Composite structures

Potentials for improved performance and function integration

Martin Wiedemann

32nd Risø International Symposium on Materials Science

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DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Overview

- Some words about the DLR – The German Aerospace Center
- Core competencies at the DLR-Institute
  Composite Structures and Adaptive Systems
- Potential contributions to further performance improvements
  - Material
  - Simulation
  - Design
  - Manufacturing Technologies
  - Function Integration
  - Composite Process Technologies
- Conclusion and Perspectives

The DLR

German Aerospace Research Center
Space Agency of the Federal Republic of Germany

DLR Sites and employees

6900 employees working

in 33 research institutes and

facilities

- at 8 sites
- and in 7 field offices.

Offices in Brussels,

Paris and Washington.

DLR Mission

To open up new dimensions for exploring the earth and the universe, for protecting the environment and for promoting mobility, communication and security:

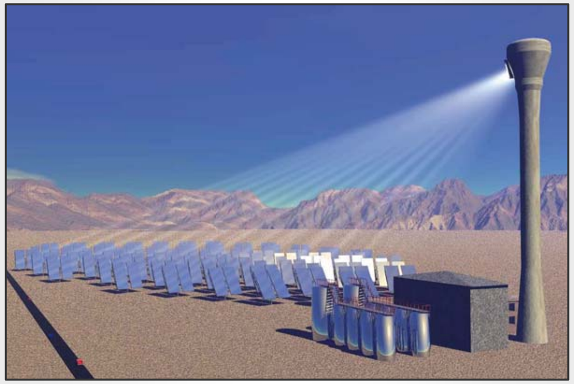
- Research portfolio ranging from basic research to innovative applications and the products of tomorrow
- Operating large-scale research facilities for DLR's own projects and as a service provider for its clients and partners
- Promoting the next generation of scientists
- Advisory services to government

DLR Research Fields

Aeronautics

Transportation

Energy

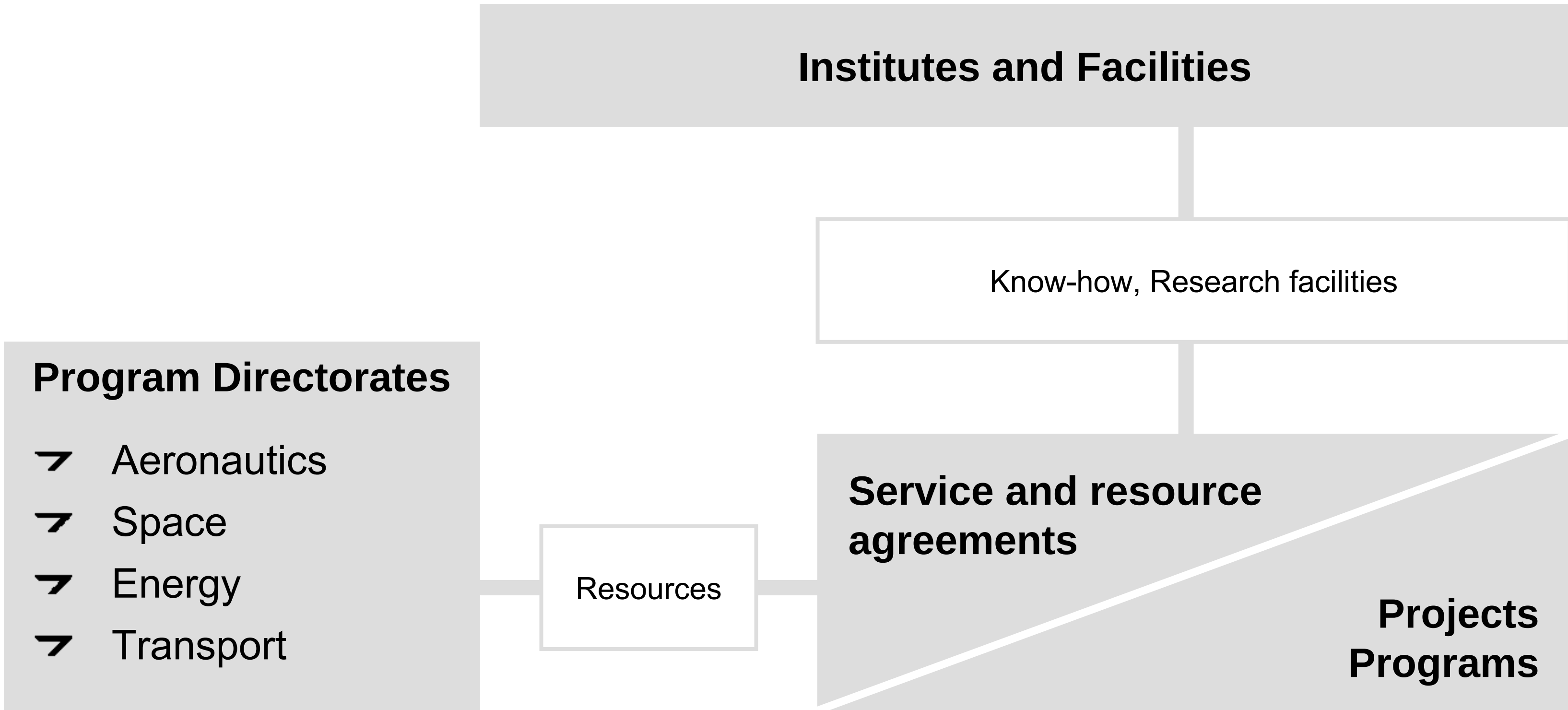


Space

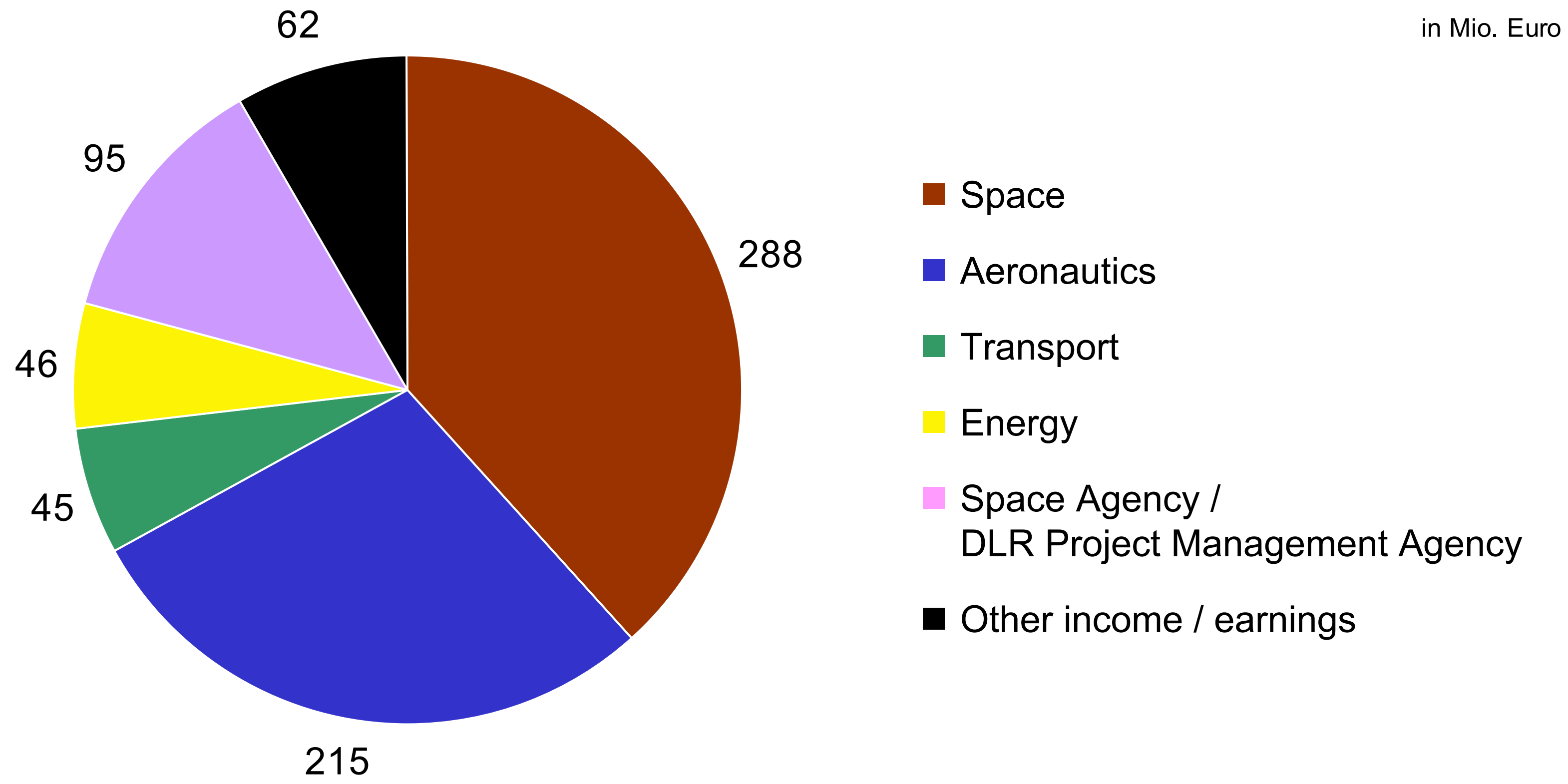
DLR Executive Board

Prof. Dr-Ing. Johann-Dietrich Wörner Chairman	■ Overall strategy and development ■ External relations ■ Corporate Communication ■ ESA Council
Klaus Hamacher Vice Chairman	■ Human Resources, Finance, Corporate Organisation ■ Quality Assurance and Infrastructure ■ Technology Marketing ■ Information technology ■ Project Management Agency
Gerd Gruppe	■ Space Agency ■ National/ESA program
Prof. Dr-Ing. Rolf Henke (temporarily)	■ Space: research, programs, projects, technology transfer
Prof. Dr-Ing. Rolf Henke	■ Aeronautics: research, programs, projects, technology transfer ■ Approved Design Organisation
Prof. Dr-Ing. Ulrich Wagner	■ Transport and Energy: research, programs, projects, technology transfer

DLR Program Management

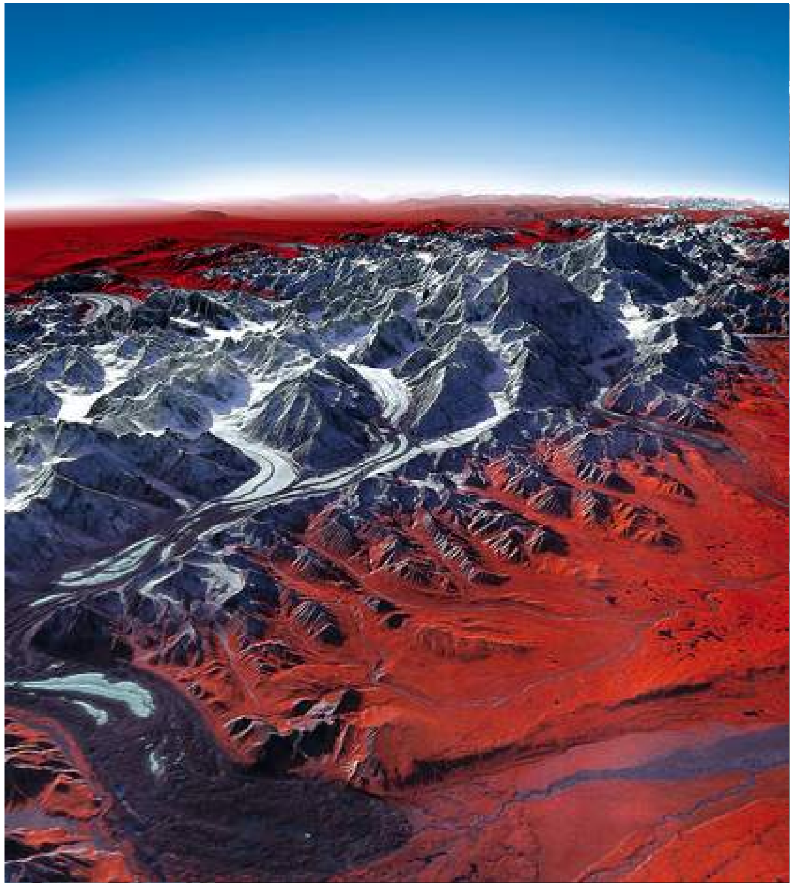


DLR Total income 2010 – Research, operations and management tasks (excluding trustee funding from the Space Agency/ DLR Project Management Agency): **751 Mio.€**



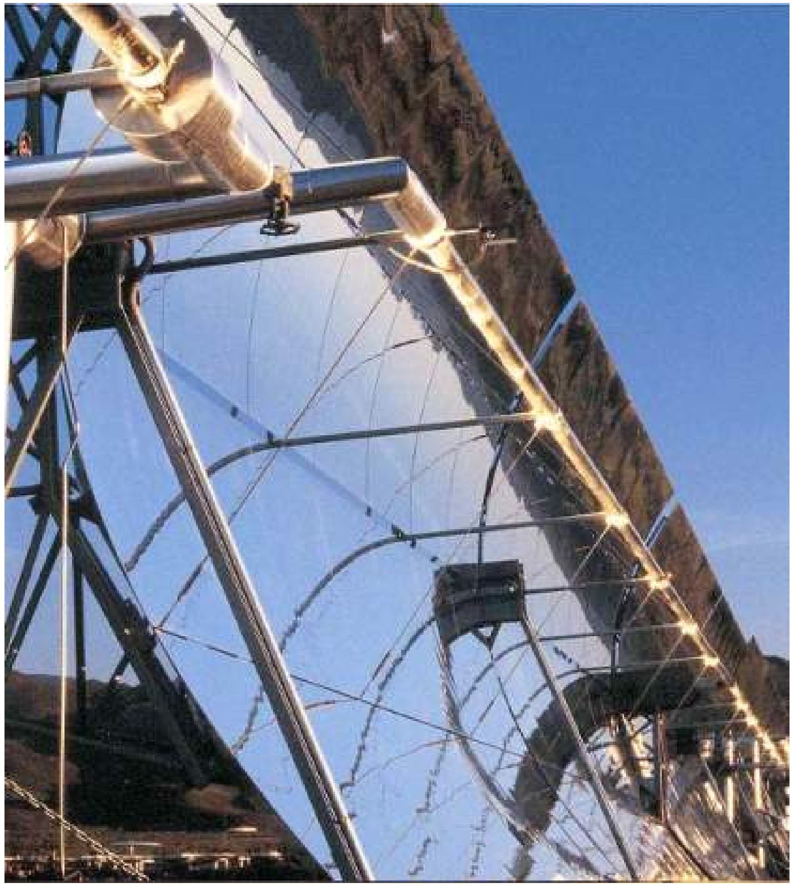
DLR Large-scale facilities (1)

- Research aircraft
- Research helicopters
- Compressor and turbine test rigs
- German Space Operations Center (GSOC)
- German Remote Sensing Data Center (DFD)

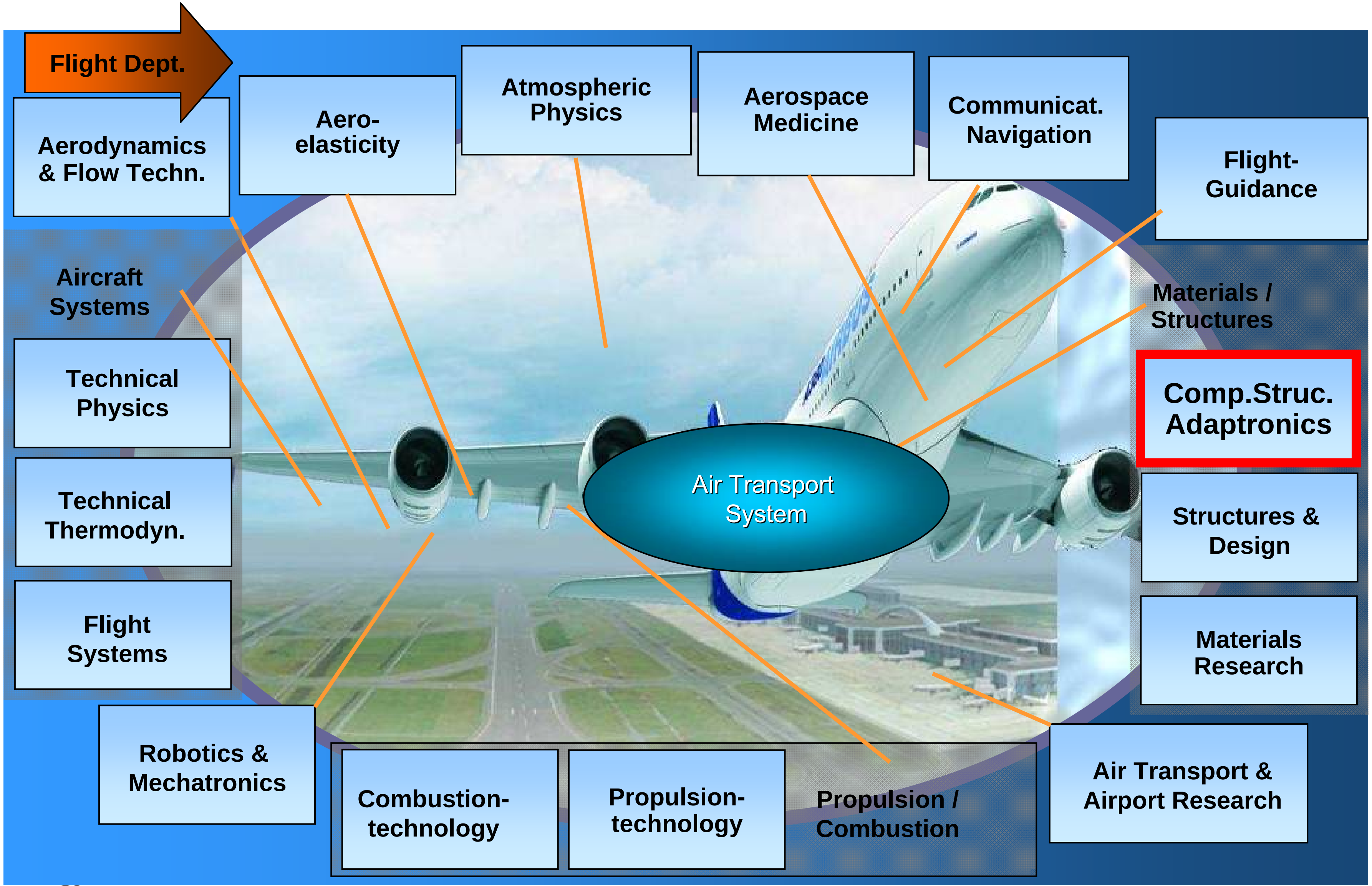


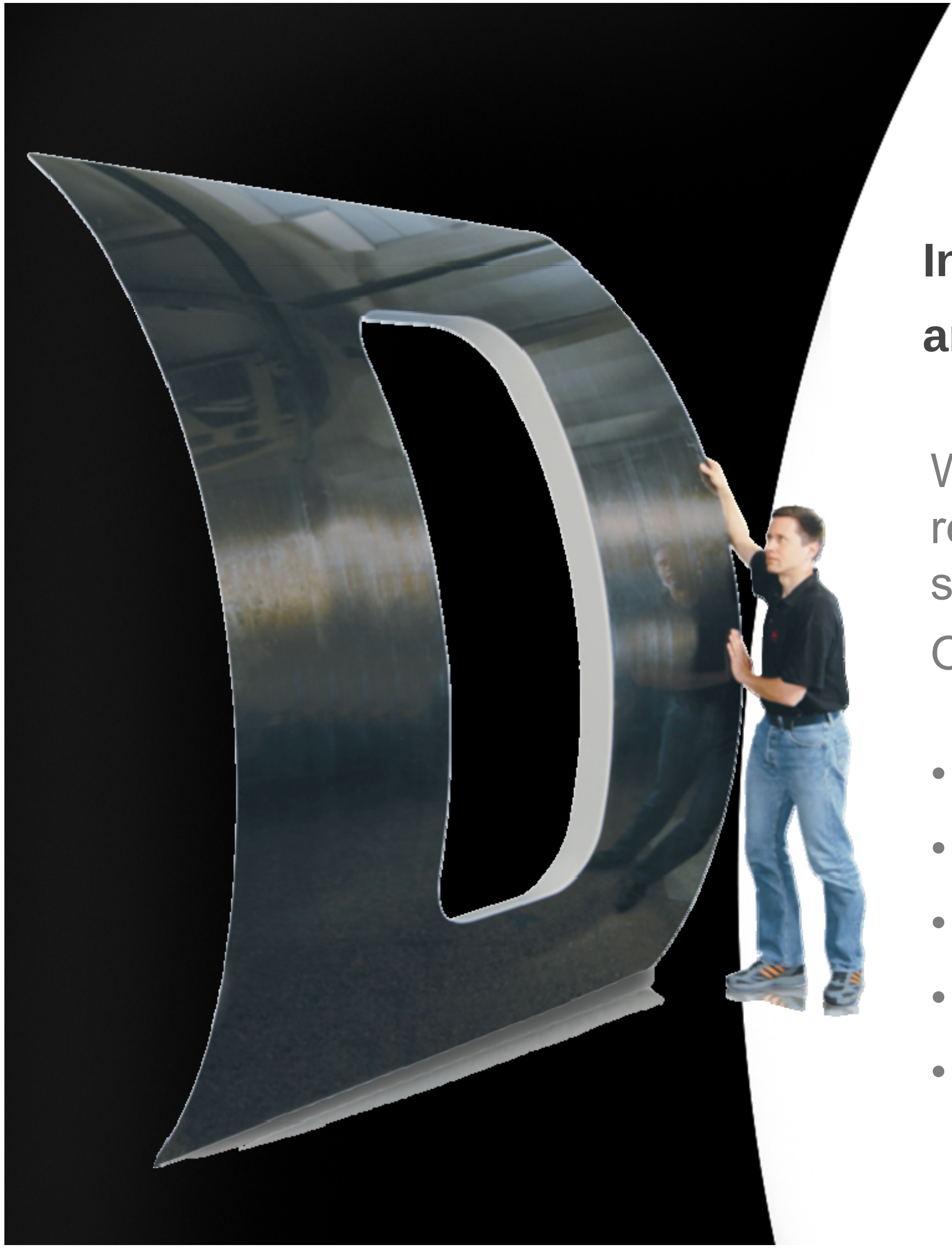
DLR Large-scale facilities (2)

- Space propulsion test rigs
- Wind tunnels
- Solar furnace
- Solar fields
- Autoclaves
- Traffic tower



DLR Aeronautics





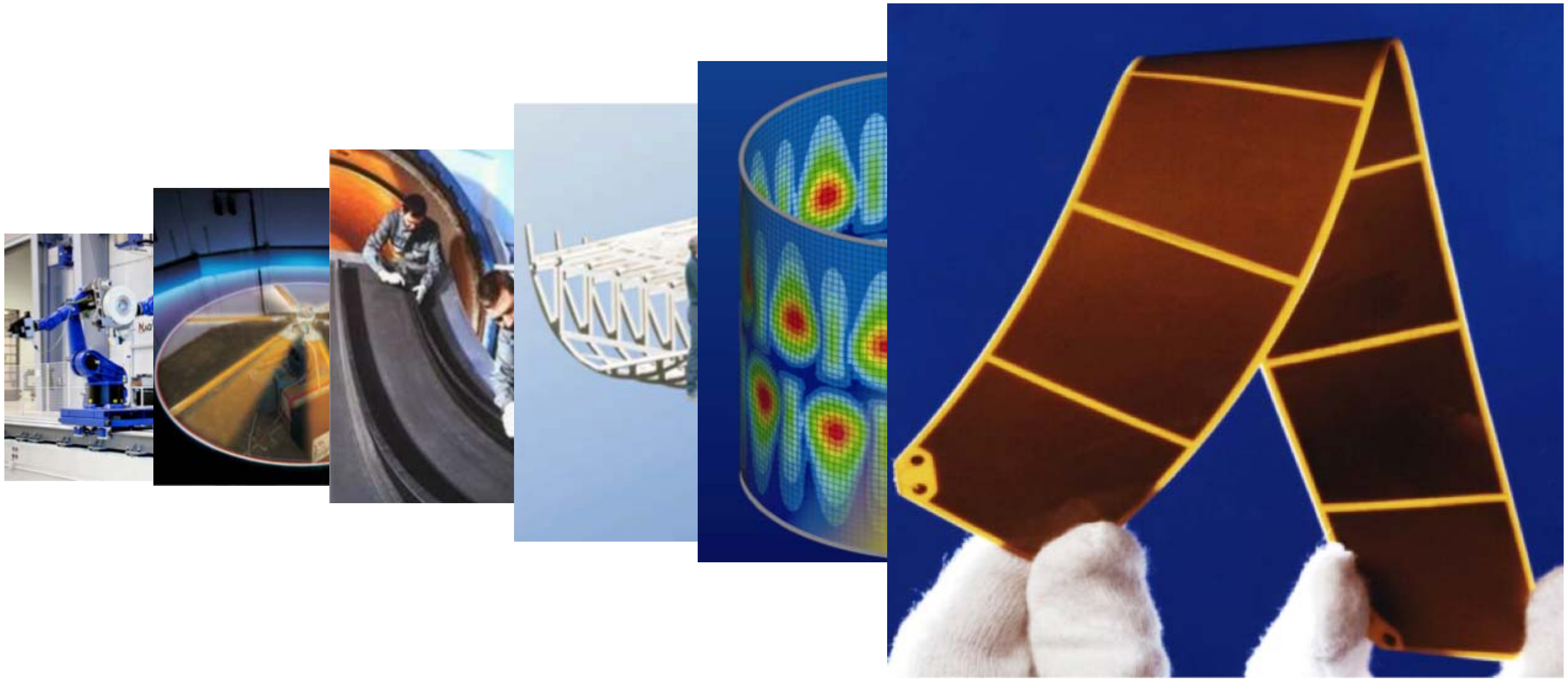
Institute of Composite Structures and Adaptive Systems

We are experts for the design and realization of innovative lightweight systems.

Our research serves to improvement:

- **Safety**
- **Cost efficiency**
- **Functionality**
- **Comfort**
- **Environmental protection**

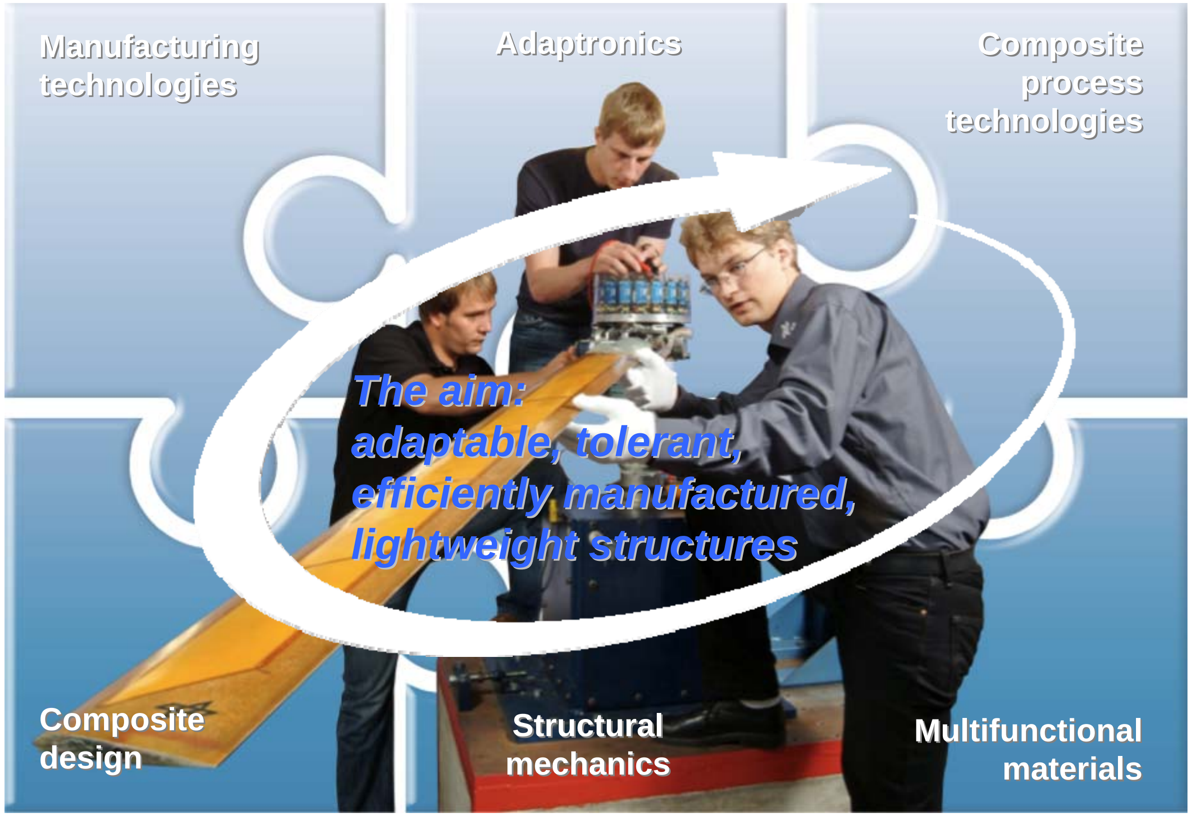
Our Professional Competences in the **Institute of Composite Structures and Adaptive Systems**



Our Professional Competences – Bricks of the **Process Chain of High Performance Lightweight Structures**

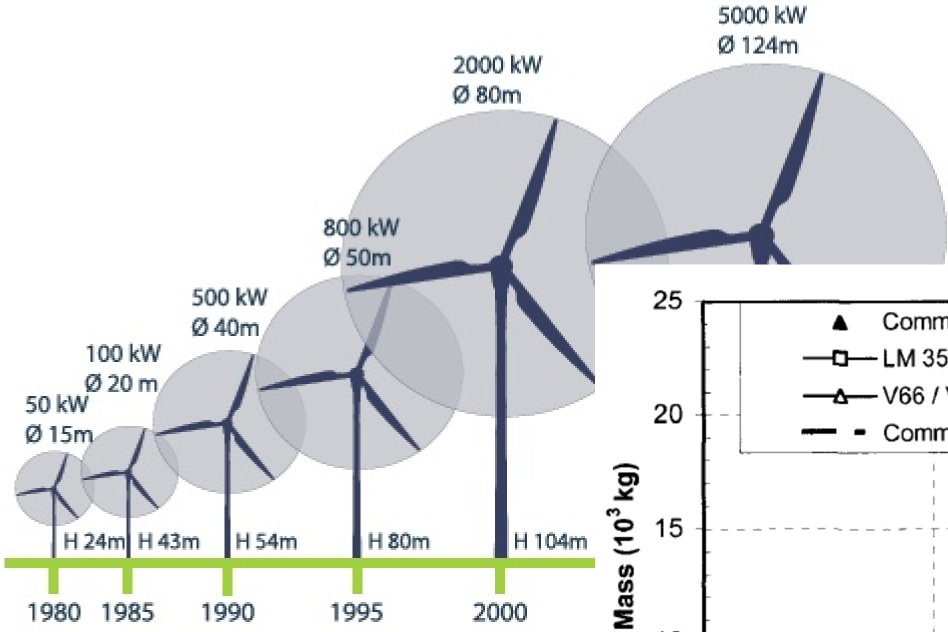
We align our research along the entire process chain for building adaptable, tolerant, efficiently manufactured light weight structures.

For excellent results in the basic research and industrial application.

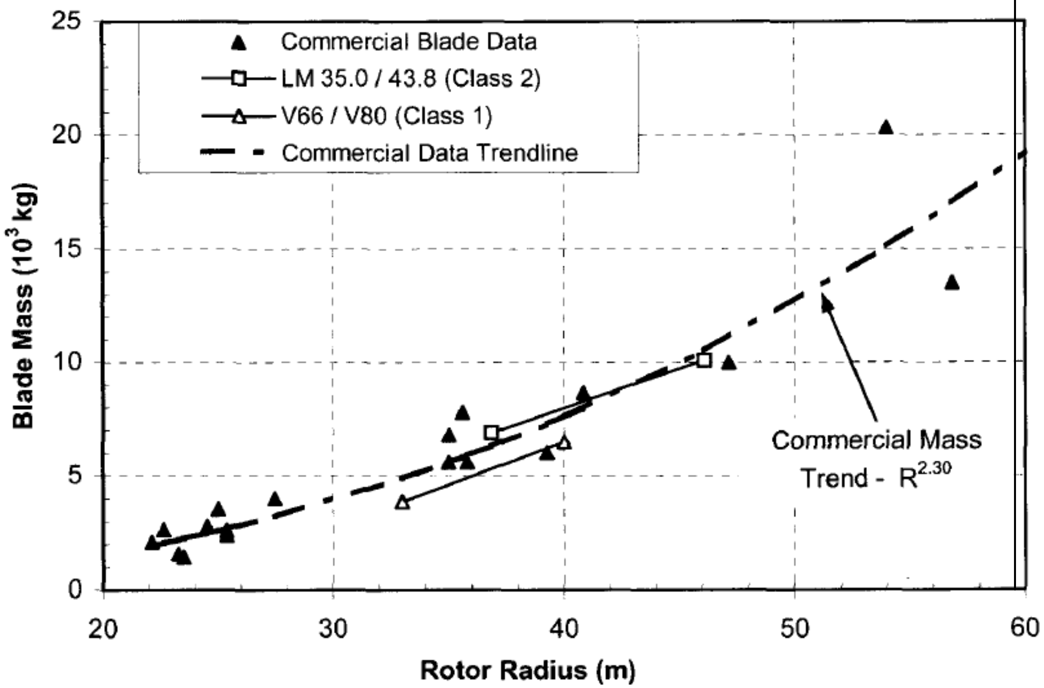


Evolution in wind turbine size

E-126 ■ 65 to



Source: www.terramagnetica.com/



Mass growth for commercial MW-scale blade designs (primarily fiberglass)

Source: Blade System Design Studies Volume II: Preliminary Blade Designs and Recommended Test Matrix;
SANDIA REPORT SAND2004-0073 Unlimited ReleasePrinted June 2004

DLR-FA Competencies and potentials for wind energy

Adaptronics

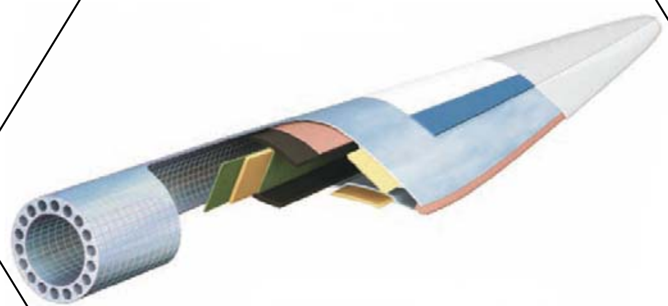
Morphing
Vibration Control

Composite process technologies

Production technologies
for large parts / high volume

Manufacturing technologies

Efficient manufacturing
and tooling concepts



Source: Gurit

Multifunctional materials

Cost efficient materials
SHM

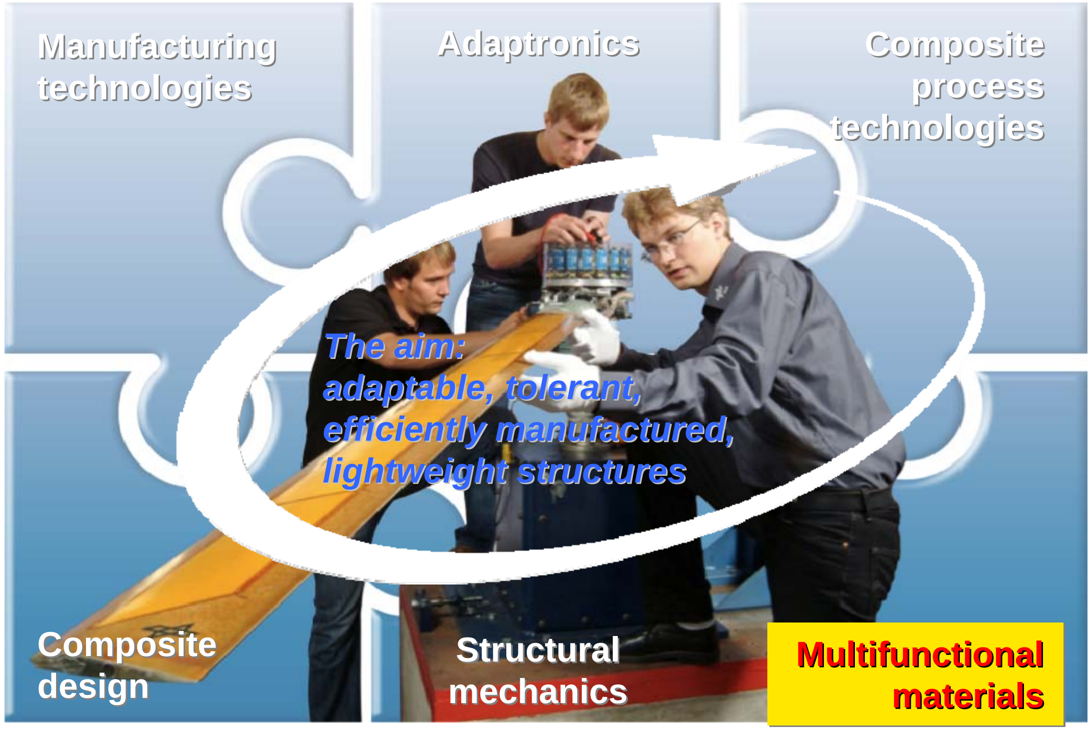
Composite design

Performance and production
optimized lightweight design

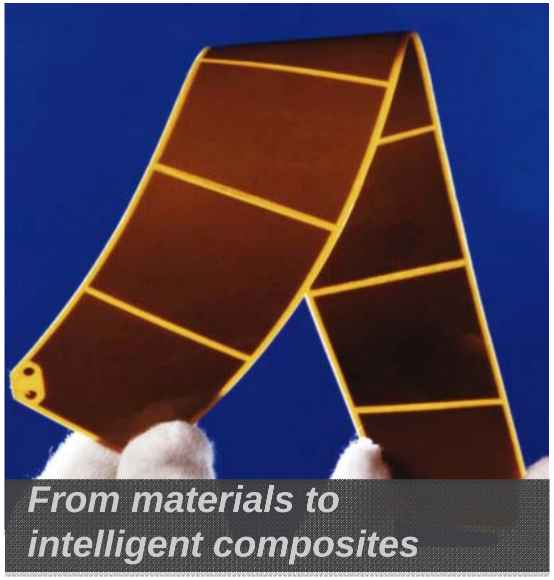
Structural mechanics

Sizing Methods, Effects of
Defects, Testing

Multifunctional materials

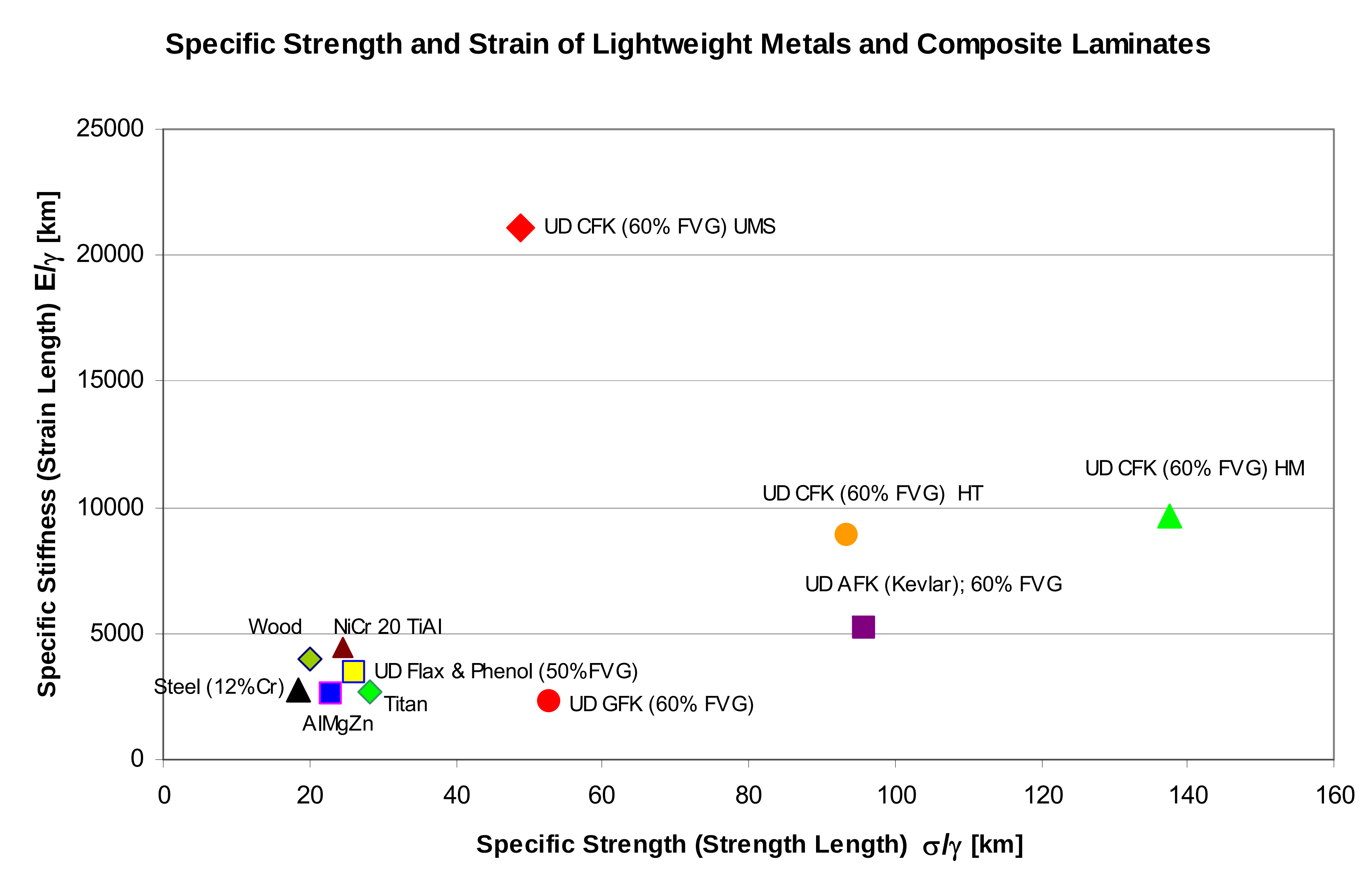


We increase the ability of the materials!



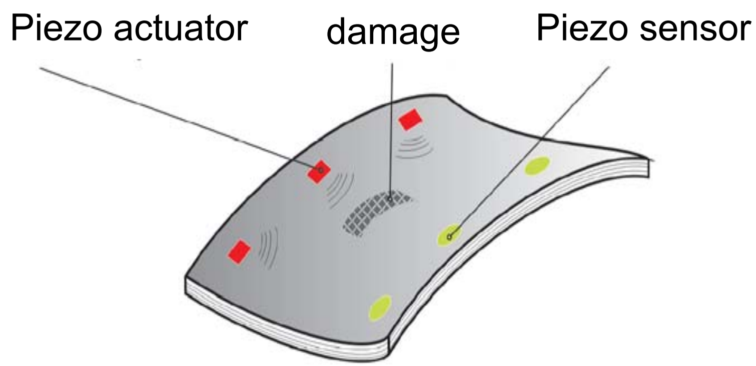
- Fiber- and nanocomposites
- Smart materials
- Structural health monitoring
- Material characterization

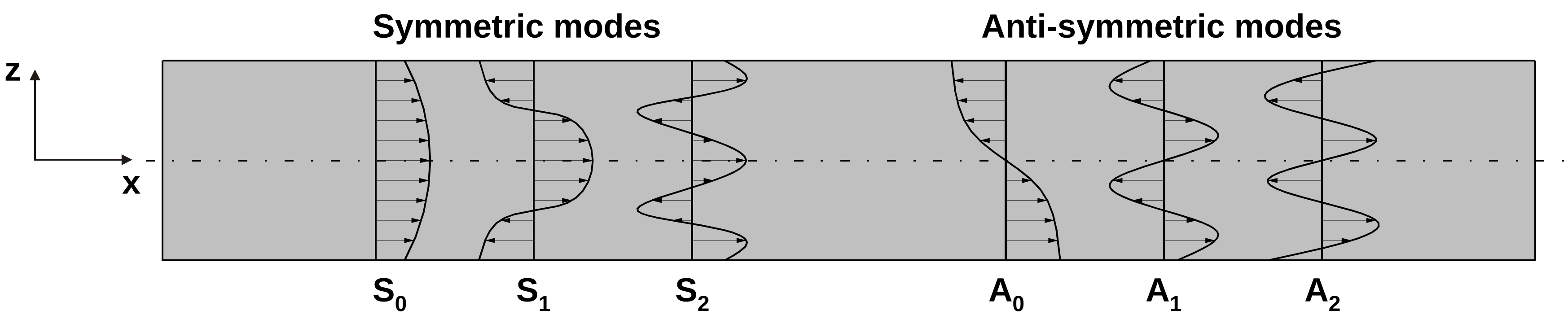
Multifunction materials



Structure health monitoring by lamb waves
Working principle

- Generation and reception of lamb-waves with piezo transducers to identify damages
- Visualization of wave propagation to allow an interpretation of the complex signals received by the piezo sensor
- Below a certain frequency fg only two modes are excited:
  - Symmetric mode (S0 - longitudinal mode)
  - Antimetric mode (A0 - bending mode)

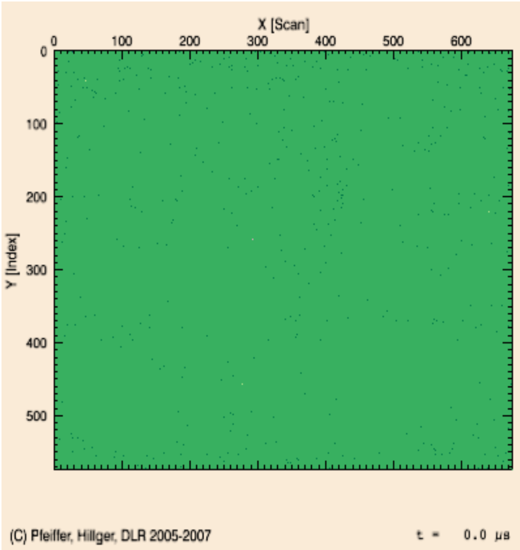


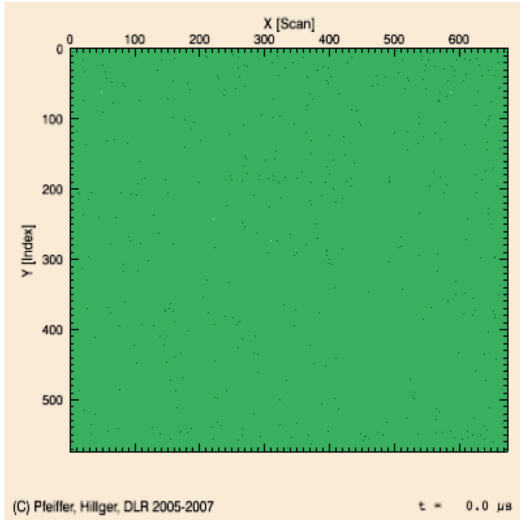


Structure health monitoring by lamb waves

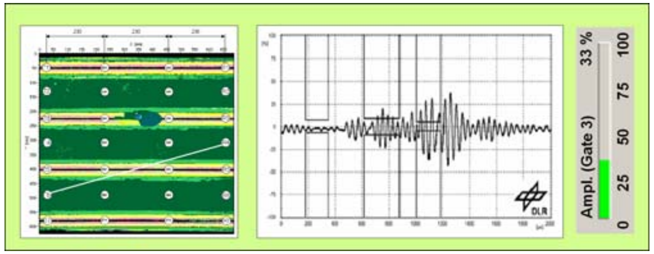
Example of structure wave propagation with and without defect

(visualized by ultrasonic measurement of surface displacements)

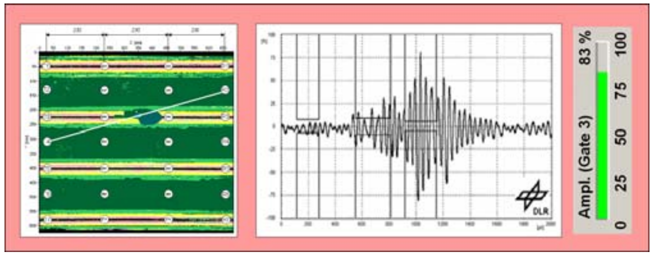




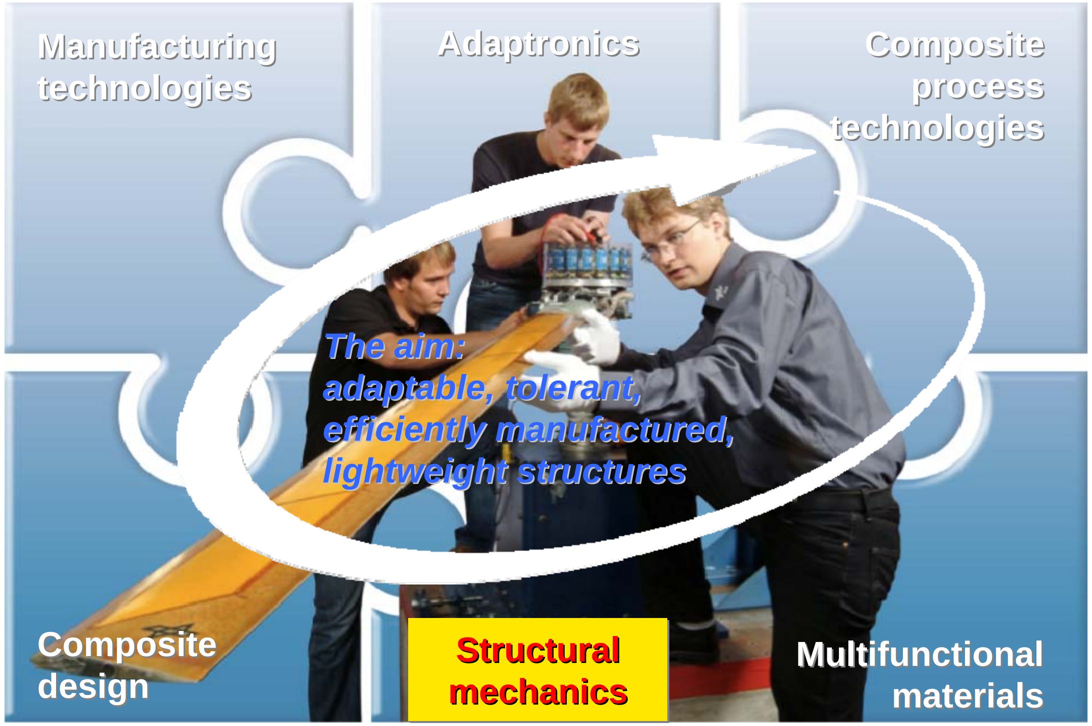
Received signal with intact stringer bonding



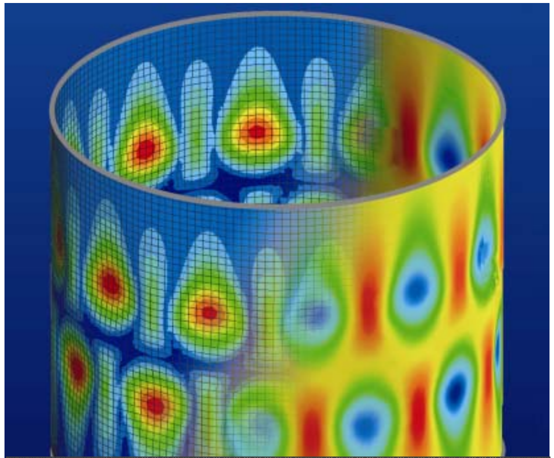
Received signal with defect in stringer bonding



Structural mechanics



With high fidelity to virtual reality for the entire life cycle!



From the phenomenon via modeling to simulation

- Global design methods
- Stability and damage tolerance
- Structural dynamics
- Thermal analysis
- Multi-scale analysis
- Process simulation

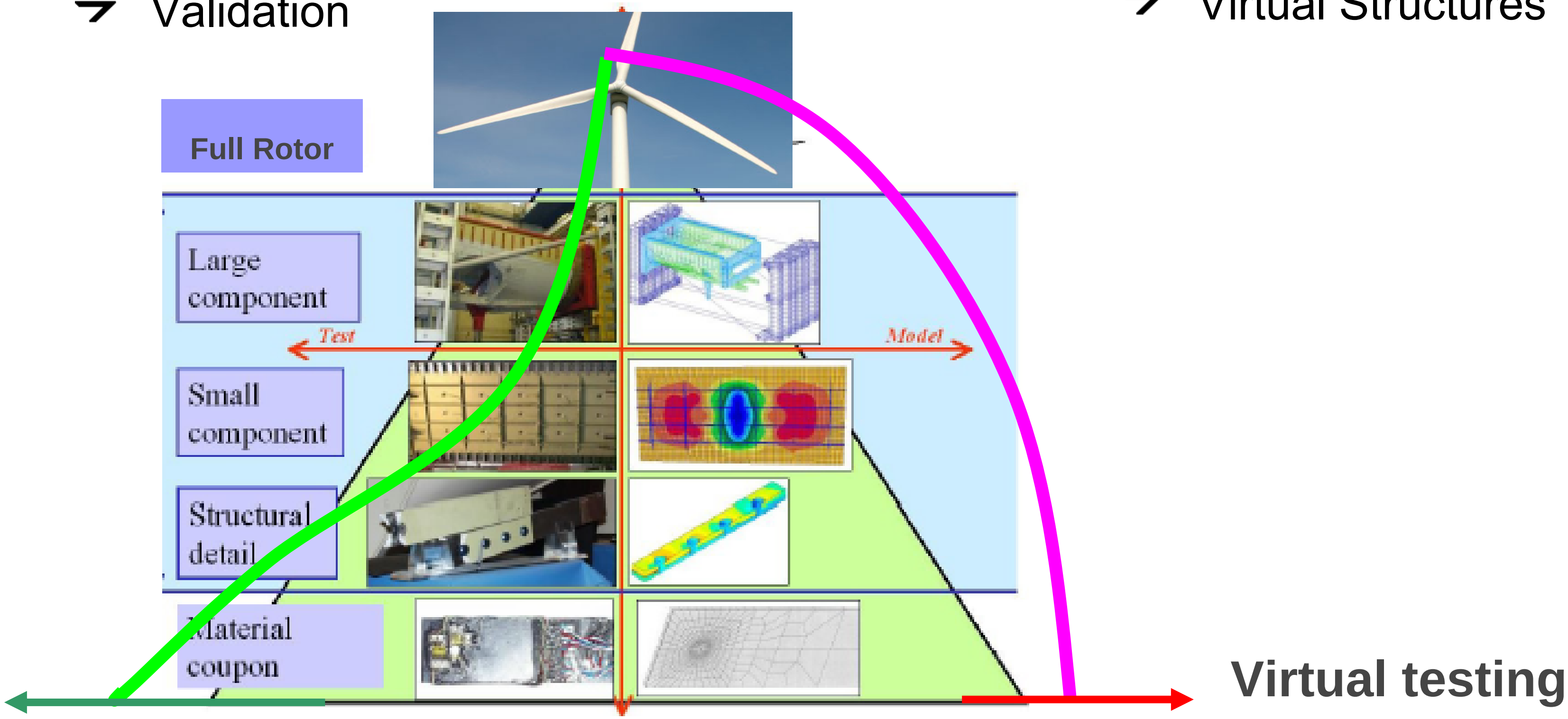
Structural mechanics - goals

Experimental

- Phenomena
- Properties
- Validation

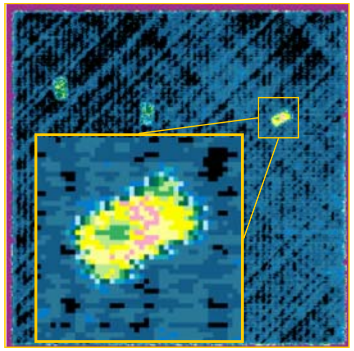
Method development

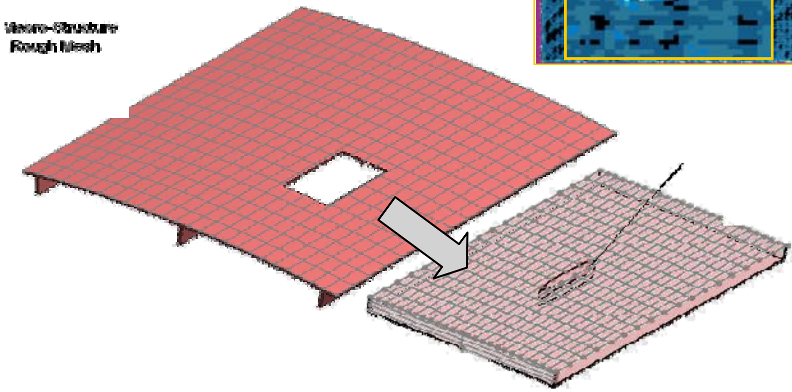
- Sizing methods
- Effects of defects
- Virtual Structures



Structural mechanics – effects of defects

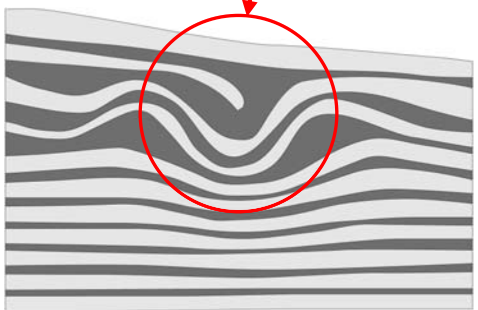
Develop validated and reliable methods to predict the strength of composite structures with manufacturing defects for assessment of defect criticality and need for repair.



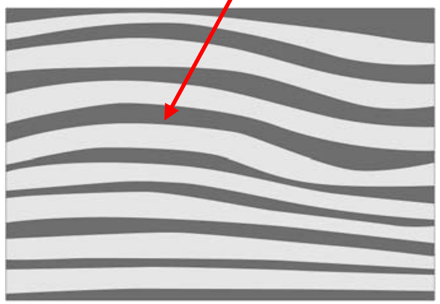


Voids

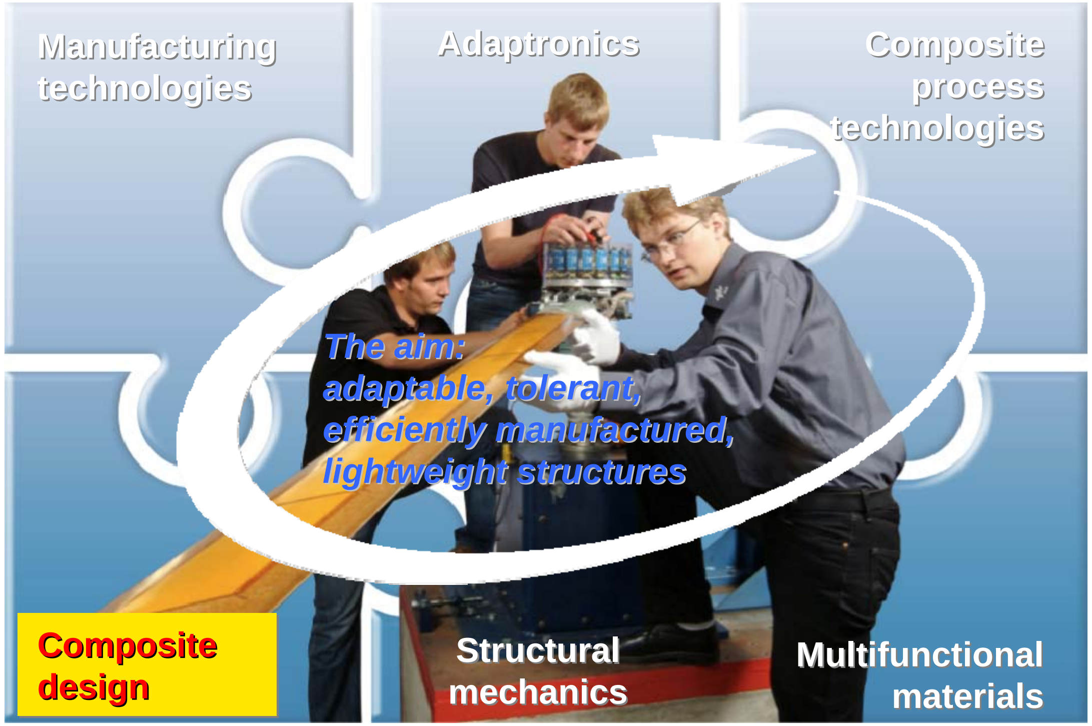
Folds



Waves



Composite design

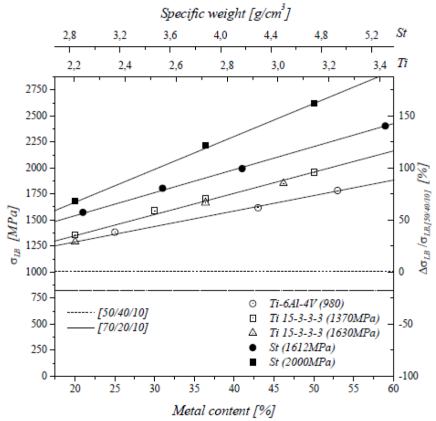


Our design for your structures!

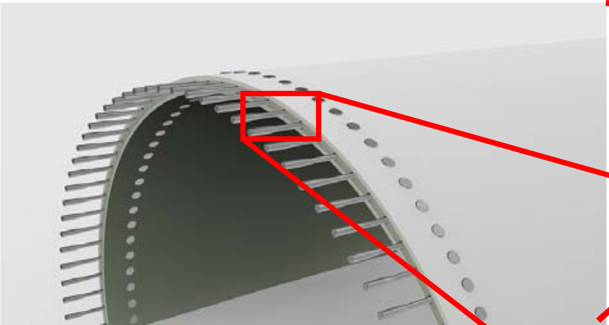
From requirements via concepts to multi-functional structures

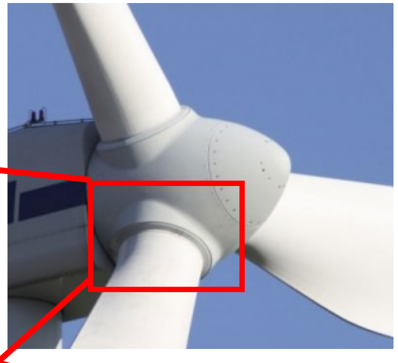
- Design and Sizing
- Structure concepts and assessment
- Multi-functional structures
- Shape-variable structures
- Hybrid structures

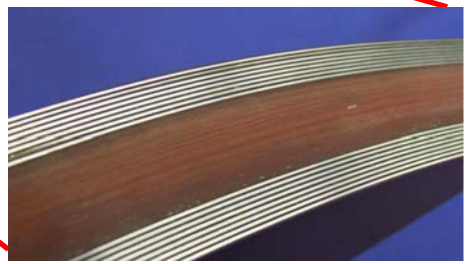
Composite design - Hybrid in couplin



Bearing strength (□LB) against the metal content for different hybrid material configurations.
Source: Axel Fink, DLR-FA







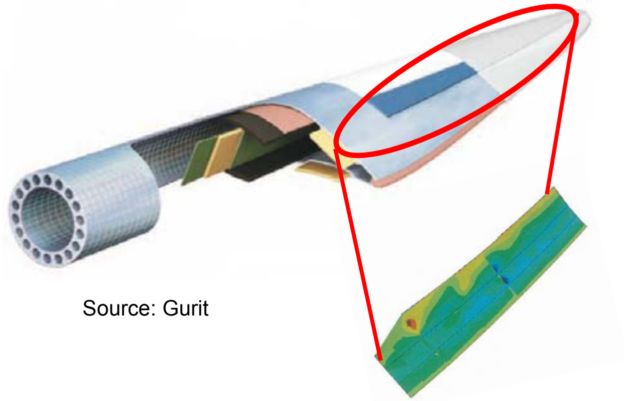
Composite Design

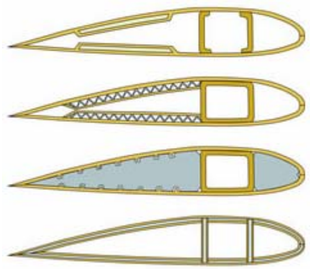
High Performance Material Combination

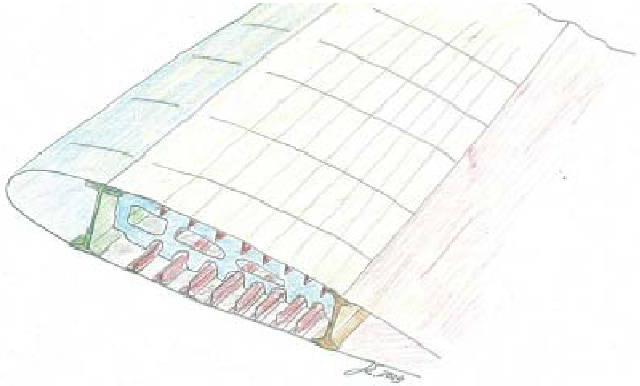
- Alternative coupling concepts for root-hub joint and blade segements
- Hybrid structures for local reinforcement of highly loaded areas
- Minimum tolerance design

Composite design – function integration

Function integration
- Coupled aero-structure design
- Force flow optimized design
- Integration of actuators, sensors, wiring, antennas…

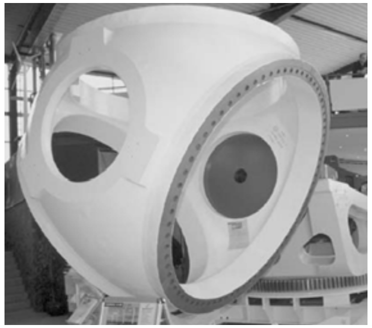

Source: Gurit


Source: www.rotortechnik.at

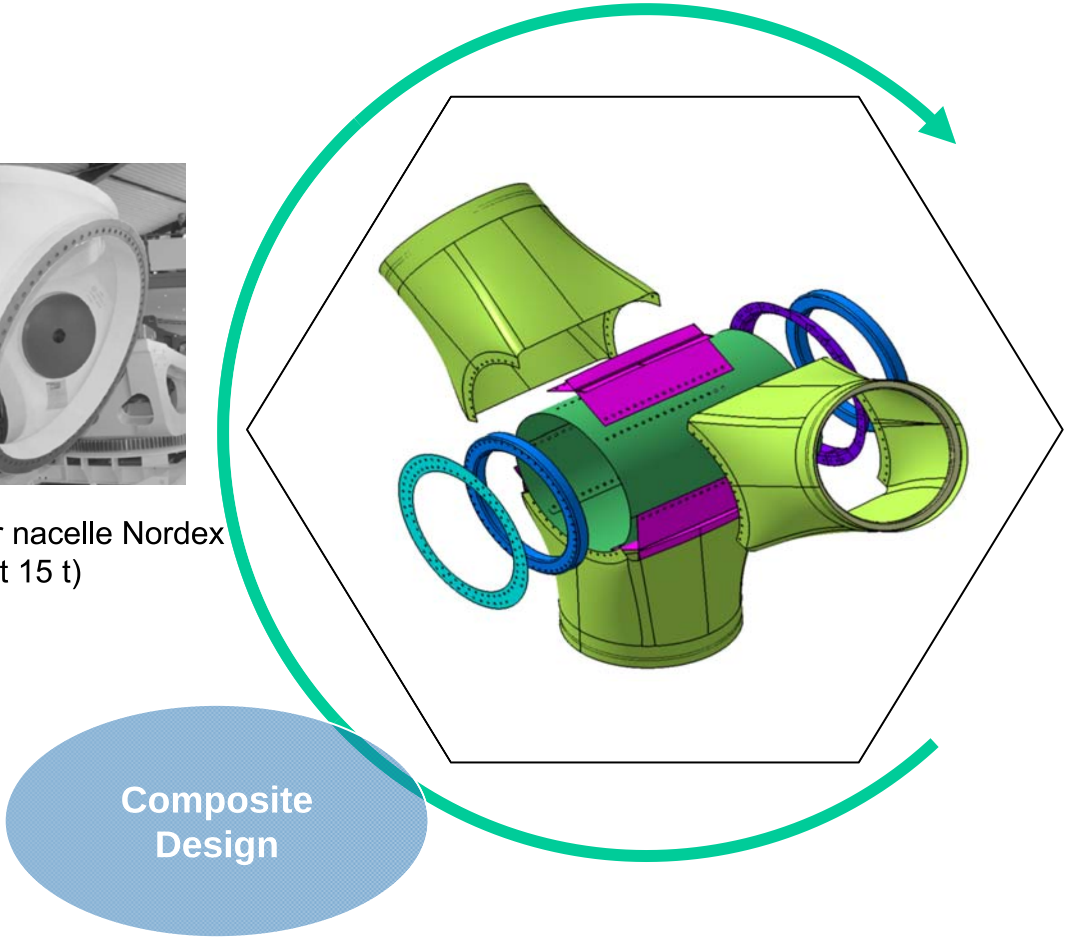


Composite design – CFRP nacelle

Source: Internet - VDE



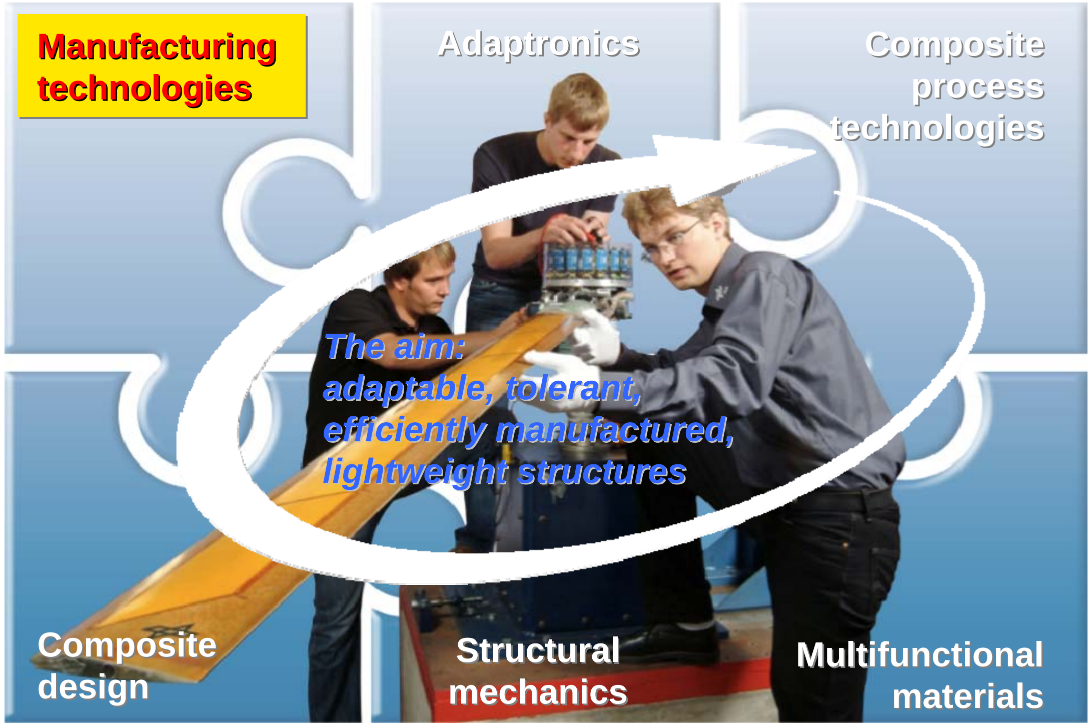
Casted rotor nacelle Nordex N-80 (weight 15 t)



Concept Study

- Differential design
- Fiber-, force flow and load bearing optimized
- CFRP root joints
- Metal Hub
- Shear load carrying joints made from metal
- Load transfer from CFRP to metal via hybrid material combination

Manufacturing technologies

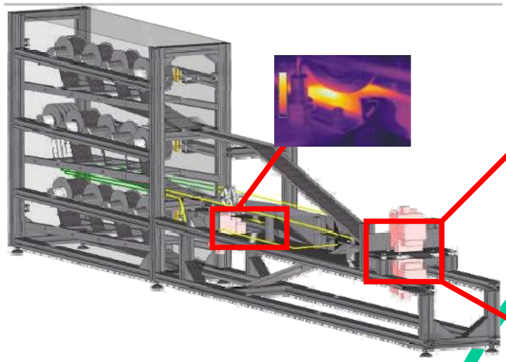


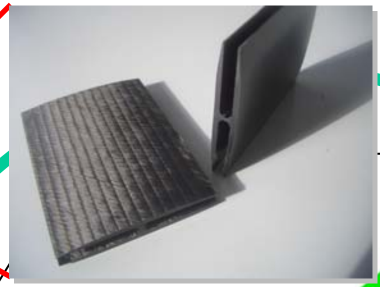
Tailored Manufacturing Concepts

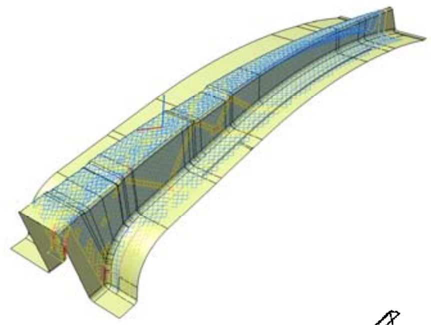

From the idea via processes to prototypes

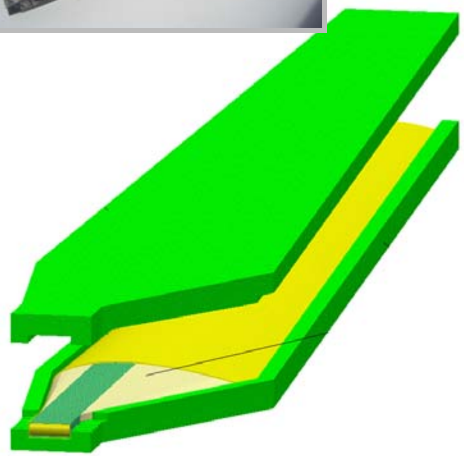
- New technologies for manufacturing
- Hybrid manufacturing
- Assembly
- Repair
- Process automation

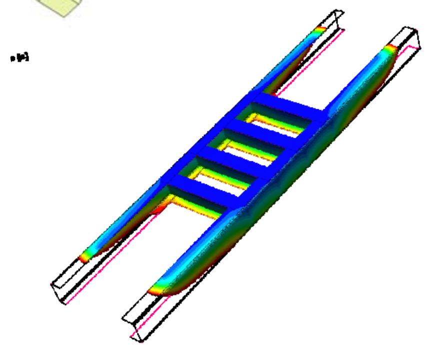
Manufacturing technologies - units and tooling







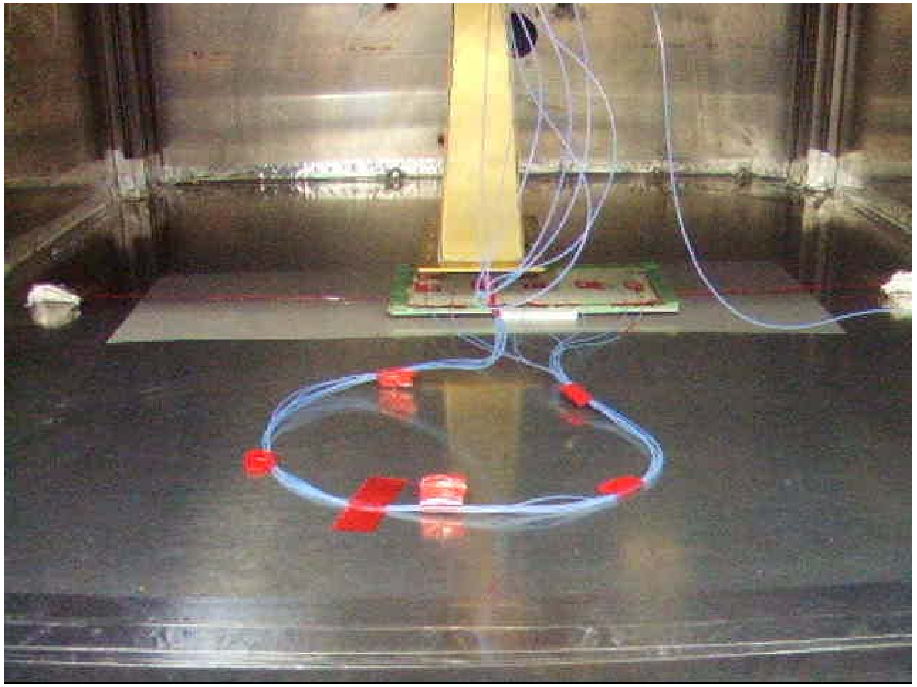




Manufacturing technologies

Concepts
- Continuous preforming
- Draping and infusion/ injection technologies
- Resin flow simulation and concepts
- Smart and flexible tooling
- Tolerance management and high fidelity production

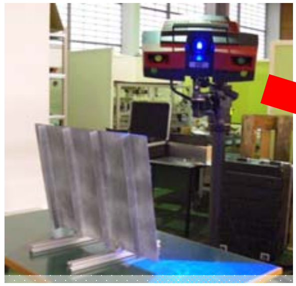
Manufacturing technologies – dielectric heating



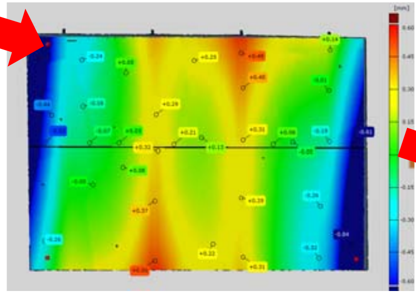
- Glasfiber composites have good dielectric properties
- Microwaves can heat resin in glasfiber laminates effectively
- The heating is contactless, selective in the resin zone and minimal since nothing else is heated

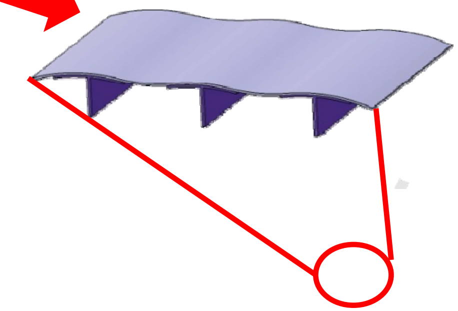
- Large parts like rotor blades can be heated by microwaves up to full polymerization
- The microwave can be used with flexible portal units for heating locally and with flexible timing

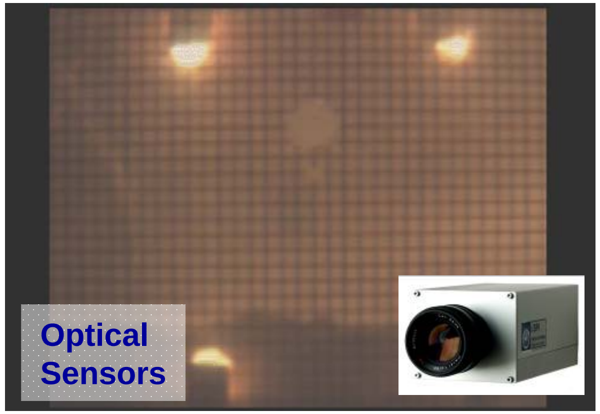
Manufacturing technologies – process control



Optical Measurement

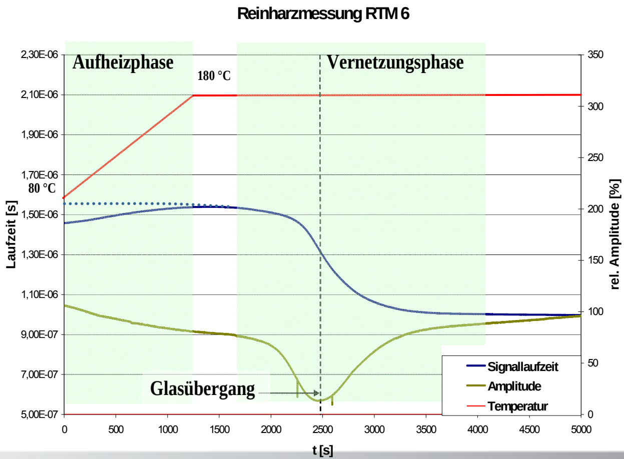


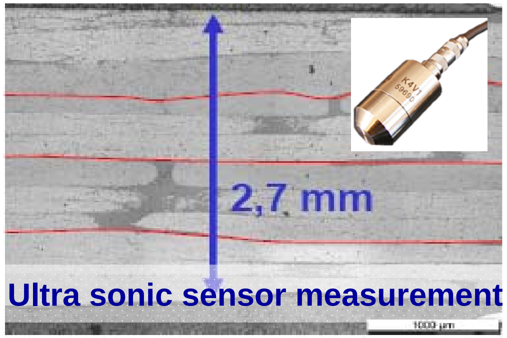




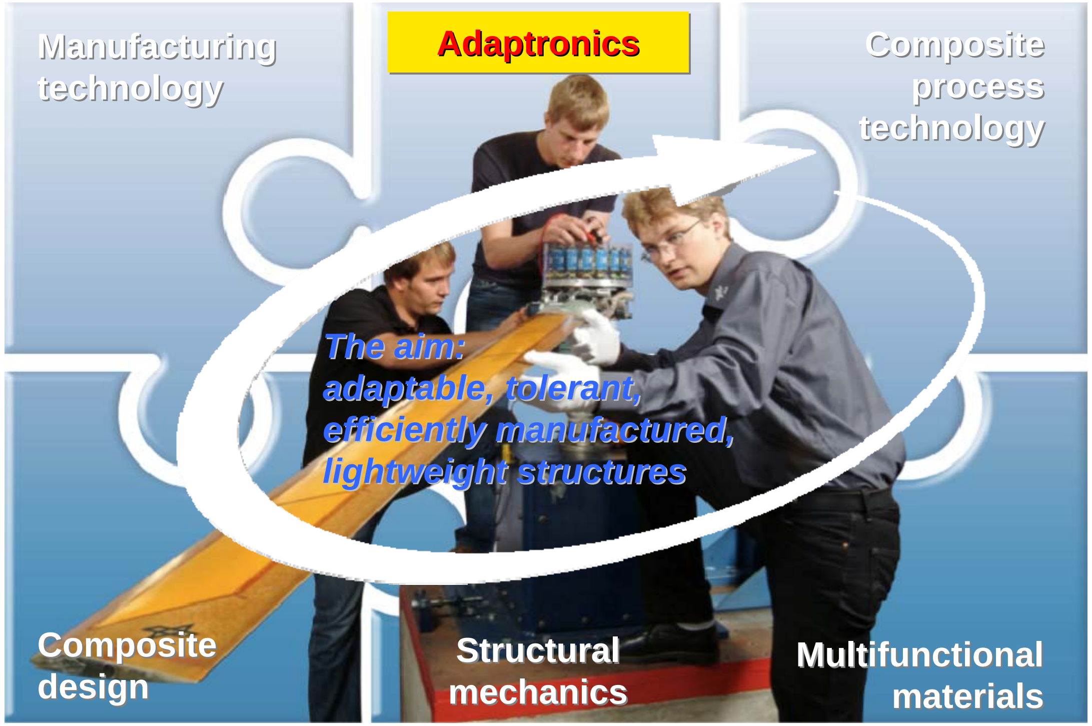
Process control

- Tolerance management
- Thickness control
- Reproducibility
- Adjustability
- Correctability

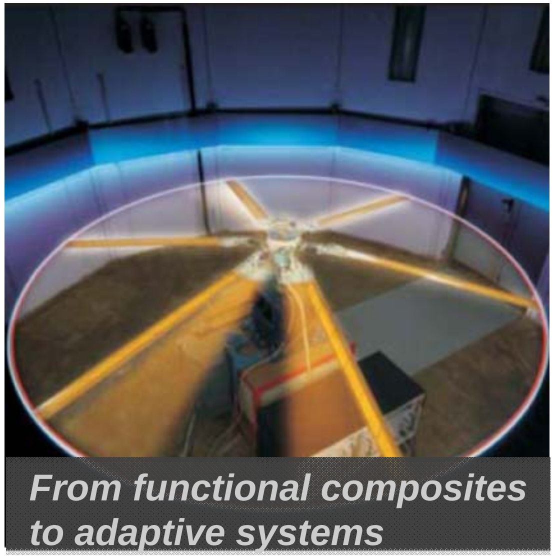




Adaptronics

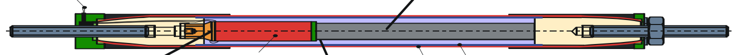


The adaptronics pioneers in Europe!



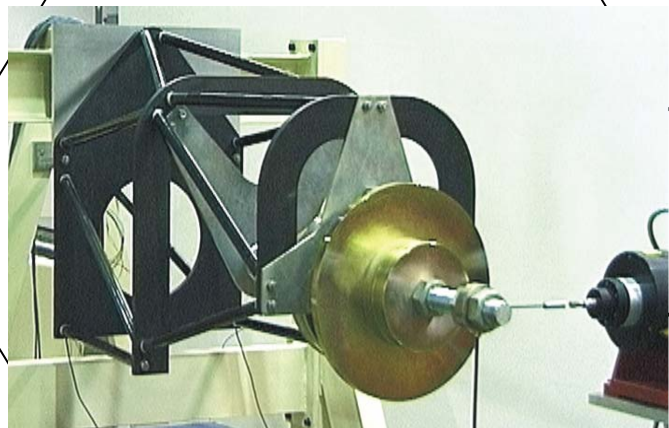
- Simulation and demonstration of adaptive systems
- Active vibration control
- Active noise control
- Active shape control
- Autarkic Systems

Adaptronics - Active Vibration Control

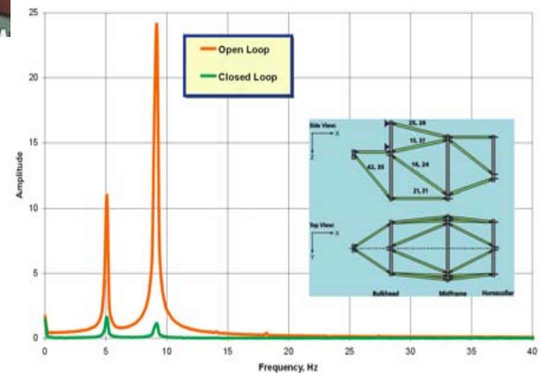


www.windturbinestar.com

Adaptronics



www.windkraftkonstruktion.vogel.de



Challenge:

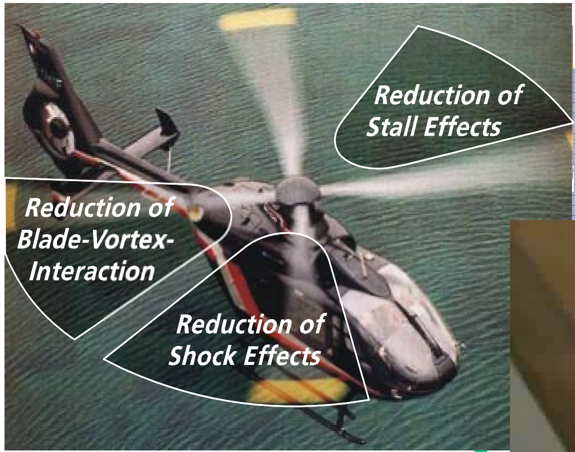
Decoupling of the blade-born vibration from transmitting into the gear box or tower

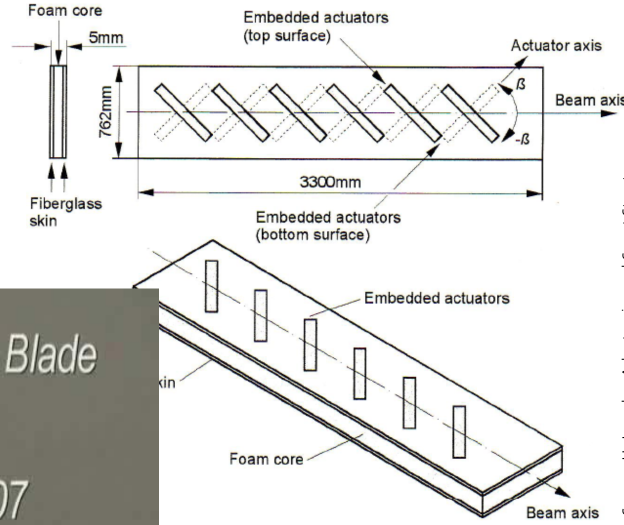
Solution:

Use of active lightweight struts with integrated piezoelectric ceramic stack actuators

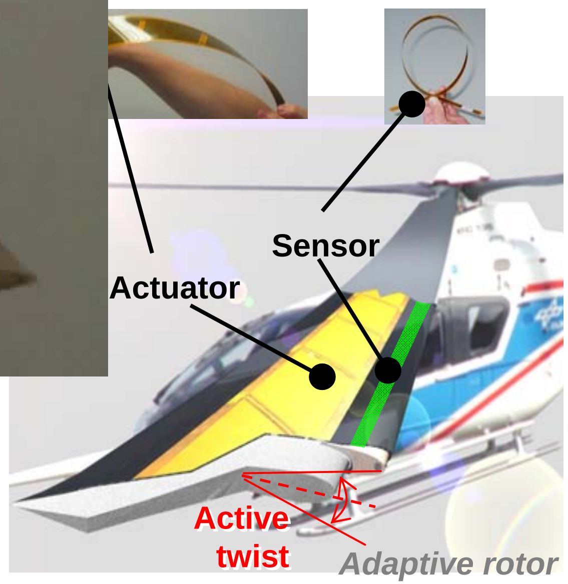
In combination with robust control algorithms a significant reduction of the vibration levels can be achieved

Adaptronics - morphing





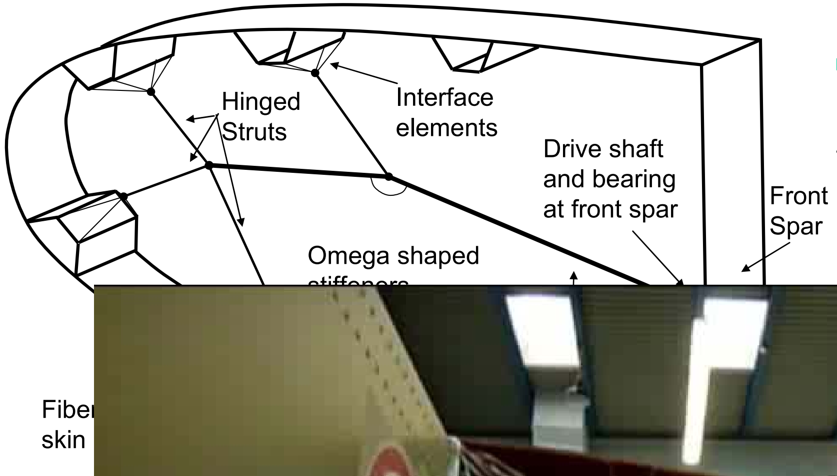
Source: H. Janocha; Adaptronics and Smart Structures; Springer-Verlag, Berlin Heidelberg New York; 1999; ISBN 3-540-61484-2

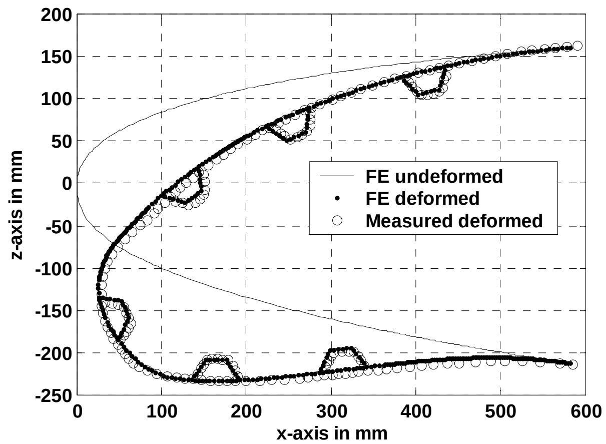


Challenge:
Individual twist actuation (+/-2°) of a helicopter rotor blade for noise and vibration reduction and performance improvement

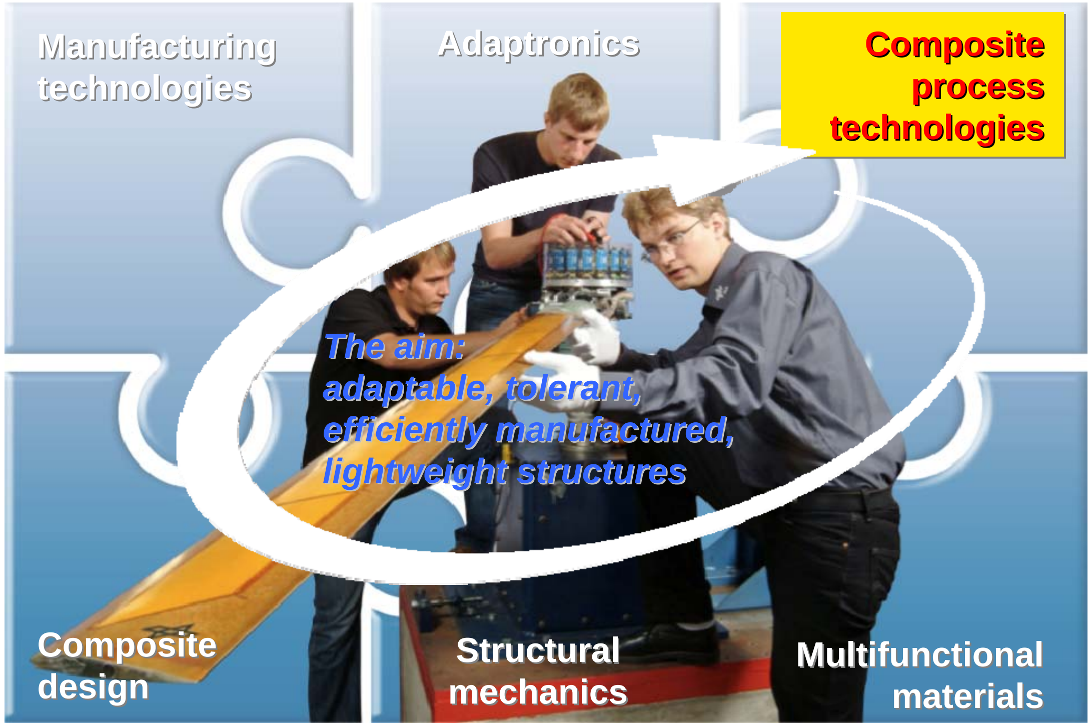
Solution:
Integration of anisotropic actuation in the rotor blade skin
Development, manufacturing and test of a model rotor blade in a centrifugal and wind tunnel test (proof of concept, validation)

Adaptronics - morphing





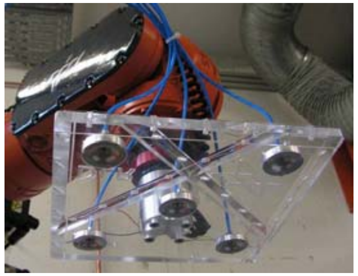
Composite process technologies

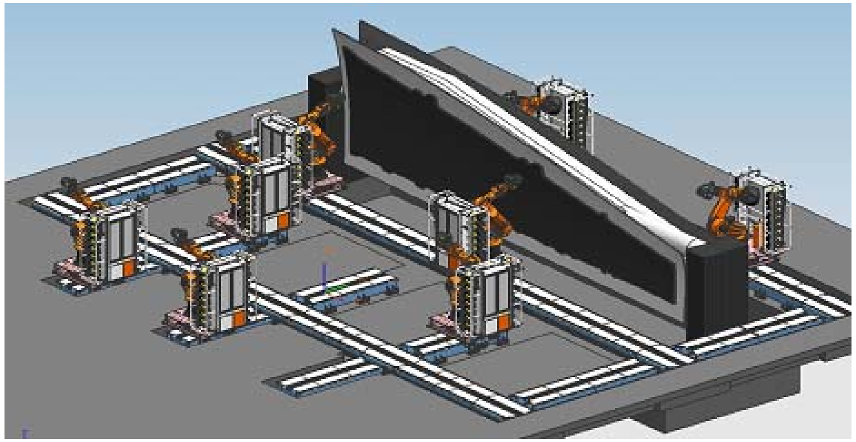


Research with industrial dimension

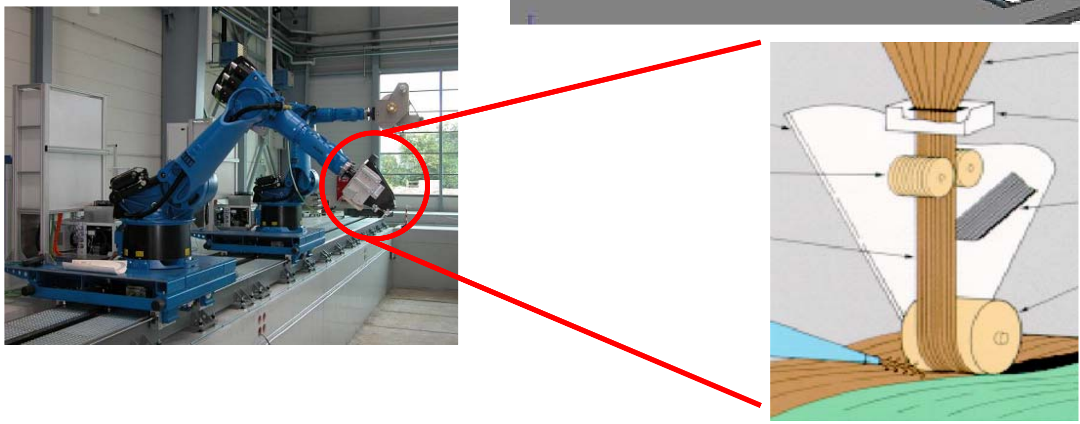
- Automated FP und TL
- Online QA within Autoclaves
- Automated Manufacturing for mass-production
- Simulation methods for maximum process reliability und process assessment

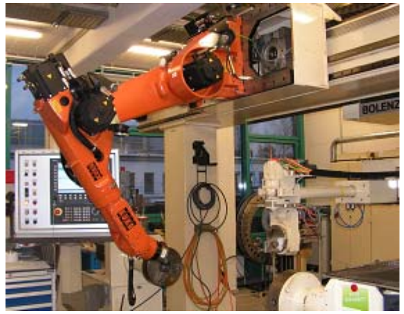
Composites Process Technologies
Cooperating robots working on large parts





Composite Process Technologies





Winding with robots

Conclusion on potentials for future improvements and function integration

- Hybrids and CFRP materials allow more lightweight and efficient design
- Structural health monitoring by lamb waves with integrated networks help to ease maintenance
- Better methods for simulation may replace full scale testing partially
- Intensive simulation of defects allow better assessment of criticalities
- Weight and material saving potentials in design of blades and nacelle
- Further function integration into the structure can be used
- Faster and less energy consuming manufacturing technologies are available
- Flexible toolings allow savings in manufacturing
- Process control for better quality is in development
- Active vibration control can be integrated into the structure
- Active morphing of structure profiles with integrated functional materials is possible, for example for gust loads alleviation
- Process technologies for fast fiber layup in large structures are in development