The Digital Twin: concept, value creation and recent work in the ReliaBlade project

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Digital Twin Definition

Precise virtual representation of a physical product or process

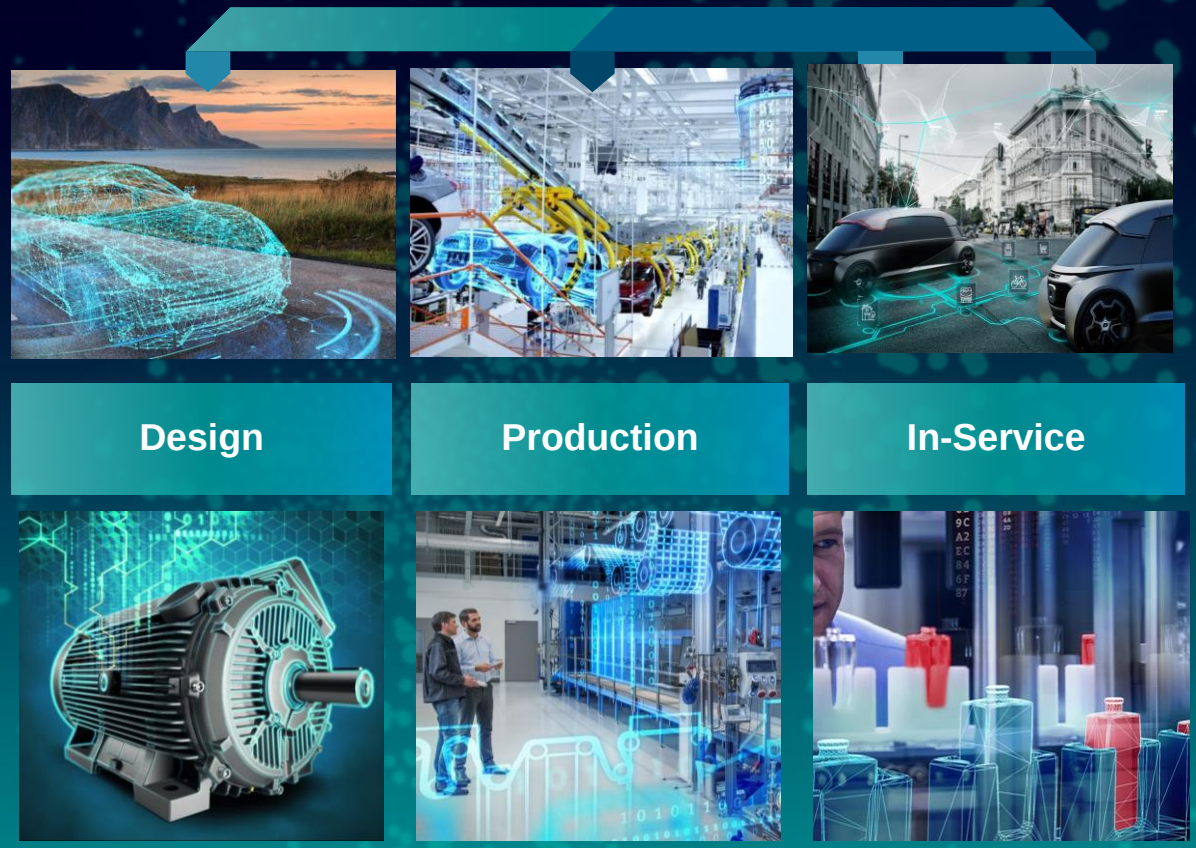
Used across its lifecycle to simulate, predict and optimize the product and production system

Made up of multiple representations or models for different aspects of physical behavior

An evolving object with a lifecycle that needs to be managed

Closed-loop digital twin provides for bi-directional connectivity between the physical asset and the virtual representation

feed back insights to continuously optimize product and production



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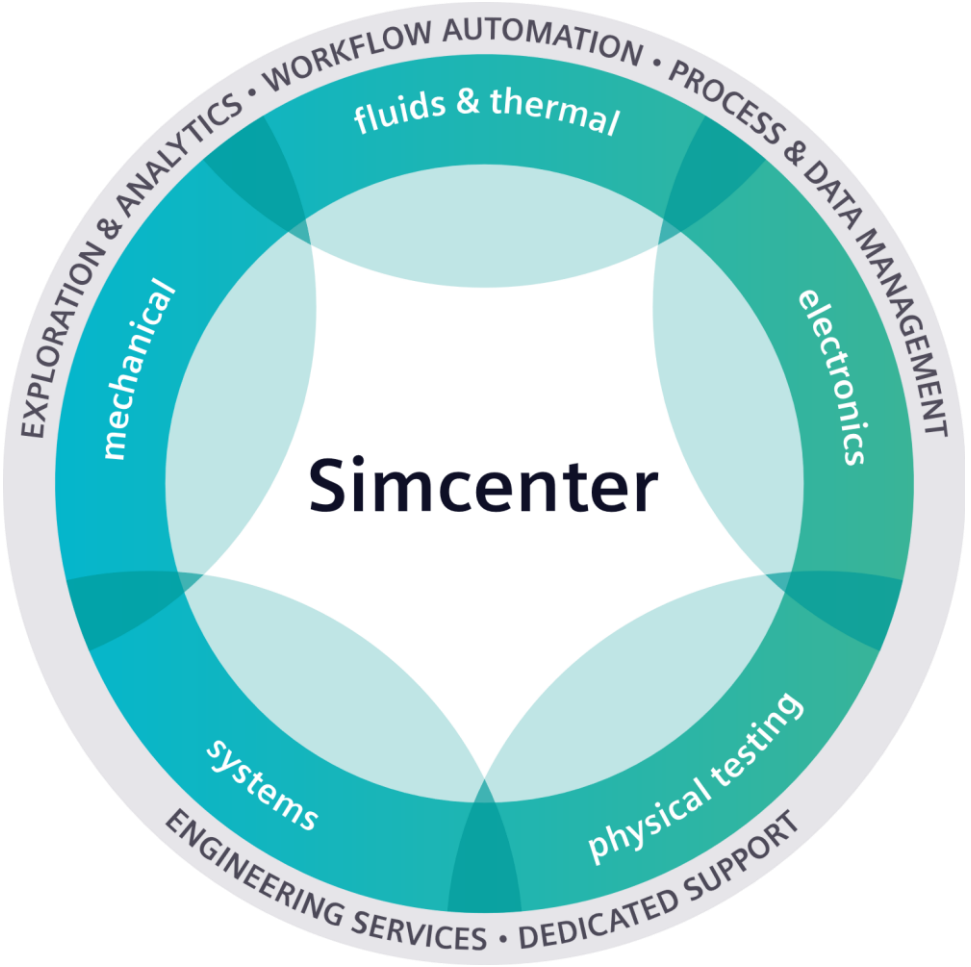
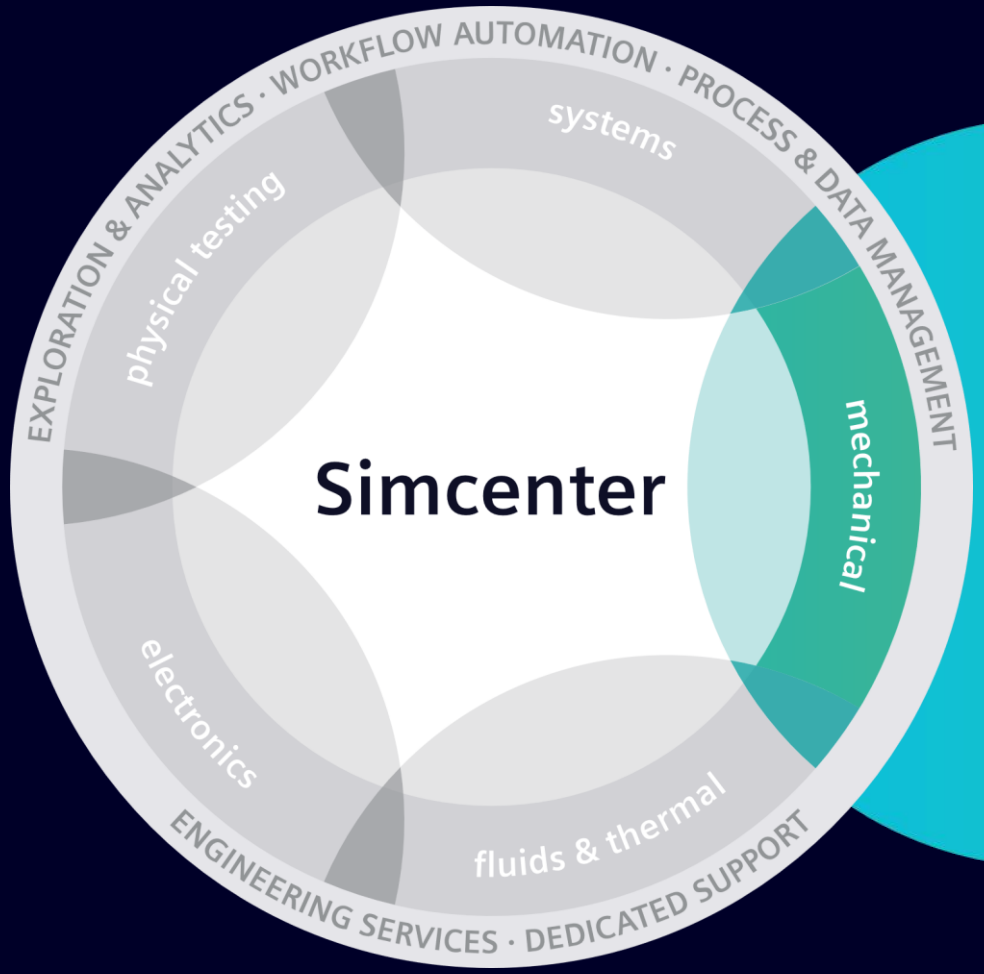
The beating heart

We believe that the comprehensive digital twin is critical to the future of engineering innovation and that simulation and test are the beating heart of the digital twin.
By providing you with insight into the real-world performance of your product or process, Simcenter allows you to accelerate innovation over the entire lifecycle.

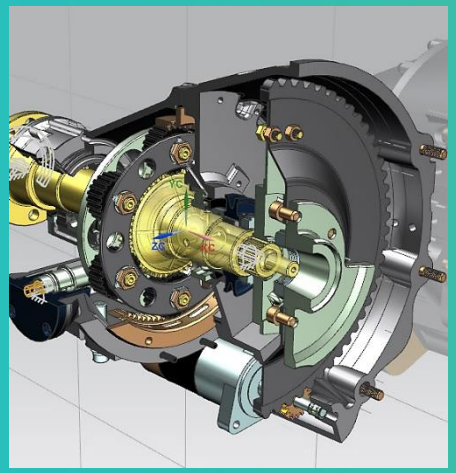
Jean-Claude Ercolanelli, Senior Vice-President, Siemens

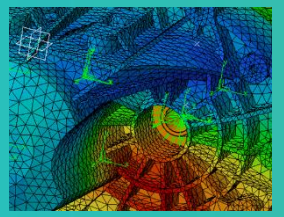


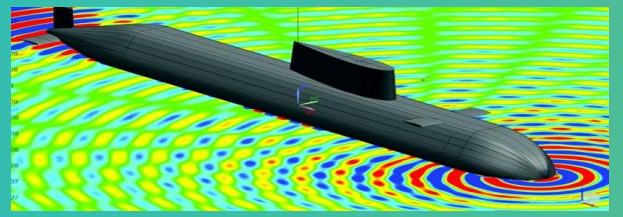
Mechanical



Predict mechanical performance across multiple disciplines using CAE







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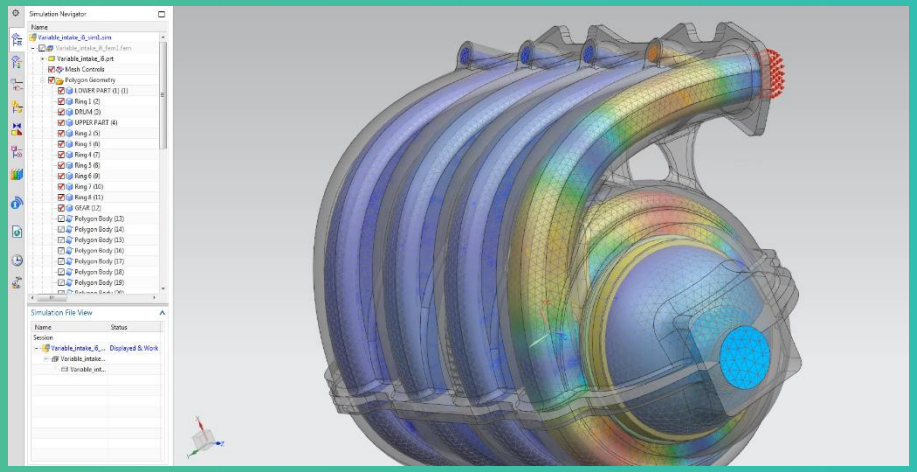
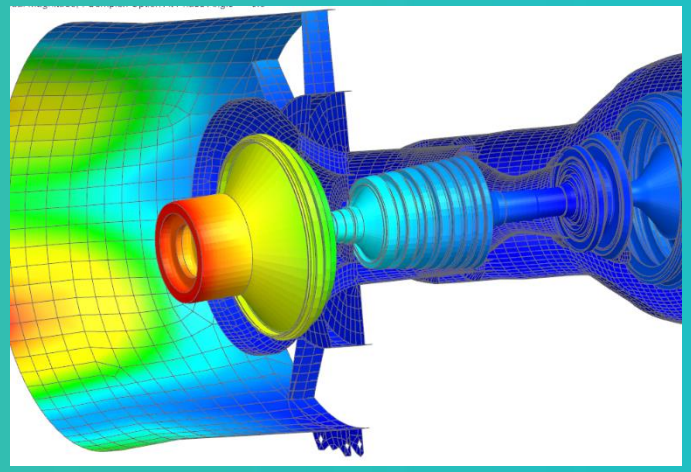
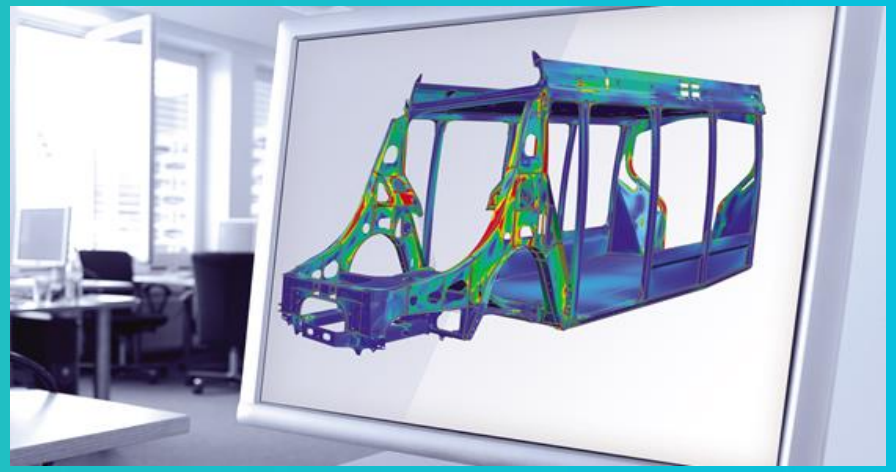

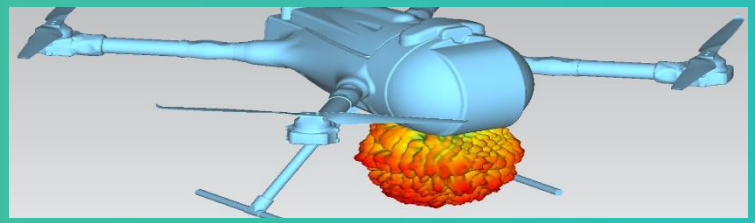

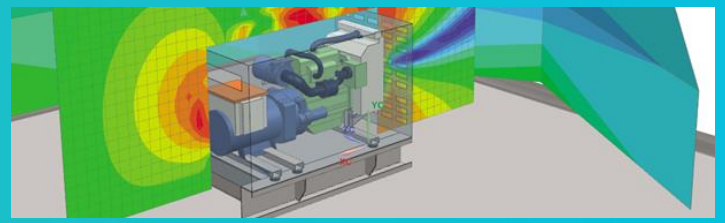

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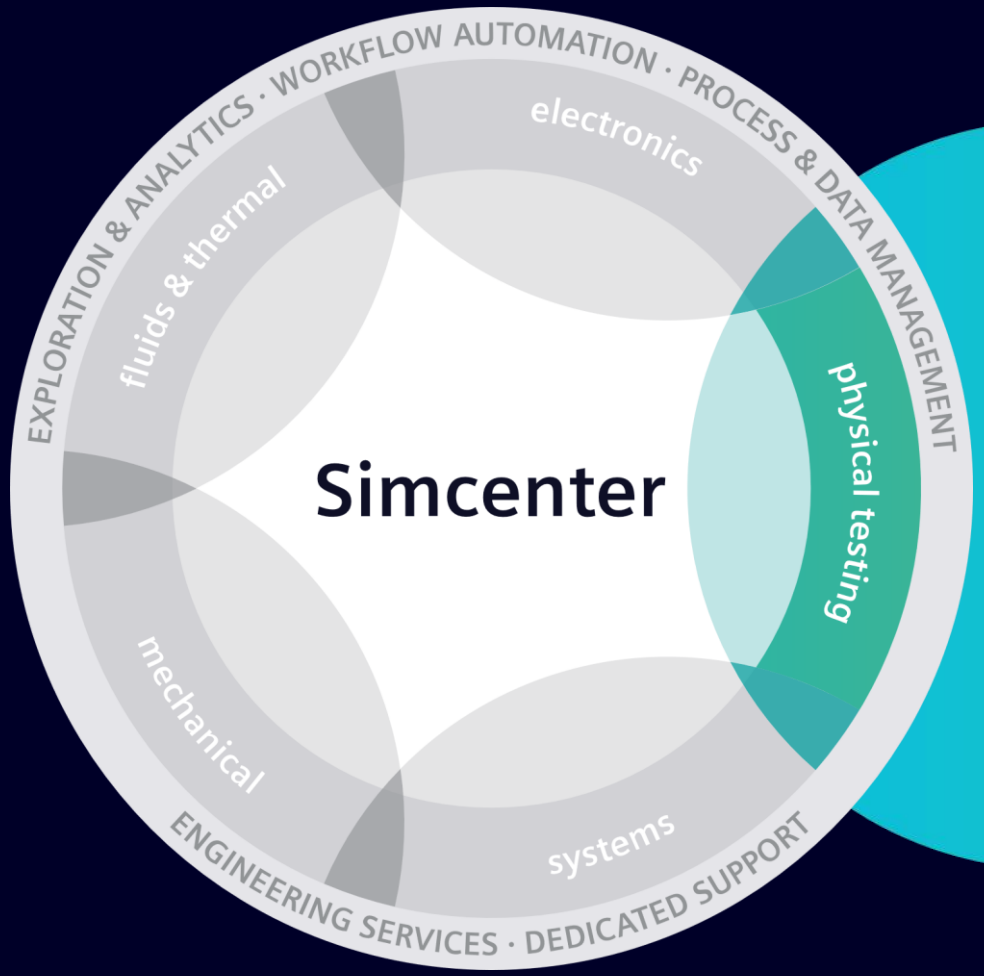
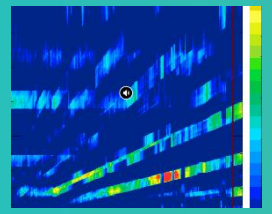
Physical testing



Drive innovation and productivity in test-based engineering



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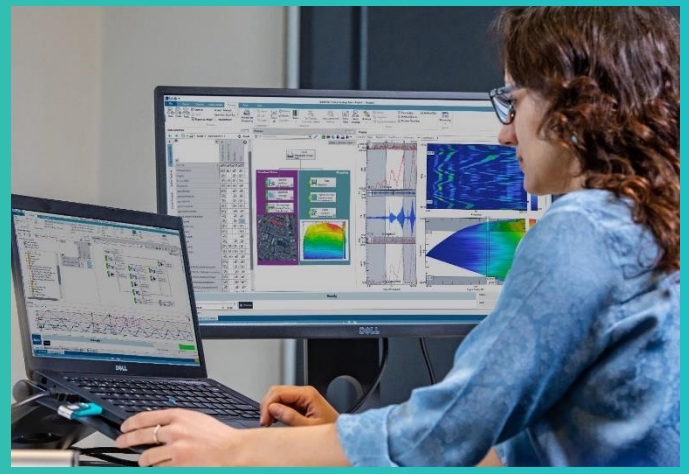




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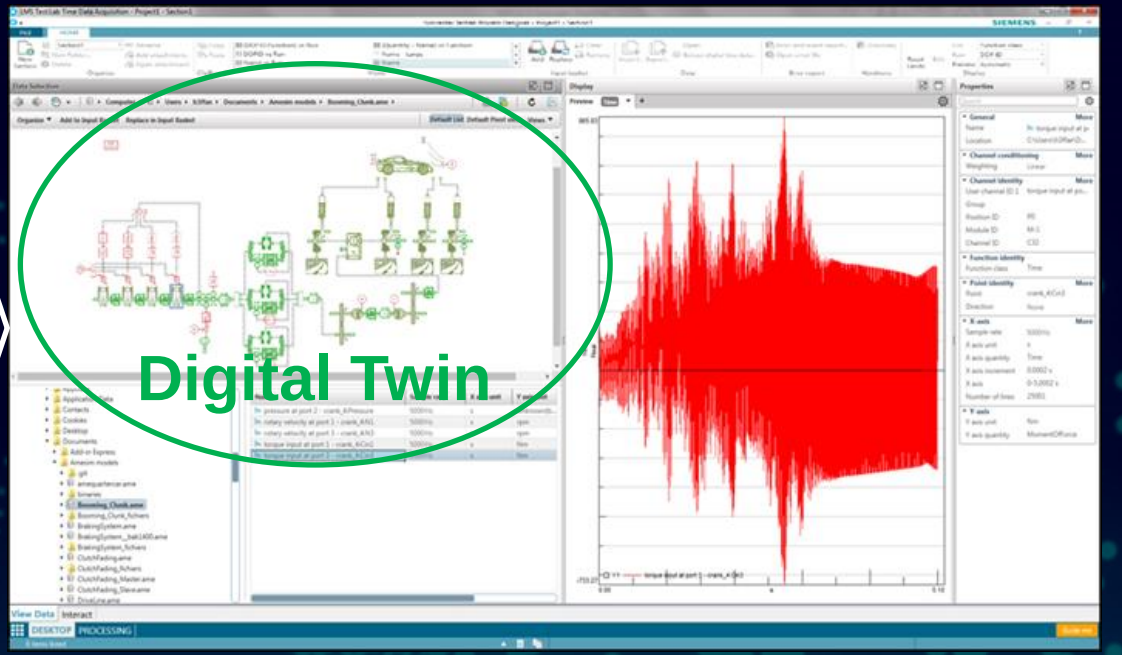
Achieve excellence in cross-domain engineering

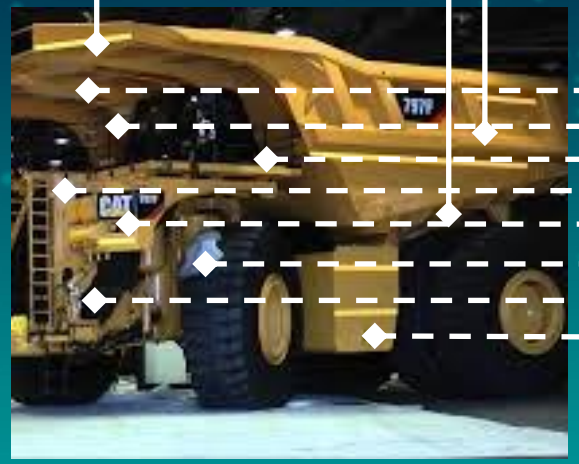
Challenge
Increase efficiency in prototype testing

Solution:
Fusion of Digital Twin with Testing
“Virtual Sensors”



Sensor Data

Sensor Data & Digital Twin



“Virtual Sensors”
- ✓ More insights
- Shorter test time
- ✓ Data at inaccessible locations

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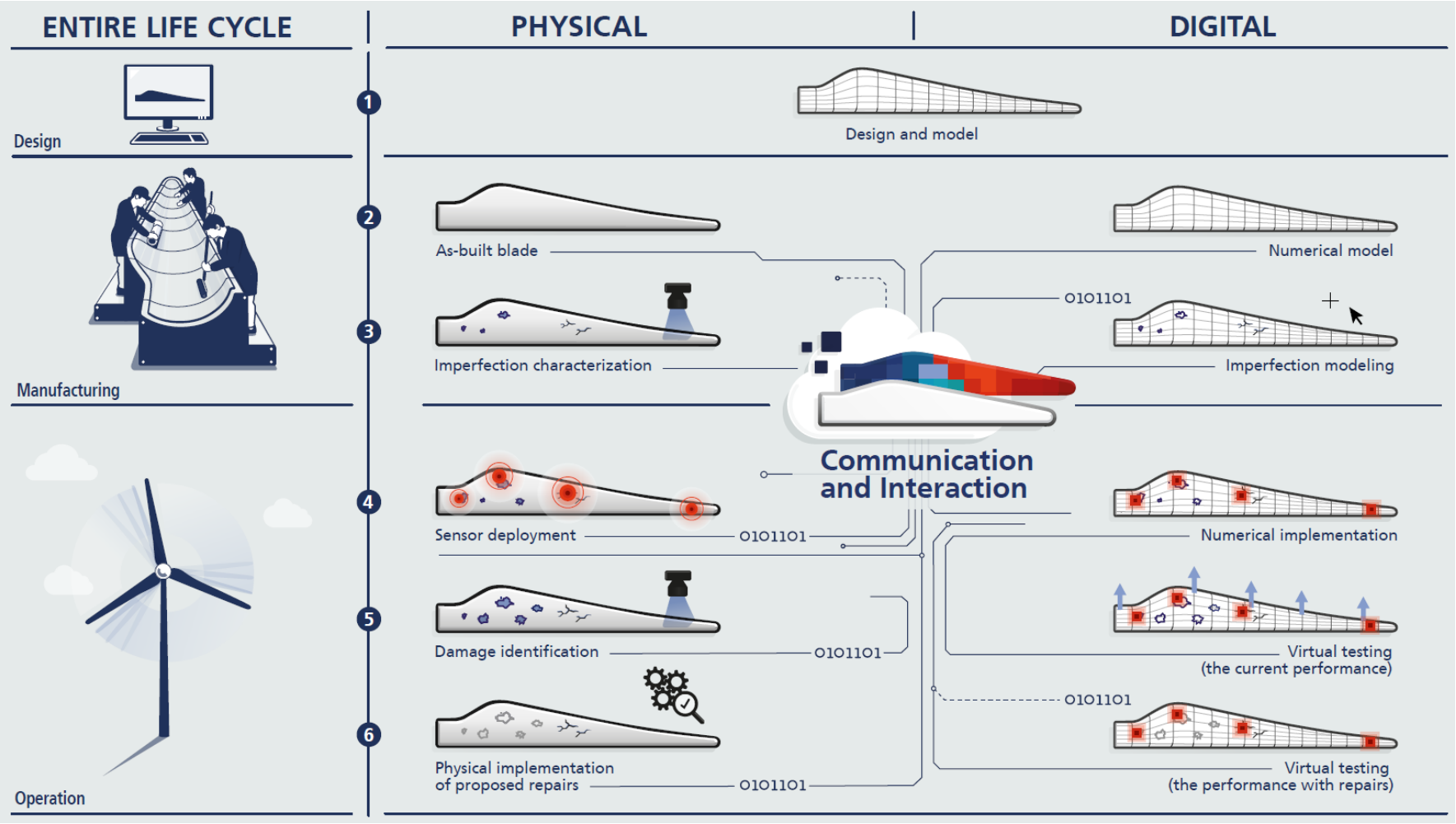
ReliaBlade – Role of Siemens Digital Industries Software



In close collaboration with DTU

- Contribute to WP1 – Digital platform integration
- Dynamic testing:
  - Baseline Test-validated Digital Twin at design stage
- Fatigue testing:
  - Virtual sensing demonstrator

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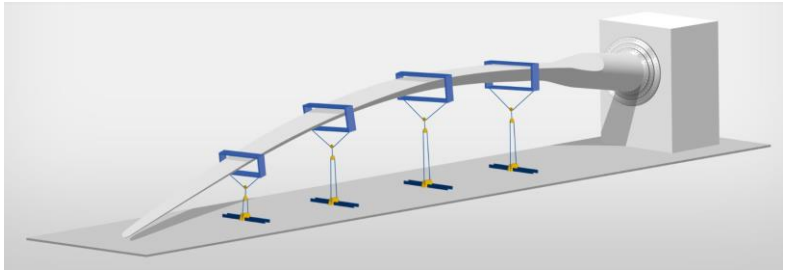
Wind turbine blade testing for certification

IEC 61400-23 standard for wind turbine blades certification

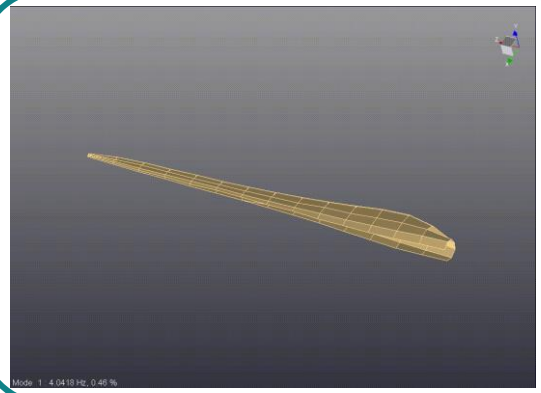
Static Tests:
verify the structural strength of the blade

Fatigue Tests:
ensure that the blade will be reaching the designed lifetime of about 25 years

Dynamic Tests:
limited to the identification of the first and second flapwise natural frequencies, and of the first edgewise one.



DTU Wind Energy Large Scale Facility



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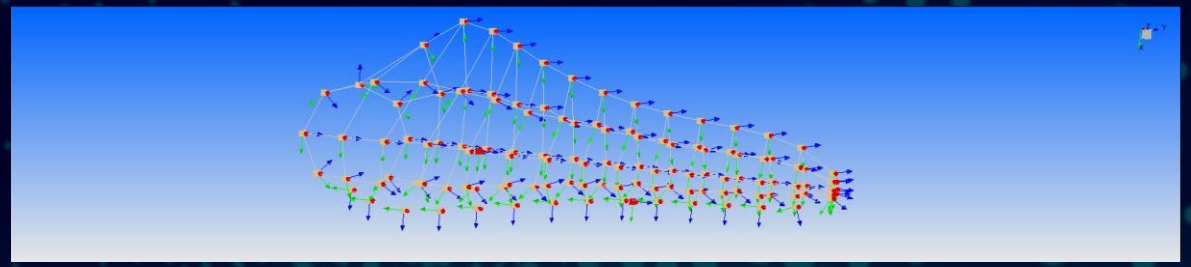
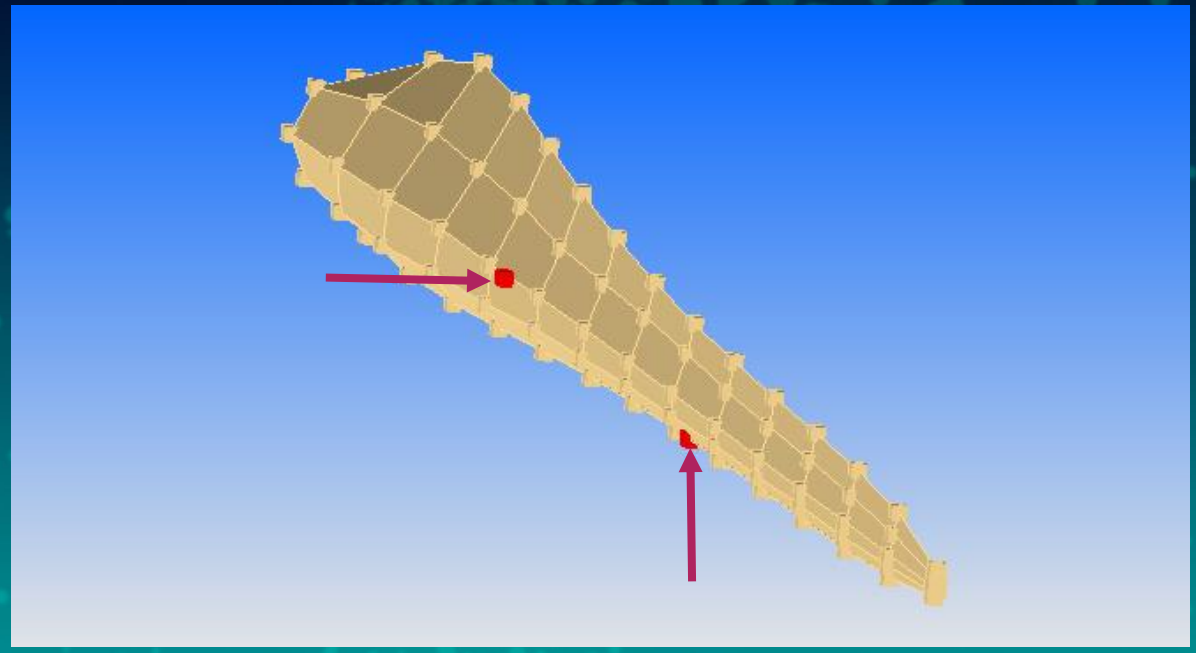
Test setup:
free-free boundary conditions for FE model validation

DTU Wind Energy
Large Scale Facility





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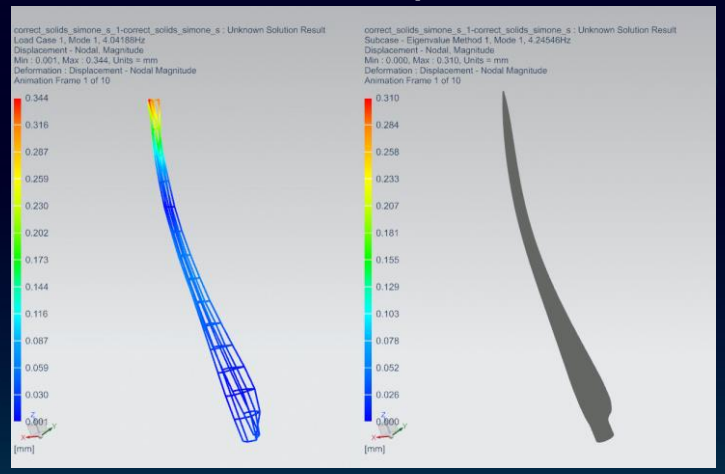
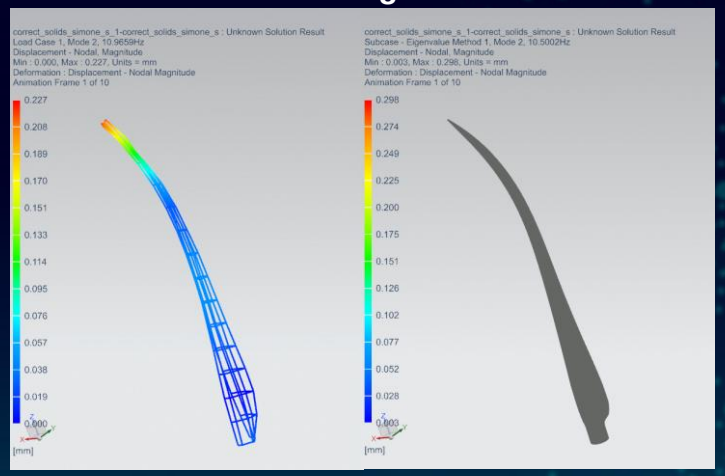
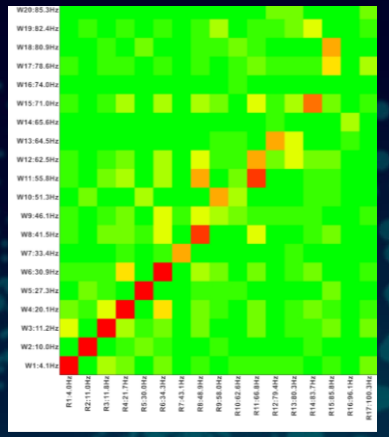
Correlation: Test vs FE model

Mode 1 – 1st flapwise mode

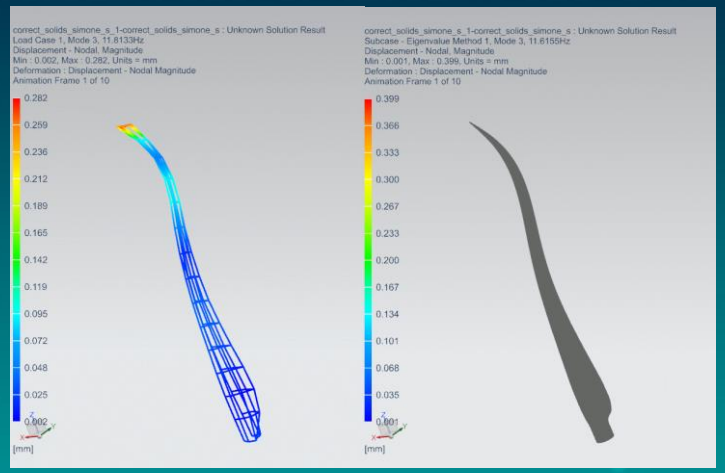


Mode 2 – 1st edgewise mode

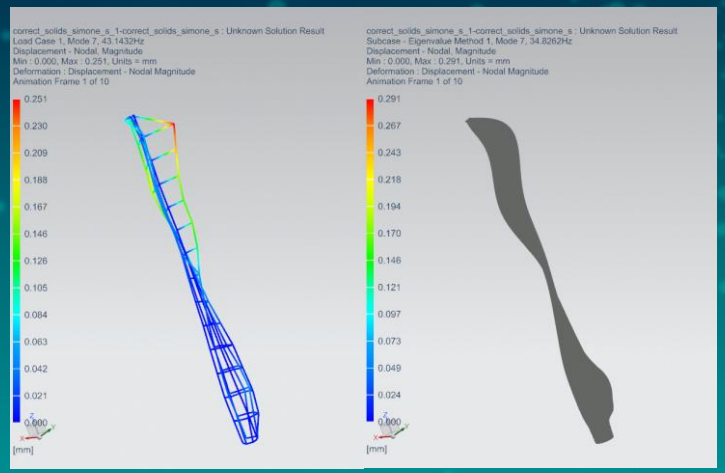


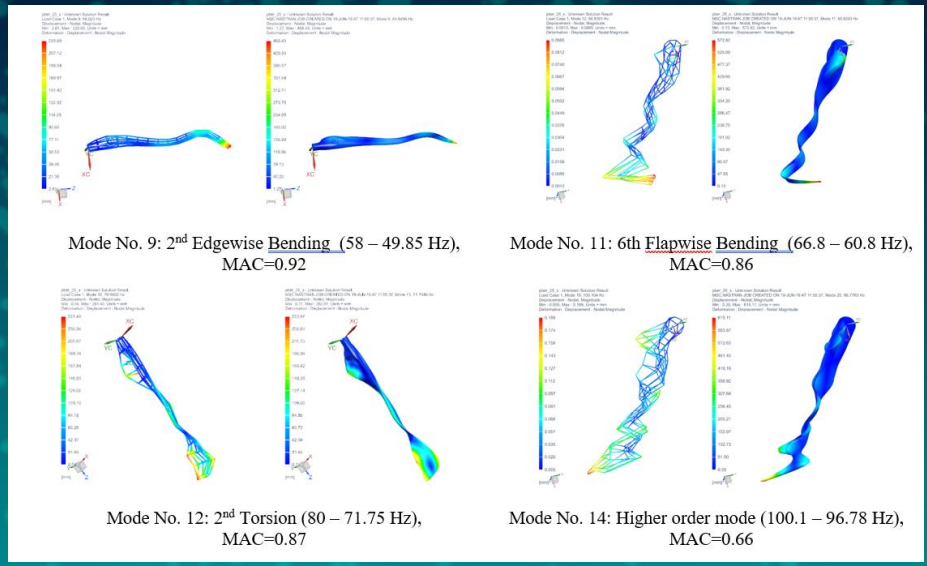


Mode 3 – 2nd flapwise mode



Mode 7 – torsional mode





Mode No. 9: 2nd Edgewise Bending (58 – 49.85 Hz), MAC=0.92

Mode No. 11: 6th Flapwise Bending (66.8 – 60.8 Hz), MAC=0.86

Mode No. 12: 2nd Torsion (80 – 71.75 Hz), MAC=0.87

Mode No. 14: Higher order mode (100.1 – 96.78 Hz), MAC=0.66

FE model provided by DTU Wind Energy

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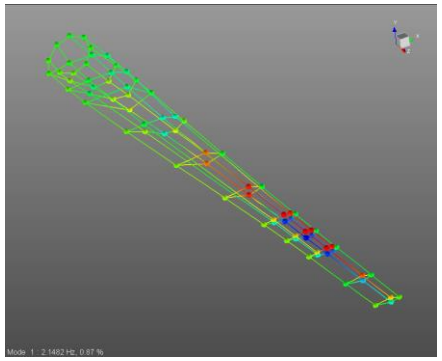
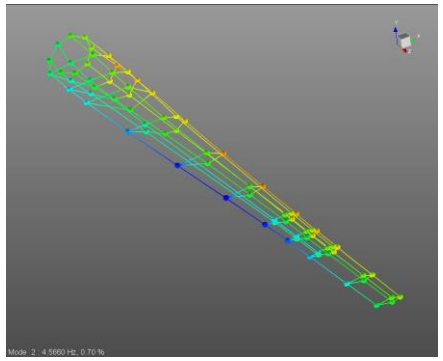
Strain-based Operational Modal Analysis
Pull & release test



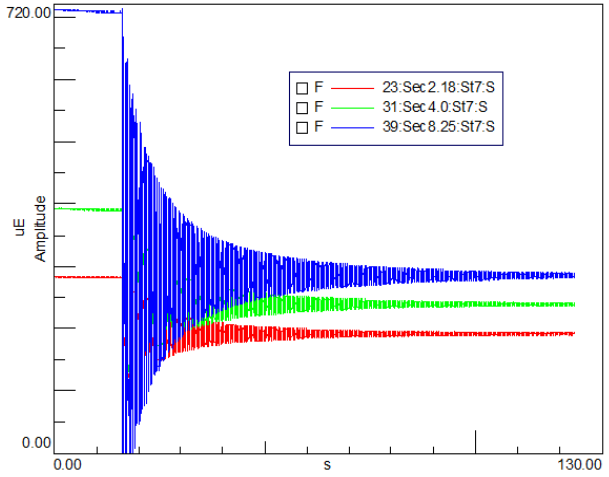


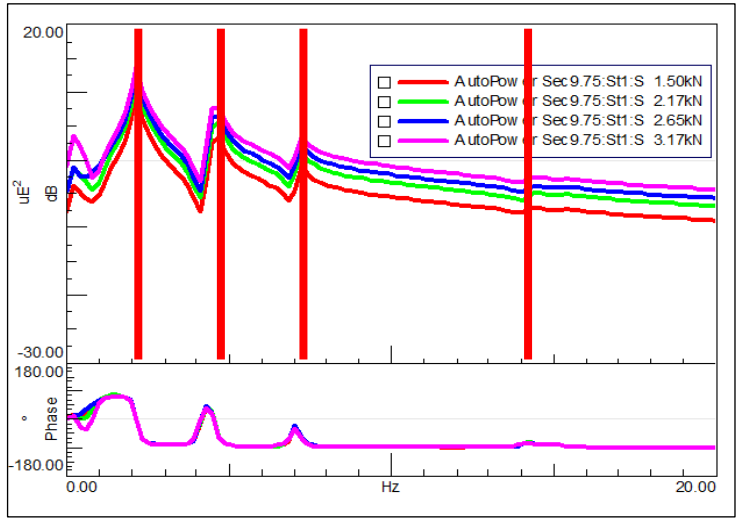
Pull & release test

- 4 different force levels (1.50kN, 2.17kN, 2.65kN, 3.17kN)
- 76 strain gauges along 12 sections

Data processing (no force, no accelerometers)

- Strain-based Operational Modal Analysis





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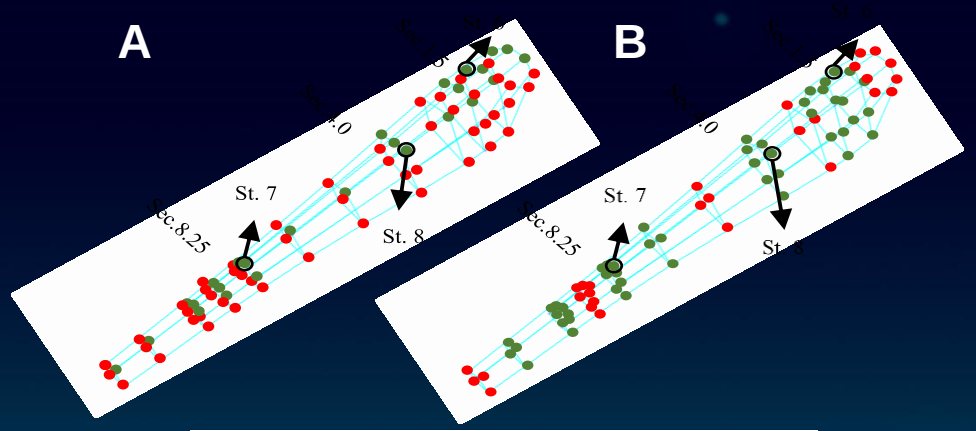
Virtual Sensing for response estimation during blade testing

Analyzed sensors configurations



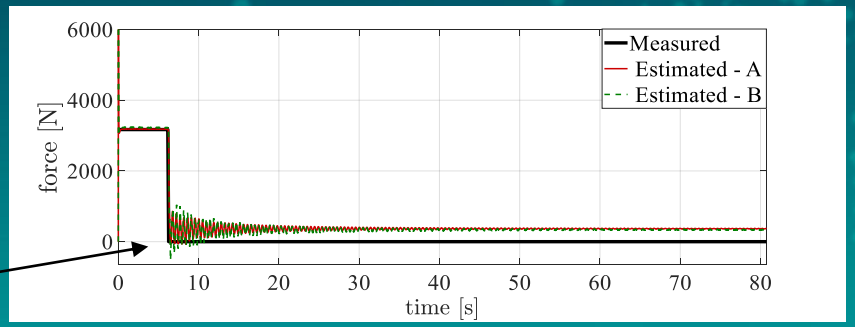
	Conf. A	Conf. B
"measured" locations	50	28
"unmeasured" locations	26	48

Pull & release tests

- Strain response acquired at 76 locations;
- Analysis of different physical sensing layouts (measured/unmeasured locations) influence on the virtual predictions delivered via the AKF (Augmented Kalman Filter).

Input estimation

Higher SD for sensors layout B involving a lower amount of sensors in the input region



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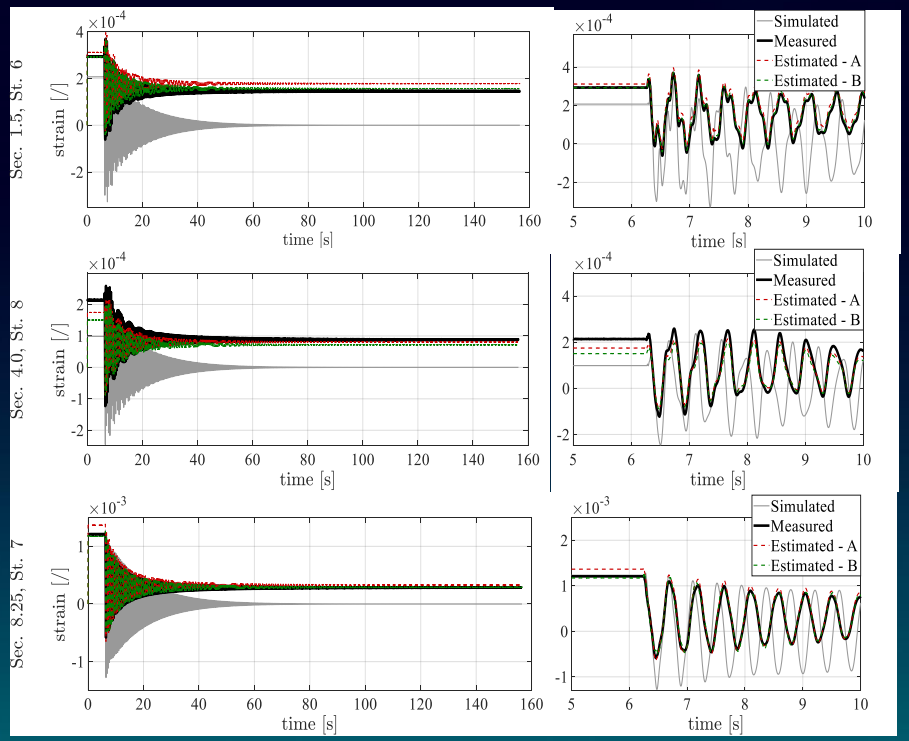
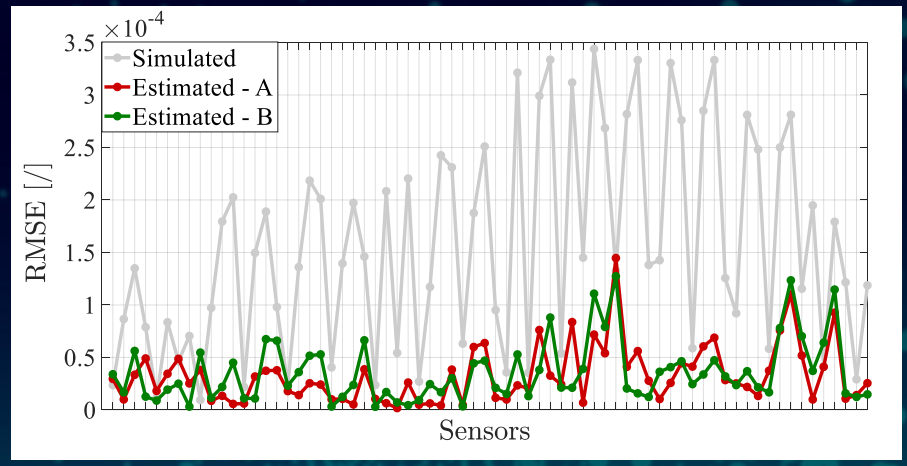
Virtual Sensing for response estimation during blade testing



	Conf. A	Conf. B
Sec. 1.5, St. 6	3.19×10^{-5}	1.09×10^{-5}
Sec. 4.0, St. 8	1.15×10^{-5}	2.11×10^{-5}
Sec. 8.25, St. 7	5.61×10^{-5}	1.58×10^{-5}

RMSE values for the above strain responses



RMSE of the simulated (grey), estimated (red – conf. A, green – conf. B) time histories with respect to the measured ones. Sensors are ordered from the blade root (left) to the blade tip (right) and in ascending order for each section

$$GE = \frac{\sum_{i=1}^{N} RMSE_i}{N}$$

Both configurations are quite comparable in terms of global response prediction error

	Conf. A	Conf. B
GE	2.421×10^{-5}	2.429×10^{-5}

Global response prediction error

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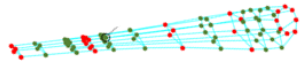
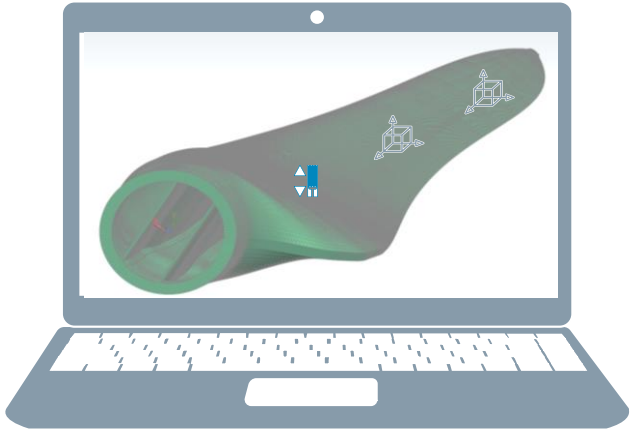
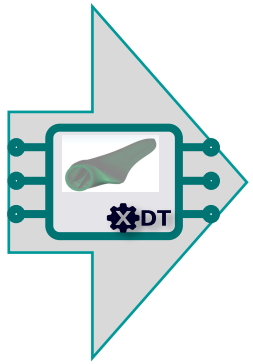
Executable Digital Twin
Measure the unmeasurable with smart virtual sensors



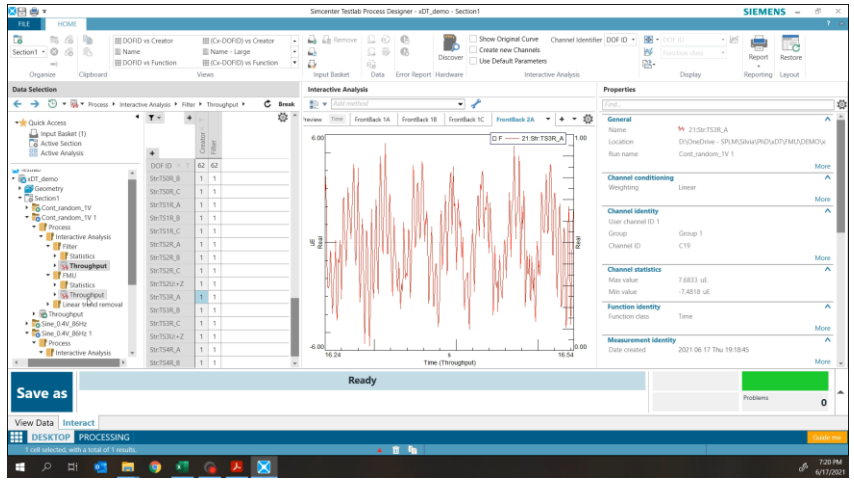
- Instrumented location
- Non-instrumented location

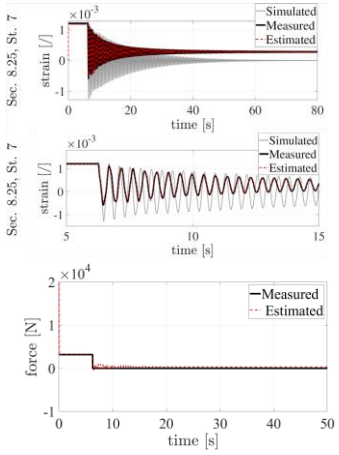
Simcenter 3D

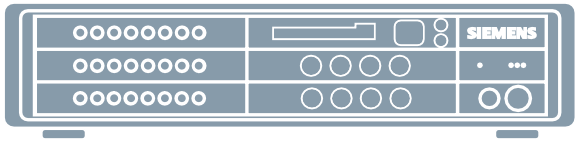


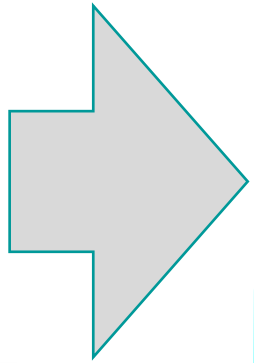


Simcenter Testlab - SCADAS









Live (processed) data to the Cloud

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Conclusions – a final note on digital twins

The **digital twin** concept sits at the center of **digitalization**

- Linking **all models and data** related to products, their production and operational performance
- Providing them to **designers, engineers, operators and service technicians** across domains
- For **product, production, construction, operation** value creation
- Different **business models to create value** for each application and lifecycle phase

New capabilities and opportunities are emerging to leverage the digital twin across the lifecycle

- This demands **novel modeling, simulation and test data integration** capabilities
- Up to **real-time models**, enabling transparent **interchange of physical and digital twin** parts
- Extend the Digital Twin with **AR/VR** for **new user experiences**
- Enabling **human in the loop**
- Allowing to **leverage the ever-increasing CPU power**
- Bring the Digital Twin **close to the prospective users** …

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