



Funded by
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TURBO

Towards turbine blade production with zero waste

Horizon Europe 101058054

TURBO public presentation

<https://turboproject.eu>

Presentation outline

■ Overview

- Consortium
- Key objectives
- Partner contributions

■ Supporting technologies

- Simulation
- In-line monitoring
- NDT of blade coatings

■ Manufacturing technologies

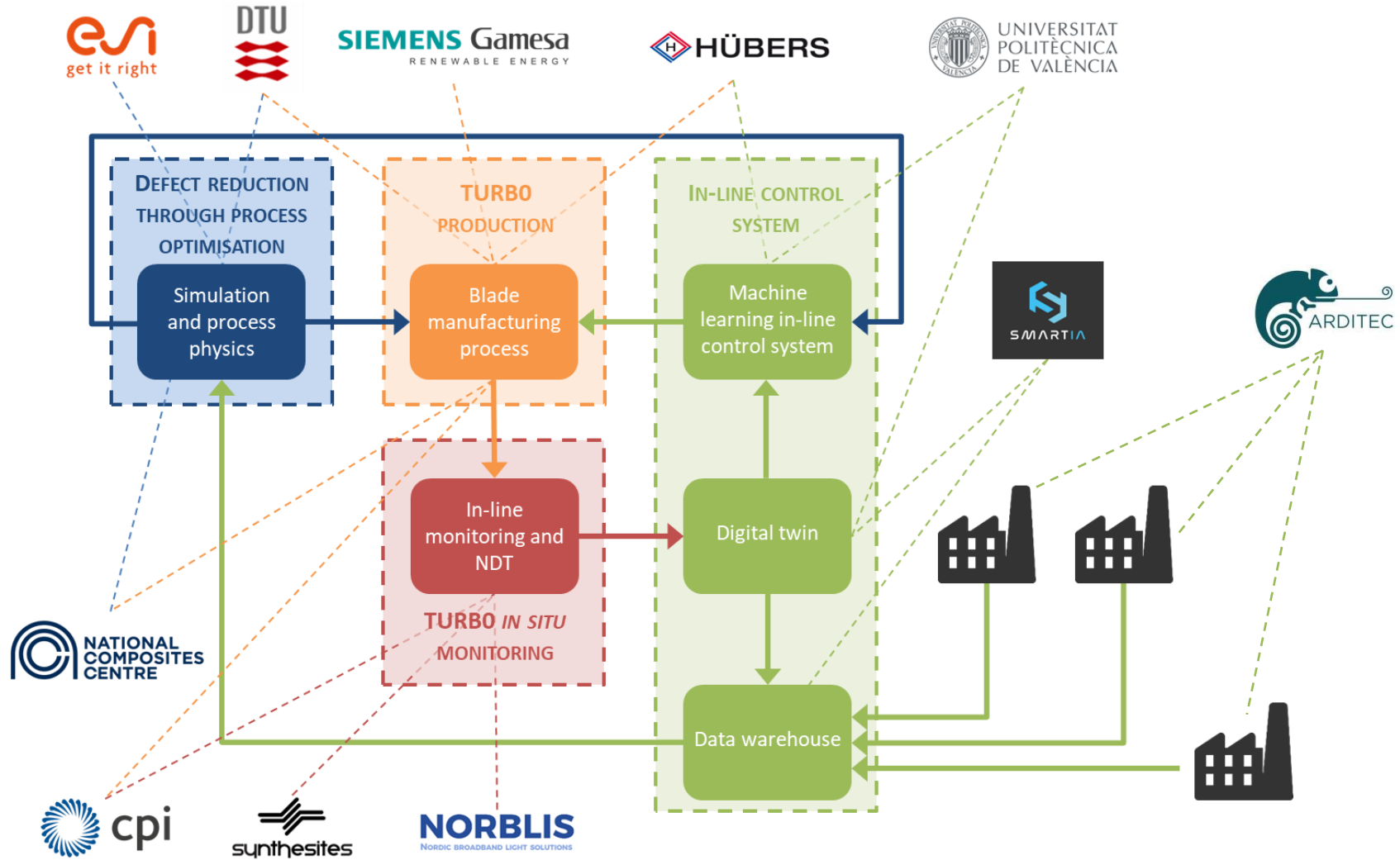
- Digital twin
- Improved composite manufacturing
- Sustainability assessment
- TURBO demo



Consortium

No.	Short name	Name	Country
Beneficiaries			
1	DTU	DANMARKS TEKNISKE UNIVERSITET	DK
2	SGRE	SIEMENS GAMESA RENEWABLE ENERGY AS	DK
3	Huebers	HUBERS VERFAHRENSTECHNIK MASCHINENBAU GMBH	DE
4	ESI	ESI GROUP	FR
5	UPV	UNIVERSITAT POLITECNICA DE VALENCIA	ES
6	SYN	SYNTHESITES	BE
7	NORBLIS	NORBLIS APS	DK
8	VIV	VIVID COMPONENTS GERMANY UG	DE
9	ARDITEC	ARDITEC	FR
Associated partners			
10	NCC	NCC OPERATIONS LIMITED	UK
11	SMARTIA	SMARTIA LTD	UK
12	CPI	CENTRE FOR PROCESS INNOVATION LIMITED	UK

TURBO partner key contributions



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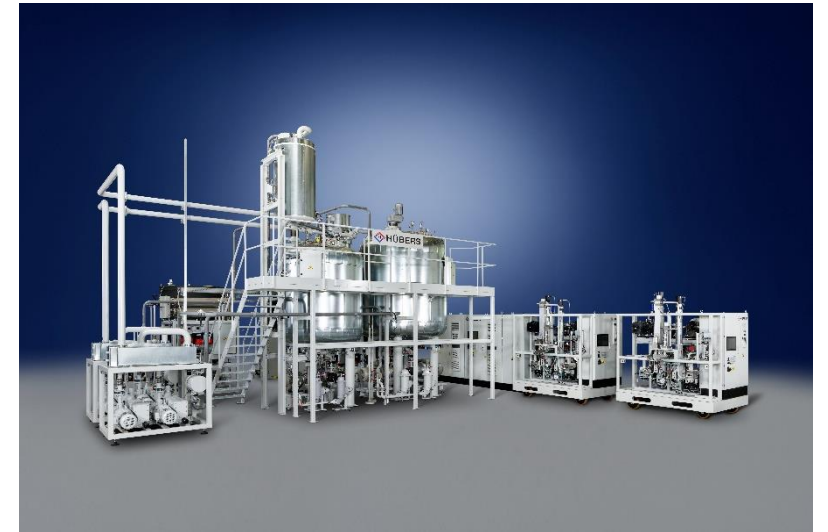
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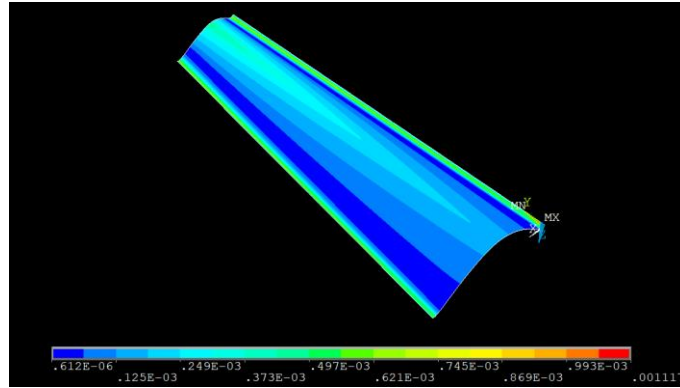


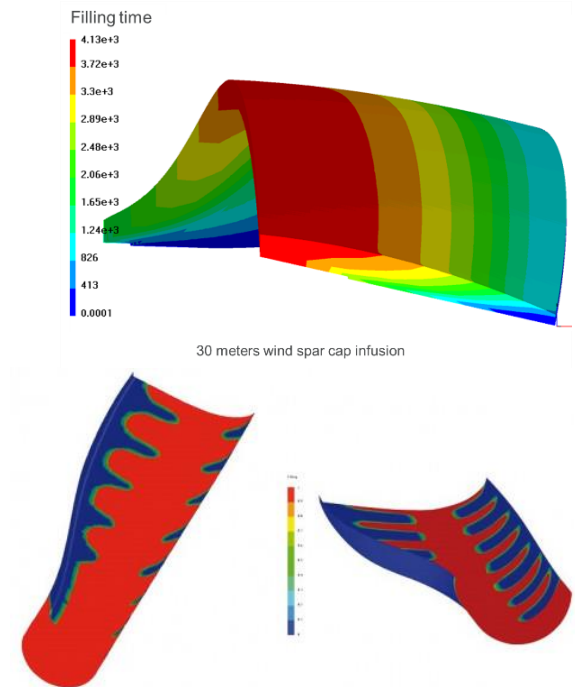
Image courtesy of DTU Construct

What ?

- Numerical simulation combined with sensor data
- Used to minimise defect formation by:
 - Defining the manufacturing processes
 - Understanding how the process should be modified in real-time in response to *in situ* monitoring data

How ?

- Multi-scale modelling of the manufacturing process
 - From virtual characterisation of the local material properties to high fidelity analysis of the manufacturing of the blade
- Exploring the field of possibilities in real time
 - By the combination of advanced AI techniques (model order reduction, machine learning *etc.*)
- Generating physical-based prediction in a decision support system for the production hybrid sensor



Images courtesy of ESI Group

In-line process monitoring

- Synthesites TURBO system will
 - Measure resin arrival during infusion and temperature measurement (≤ 56 points)
 - Calculate online resin viscosity and gelation time
 - Track the evolution of glass transition temperature (T_g) at several locations
 - Broadcast all data in real-time to help define system control signals



Images courtesy of Synthesites



- CPI will develop a TURBO embedded wireless sensor system
 - Measures resin arrival and temperature
 - Fabricated on flexible substrate
 - Wireless communications will send data from inside the mould (*i.e.* LoRaWAN)

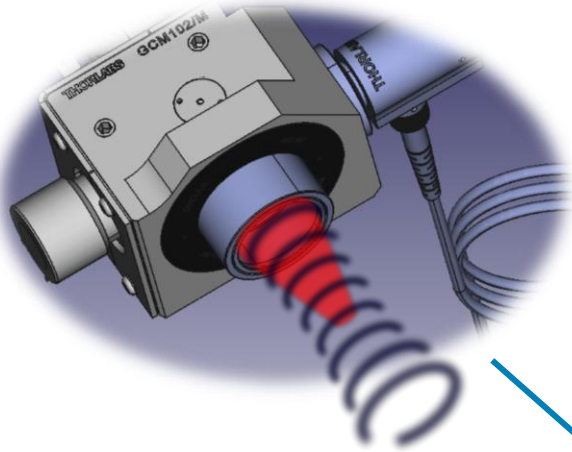


Images courtesy of CPI

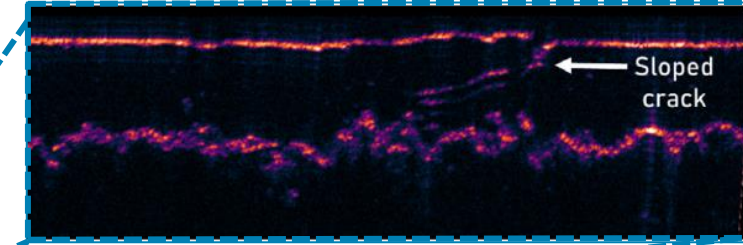


NDT of blade coatings

- First industrial-scale combined ultrasound and mid-IR optical coherence tomography (OCT) scanner



- For sub-surface defect detection



- Deep penetration of ultrasound combined with new technology of mid-IR OCT



- Demonstrated on ship hulls

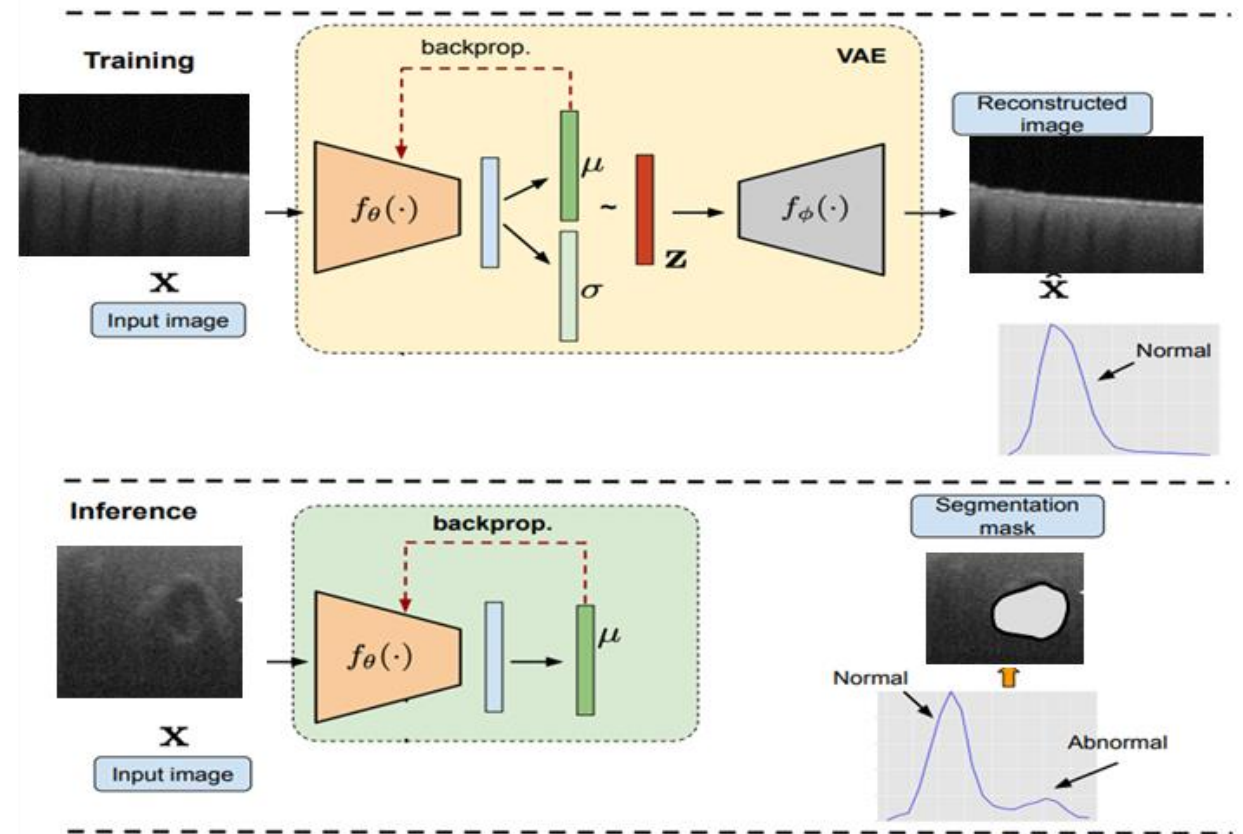
Petersen, Christian R., et al. "Non-destructive subsurface inspection of marine and protective coatings using near-and mid-infrared optical coherence tomography." *Coatings* 11: 877 (2021).

Machine learning analysis for NDT of blade coatings

- DTU will develop a supercontinuum extending to longer mid-IR wavelengths (e.g. 4 μm)
 - These wavelengths penetrate deeper than traditional near-IR OCT systems (typically 1.3 μm)
 - Source is based on a 2 μm laser to pump ZBLAN fibre

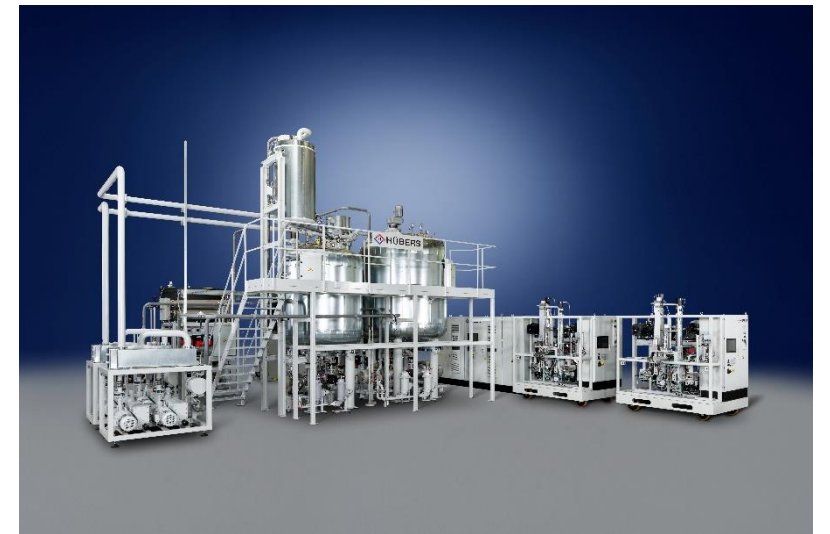
- UPV will develop machine learning based algorithms
 - Unsupervised anomaly detection techniques
 - Used to detect and segment different defects in OCT images without annotations

Constrained unsupervised anomaly classification and segmentation



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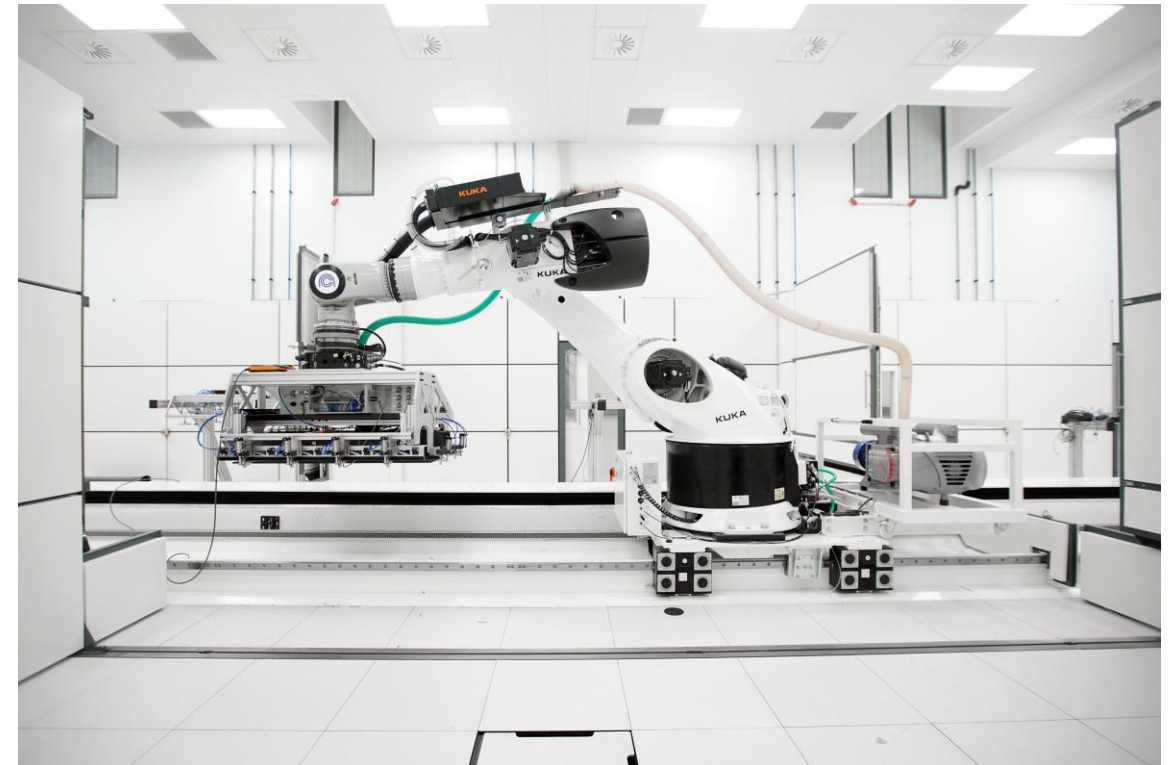
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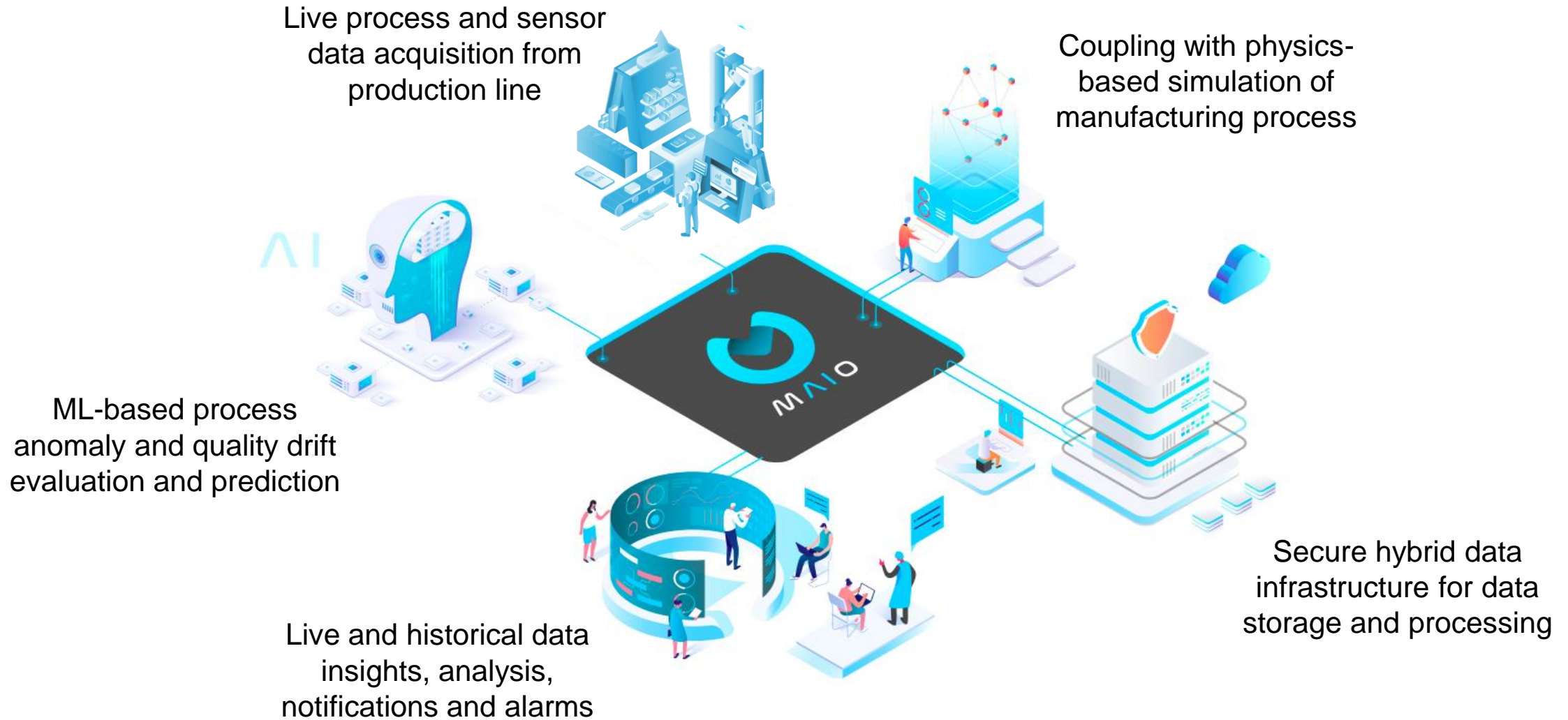
TURBO digital twin framework



- Smartia and NCC will develop a self-adaptive manufacturing process
- Digital framework for zero waste wind turbine blade manufacturing
- Key steps:
 - Scale-up of manufacturing and simulation to a full scale blade demonstrator
 - Combine process and sensor data with machine learning and physics-based simulations
 - Provide live manufacturing quality insights and corrective feedback loop control
 - Development of a secure digital twin architecture scalable for industrial production environments



TURBO digital overview



Improved composite manufacturing

- Hübers offers the most advanced process and plant technology for blade manufacturing on the market
 - Continuous degassing of material components
 - Constant monitoring of the infusion material mixing ratio processing temperature
 - Direct infusion in a closed system (without buffer/transfer vessels)
 - Active, controlled conveyance of material into the mould
- Hübers plants are currently in operation at SGRE facilities in Aalborg (DK), Hull (UK), and Le Havre (FR)

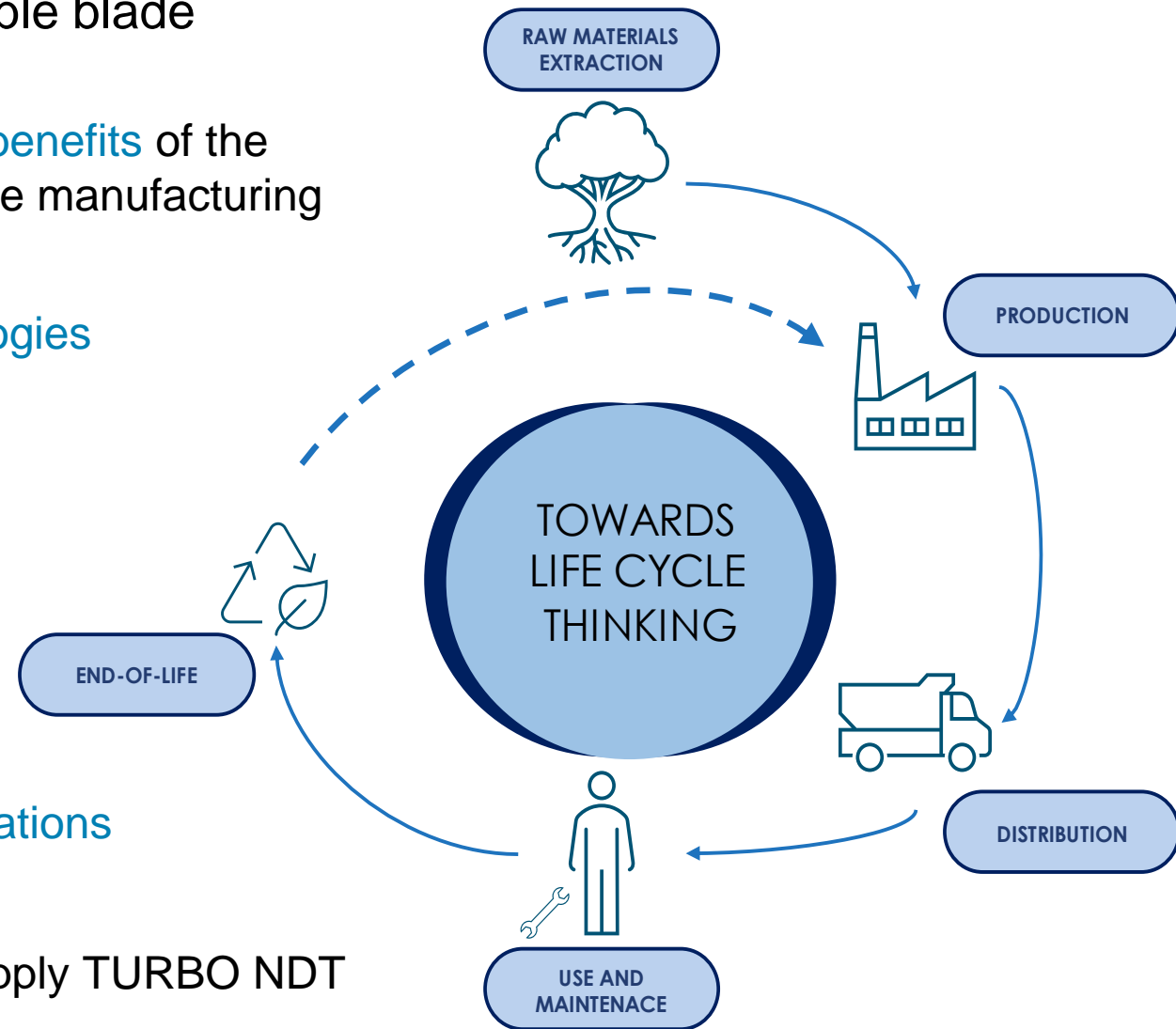


Image courtesy of Hübers Verfahrenstechnik Maschinebau GmbH

- TURBO objective and tasks
 - Hübers and SGRE will integrate the TURBO advances into infusion and control systems, particularly
 - Lessons from process simulation
 - Machine-learning based analysis of the digital twin based on in-line process monitoring and NDT
 - These objectives require a:
 - Manufacturing system interface to interpret and process the data from simulation and digital twin
 - Real-time infusion control system (hardware and software) based on data from the in-line sensors and NDT devices during infusion

Sustainability assessments

- Arditec will help to develop circular and sustainable blade manufacturing by:
 - Assessing the **environmental, economic and social benefits** of the innovative value chain in comparison to current blade manufacturing processes
 - Using **standardised life cycle assessment methodologies**
 - LCA (ISO 14040/14044)
 - Life Cycle Costing (LCC, ISO, 2006)
 - Social LCA (UNEP/SETAC)
 - Developing **circular pathways** for production waste
 - **Material Circularity Indicator (MCI)** methodology developed by the Ellen MacArthur Foundation
 - Contributing to current **relevant standards and regulations**
 - IEC 61400-5/IEC 61400-28-2/REACH
 - **Training** SGRE personnel to operate the sensors, apply TURBO NDT methods and interpret the results



TURBO demo

- SGRE will dedicate space in its Aalborg factory to preparations for the TURBO demo
- A large section of a >80 m blade will be used to demonstrate TURBO advances
 - Allows analysis of large blade aspects not possible on a smaller scale blade
 - Assess how TURBO technology can be integrated into a real production line
 - Quantify benefits in terms of improved quality and reduced scrap



Images courtesy of Siemens Gamesa Renewable Energy A/S.

Thank you for your attention!



General enquiries

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