

Prof. Dr.-Ing. habil. M. Gude
Kiel, 27./28.01.2026 - MariLight Network Meeting 2026

From vision to innovation: Development of composite-intensive lightweight construction methods in the automotive industry – a catalyst for the maritime industry!?

VISION

The ILK is the leading international institute for research, development in the field of function-integrative lightweight engineering based on sustainable multi-material design



ILK-TEAM

245

employees in a broad interdisciplinary team



70

years of lightweight research in Dresden

YOUNG TALENTS

80

graduates per year



CONTINUOUS RESEARCH AND DEVELOPMENT CHAINS

Material, Modelling, Simulation, Design, Processing, Quality, LCA



>1 

Start-Up a year (at present 18)



INDUSTRIAL COOPERATION

with European large-scale industry and regional SMEs



~1.000

Alumni since 1997



35% Basic research

35% Application-oriented research

30% Industrial Development



Promoting initiatives for children, women and young talent
ACL e.V.
juniorING e.V.



INTERNATIONAL NETWORK

among others with partners in UK, Poland, Korea, China, Singapore, Romania, Australia, USA



Overview

Introduction

Challenges and innovation potentials in maritime economy

Review: Visions and innovations in automotive industry

Parallelisms and special features in maritime economy

Selected ongoing lightweight approaches in maritime sector

Maritime economy in Germany

- Value added: €50 billion/year; Employees: 400,000*
- Decarbonization of energy supply
- Securing national and global logistics chains



Sustainability, securing jobs and locations, expanding infrastructure

Challenges

- Climate change
- Shortage of resources and material availability
- Dynamic economic conditions



Transformation of society and industry towards sustainable action and economic activity



Offshore Energy platform and wind turbines



Transportation and handling of goods and energy

*"Maritime Wertschöpfung und Beschäftigung in Deutschland", Studie im Auftrag des BMW, 2021

Dominant maritime designs and technologies

Welded thick-walled steel structures

- Geometric notch effects caused by weld seams
- Embrittlement and metallurgical notches
- Thermal distortion and large geometric deviations
- Welding limits material selection
- Deformations due to high dead weight in the manufacturing process
- High handling costs
- Lightweight construction potential largely exhausted



Welding process



post processing

Holistic lightweight engineering – Enabler for material efficiency



Lightweight design

- Use of high-performance materials
- Reduction of wall thickness by multi-material design
- Increased design freedom

&

Adhesive bonding technology

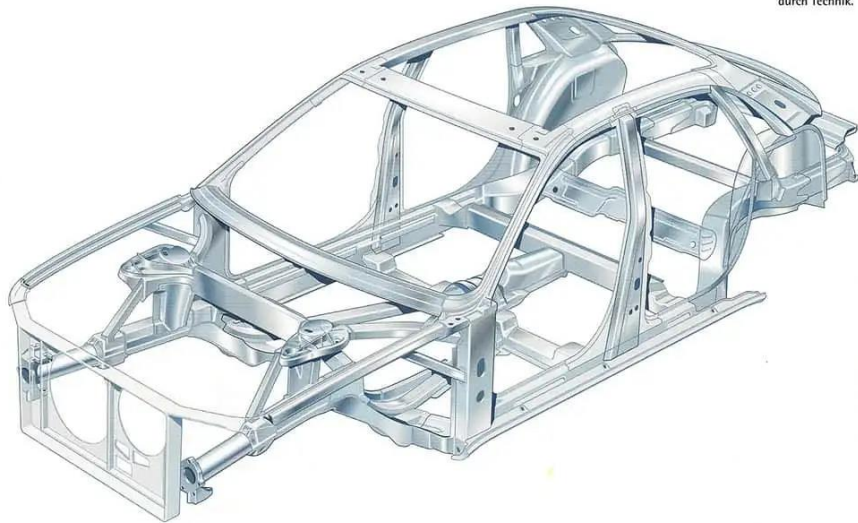
- Low-heat/low-energy bonding of similar and dissimilar materials
- Large structures with increased efficiency
 - Reduced energy consumption and rework
 - Draft, payload, wingspan

Challenge: In-depth knowledge and openness on the part of industry are necessary to bring about a paradigm shift.

Review – Analogue automotive industry

~1990s: Competition of metal materials, design concepts and processes in automotive industry for advanced car body to fulfill efficiency requirements

Audi Space Frame ASF
Concept Car



1993: Concept study, Audi limousine
later Audi Space Frame (ASF) in AI design



2002: UltraLightSteelAutoBody - Advanced Vehicle Concept
(ULSAB-AVC), (advanced) high strength steel design

DFG-Collaborative Research Centre SFB 639 (2004 - 2015)

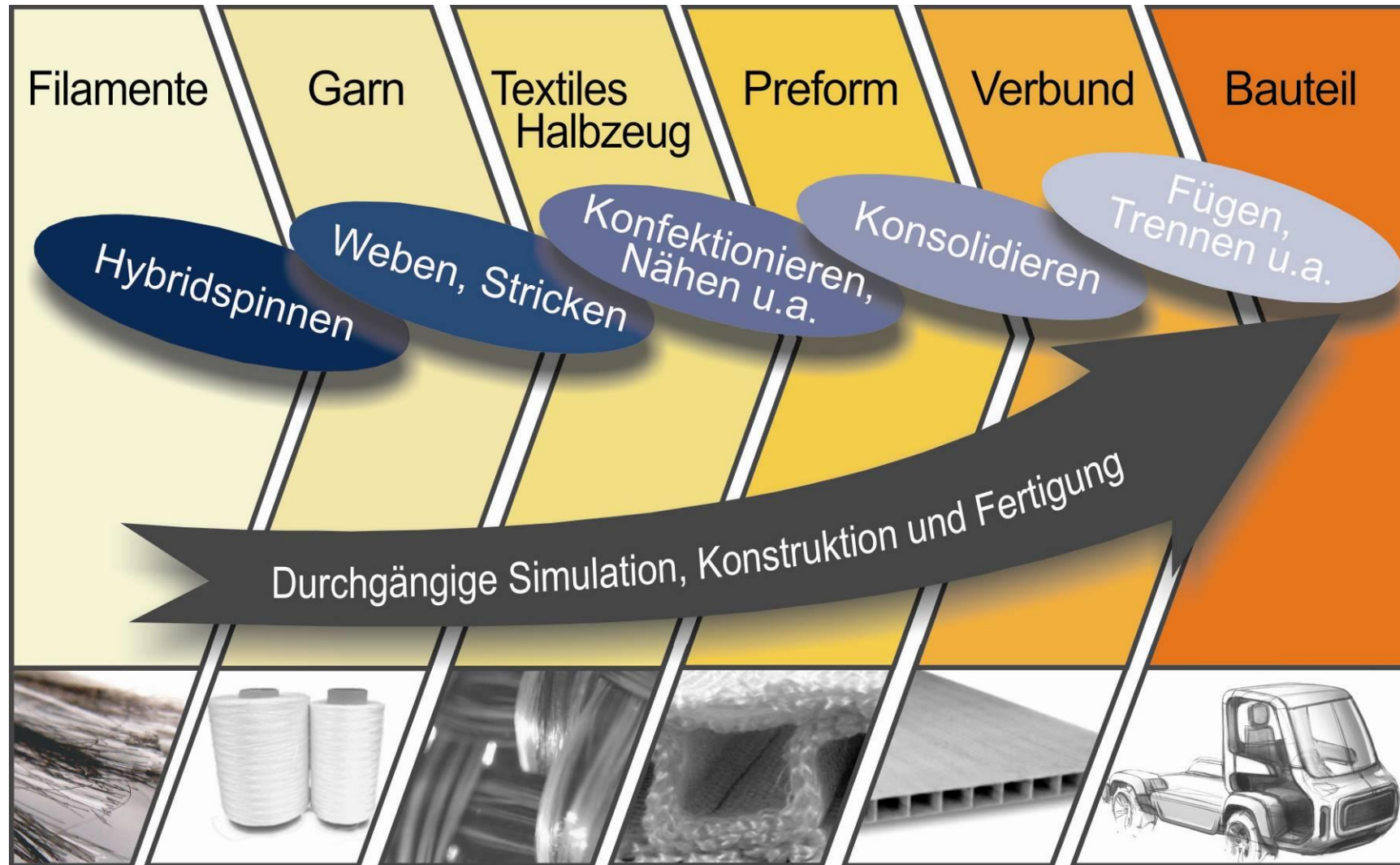


Textile-reinforced Composite Components for Function-integrating Multi-material Design in Complex Lightweight Applications

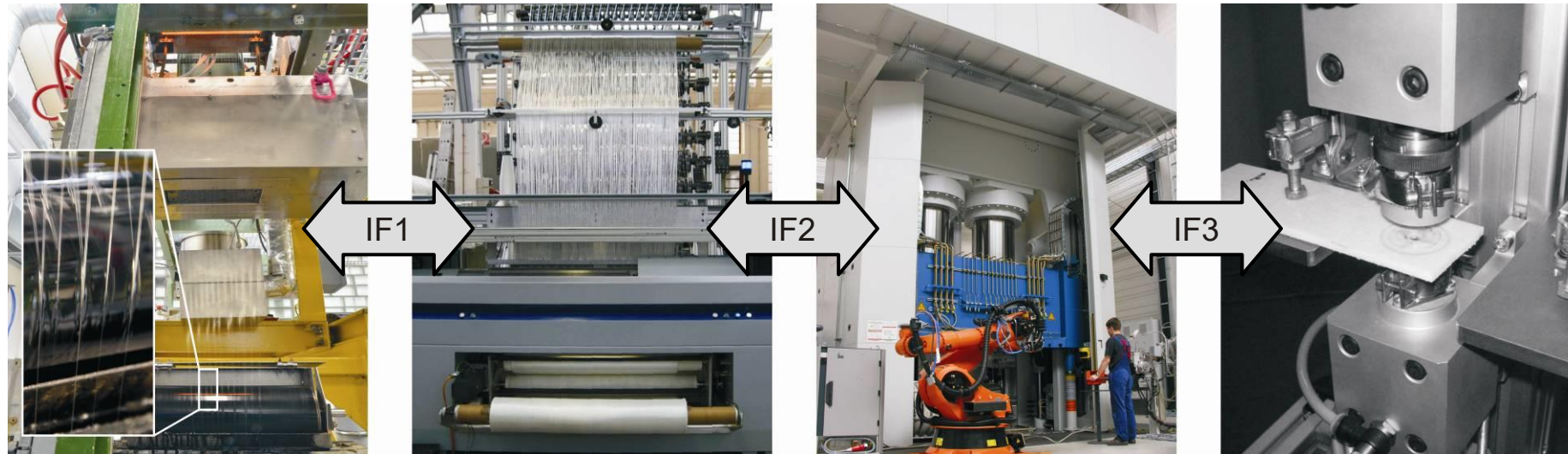
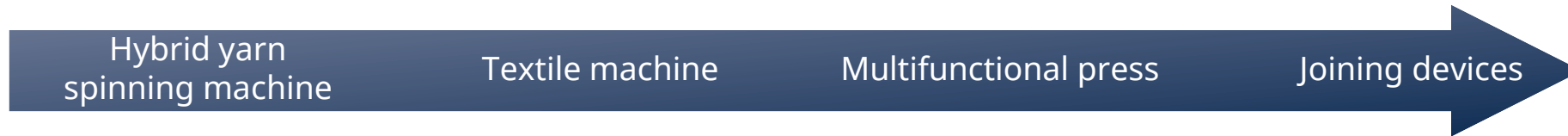
Unique textiles – hybrid construction designs – functional integration – lightweight design to increase energy and material efficiency

- Scientific principles and methods for the development and use of innovative textile composites
- Continuous calculation methods for virtual product development
- Technologies for application-ready lightweight structures in functionally integrated composite construction
- End-to-end theoretical and technological analysis of the process chain

From filament to component part



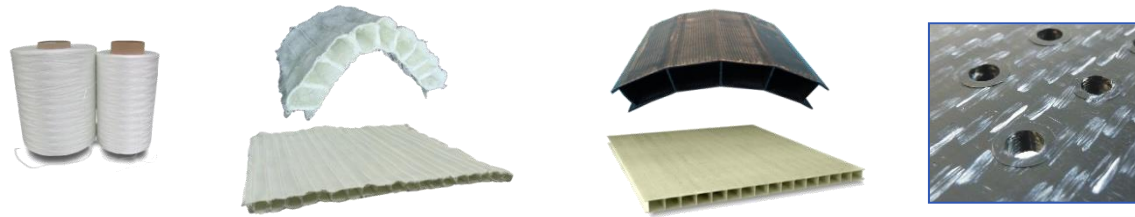
Continuous process chain developments



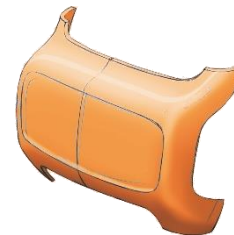
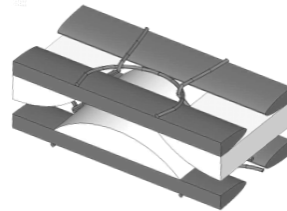
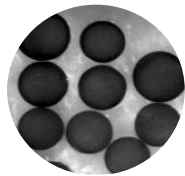
IF1: interface yarn – textile IF2: interface preform – processing IF3: interface composite - component

Hybrid yarn-textile-thermoplast (HGTT) - example material: glass fibre and polypropylene

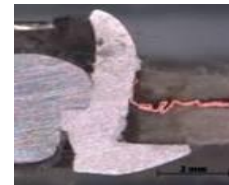
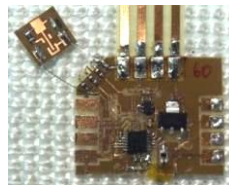
Generic technology demonstrator



SFB - process chain



SFB - simulation chain

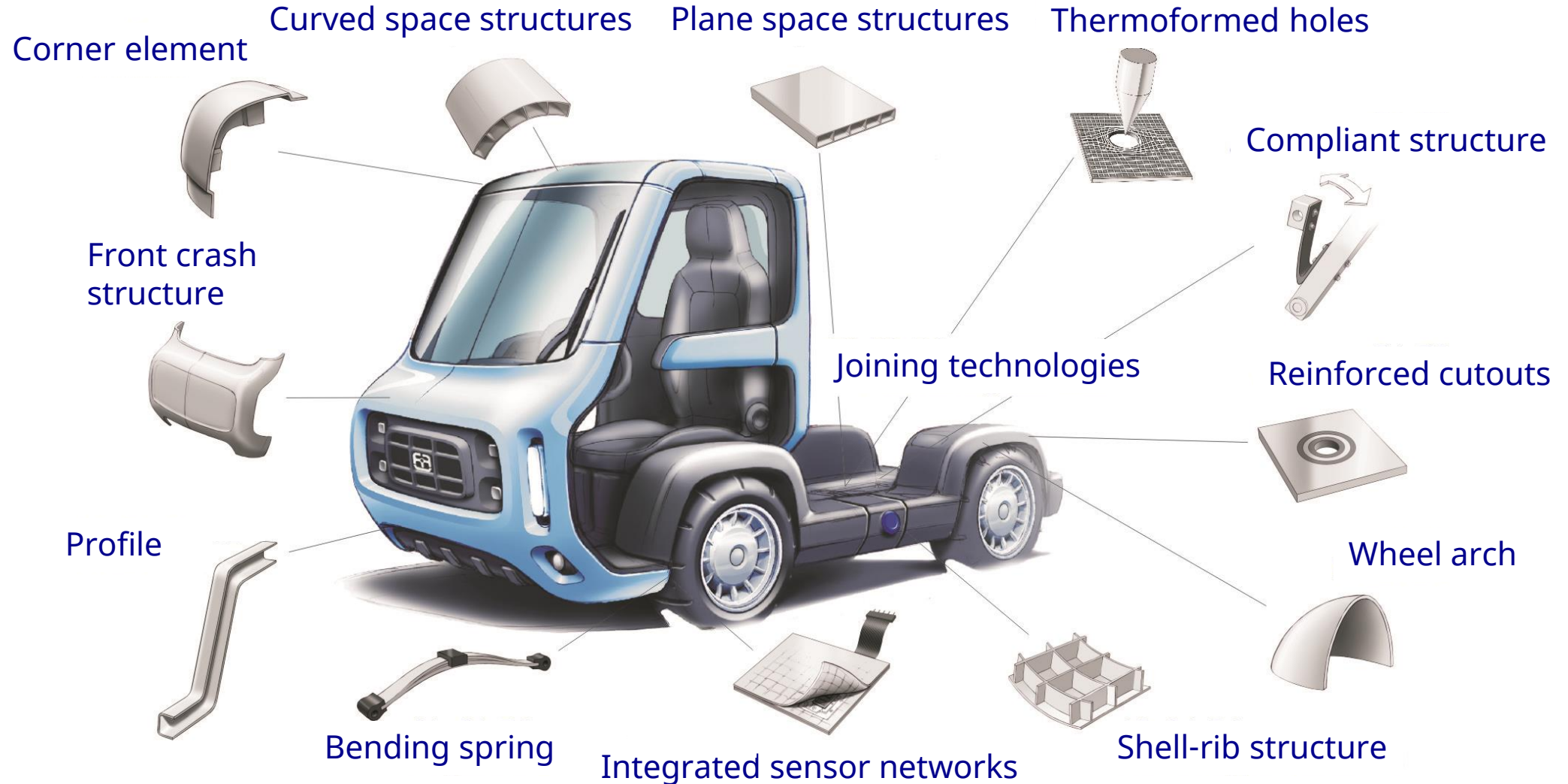


Function integration



Function-integrating vehicle demonstrator (FiF)

Textile reinforced structures for demonstrator



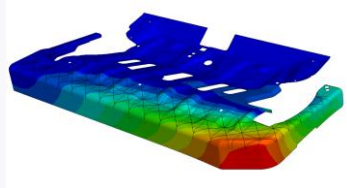
Textile reinforced structures for demonstrator



Innovations from SFB 639: Seat shell



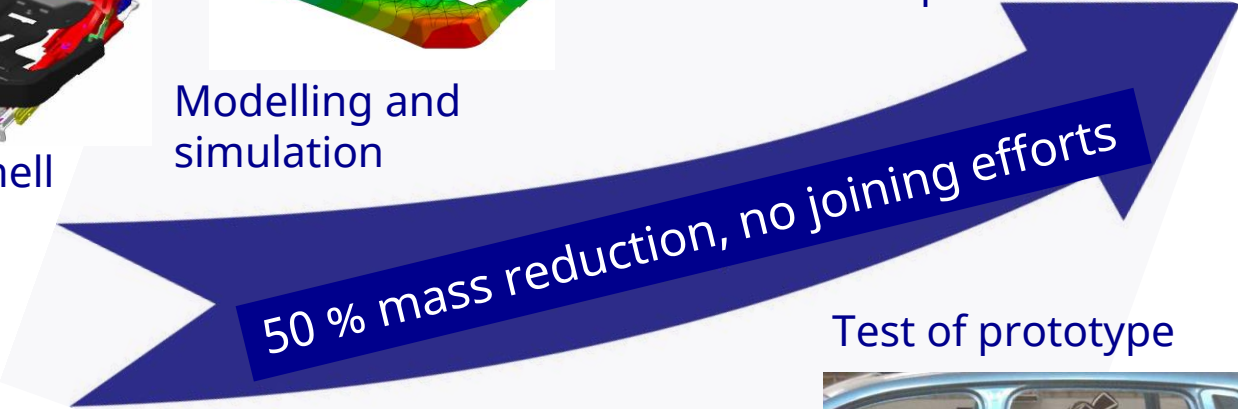
Design of seat shell



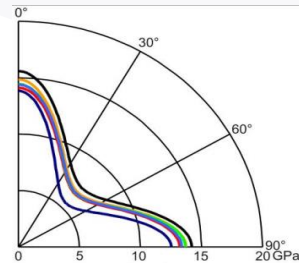
Modelling and simulation



Process development



Material development and characterization



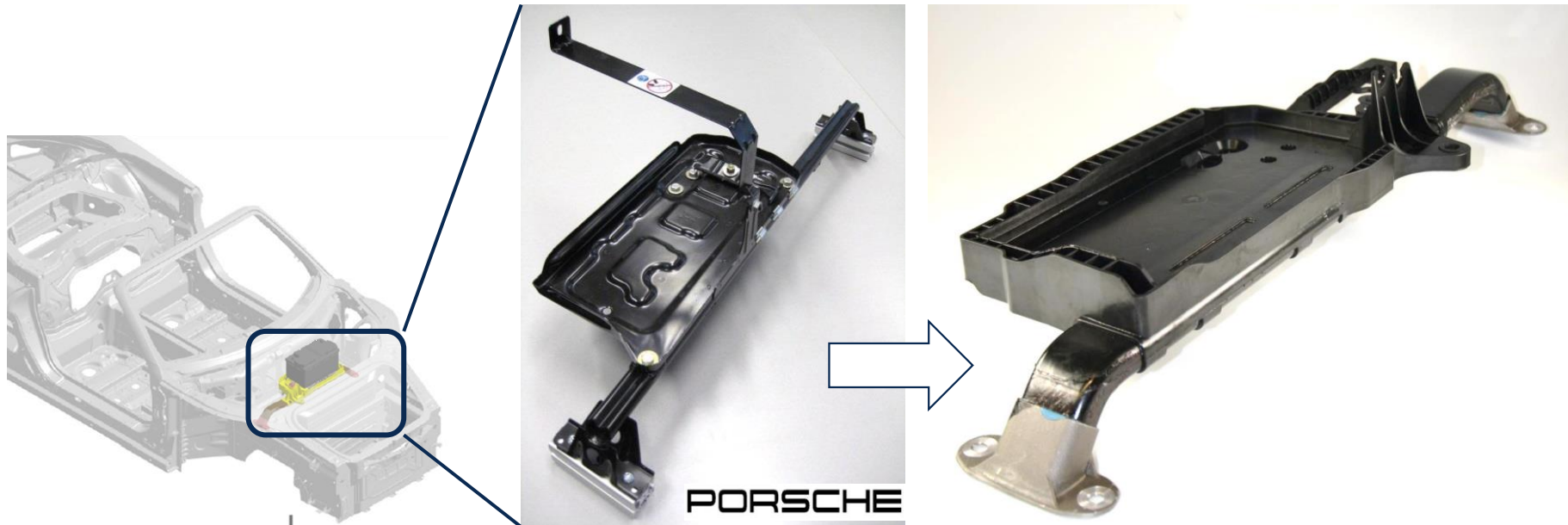
Test of prototype



Innovations from SFB 639: Battery carrier

- Development of battery carrier in thermoplast-hybrid design
- Overmoulding of thermoplastic FRP hollow profiles
- Test for crash load case

e-generation



Quelle: Porsche AG

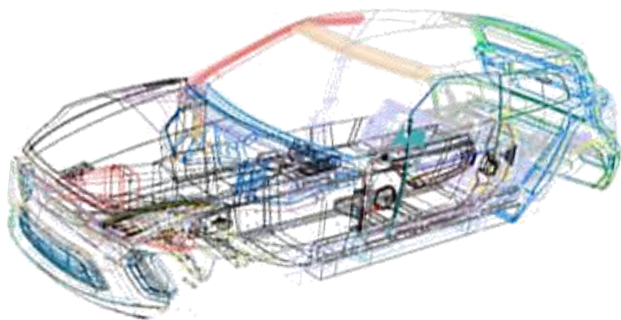
Welded metal
reference structure

Hybrid thermoplastic composite
structure

Innovations from SFB 639: InEco[®]-Project



From the idea to the ready-to-run InEco[®] prototype car



Parallel Developments in Automotive Industries



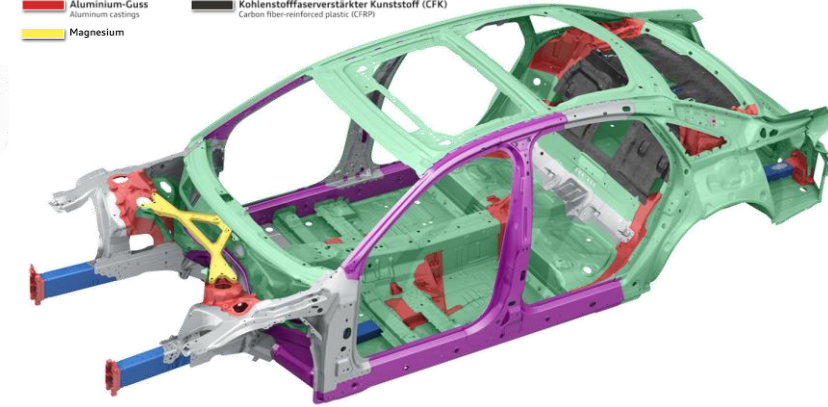
2013: BMW i3
CFRP chassis/Al drive modul



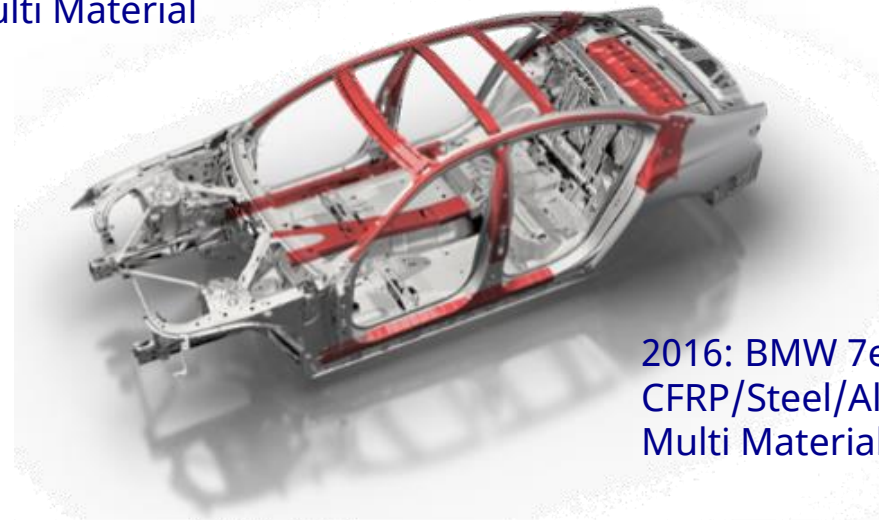
- Aluminium-Blech
Sheet aluminium
- Aluminium-Guss
Cast aluminium
- Aluminium-Profil
Aluminium profile
- CFK
CFRP

2013: Audi R6 e-tron
CFRP/Al-Multi Material
Design

- Aluminium-Blech
Aluminium sheet
- Aluminium-Profil
Aluminium section
- Aluminium-Guss
Aluminium castings
- Magnesium
- Ultrahochfester Stahl (warmumgeformt)
Ultra-high strength steel (hot-formed)
- Konventioneller Stahl
Conventional steel
- Kohlenstofffaserverstärkter Kunststoff (CFK)
Carbon fiber-reinforced plastic (CFRP)



2017: Audi A8 L
CFRP/Steel/Al-Multi
Material Design

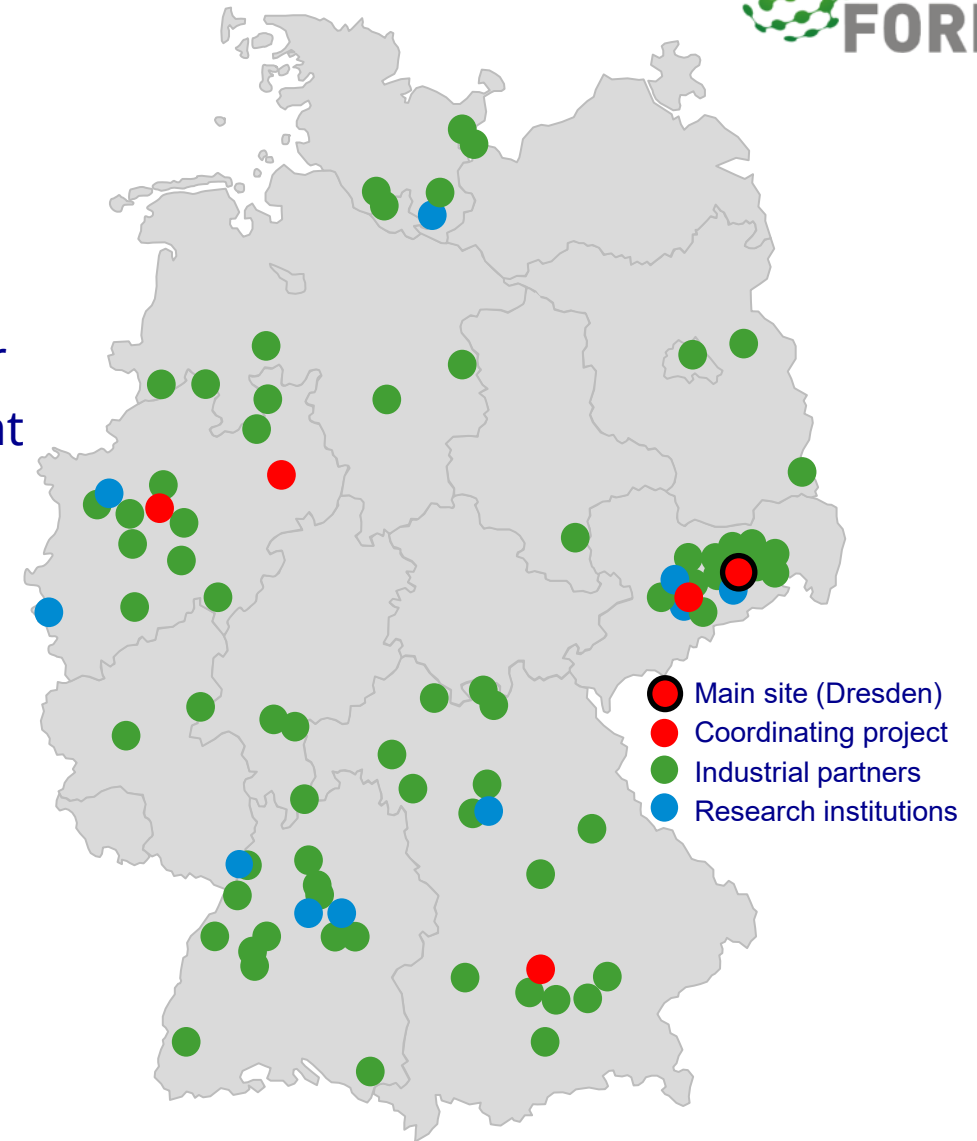


2016: BMW 7er
CFRP/Steel/Al-
Multi Material Design

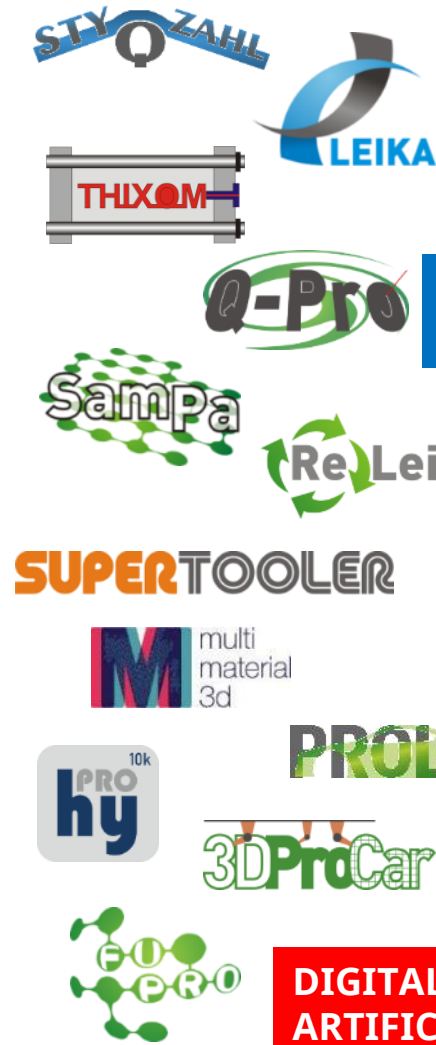
BMBF platform FOREL (2013)

open - independent - pre-competitive

- **Systemic Research in Function-Integrative System Lightweight Engineering in Multi Material Design** for the targeted elimination of existing gaps in development and process chains in electric mobility
- Establishment of a **Pre-competitive Lightweight Construction Research Network**
- **Cross-Industry Technology Centre** providing key technologies ready for series production



Technology Highlights 2014 - 2022



HYBRID-TECHNOLOGIES

RESOURCE EFFICIENCY

RECYCLING

GENERATIVE MANUFACTURING

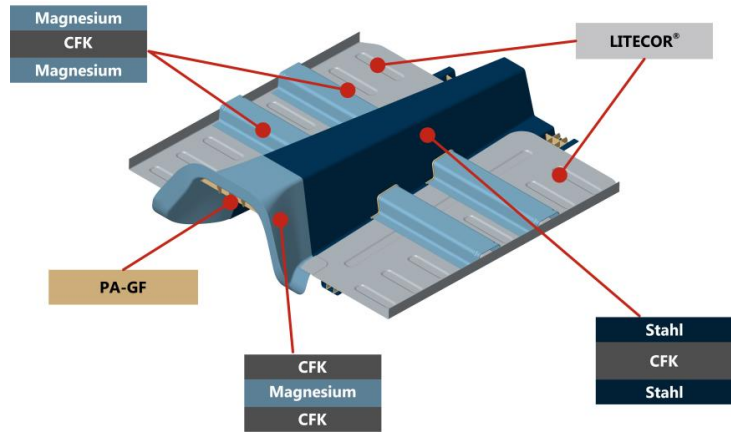
NOVEL DESIGNS

3D-PREFORMING

DIGITALISATION + ARTIFICIAL INTELLIGENCE

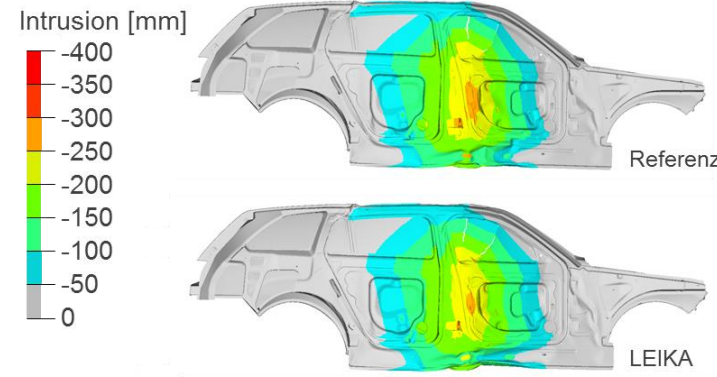
Multi material design for lightweight car bodies – floor panel

Innovative material mix



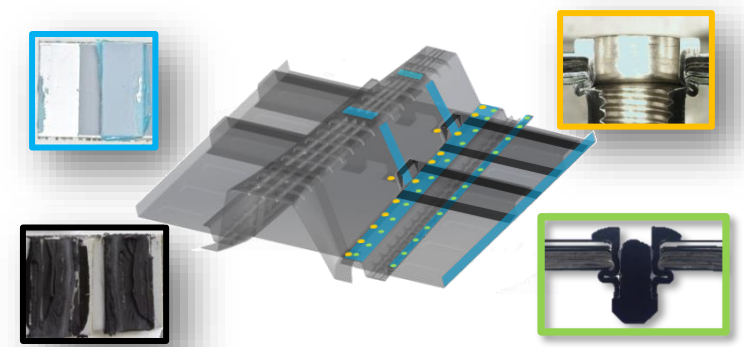
Quelle: thyssenkrupp AG

Full vehicle simulation



Quelle: IKA (RWTH Aachen)

Material-specific joining technology



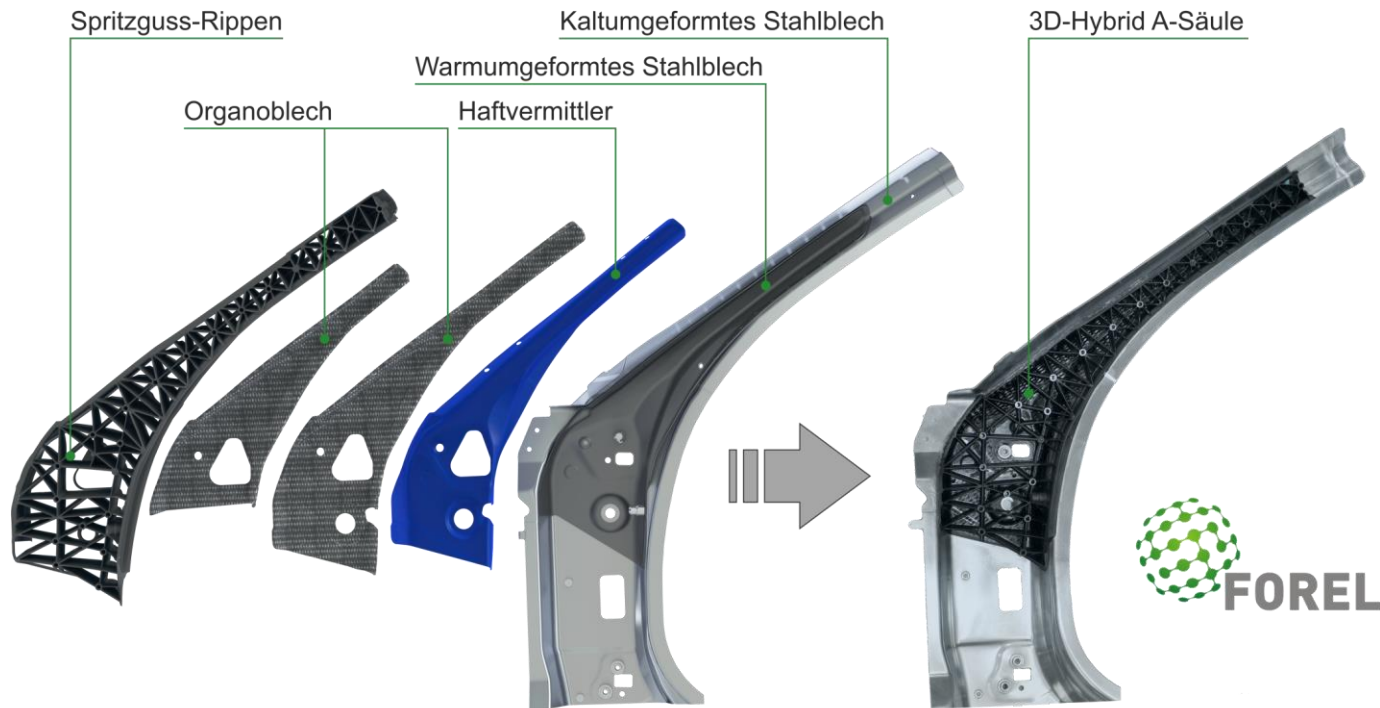
Quelle: LWF (Uni Paderborn)

Underbody demonstrator



3D Hybrid Technology – A-pillar

Quality-assured, virtual development of process chains for the manufacture of hybrid lightweight structures



- **Linking established individual processes** to form a closed process chain
- **Increase in the degree of automation**
- Surface modification for improved adhesion of different materials (e.g., steel and plastic)
- Introduction of **virtual and real quality assurance methods** through coupled process simulation



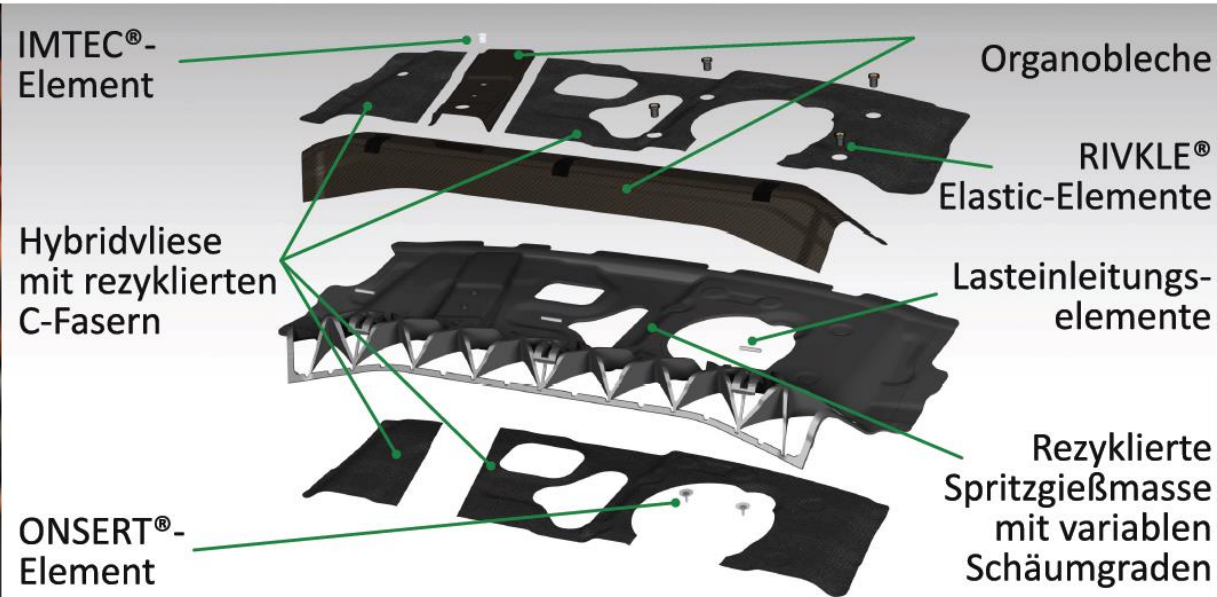
GEFÖRDERT VOM



BETREUT VOM



Hybrid thermoplastic composite design – rear wall top section



- Integration of versatile inserts (organic sheets, nonwovens and connecting elements) in the **one-shot injection moulding production process** "foaming moulds" with highly complex automation
- **Proportion of recycled material approx. 80 %**



Parallelisms and special features in maritime economy

Common challenges

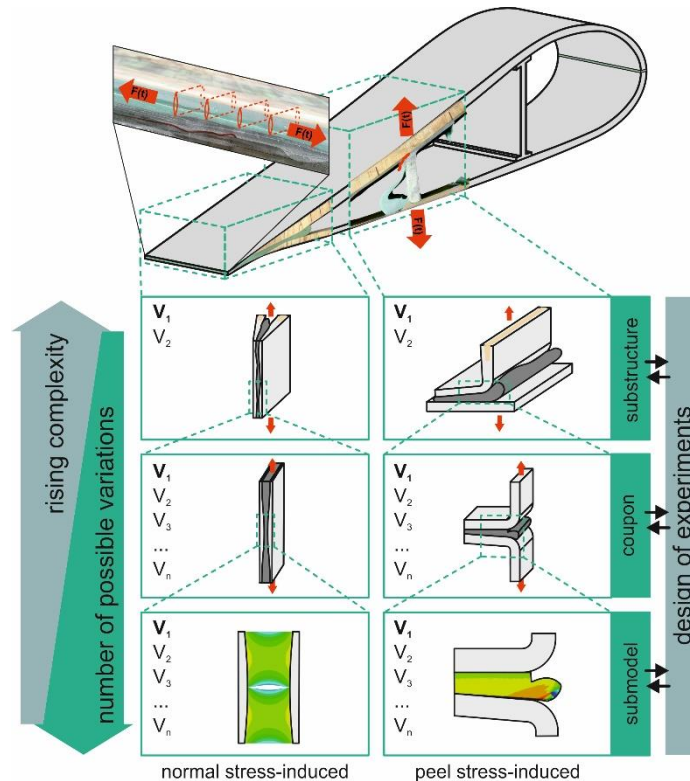
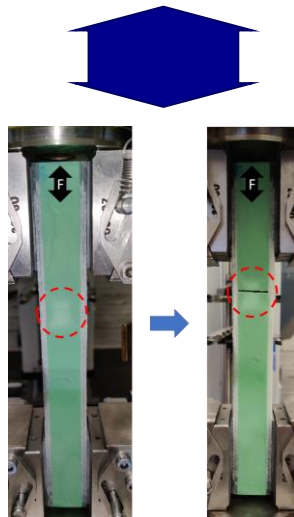
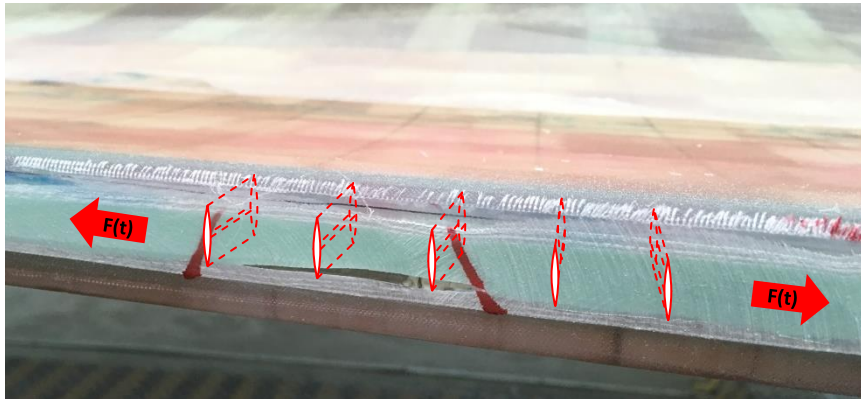
- Lightweight approaches by advanced materials and material-adapted designs
- Multi-material design requires adapted joining technologies and processes
- Reliable simulation models for process and structural design
- Novel reproducible/robust manufacture and assembly processes

Maritim specific features

- Undefined production and assembly conditions at shipyards
- Low automatization due to small series or single piece production
- Large structures and manufacturing deviation complicate assembly and (adhesive) joining processes
- Harsh operating conditions for maritime structures

Project LeVaDi-I

Fatigue life analysis for adhesive bonds in large FRP structures with varying adhesive layer thicknesses



Challenge

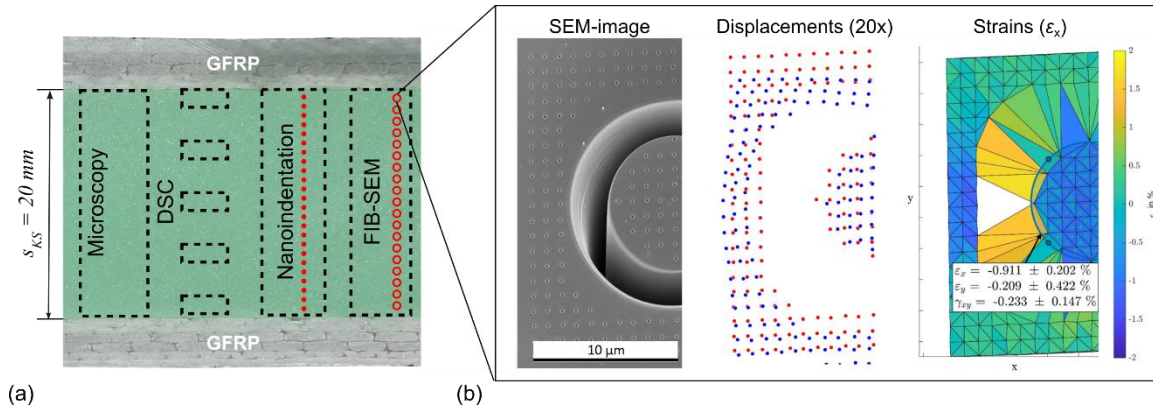
- Manufacturing-induced imperfections: Varying edge geometry and layer thickness
- Service-induced defects: Crack initiation in adhesive layer under cyclic loads
- To date, service life calculation assumes defect-free adhesive layer → **great uncertainties**

Goals

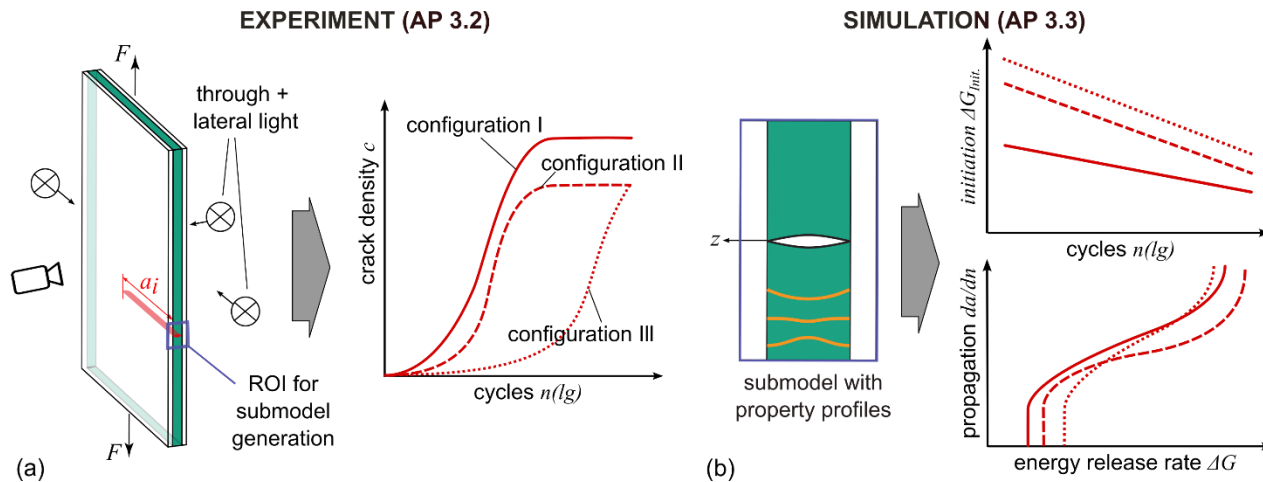
- Characterization and classification of imperfections
- Investigation on crack initiation and propagation in coupon tests and submodel simulations
- Substructure tests with combined deviations to verify scalability
- Practical investigation methodology and design guidelines

Project LeVaDi-II

Process-structure-property relationships in cyclically loaded adhesive layers with heterogeneous property profiles



(a) Exp. characterization of property profiles, (b) Microscale residual strain measurement by FIB-SEM



(a) Test method with image-based crack detection, (b) submodel simulation approach

Challenge

- Complex influences of varying adhesive layer thickness on damage behavior in large FRP structures → especially cross-linking reaction and residual stresses

Goals

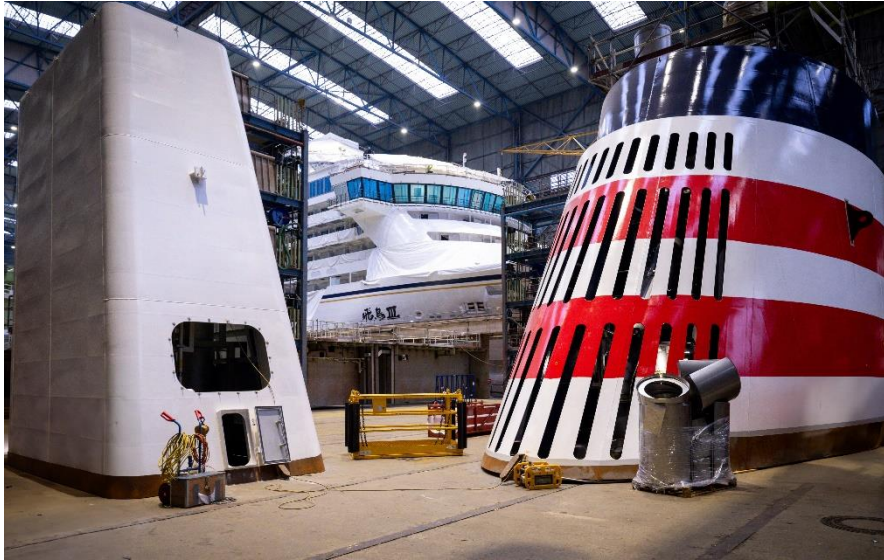
- Investigation of the process-structure-property relationships
- Development of manufacturing methods for transferring large-structure-typical property profiles to laboratory scale
- Development of test methods for characterizing cyclic damage on laboratory scale
- Investigation of layer thickness mechanisms on crack initiation and growth

Project BigBond

Life-cycle processes and design concepts for adhesively bonded large maritime structures



BIGBOND



Goals

- Life cycle processes and design concepts for adhesively bonded large-scale maritime structures
- Reducing the ecological footprint in maritime sectors by means of lightweight design
- Circular economy for used materials and structures
- Concepts and technologies for the efficient disassembly of bonded structures



Conclusions

- Innovation obstacles often caused by missing branch specific know-how, single stakeholder restrictions and strict/conservative regulations
- Comprehensive scientific approaches necessary to accelerate innovation processes
- Consideration of historic parallelisms might help to address branch specific challenges
- Lightweight approaches in maritime sector successfully started
- Development in networks and cross-project cooperations help to accelerate innovations

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