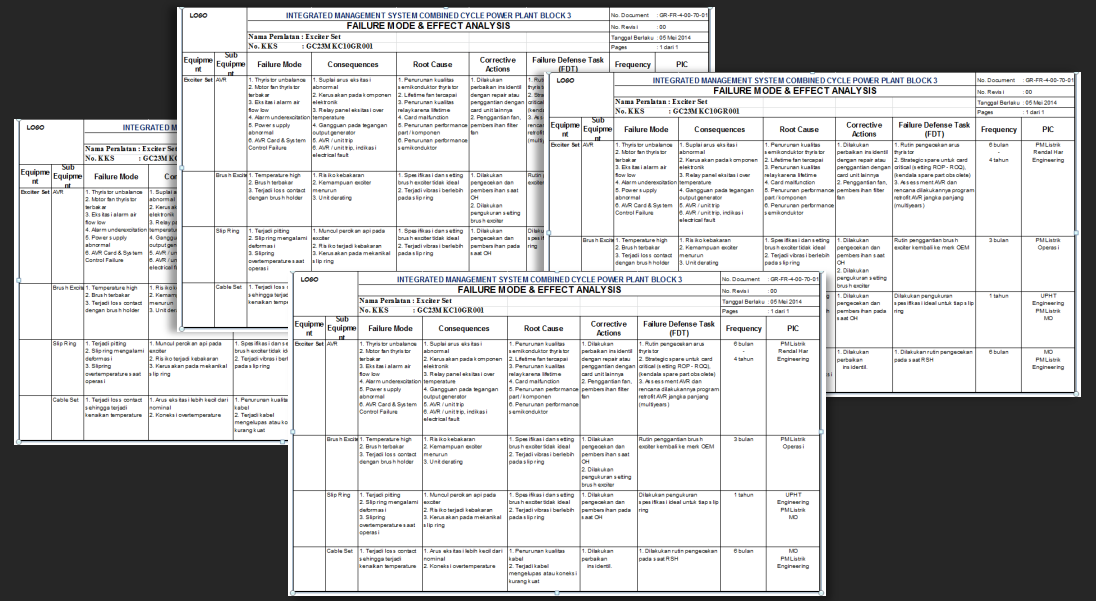
- Autonomous analyses undertaken
- Objective fault identification
- Minimal time to produce analyses (manual process)
- Fast repetition of analysis
- Supports Knowledge capture
- Supports complete system understanding
- Reduced errors of ETL
- Supports digitalization and Industry 4.x

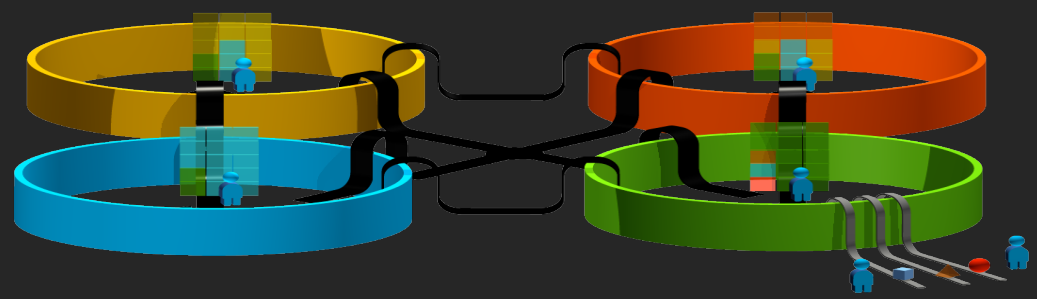
Digital Twin Approach Vs Data Science only approach

Digital Twin solution (Engineering + Data Science)		Data Science only Solution	
Every incipient failure is identified from the list of syndromes generated from the Model. The cause and next/end effect is also provided by the Model	Model the system	Engineering context is not taken into consideration	Data can only be interpreted from a list of previously occurred failures
	Design the sensor set		
	Collect Data (Targeted)	Collect Data (Not Targeted)	
	Identify pattern based on Model	Identify pattern based on SME input	
		Verification with SME	
	Alarms / Alerts	Alarms / Alerts	
	Validation	Validation	

Issues with Data Science only approach

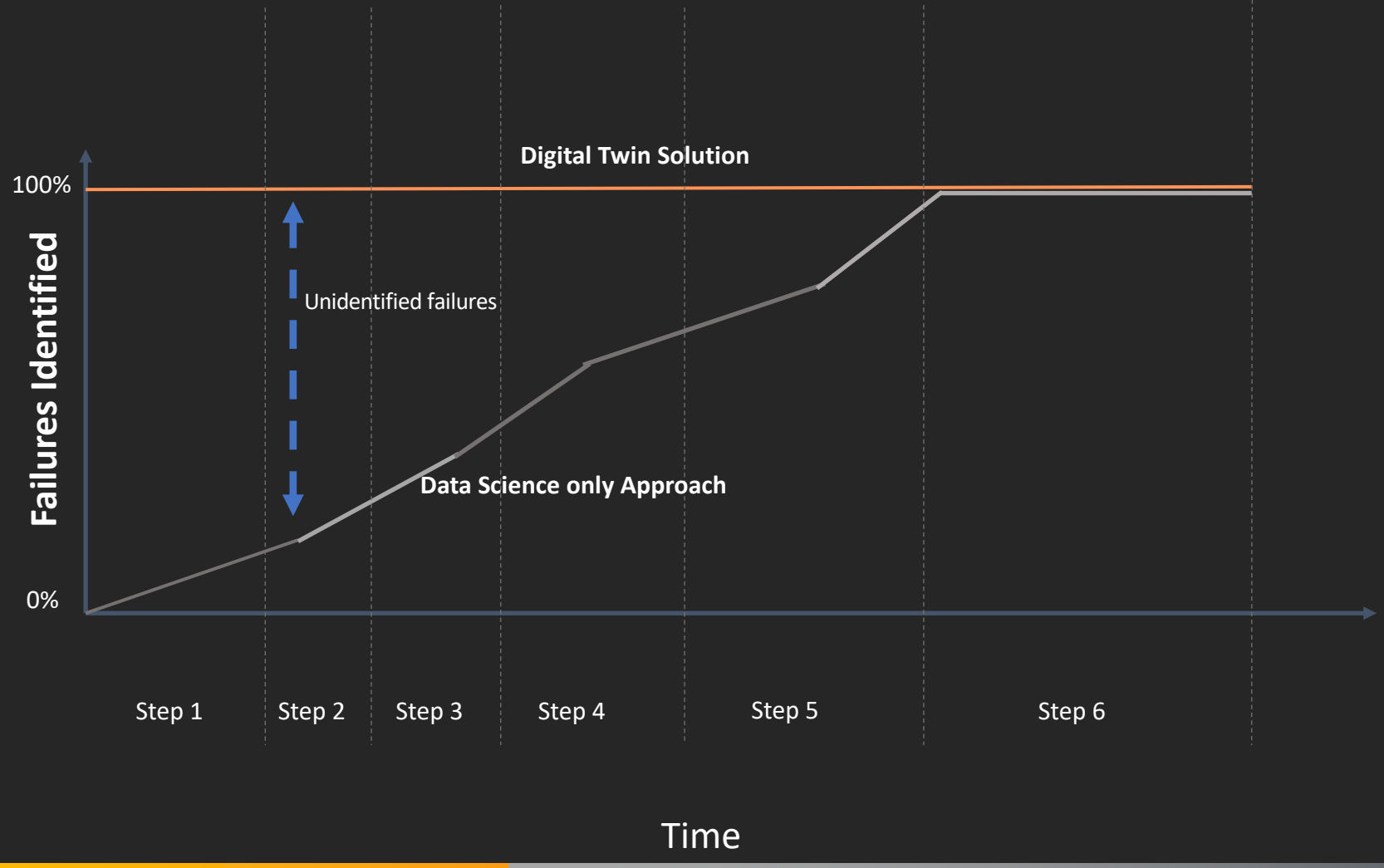
- Disconnected engineering tools
- Communication disconnects
- PHM as an afterthought
- Manual approach
- Subjective process
- Lack of consistency
- Lack of integration
- Lack of configuration management
- Limited reusability of data
- Limited knowledge capture / transfer


INTEGRATED MANAGEMENT SYSTEM COMBINED CYCLE POWER PLANT BLOCK 3
FAILURE MODE & EFFECT ANALYSIS
Nama Peralatan : Exciter Set
No. KKS : GC23M KC10GR001



Digital Twin Approach Vs Data Science only approach

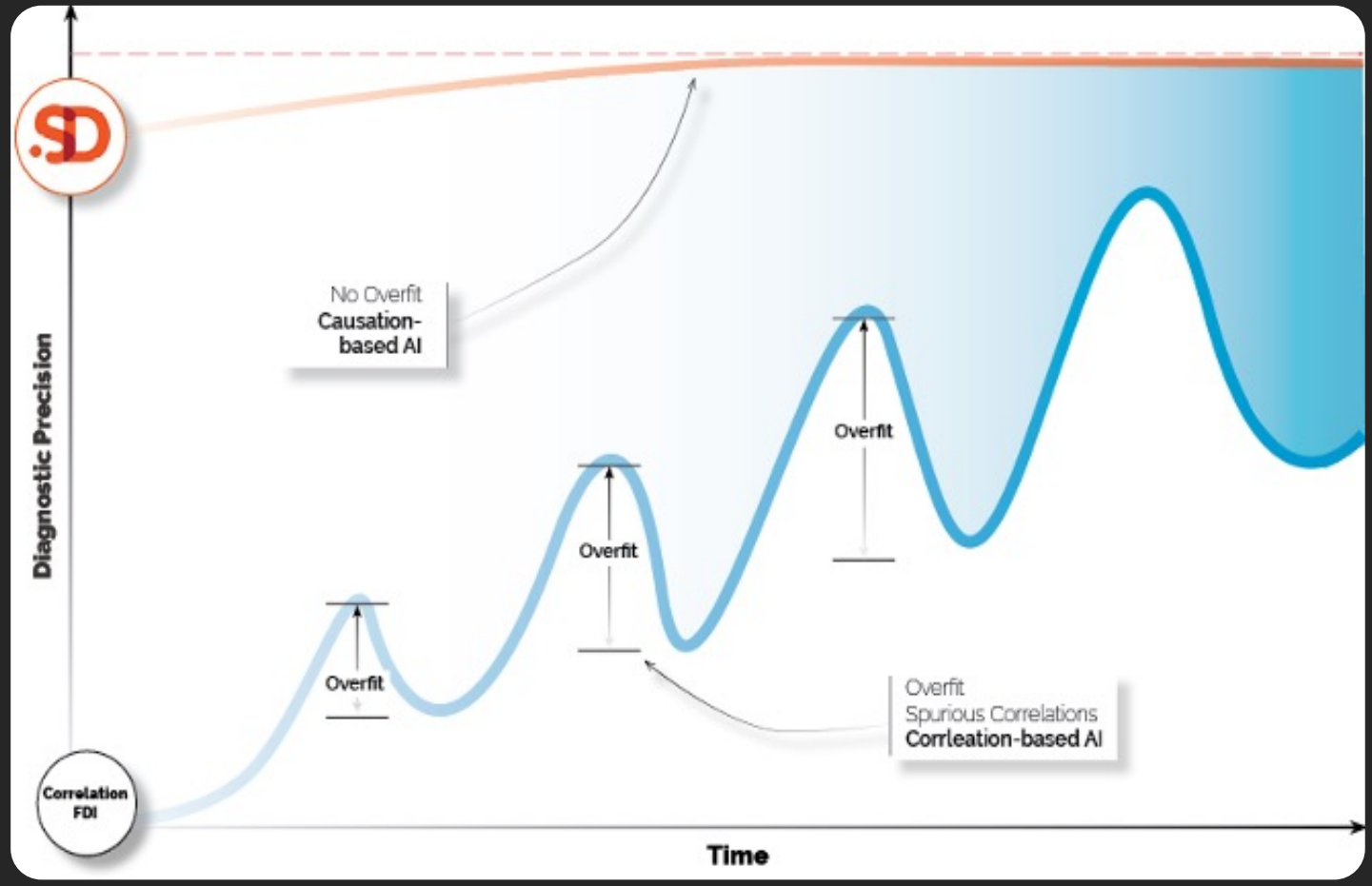
Data science only approach must wait till all failures to occur to reach 100% confidence and therefore increase risk/cost.



Issues with Data Science only approach

'Overfit' - where system responses are incorrectly attributed to failures based on an incomplete training set and lack of domain knowledge.

- Data – lack of simulation data
- Data - lack of test data
- Data – lack of operational data

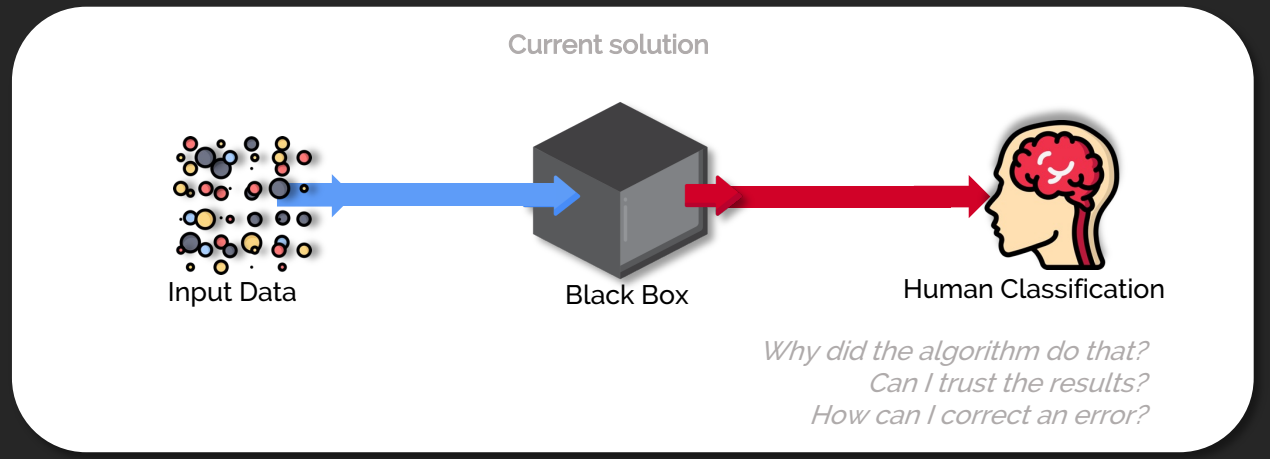


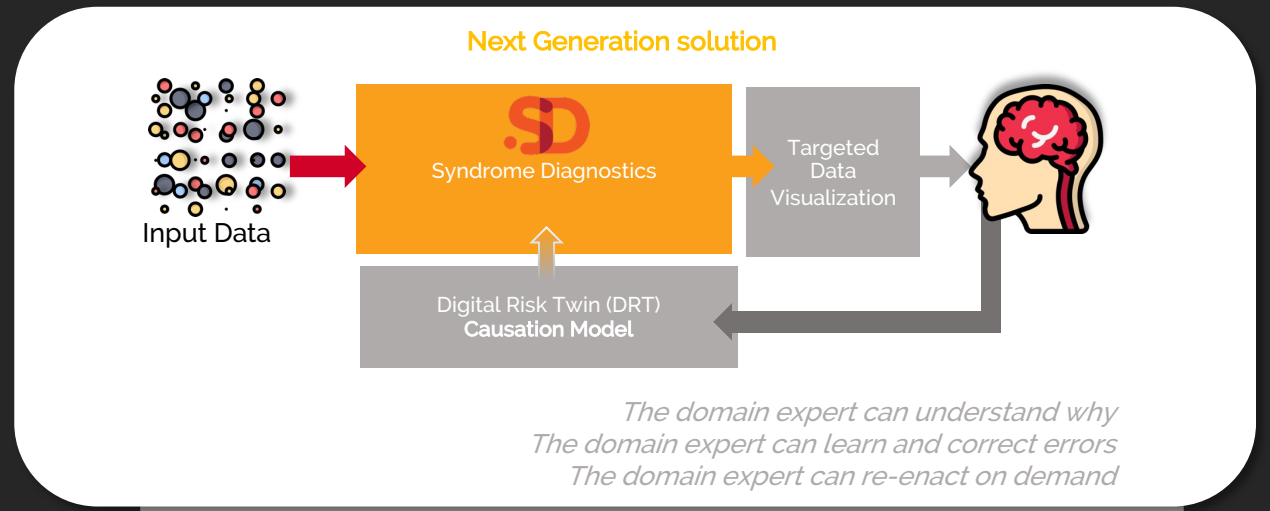
Advantages of Digital Twin solution

Explainability and Traceability

- More traceable due to step-by-step procedure, so FDI is not a black box

- Essential for systems that require certification (e.g. aerospace) or classification (e.g. marine)





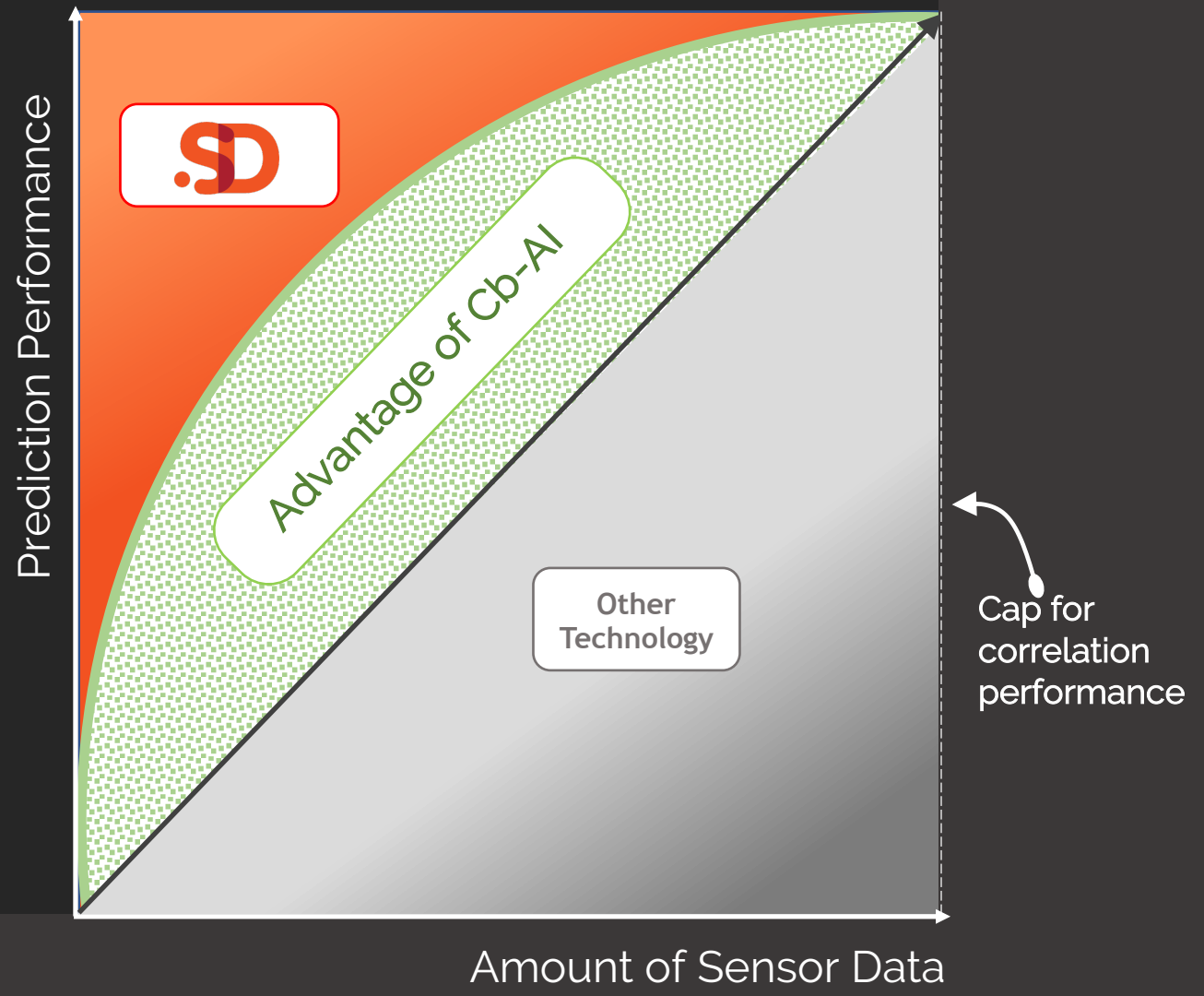
Comparison between explained and non-explained predictions

"Explainable AI for RAMS"
68th Annual Reliability and Maintainability Symposium (2022) - Navid Zaman, Evan Apostolou, Yan Li, Ken Oister

Advantages of Digital Twin solution

Requires Less Data

- SD can work with limited (or no) operational data for functional failures (DDT)
- SD only need to classify deviations (high and low)
- Bond simulations in the DDT can be used for training



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Applying a Digital Twin To PHM

MADe
MAINTENANCE AWARE DESIGN

Model-based RAMS

Analyses Integration

SD
Syndrome Diagnostics

Causation-based AI

Digital Twin Creation

A digital representation of the asset.

Risk & Safety Simulations

A series of simulations that enable the designer and operator to understand all possible failures and failure paths

Maintenance Optimization

An analyses set that enables evaluation of maintenance types and better understanding of existing maintenance schedules

Sensor Optimization

An analyses that optimizes the placement of sensors to minimize sensors for maximum failure coverage

Failure Detection & Isolation (Incipient)

Where components and sub-systems have an incipient failure states, SD can detect and isolate the cause of the failure before it happens.

Failure Detection & Isolation (Immediate)

Where components and sub-systems do not have a incipient failure state, SD can detect the cause of the failure once it has failed.

Advantages

- Objective analyses
- Repeatable analyses
- Understand system
- Knowledge capture
- Explainability/Trace

Advantages

- Full coverage
- Based on physics of engineering
- Objective
- Influence design

Advantages

- Minimize over-servicing of assets.
- Best service paradigm for environment

Advantages

- Minimize sensor cost / Maintenance costs & resources

Advantages

- Identify cause of failure
- Reduce downtime
- Move towards CBM

Advantages

- Identify cause of failure
- Reduce diagnosis times
- Reduce downtime

~~Live~~ Demonstration

Syndrome Diagnostics

Syndrome Diagnostics

Syndrome Diagnostics (SD) uses Causation-based AI to provide real-time Fault Detection and Isolation of critical failures for complex systems.

Operational data is acquired in real-time from the diagnostic architecture of an asset (sensors), then processed to identify signal combinations that indicate an incipient failure in real-time.

SD then generates configurable alarms & alerts based on system health state to trigger remedial actions.

<u>Outcomes</u>

- Real-time Fault Detection / Isolation
- Residual Life Estimation
- Optimized System Availability

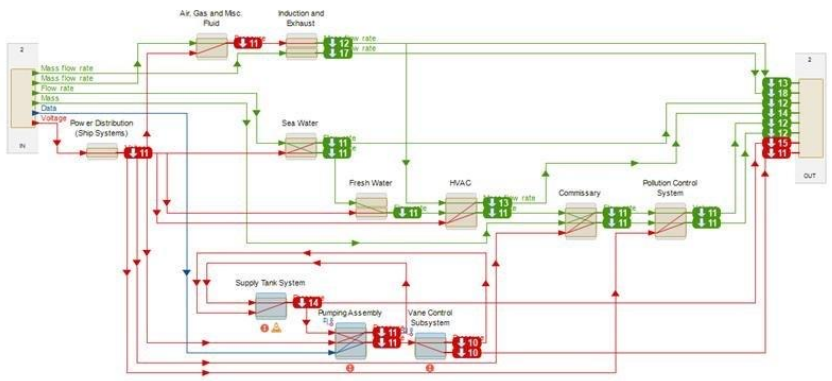
MADe
MAINTENANCE AWARE DESIGN

Guided Reporting Inspection

SD
Syndrome Diagnostics

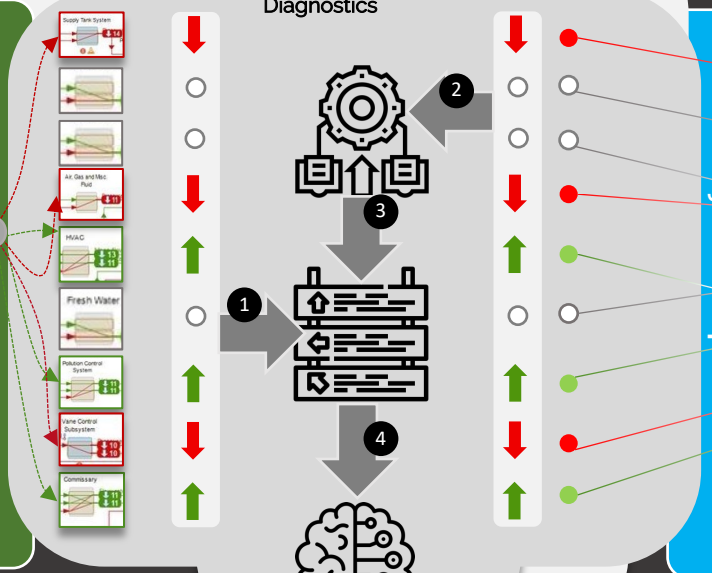
GRIt.

Asset

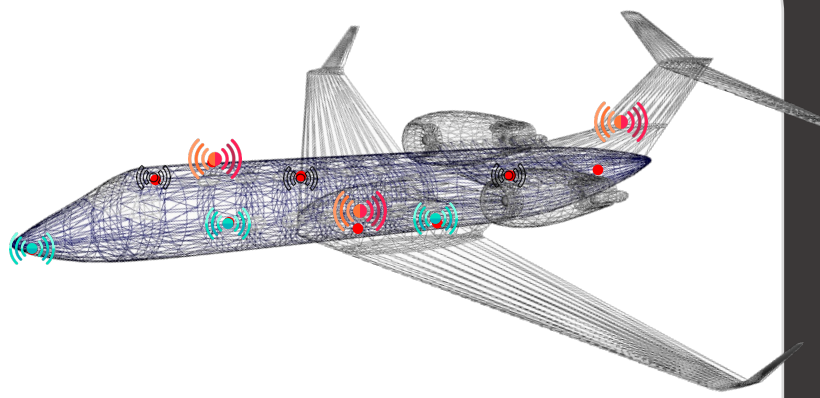


Model Updates

Model Outputs



System Outputs



Availability Optimization

AIF

MIF

Fault Isolation

Fault Detection

Health Condition

Residual Life

Operations

aFracas

MMS

Model Updates

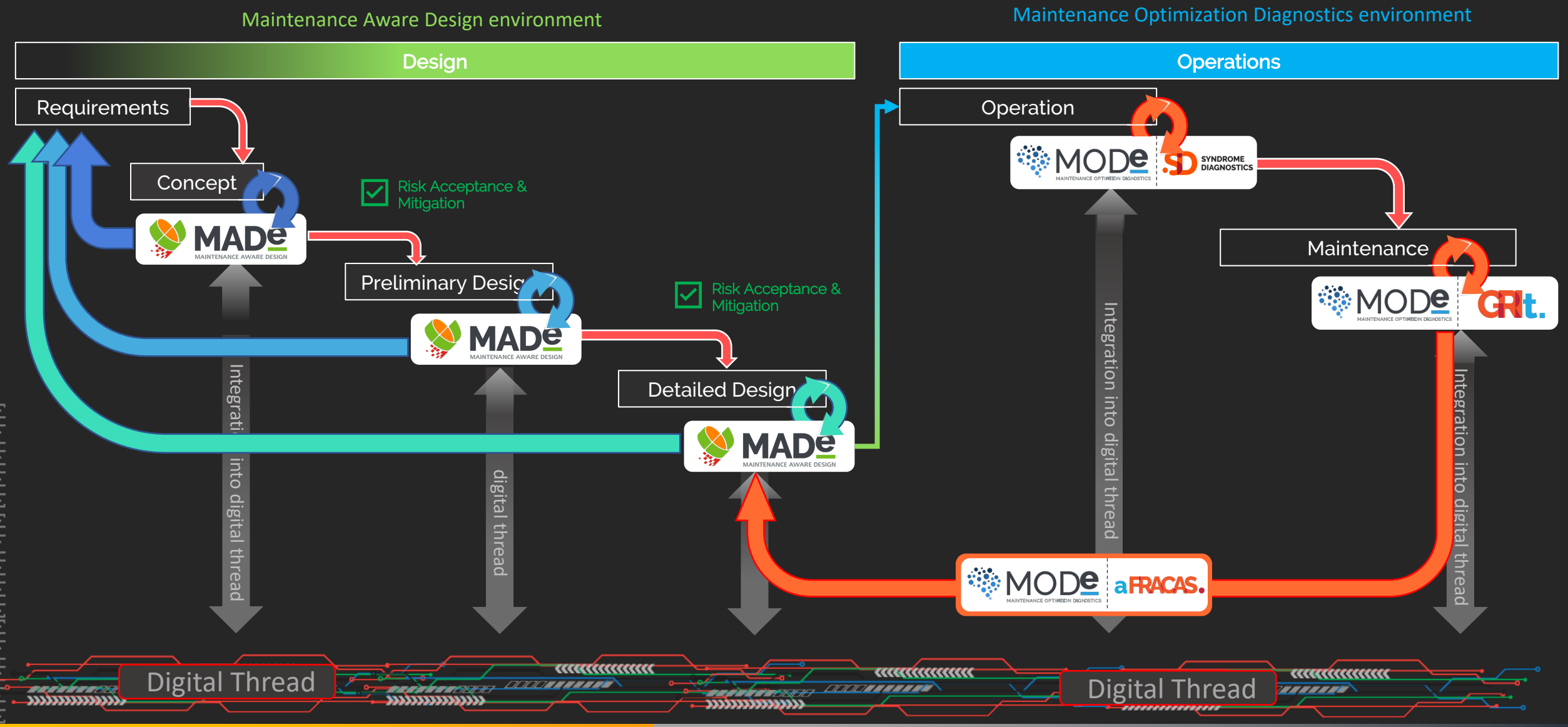
Asset Condition

Optimised Maintenance

SD Video

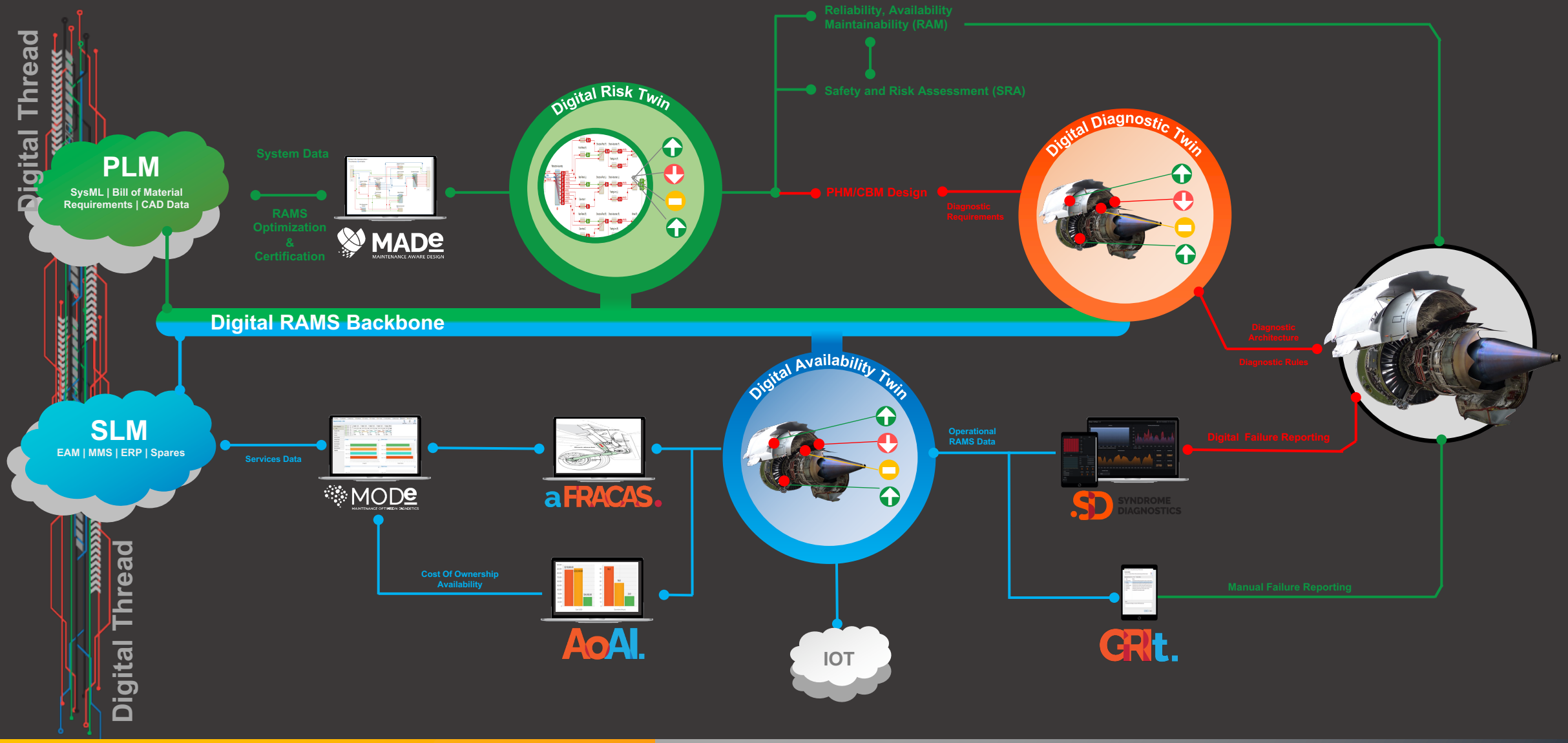
SD Video

Close-the-loop



The PHMT Ecosystem

PHM Technology
Decisions better made



Conclusion

The Digital Twin approach requires that you solve engineering problems, not data science problems.

It is essential that engineering principles, knowledge and understanding are ‘built into’ PHM systems.

Causation-based AI leverages Digital RAMS Twins and Data Science to achieve reliable FDI for complex, mission & safety-critical systems.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End