Smarter Testing in Aerospace Manufacture

3DMC Aachen 2022

Paul Richardson - Airbus
Mike Campbell – National Physical Laboratory
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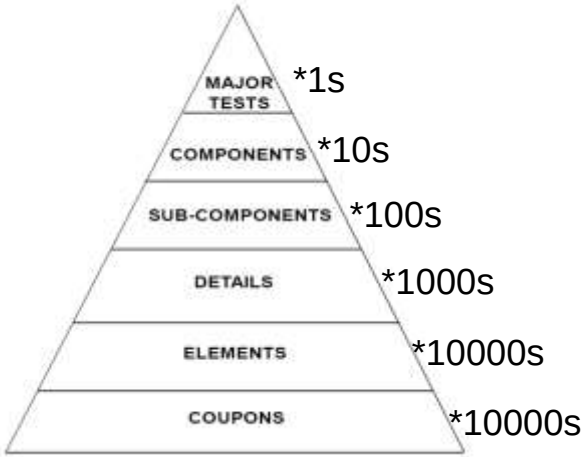
Current testing approach

AS-IS today

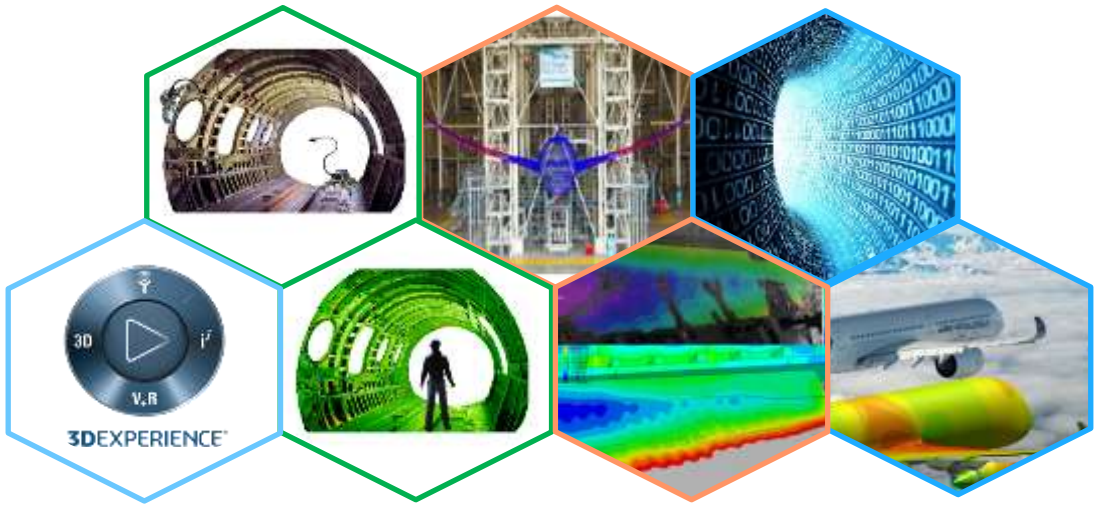
- Extensive and expensive structural testing
- Structural certification requirements CS25
- Test validated stress methods and analysis processes
- Working in silos (physical-virtual-customers)
- No single point of access to data



*Typical Certification Tests

Way forward

- Traditional testing pyramid approach needs to be optimized
- Radical rethinking of conventional certification processes
- New and novel ways of testing and data acquisition
- Integrate Virtual Testing and physical testing
- Exploit data analytics and design of experiments



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ATI - Smarter Testing project

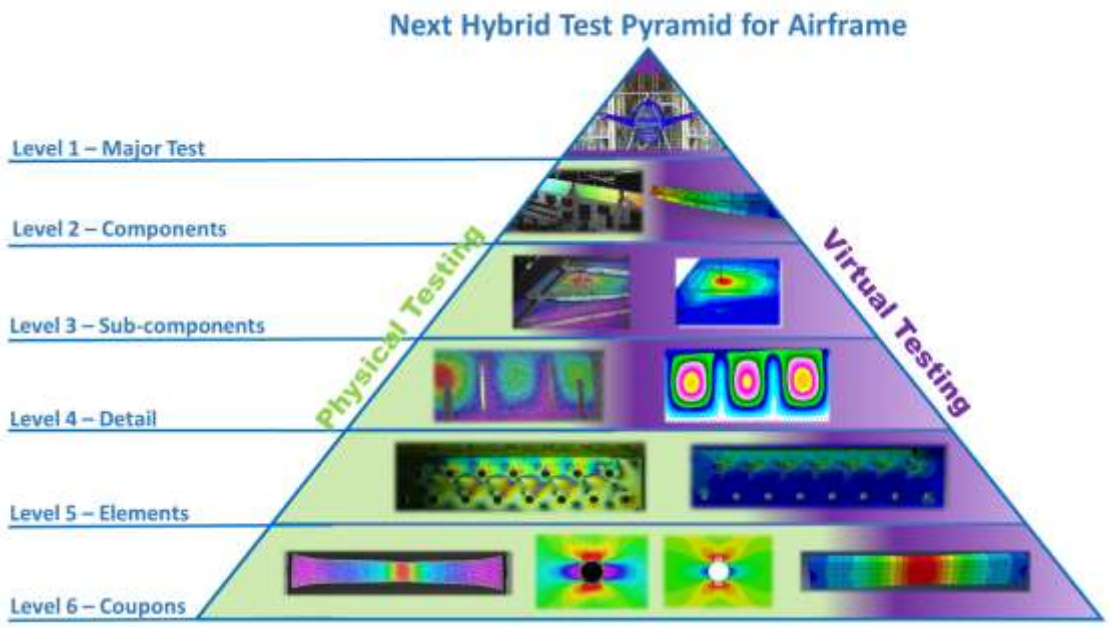
Start: 1st January 2021
Finish: 31st December 2024

Project summary

The Smarter Testing project aims to develop a novel testing and certification process for airframe structures through the use of an optimised test campaign that will combine virtual and physical tests.

The maturity and confidence of virtual testing will be increased at lower levels of the test pyramid using advanced measurements, data correlation and data analytics.

This will be hosted on a web-based environment which provides digital continuity between virtual and physical tests to increase the use of simulations that supports the whole lifecycle of the product, from early design to type-certification.



Objectives

- Provide a step reduction in development lead-time and enable the Product Development Plan to be achieved within 5 years with the use of optimized hybrid tests
- Reduce testing costs by optimizing the test pyramid and supporting the elimination of the full scale major physical static test
- Increase product maturity at Entry Into Service by providing data earlier in the development cycle.

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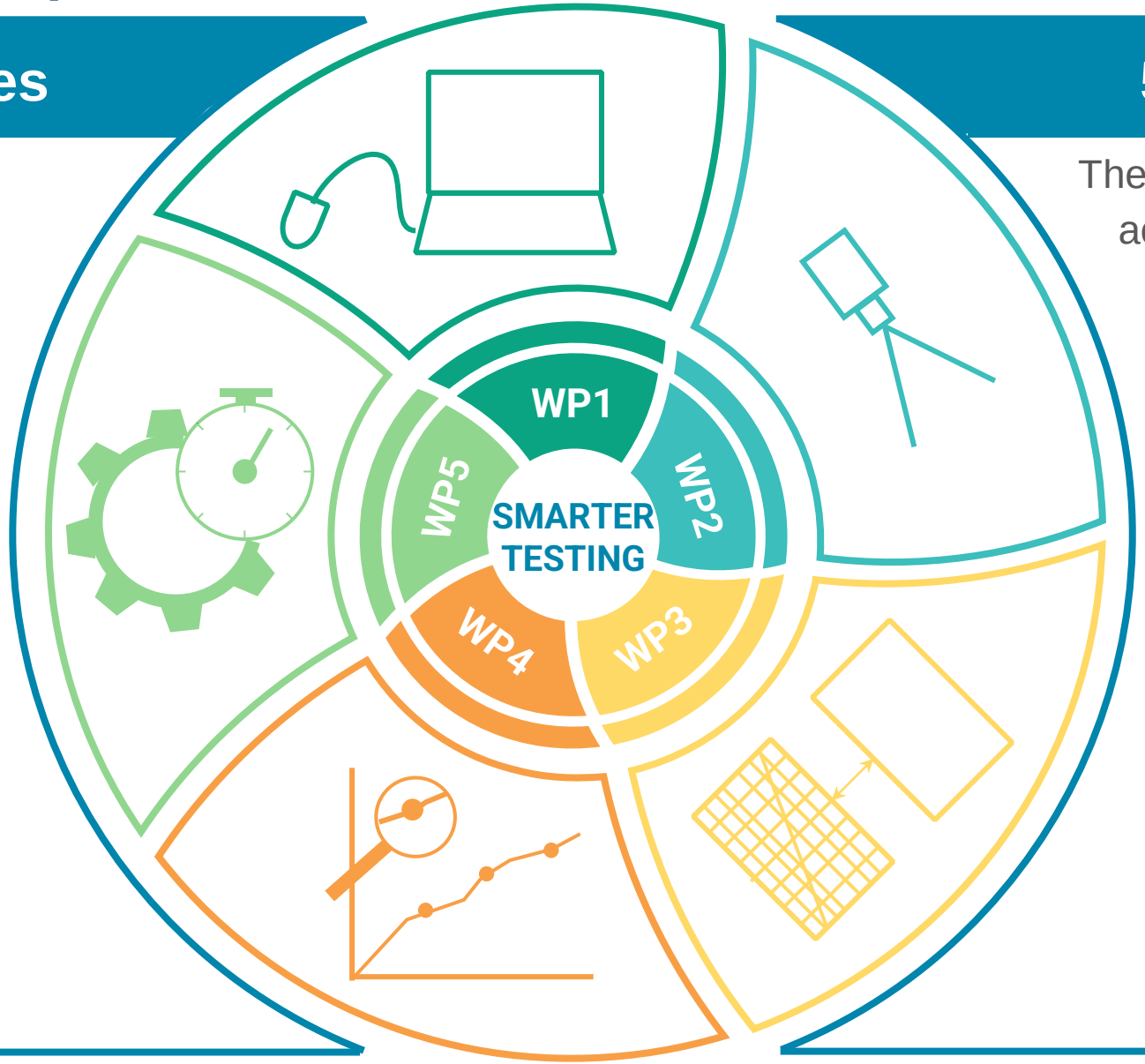
Smarter Testing - Simple Overview

[Airbus Amber]

Top Level Objectives

- Support the replacement of the full scale major static physical test with virtual testing
- Enable the 5 years PDP timeline with an optimised major fatigue test campaign
- Become the Centre of Excellence for Smarter Testing



5 Key Capabilities

These objectives will be met by achieving TRL6 across 5 key capabilities:

- Data Correlation
- Condition-Led Inspection + Test Protection
- Digital Continuity
- Accelerated Physical Testing
- Competences and Transformation

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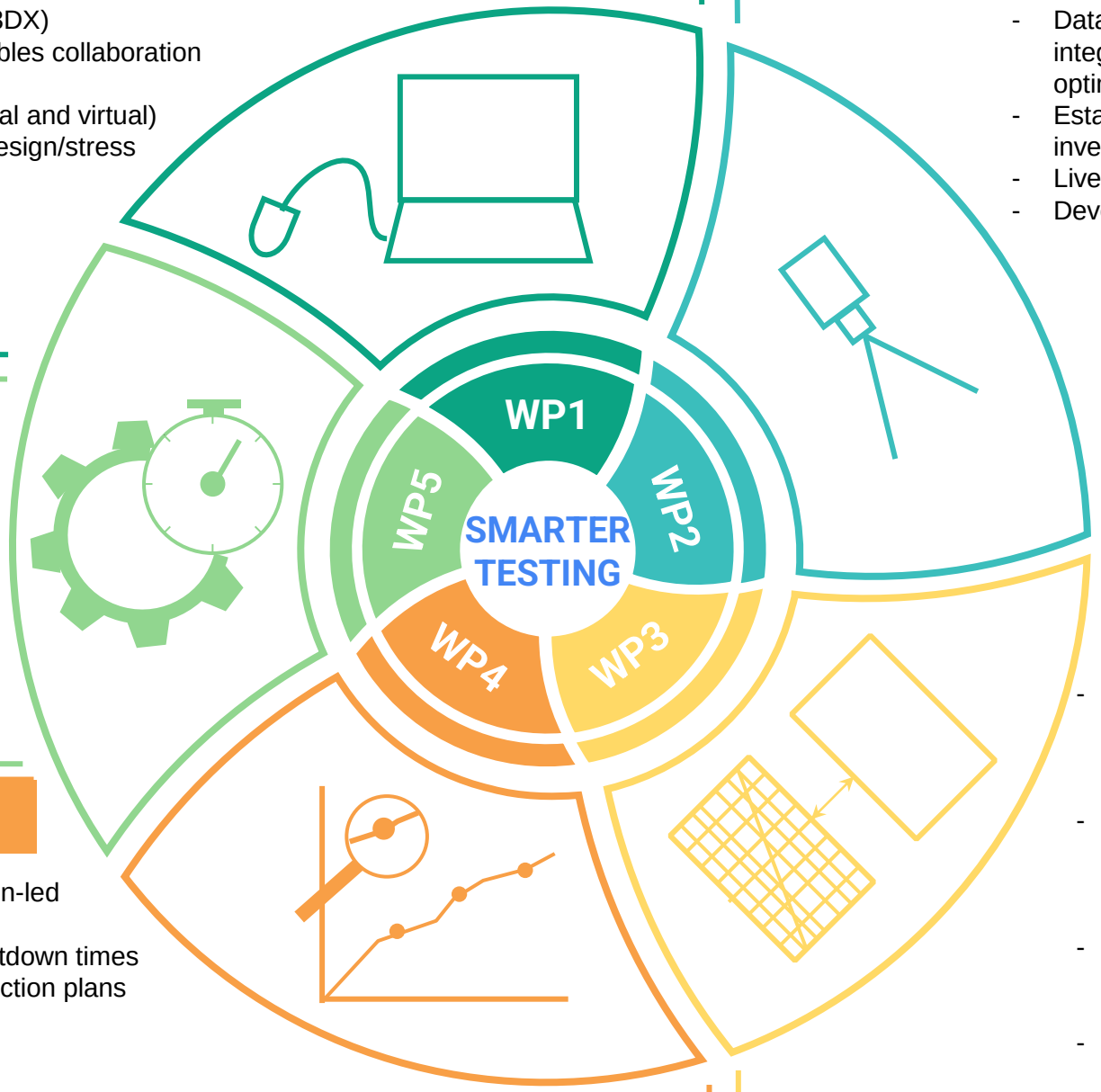
WP1: Data Driven Platform

- Development of collaborative environment (3DX)
- Provides a web-based environment that enables collaboration between customers and engineers
- Single point of access to all test data (physical and virtual)
- Enables digital thread to link test data with design/stress and manufacturing data

WP2: Advanced Measurement Technologies

- Data acquisition and physical set up - an integrated multi-system camera setup to optimise large scale testing
- Establish global referencing network and investigation common target capabilities
- Live monitoring capability
- Development of uncertainty quantification



WP5: Test Optimisation

- Development of advanced testing solutions for the optimisation of test design, setup and performance
- Development of test systems simulation capabilities, control systems and hydraulics
- Development of test execution optimisation capabilities

WP3: Advanced Quantitative Data Correlation

- Automation of existing correlation methods and development of methods for quantitative comparison of advanced measurements and virtual test data
- Quantification and management of uncertainties in test and simulation to enrich correlated data with coherence and variance values
- Data correlation strategy development to enable Test Protection and Condition-led Inspection
- Finite Element Models Validation framework to enable Hybrid Test Pyramid deployment through virtual testing

WP4: Advanced Data Analytics

- Methods will be developed to enable condition-led inspections and predictive test maintenance
- Enables reduction of planned/unplanned shutdown times
- Provides recommendations to optimise inspection plans

WP1: Data Driven Platform

- Development of collaborative environment (3DX)
- Provides a web-based environment that enables collaboration

Collaborative user interface for all data

WP2: Advanced Measurement Technologies

- Data acquisition and physical set up - an integrated multi-system camera setup to

Acquiring data

WP5: Test Optimisation

- Development of advanced testing solutions

Physical test optimisation

WP3: Advanced Quantitative Data Correlation

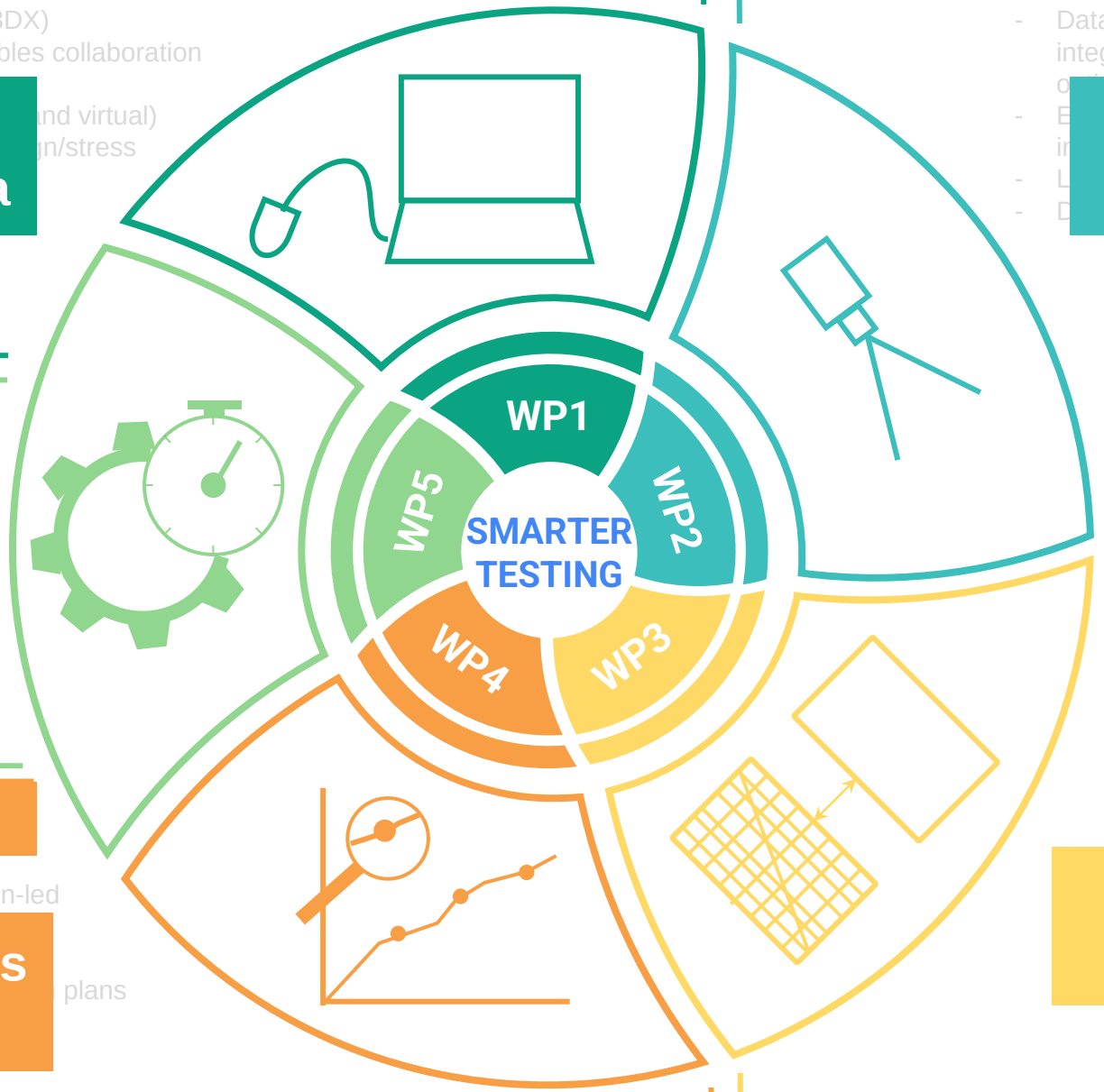
- Enable comparison between physical and virtual test data
- Ability to see real value of coherence and variance in a complex structure and reduce

Correlating data

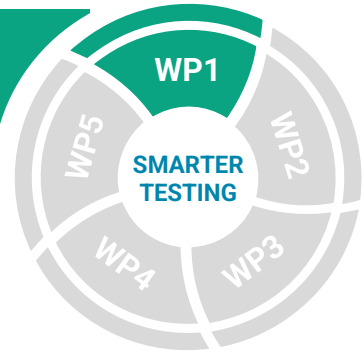
WP4: Advanced Data Analytics

- Methods will be developed to enable condition-led

Predicting damages and failures

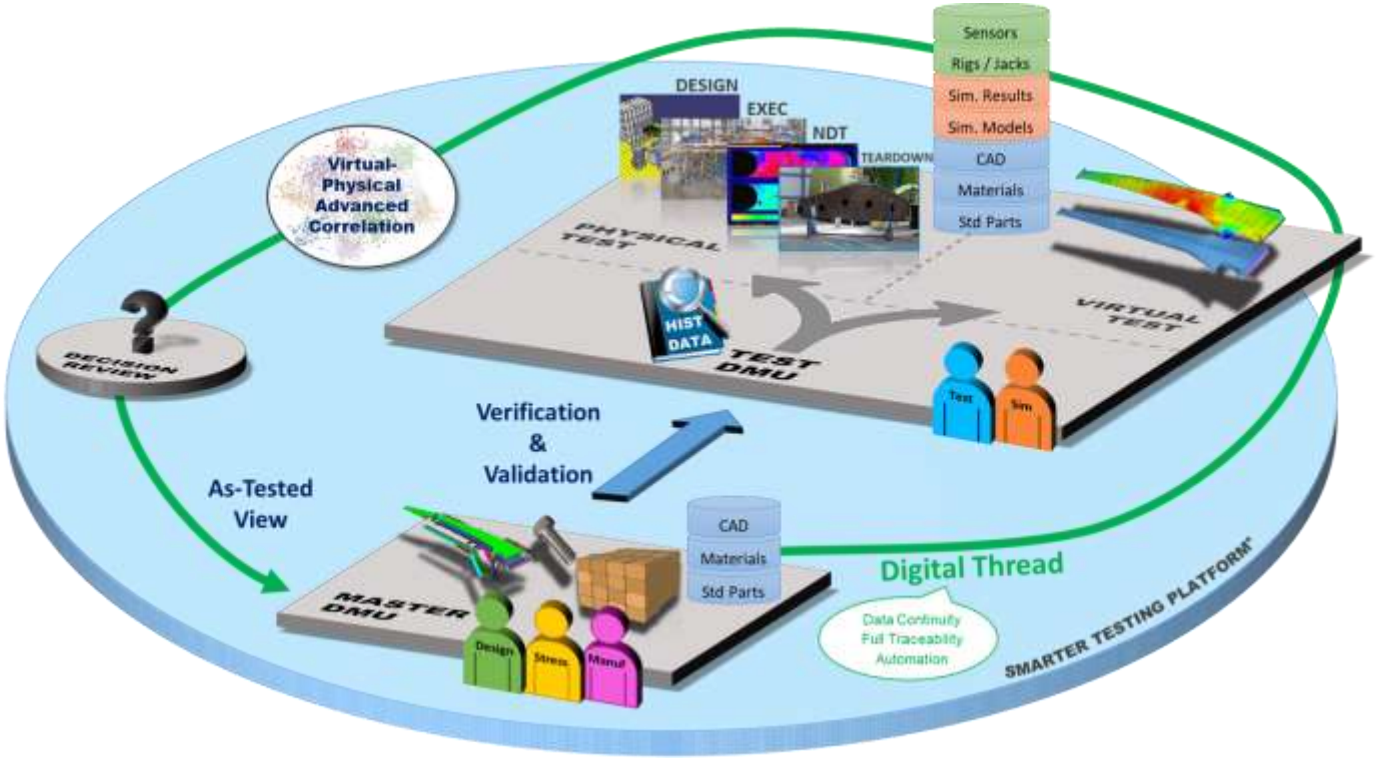


WP1: Data Driven Platform

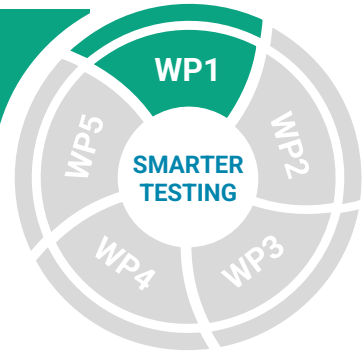


Development of a **collaborative environment** based on Dassault Systèmes 3DExperience that seamlessly connects the virtual and physical test processes.

- Provides a web-based environment that enables collaboration between customers and physical/virtual test engineers.
- Provides a single point-of-access to all test data (physical & virtual), including:
  - Test DMU with instrumentation and measurements information.
  - FE analyses that predict structural behaviour up to and including failure.
  - Advanced inspections that monitor structural behaviour up to and including failure.
- Enables a Digital Thread to link test data with design/stress and manufacturing data.



WP1: Data Driven Platform



Smarter Testing – Data-Driven Platform

End-to-End Test Lifecycle Management

Test Requirements Management and Planning

Test Requirements Management

Customer Design, Configuration and Alignment to Reqs

Verification & Validation Strategy and Plan

Plan and Schedule Tests

Test DMU Creation, Management and Assembly

Test DMU Management

Virtual Test Models

Physical Test Models

Virtual Test Execution and Results Dissemination

ENABLERS

Ontologies and Data Models

Test Data Exchange Specifications

Roll up results for reporting to certification bodies

Update Verification & Validation Plan according to changes & Issues

V + R Comparison

Physical Test Monitor and Results Delivery

Physical Test Execution

Physical Test Assembly

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Correlation, Validation and Deployment

Physical Test Execution and Monitoring

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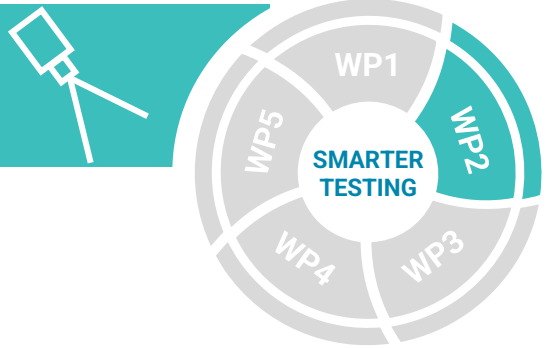
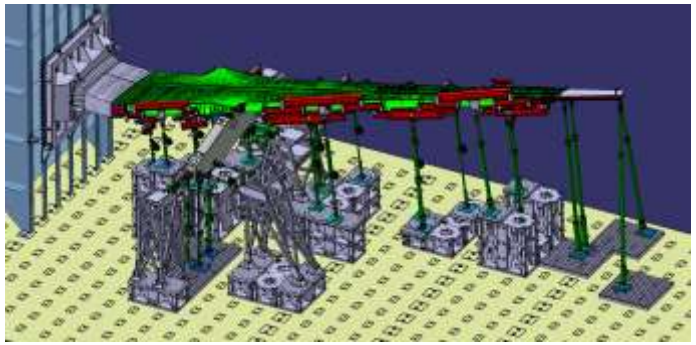
WP2: Advanced Measurement Technologies

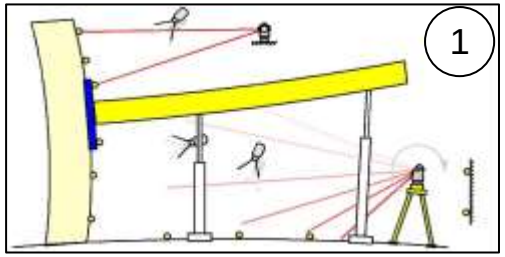


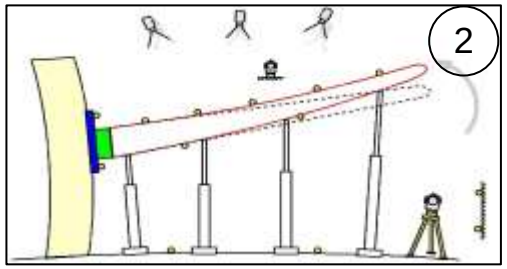
Advanced measurement technologies will be further matured to ensure that required Quantities of Interests (QoI) can be captured at the right scale, granularity, at the right time, at the required frequency and with defined uncertainties.

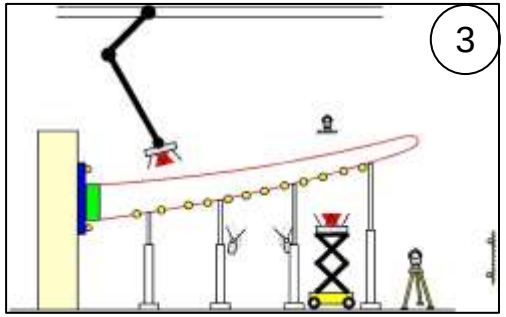
These measurements will support the below capabilities:

1. **Validation of simulations** for certification
2. **Condition-led inspection** to reduce test lead times
3. **Test protection** to prevent premature failure of test systems









Key Enablers:

- ➔ Data Acquisition / Physical Setup
  - ◆ Designing and building an integrated multi-system camera setup to optimise large scale testing
  - ◆ Establish global referencing network and investigate common target capabilities
- ➔ Digital Continuity
  - ◆ Establish a measurement workflow for each technology to demonstrate against QOI
  - ◆ Live monitoring capability
- ➔ Uncertainty Quantification

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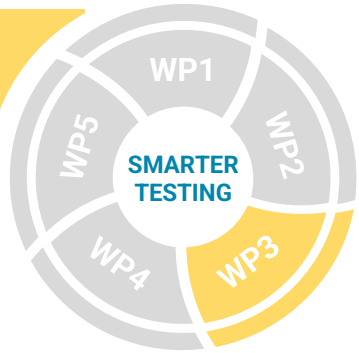
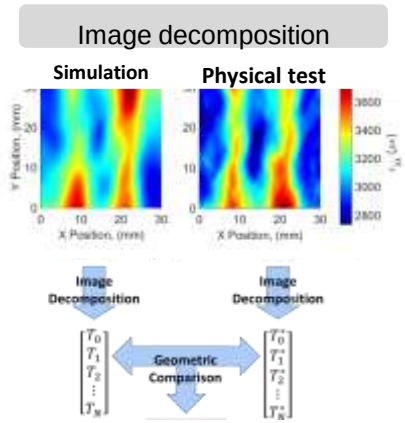
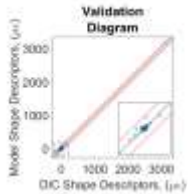
WP3: Advanced Quantitative Data Correlation

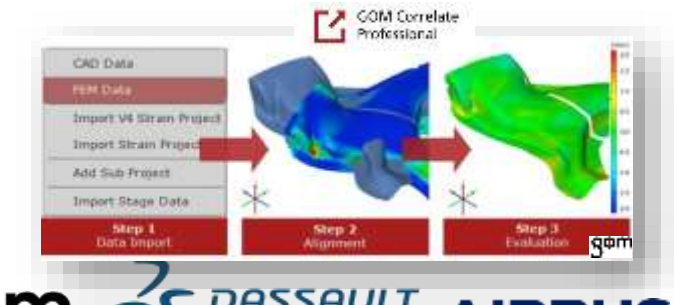


Automated quantitative data correlation methods and processes will be developed that will enable the comparison between physical and virtual test data to see a real deterministic value of coherence and variance in a complex structure and reduce analysis times.

- Modelling and Simulation Credibility for ES elimination and EF optimisation
- Definition of requirements and intended purpose, framework for correlation
- Documenting workflow and outputs of all the measurement systems of interest and simulations
- Uncertainty quantification (measurement/data science/simulations) and propagation
- Development and implementation of quantitative data correlation from 1D to 3D strategy and methods.
- Demonstration of capabilities.







Automate

Existing validation methods/processes
Links between platforms and tools

Innovate

Advance correlation capabilities
Test protection/Condition-led inspections

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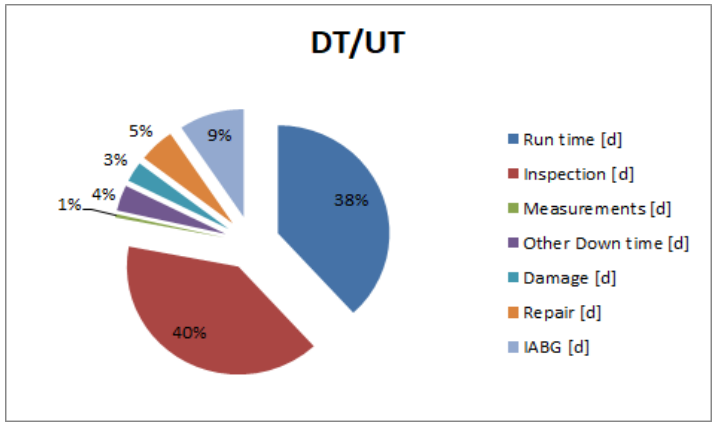
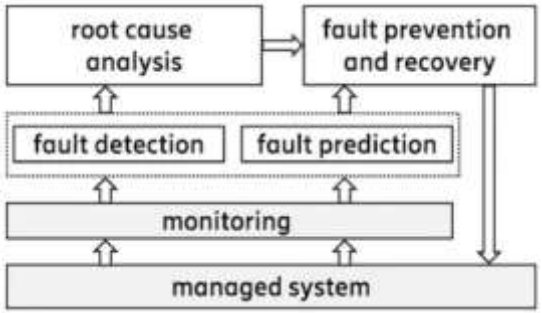
WP4: Advanced Data Analytics

Advanced data analytics methods will be developed to enable condition-led inspections and predictive test maintenance.

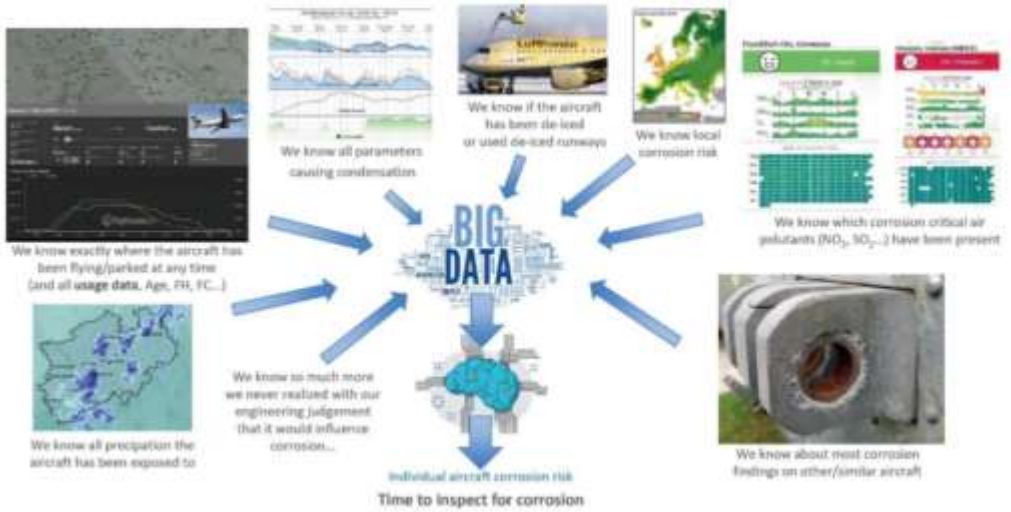
- Condition-led inspections in order to reduce planned shutdown times by providing recommendations to optimize inspection plans.
- Predictive test infrastructure maintenance to de-risk unplanned infrastructure failures and reduce unplanned downtime
- Test protection to protect the test specimen and infrastructure from a premature catastrophic failure during a static test.



<50% uptime in a recent Fatigue Test



Ideal fault management system [1]



Data driven based condition-led inspections - aircraft maintenance: corrosion control by usage-driven inspections [2]

[1] A look at automated fault management with machine learning, Ericsson Blog, 2019
https://www.ericsson.com/en/blog/2019/6/automated-fault-management-machine-learning
[2] EASA Concept Paper: First usable guidance for Level 1 machine learning applications

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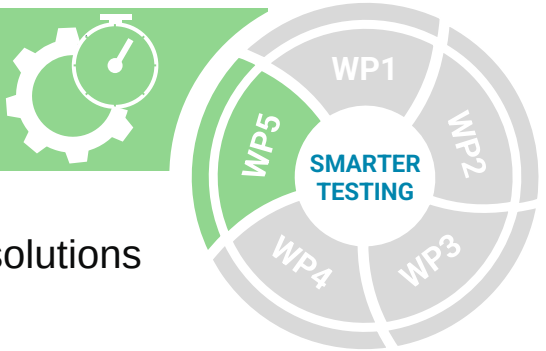
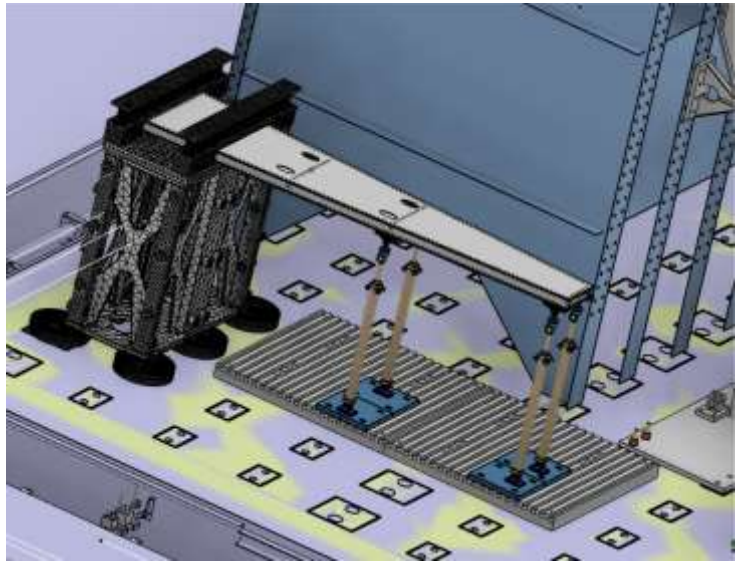
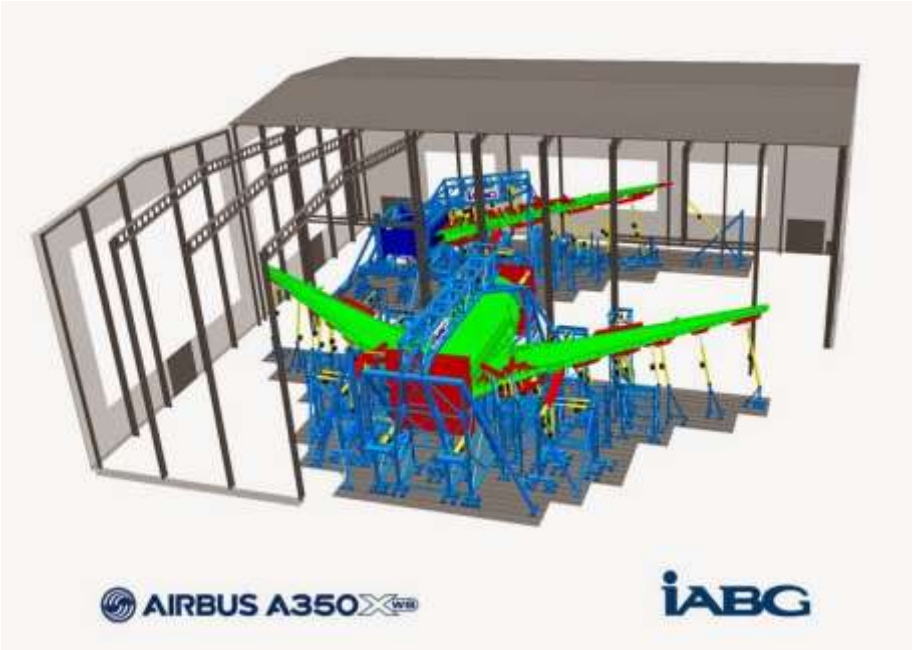
WP5: Test Optimisation



In order to achieve reduced lead times and deliver data earlier in the development phase, advanced testing solutions will be developed for the **optimisation of test design, setup and performance**.

- Guidelines for optimised test plans scenarii to fit PDP 5 years
- Development of test systems simulation capabilities and control systems and hydraulics
- Development of test design, manufacturing and setup optimisation capabilities
- Development of test execution optimisation capabilities e.g. test strain control





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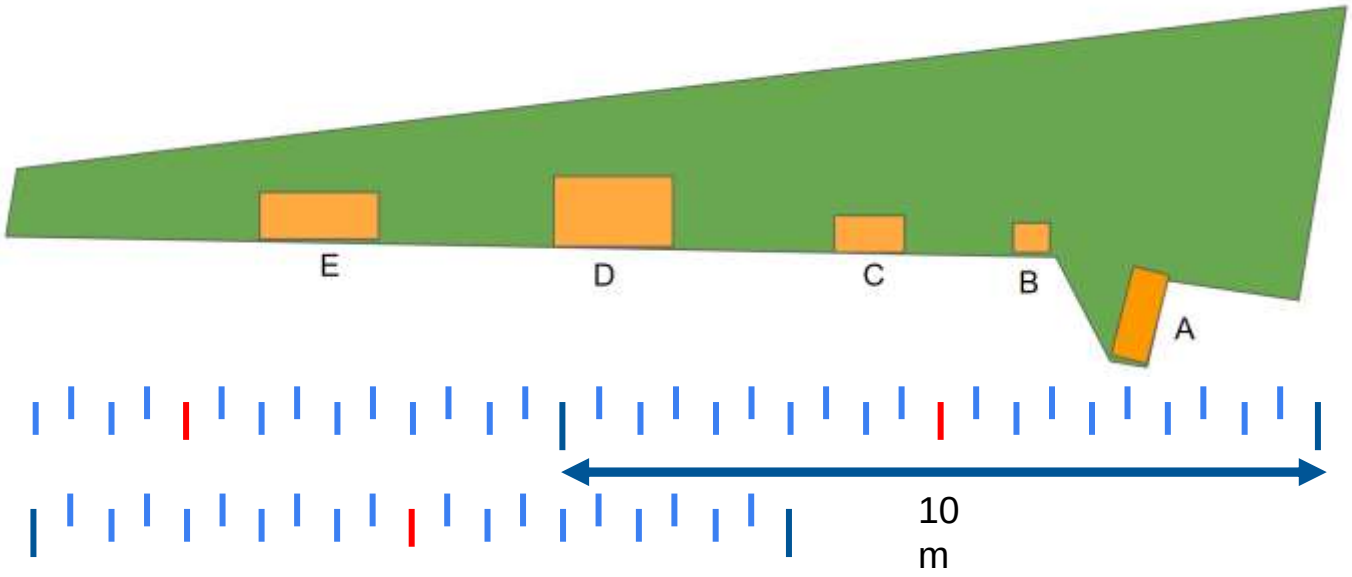
Dimensional Measurement Challenge

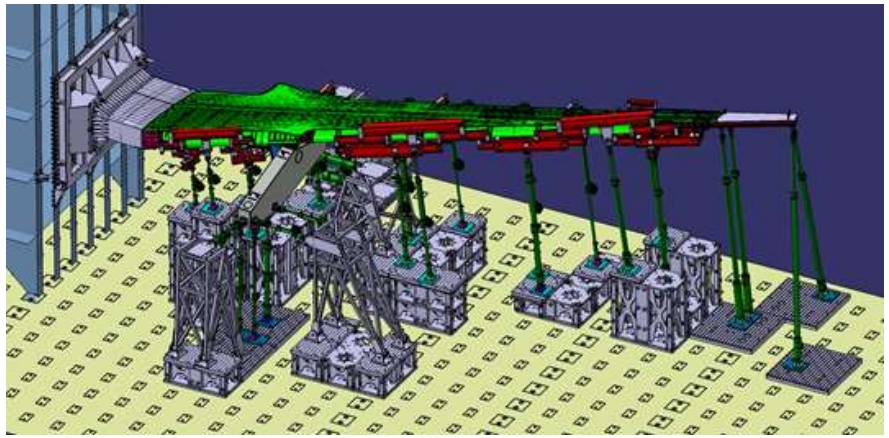
Measurand – Wing shape
- Deflection – global displacement
- Tip/tilt – angular displacement

Target positions
- 20 in y-axis
- 5 in x-axis

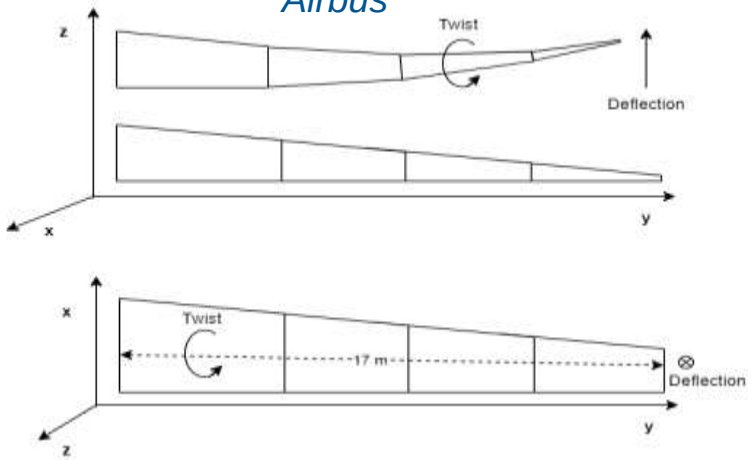
Two Load cases:
- Low – held for minutes
- High – held for seconds



Test demonstrator – plan view – *Courtesy of Airbus*



Single Aisle wing test– *Courtesy of Airbus*



Wing Shape measurands

Approx. areas and vertical change

A: 1.25m x 0.6m, ± 0.5m
B: 0.5m x 0.25m, ± 0.5m
C: 0.75m x 0.5m, ± 0.6m
D: 0.9m x 0.6m, ± 1.5m
E: 0.7m x 0.5m, ± 5.0m

Measurement Requirements

Measurements

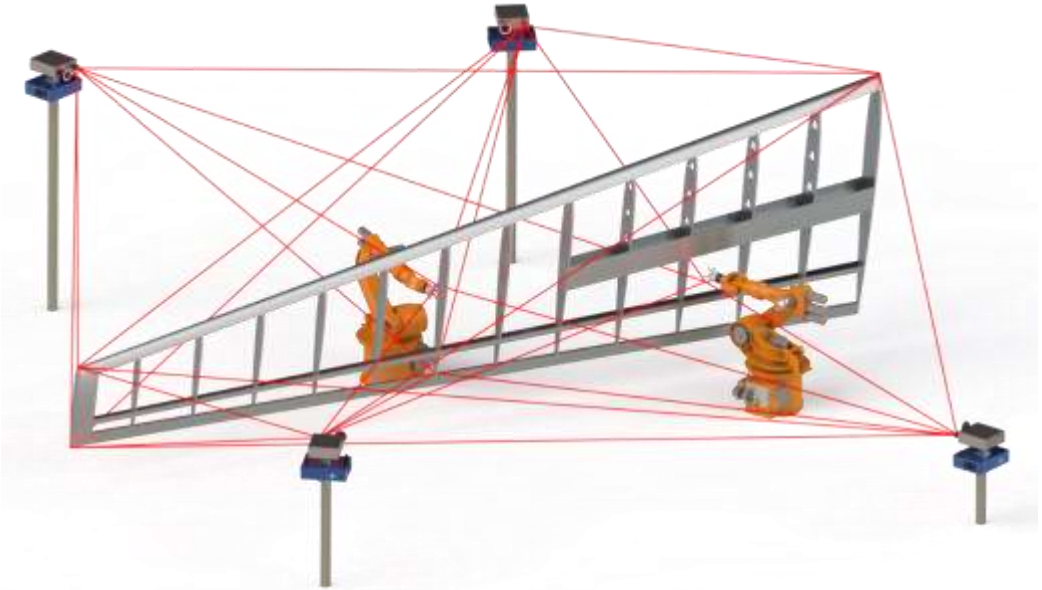
- Large volumetric coverage
- Global reference frame
- Simultaneous or rapid sequential measurement of multiple targets
- Low cost targets
- Targets with large acceptance angle

Smarter testing - Confidence in data

- Measurement-specific uncertainty evaluation
- Proven calibration to standards
- Traceability to the SI metre

Faro Vantage E
courtesy of Faro

GOM ATOS fringe projection system
courtesy of GOM



NPL OPTIMUM – A novel coordinate measurement system

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