



AUTOMOTIVE



INFOCOM



MOBILITY, ENERGY &
ENVIRONMENT



AERONAUTICS



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Full-Scale Fatigue Testing – Pioneering Future Aircraft Certification?

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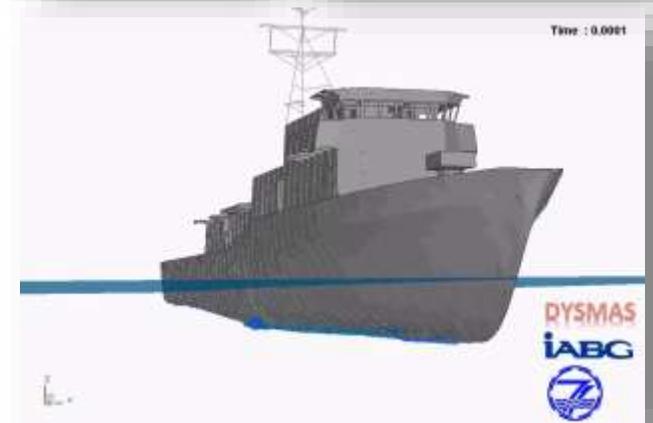
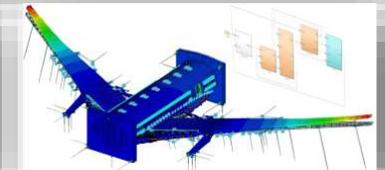
WHO IS IABG?

IABG is a strategic partner for the aeronautics industry and the international benchmark for testing of complex structural components.

- More than 30 full scale structural tests and thousands of components have been tested by IABG over the last decades, e.g.
 - Military aircraft (Eurofighter, F/A-18, Tornado, Airbus A400M, F104G)
 - Entire Airbus family (A300 to most recent Airbus A350 XWB)
 - Bombardier (C-Series, now A220)
 - General aviation aircraft (Pilatus PC-24, Extra 400, Grob G180)
 - Commuter aircraft (PC-12)
 - Trainer aircraft (Pilatus PC-21, Grob G120-TP)

IABG provides services to various industrial branches in the fields of innovative method development, simulation & virtualisation.

- Automated simulation chains
- Code & tool development
- Design optimisation
- System and process simulations
- Multi-physics simulation
- Concepts of virtual product development
- Certification support through virtual processes



INTRODUCTION

- Our industrial working environment appears to be in upheaval:
 - digitalisation, internet of things, artificial intelligence, big data, ... and virtualization.
- Hopes are that with increasing simulation capabilities the need for (physical) testing should decrease.
- While there is a consensus that for certifying a new aircraft the Full-Scale Fatigue Test (FSFT) may not be discarded itself, its pioneering potential in view of future trends affecting aircraft certification should be unfurled and exploited.

EVOLUTION OF FULL-SCALE-FATIGUE-TESTS (FSFT)

- In the last 20 years significant progress has been made in terms of

- Measurement coverage
- Applied power (hydraulic/ pneumatic power consumption)
- Test speed & accuracy

- The gain in test speed was diluted by

- Increase in loading complexity
- Increase in measurement campaigns

- Down time is still significant and varies based on

- The number and characteristics of unexpected damages
- The prompt availability of engineering support (particularly in large programs)
- The complexity of required repair solutions
- The availability of parts and repair teams

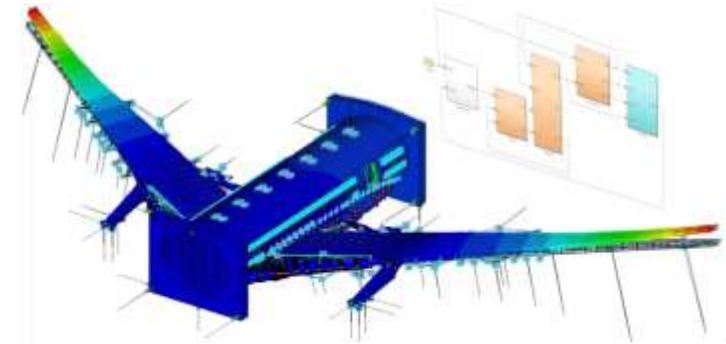
- The average net testing time of an FSFT covering 2.5–3 design lives has remained roughly the same (approx. 1 year) but it now allows for significantly higher loading complexity, cycling capacity and data generation capability



EVOLUTION OF VIRTUAL QUALIFICATION SUPPORT CAPABILITIES

- Multi-Physics models to simulate the dynamic test rig behavior under real test conditions, e.g.

- Structural dynamics model of the a/c specimen and load introduction
- Non-linear models of hydraulic actuators, valves and piping system
- Thermodynamic model of the air inflation system



- Virtual models to calibrate the control system

- Improvement of commissioning w.r.t. time and quality
- Increase of test speed & accuracy

- Improved test performance, e.g.

- Awareness of dynamic test rig behavior
- Optimization of loading trajectories
- Flexibility and margin for changes in the test configuration
- Troubleshooting capabilities



➤ Simulation techniques and computational power have significantly improved the preparation and performance of Full-Scale Fatigue Testing

CERTIFICATION – VIRTUALLY NO CHALLENGES?

Status Quo	Classification	Accepted approach
	New Structure	Analysis, supported by new strength testing of the structure
	Similar New Structure	Analysis validated by previous test evidence and supported with additional limited testing
	Derivative Structure	Analysis, supported by previous test evidence

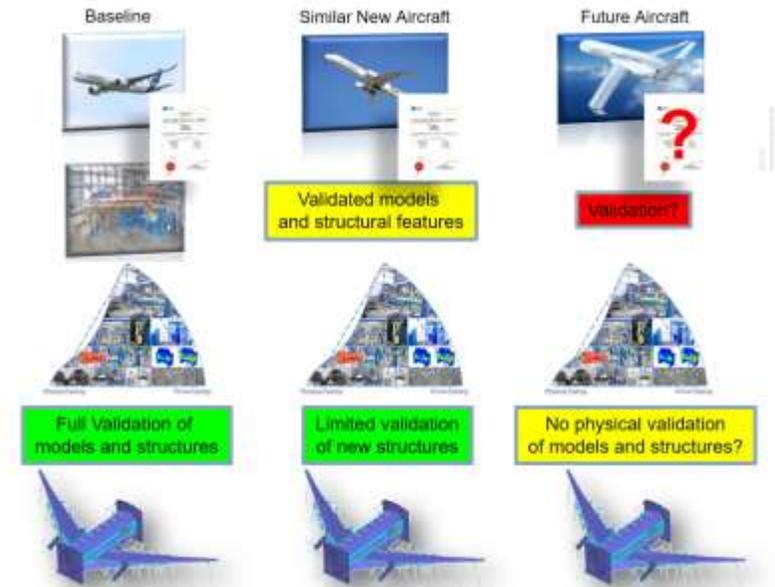
■ Stumbling blocks down the road to Certification by Analysis

- How to provide evidence of the unprecedented?
- Can evidence be substituted by credibility?
- Can new models be validated by existing models?
- How to tackle uncertainty?
- At which level does probability turn into safety?
- Can possibly big data fill the gap?

■ Certification by Analysis implies a paradigm shift:

- From confirmation to affirmation, from evidence to forecast

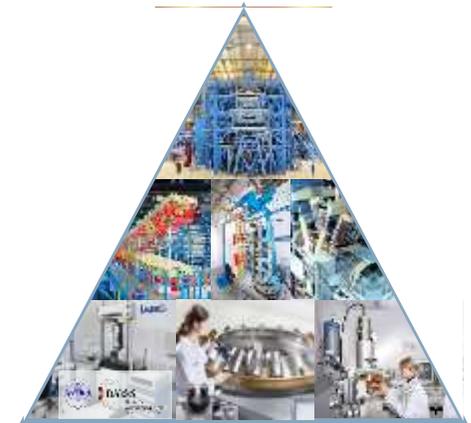
➤ Whenever we implement new technologies, we will not want to abstain from gathering physical evidence in order to be safe ab initio.



EVOLUTION OF THE TEST PYRAMID

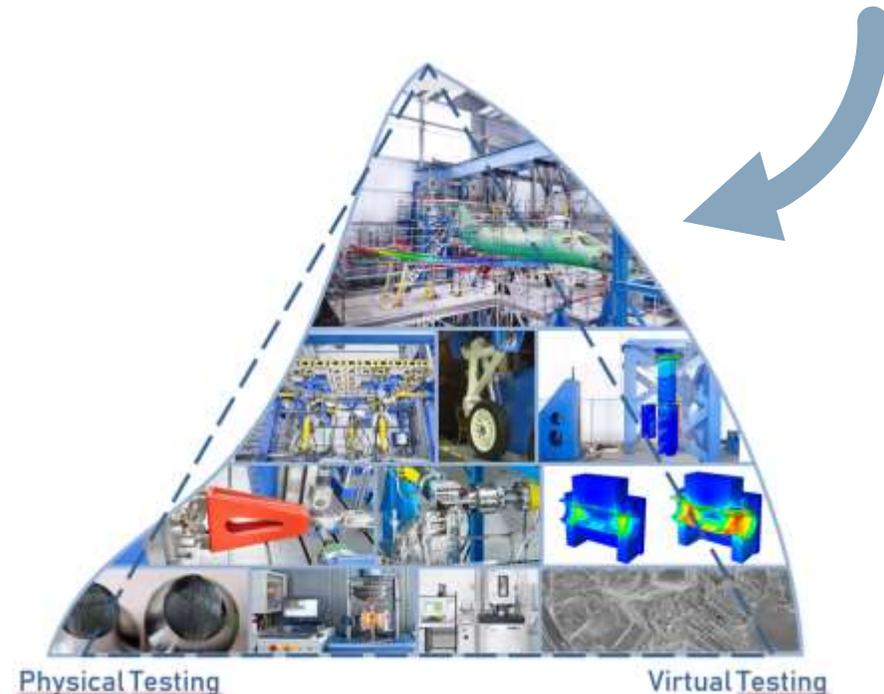
■ “Classical” test pyramid

- Is employed as a cornerstone to model validation
- Virtual models are used to improve understanding of the basic behavior and variations of design features
- Final designs are intensely tested across the test pyramid to safeguard qualification/ certification of complex systems



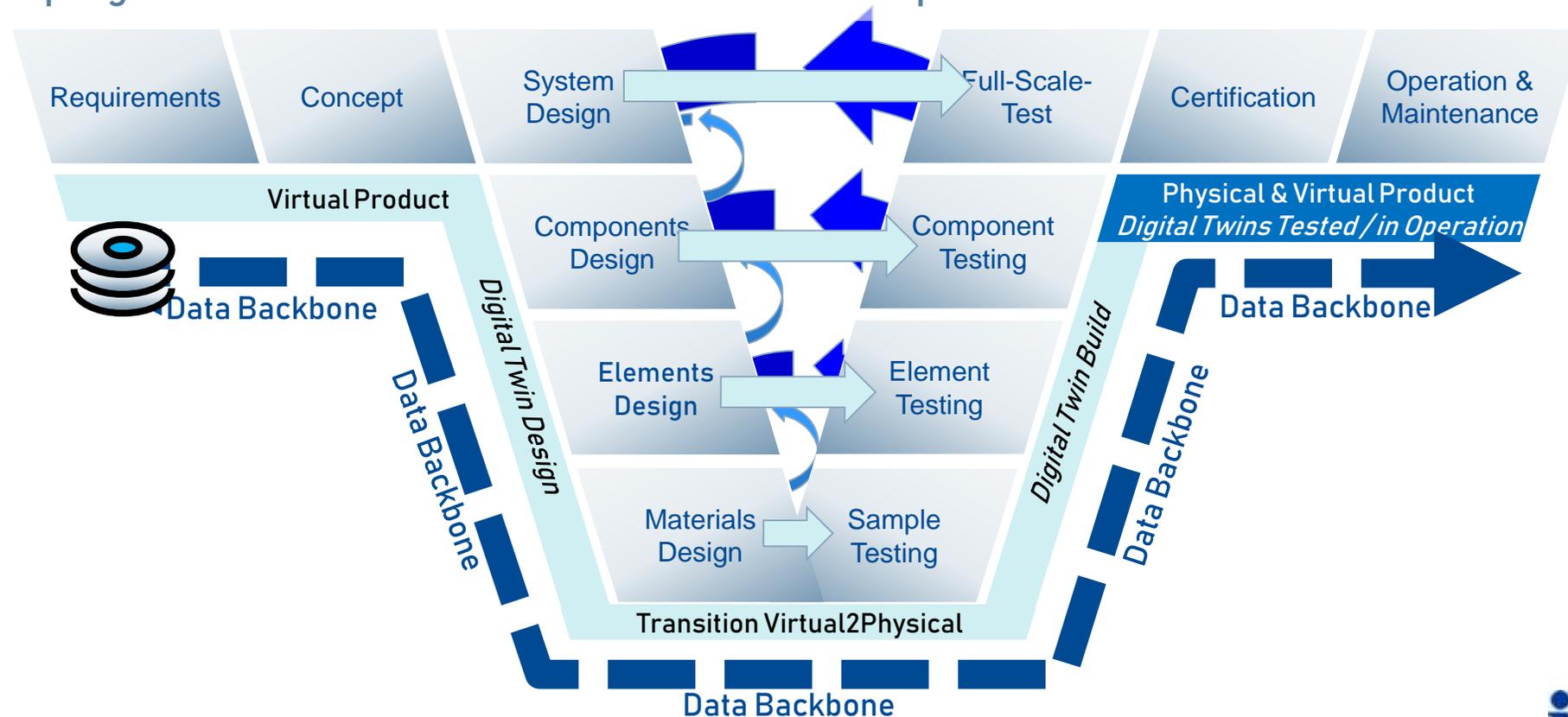
■ “New” test pyramid

- Re-shape the test pyramid to further speed up time to market
- Achieve certification with less physical, more virtual testing
- Enhance tailoring, optimisation and exploitation of validation activities (“symbiosis” of simulation & test)
- Systematically pursue a CbA approach starting from the middle levels of the test pyramid
- Furthermore substantiate the toolset to design, support and exploit the FSFT
- Develop one by one the elements needed for a future digital twin



FSFT - PART OF AN AGILE PRODUCT DEVELOPMENT CONCEPT

- Product owner concept allows for frequent adjustments of development goals and their prioritization
- Features: continuous deployment of progress (e.g. virtual models), invigoration of the data backbone
- Advantages: front-loading of testing to safeguard results and avoid late/ costly corrections
- Early synchronization and continuous survey/alignment of FSFT concept with overall development and validation progress ensures a fast realization and efficient performance



EXPLOITING THE POTENTIAL OF THE FSFT

HIL-Testing

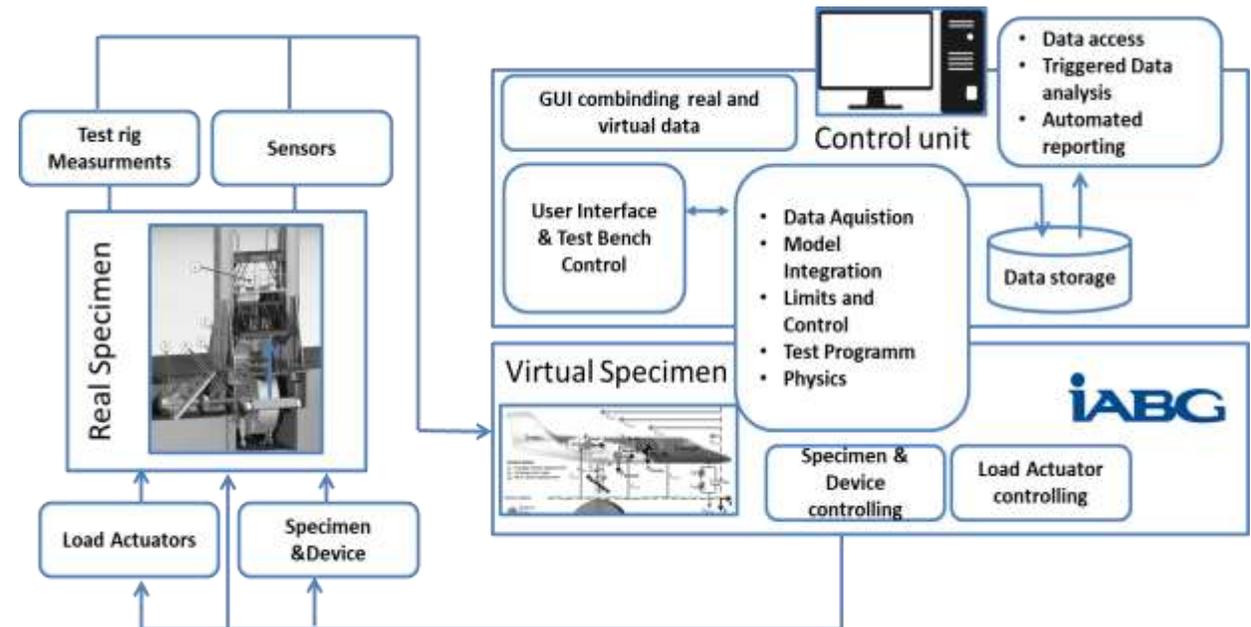
- Test hardware and virtual representations of feedback hardware/ components/ systems are closely interfaced thus generating a hybrid test set-up
- Test hardware is controlled/loaded using model output data. The models receive and process feedback from sensors installed on the hardware. Applying a closed-loop control, significant advantages compared to a pre-determined testing program without feedback can be achieved.

Advantages:

- More realistic test program
- Test of abnormal conditions
- Front-loading of test activities
- Useful test data for virtually represented systems

Caveat:

- Need to safeguard the test envelope



EXPLOITING THE POTENTIAL OF THE FSFT

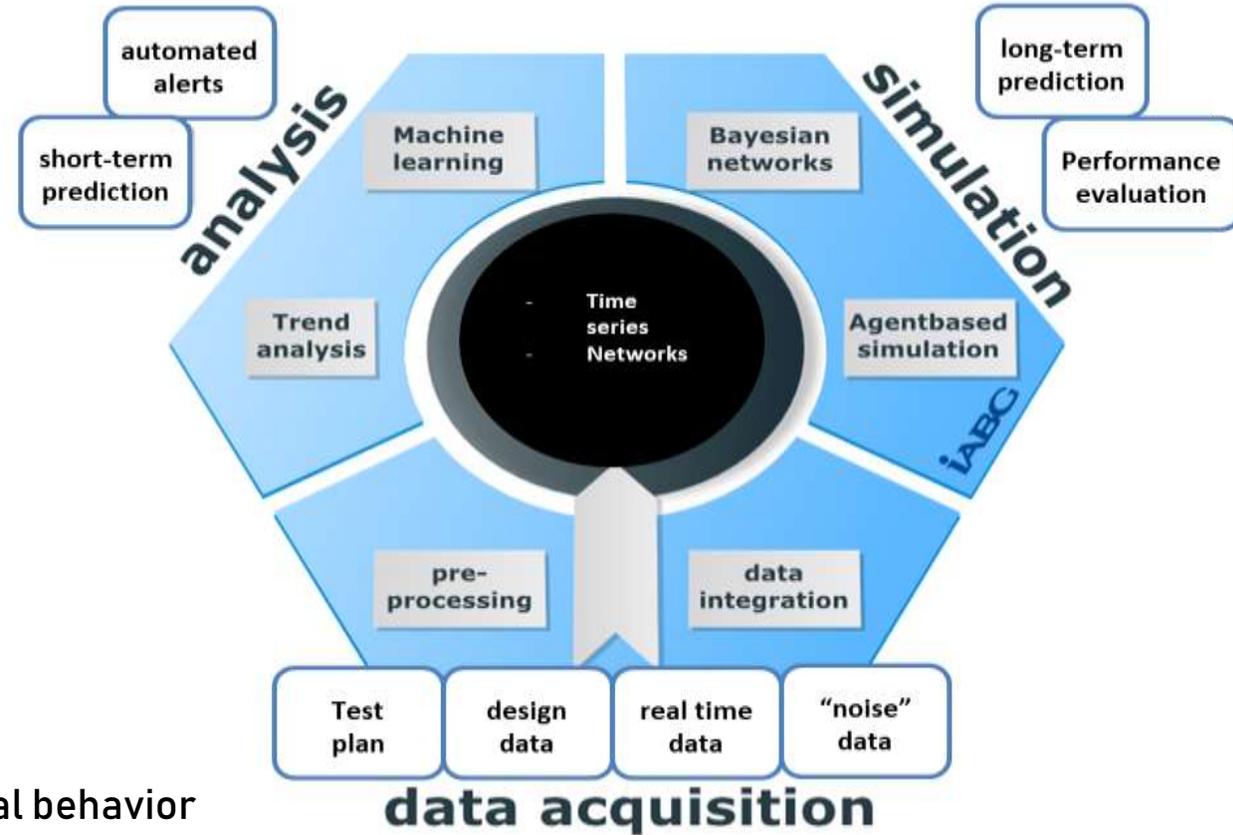
Data Science and Machine Learning

■ Status Quo:

- Negligible use of test data during the test!
- Huge amount of test data not/incompletely being analyzed after the test!
- Test data acquisition not optimized for automated data processing and analysis

■ Prospects:

- Full-fledged trend monitoring during the test
- Event-driven inspections
- Performance-based test management
- Structural life tracking
- Damage prediction and monitoring
- Substantially improved insight into complex structural behavior
- Testbed for in-service applications of machine learning algorithms



EXPLOITING THE POTENTIAL OF THE FSFT

Structural Health Management/Maintenance

- The FSFT is the ultimate ground-based representation of in-service operations and is a huge effort to set up.

So, why not use it for ...

- Structural Health Management Systems Development:

- Functional, operational and durability tests of sensors
- Test of large-scale sensor networks and related data acquisition systems in a relevant environment
- Investigation of energy-harvesting technologies (sensors, data acquisition & communication/telemetry)
- Qualification of SHM systems up to TRL6

- Maintenance/Data Analytics:

- Test of neural networks/ ML algorithms for maintenance purposes
- Investigate & improve robustness w.r.t. data conditioning, dropouts etc.
- Test of strategies to account for repair/replacement of structures & sensors
- Test of in-service tools for analysis, interpretation and visualization of data
- Attain valuable training data sets, provide an initial database for new aircraft types lacking operational experience

- The FSFT is a readily available opportunity not only for product development, but as well to anticipate product sustainment!



EXPLOITING THE POTENTIAL OF THE FSFT

Digital Twin – a look through the spyglass

- Need a “real twin” for the digital one?
 - As designed? ... no doubt about that!
 - As configured? ... of course!
 - As manufactured? ... definitely yes!
 - As assembled? ... well, it’s a digital twin – yes!
 - As instrumented? ... no need to say that!
 - As operated? ... that would be appreciated!
 - As repaired? ... even better!
 - As aged? ... sure, that’s what it’s all about...

- So, if the answer to these questions is “Yes!”, the FSFT is the demonstration platform you are looking for!

- *A “sweet” drop of bitterness: In today’s FSFT there are systems missing like actuators, engine and avionics, so you may need to simulate their data so as to generate a fully operable environment for your digital twin. Having sorted out all the other problems of a digital twin before, this should pose no challenge!*

- On the look-out for the digital twin, the FSFT is a veritable asset!



CONCLUSION

- Due to its unmatched complexity and value, FSFT remains the ultimate benchmark and representation of flight operations; it is and will remain (for long) an essential asset of aircraft certification
- The FSFT is an enabling and hence valuable demonstration platform for the majority of upcoming technological developments
- The FSFT can be further exploited thus enabling better-informed certification and PLM activities
 - Model validation
 - Real-time data analysis
 - Training of ML algorithms
 - Life consumption tracking
 - Damage prediction
 - SHM development & testing
 - Provision of databases and algorithms for MRO
 - Digital Twin development & verification

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