

VIRTUELLES PRODUKT UND DIGITALE ZWILLINGE FÜR DIE ENTWICKLUNG INNOVATIVER FLUGZEUGKOMPONENTEN

Fachveranstaltung "Digitalisierung in der Luftfahrt" 12.09.2023

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DAS VIRTUELLE PRODUKTHAUS

Embedment into new DLR Aeronautics Strategy



Low-Emission Propulsion

- Direct combustion of H₂
- Fuel Cell
- Battery
- SAF



Energy-Efficient Aircraft

- New configurations
- Flight physics & components
- Weight reduction by lightweight construction



Emission-Reduced Air Transport System

- Climate-optimized routing
- Atmospheric research
- Impact assessment



Digitalisation

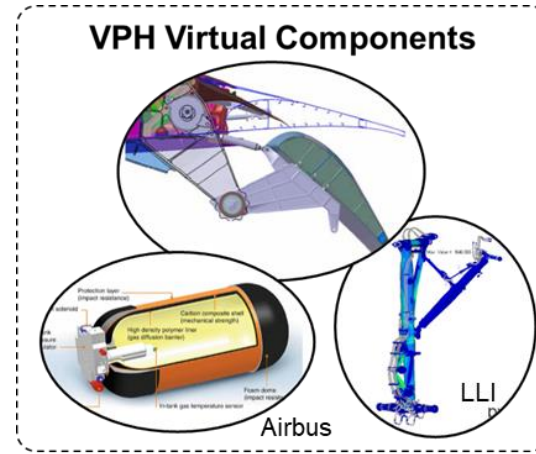
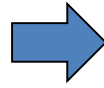
- Virtual Certification
- Digital Twin
- Virtual OEM

- **DLR Aeronautics Strategy** → Digitalisation as „Enabler“ for Zero-Emission Aviation / EU Green Deal
- DLR as “**Virtual OEM**” → virtual product & technology development for/with industry & authorities
- **VPH** as integration center / plateau → VC for specific components & industrial **use cases**

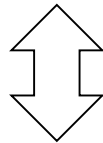
VPH: Vision & Objectives



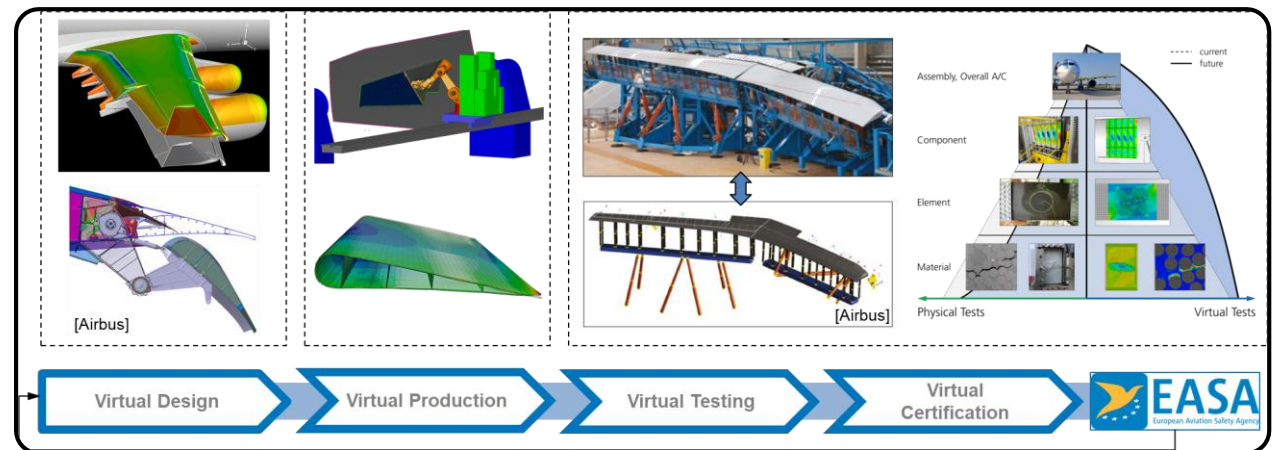
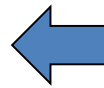
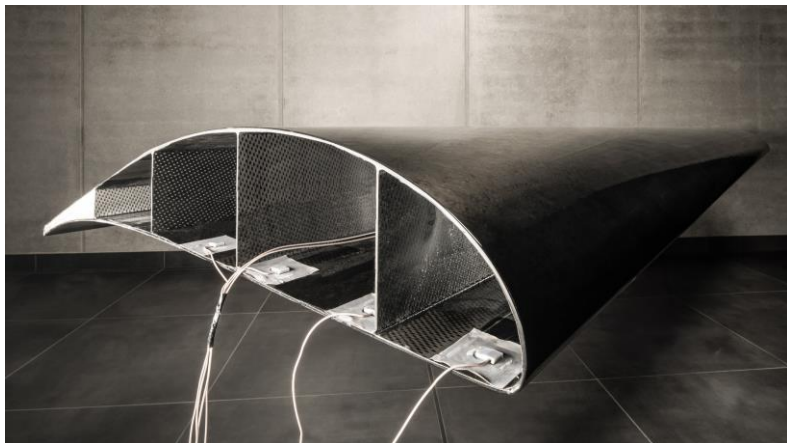
Virtual Product



- Virtual product as enabler for more efficient & climate-friendly a/c development & operations
- DLR VPH as R&T plateau for virtual product development & digital a/c certification
- Close interaction of industry, research & EASA @ VPH



Physical Product

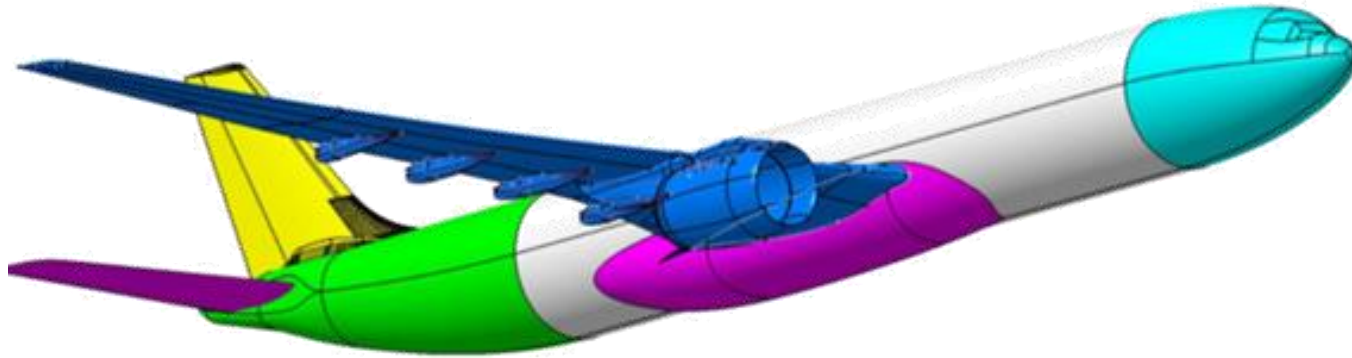




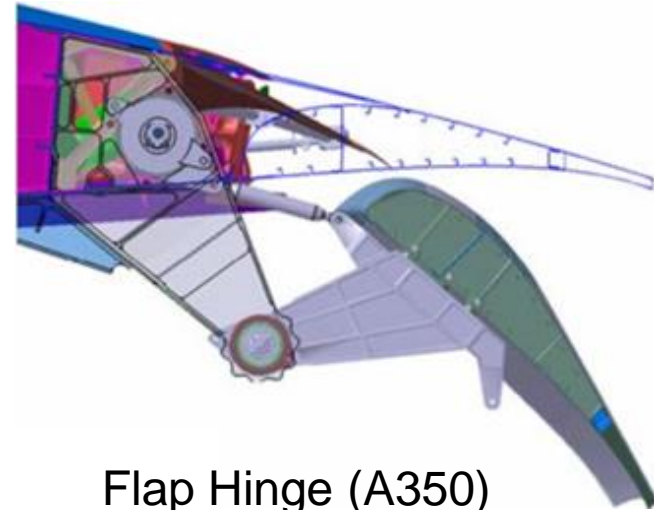
MANUFACTURING VALIDATION

Virtual Manufacturing

Target Structure

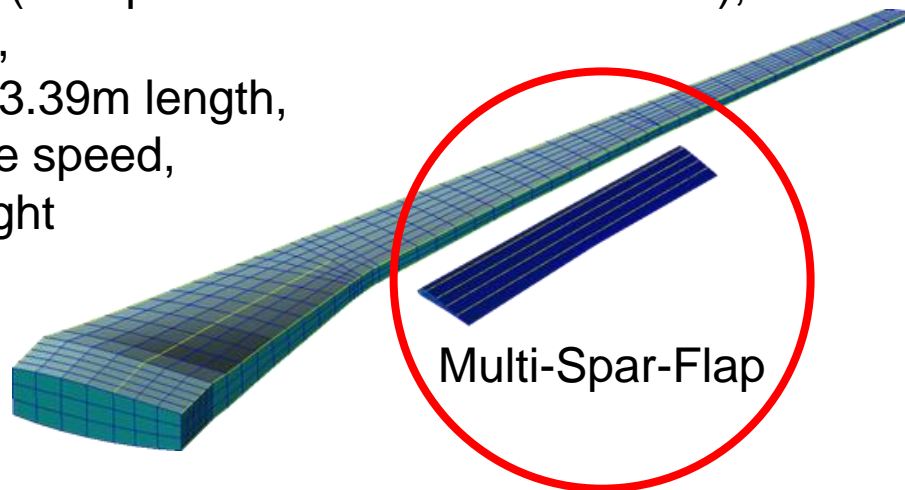


AIRBUS



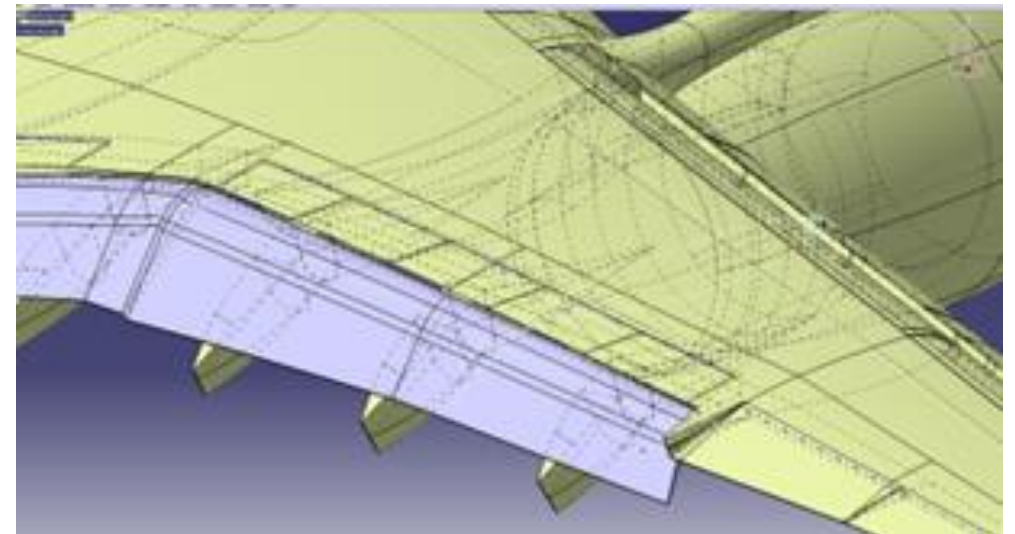
Flap Hinge (A350)

Airbus XRF 1 (Comparable to: Airbus A330-300),
max. 292 PAX,
60.3m span, 63.39m length,
880km/h cruise speed,
233t max. weight



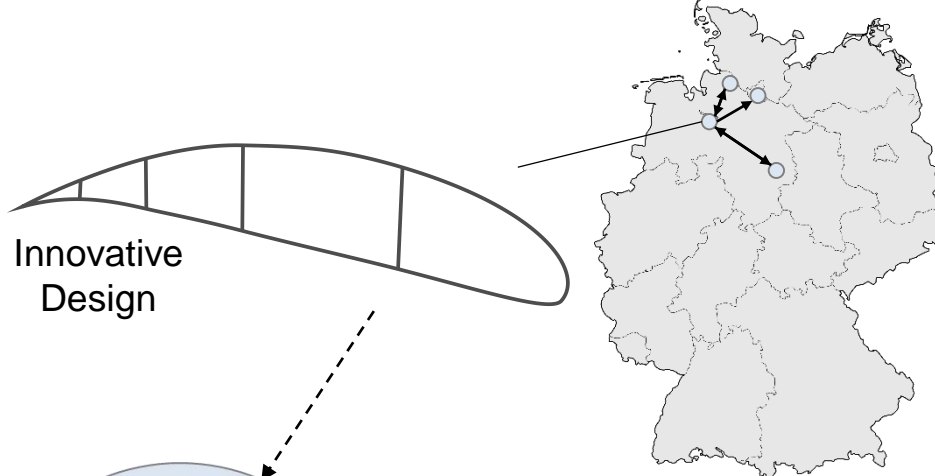
Multi-Spar-Flap

Flap CAD Model



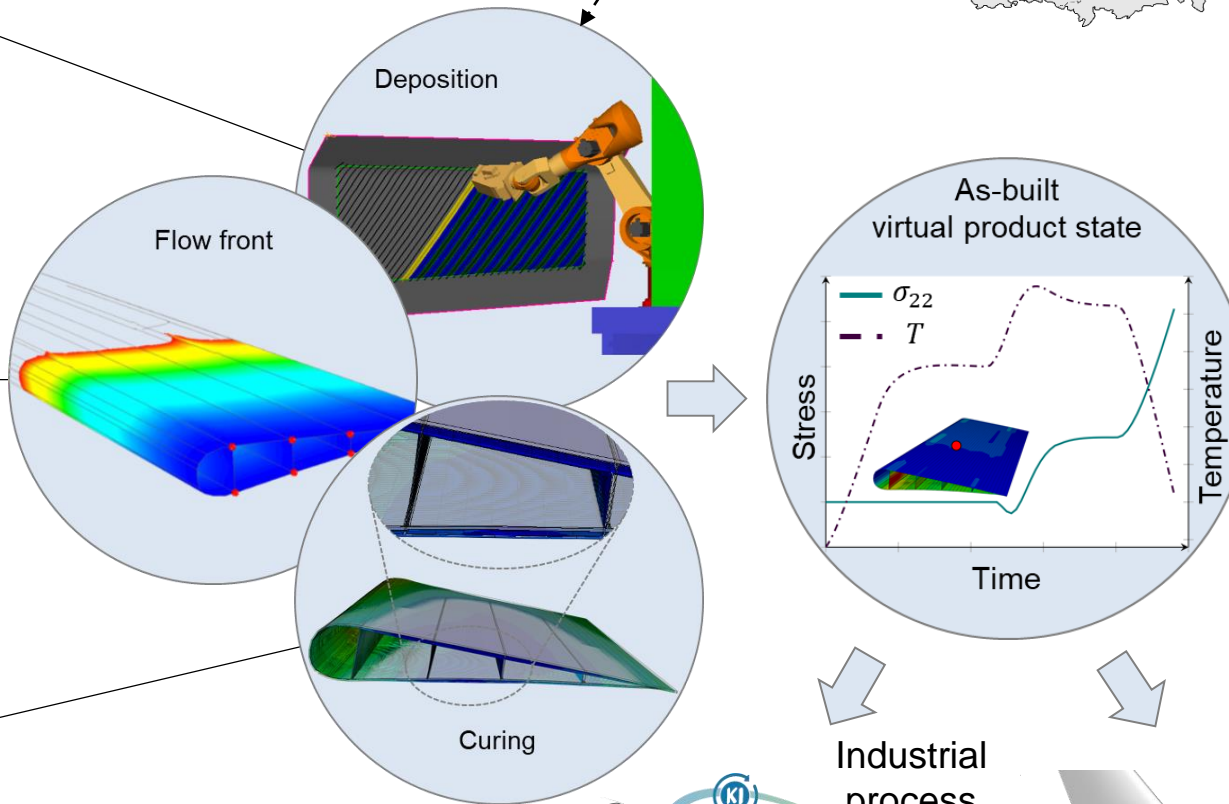
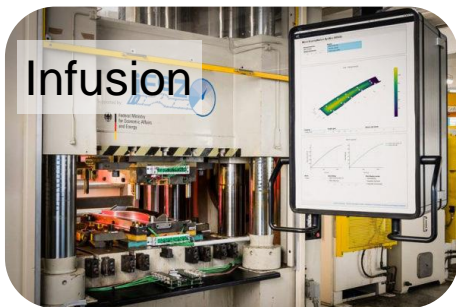
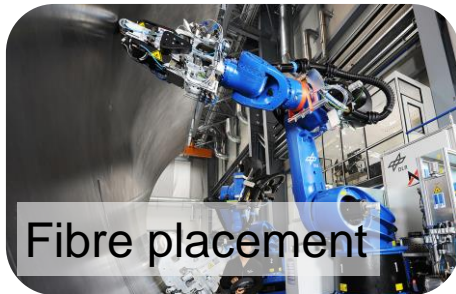
Outboard Flap

Virtual Manufacturing Strategic Focus



Goals:

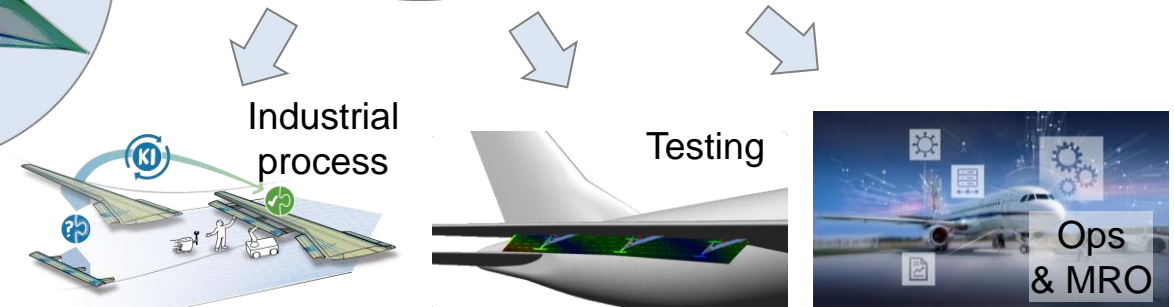
- Validation @ VPH
- Measurements
- Data & digital twin
- Answer questions



Understanding of structure for

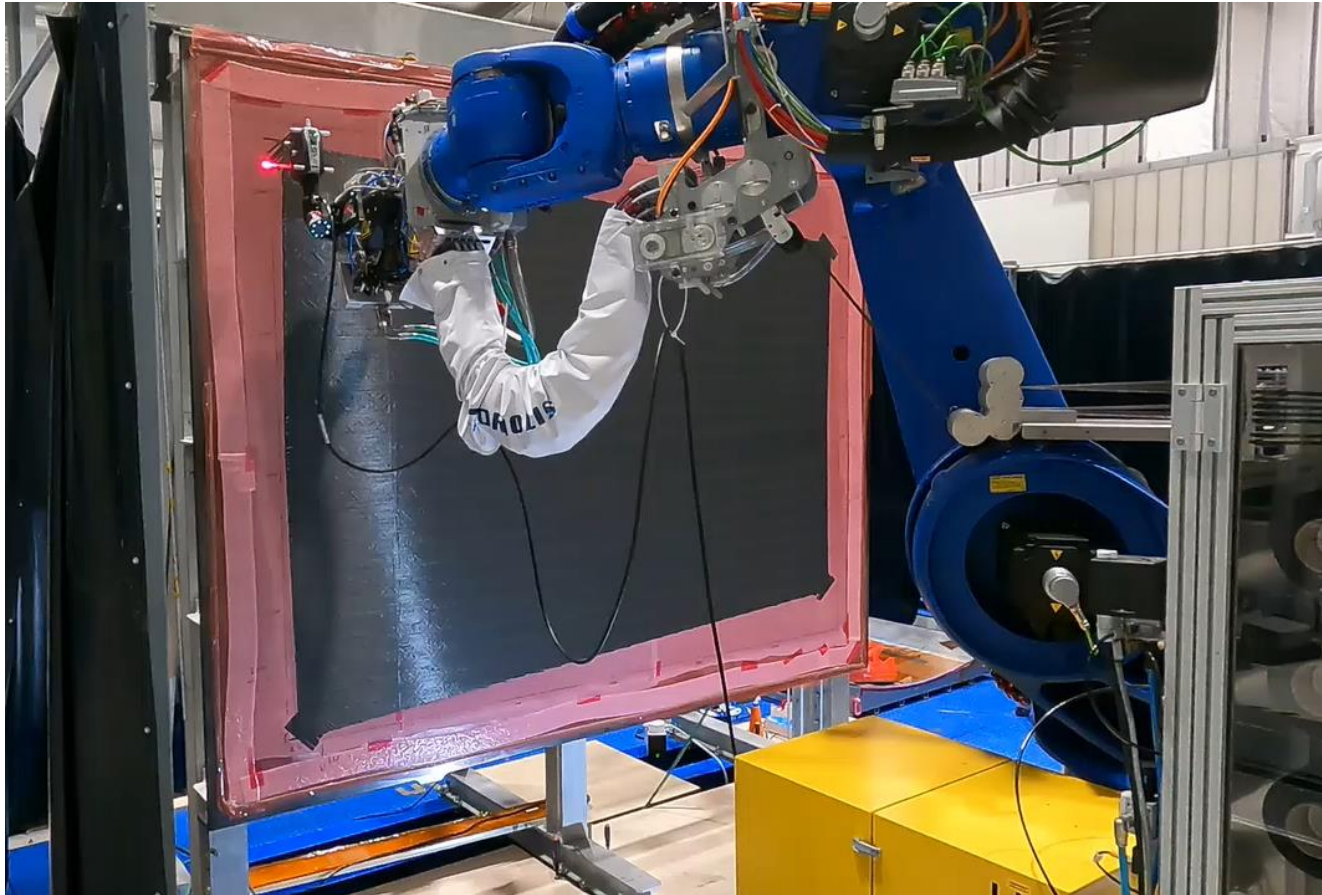
- Industrial process
- Virtual/physical testing
- Ops & MRO

Towards certification

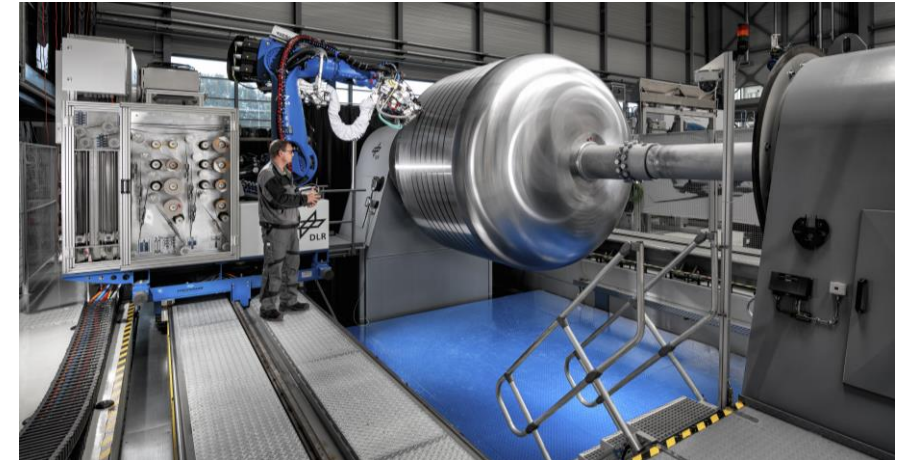


VPH Virtual Manufacturing

Automatic Fibre Placement



Dry Fibre Placement

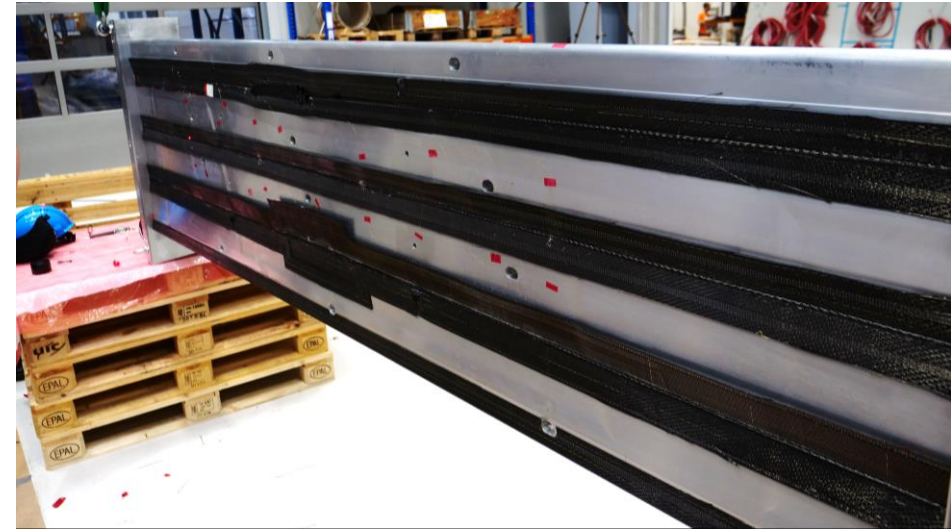


DLR-GroFi Multi Purpose Production Center

- Tailored layup
- Material / technology hybridisation
- Waste minimisation
- **Layup monitoring**

VPH Virtual Manufacturing

Preforming



Konsolidierung der Holmpreforms

DLR-MACS Autoclave

Bladder
preforming
of dry fabric
based spar
Laminate

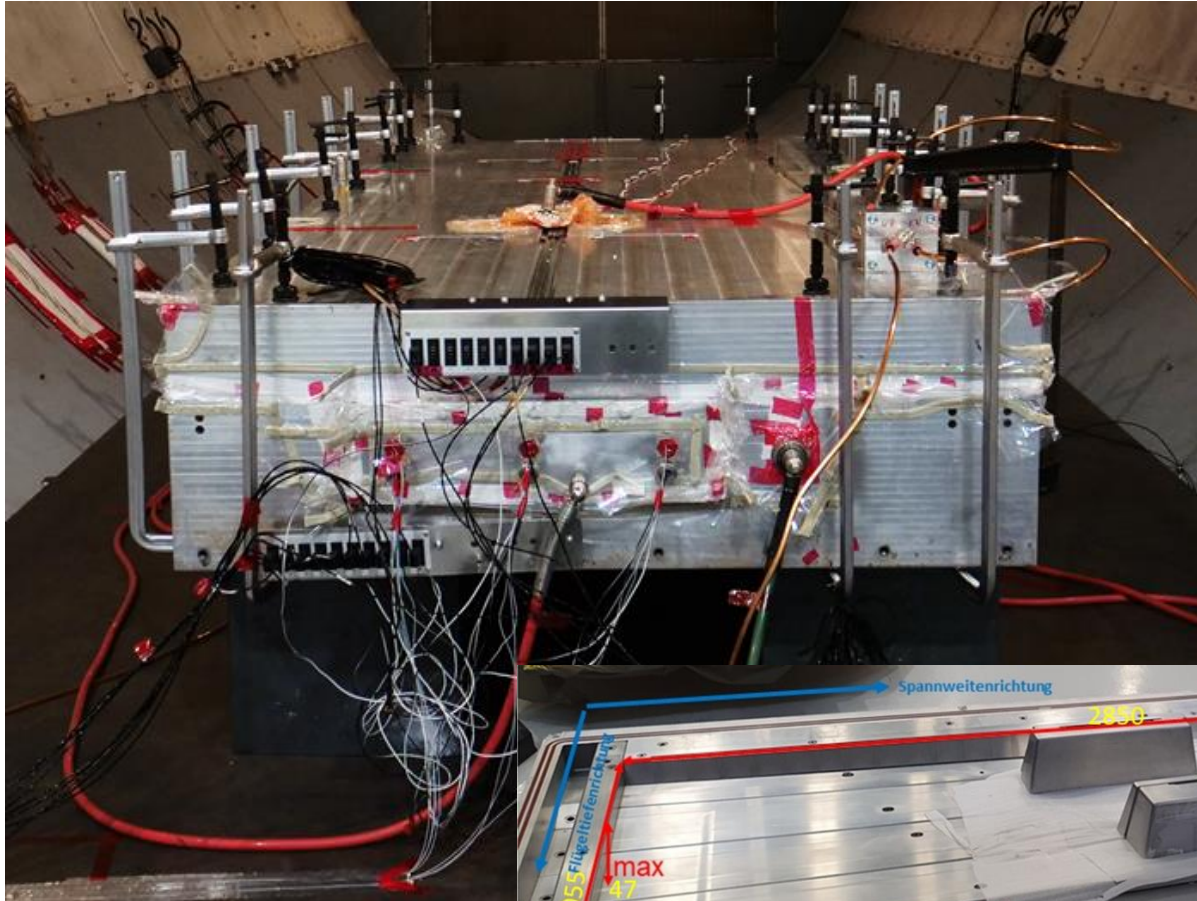
Autoclave
activation of
Binder

- Utilisation of prefabricated dry fibre products
- Complex shapes by draping of areal products
- Flow optimised fibre products
- Potential utilization of toughened fibre products
- **Monitoring of areal weight & binder activation**

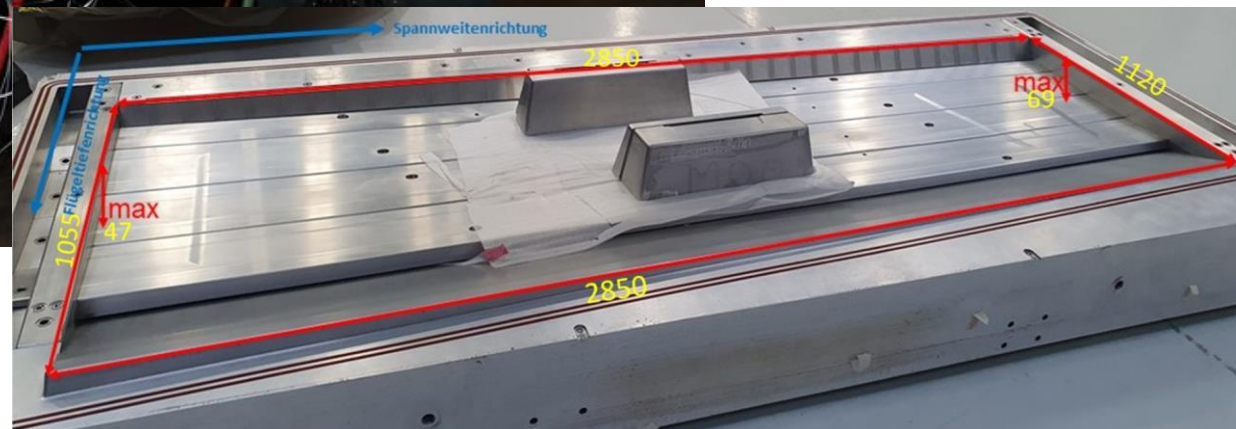
VPH Virtual Manufacturing

Curing

- Hybrid process to enable RTM process without dedicated large press
- Energy efficient curing process in final series production (e.g. isothermal)
- Fully defined composite structure
- Processing of dry fibre products
- **Resin flow and cure monitoring**



Modified Multi-Module closed Mould provided by **AIRBUS**



DLR-BALU Autoclave

A close-up photograph of a person's hand holding a tiny, white, square-shaped sensor chip between their thumb and index finger. The person's face is blurred in the background, and the background is a solid blue color. The sensor chip is very small, appearing as a tiny white square.

SENSORS

Sensor concept

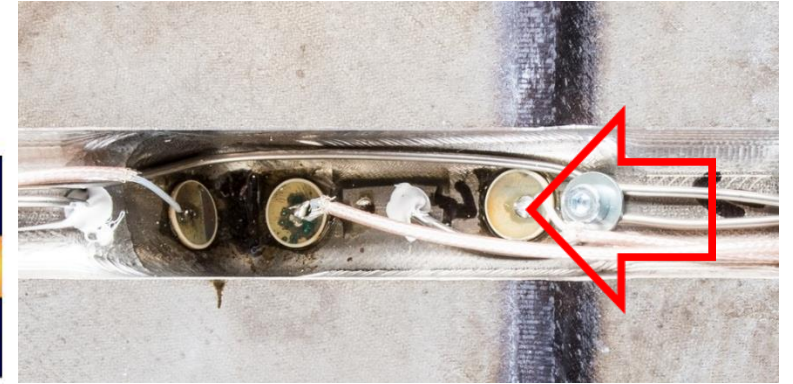
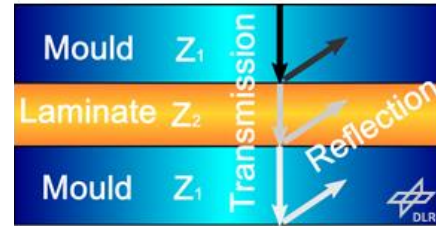


Measur. value	Sensor type	Number	Object	Process step
Temperature	Thermocouple	36	Tool	All
Pressure	Pressure sensor	1	Tool	Injection
Flow front	Ultrasonic	24	Tool	Injection
Degree of cure	Gelnorm PDE	1	Specimen	Injection, curing
	Dielectric sensors	4	Specimen	Injection, curing
Mechanical strain	FBG	8x4	Specimen	Curing

Ultrasonic (US) sensors (24)

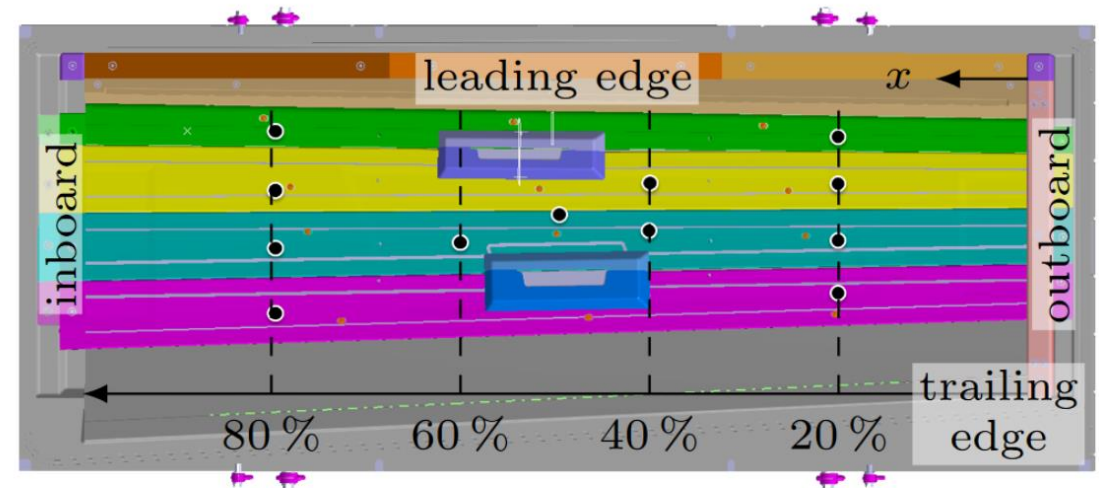


Works without contact to part and measures the flow front (pulse-echo),
measurement of the degree of cure is possible with transmission (sender/receiver)



Boundary conditions

- Flat and parallel surfaces
- Wall thickness from 10 to 80 mm



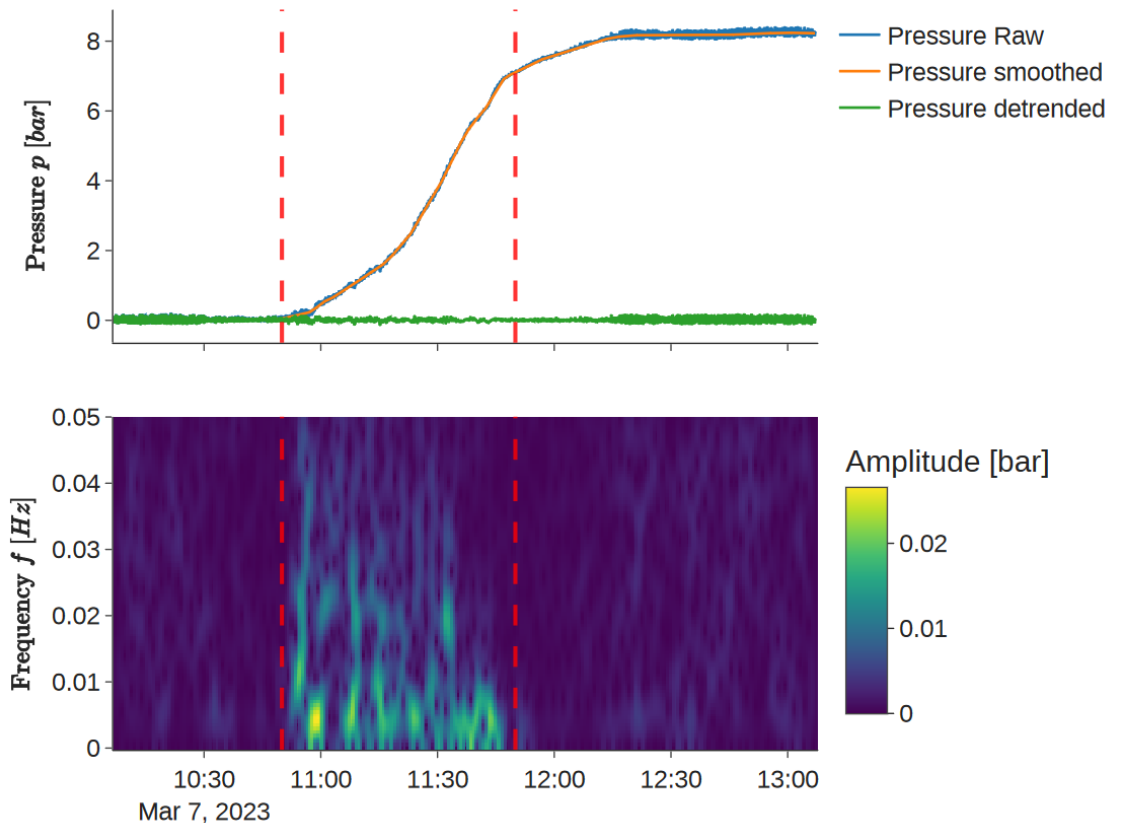
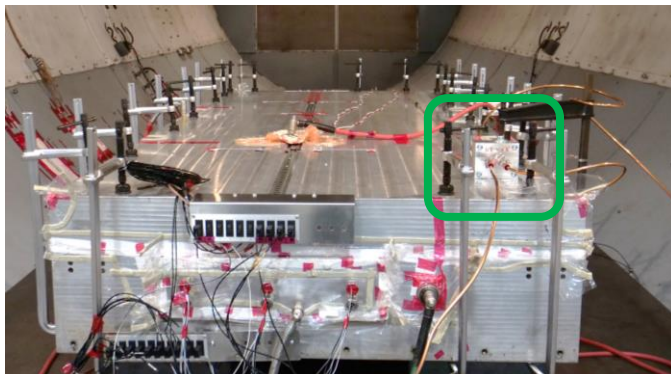
(a) US sensor & TC locations

Pressure sensor (1)

Measures the pressure in the vacuum line and is able to monitor void movement in a running liquid composite molding process

Boundary conditions

- The sensor is installed in a separate housing
- The separate housing must be cleaned before the next manufacturing process



Thermocouples (36 TCs)

Measures temperatures inside of the tooling

Boundary conditions

- Blind hole filled with thermal paste
- *Integration in same pockets as ultrasonic sensors is possible, as seen in the pictures on the right side*



Dielectrical analysis (1+4 DEA)

Measurement of degree of cure for comparison with the predictions made by simulations

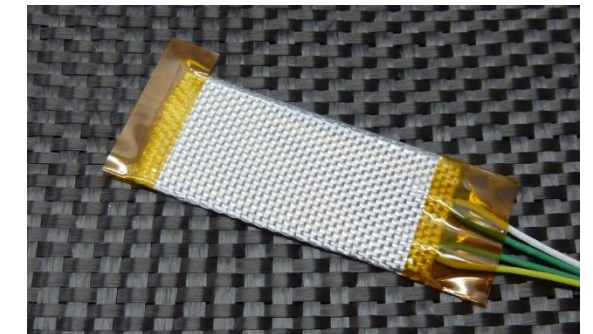
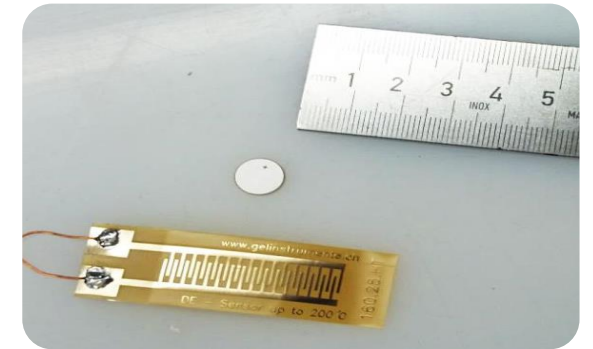
Boundary conditions

- Available as screw-in and single-use sensors
- The sensors must not be short-circuited
- The disposable sensors are flexible plastic films with a printed circuit that must be integrated into the part

Tool-mounted sensor



Disposable film sensor

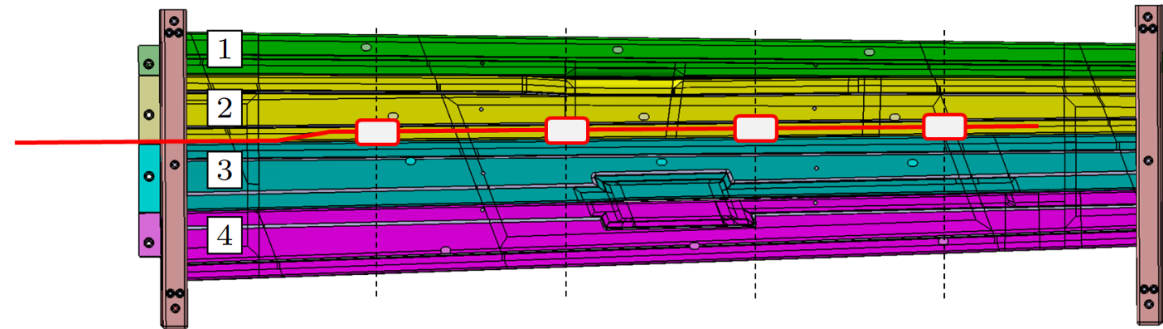


Fibre bragg gratings (8x4 FBGs)

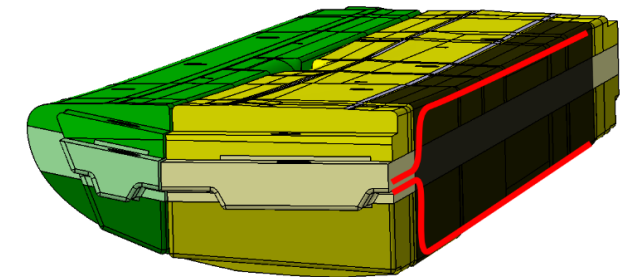
Measures mechanical strain inside of the specimen

Boundary conditions

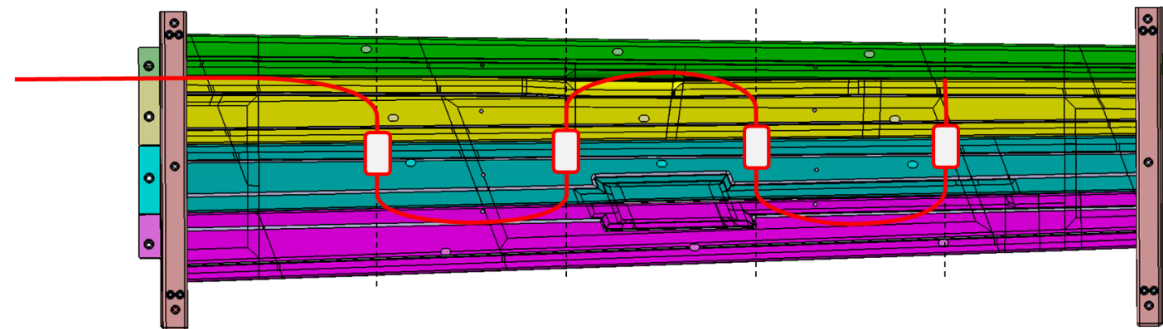
- Must be integrated into the part
- Cannot be bent



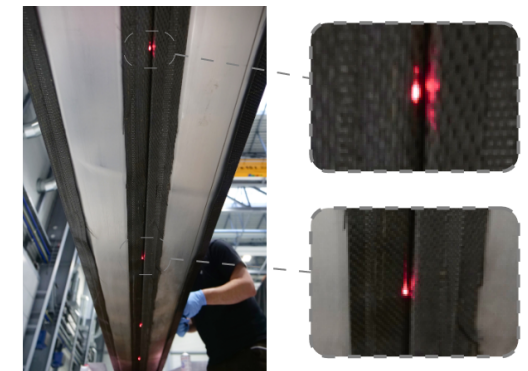
(a) Span-wise positions for one fibre



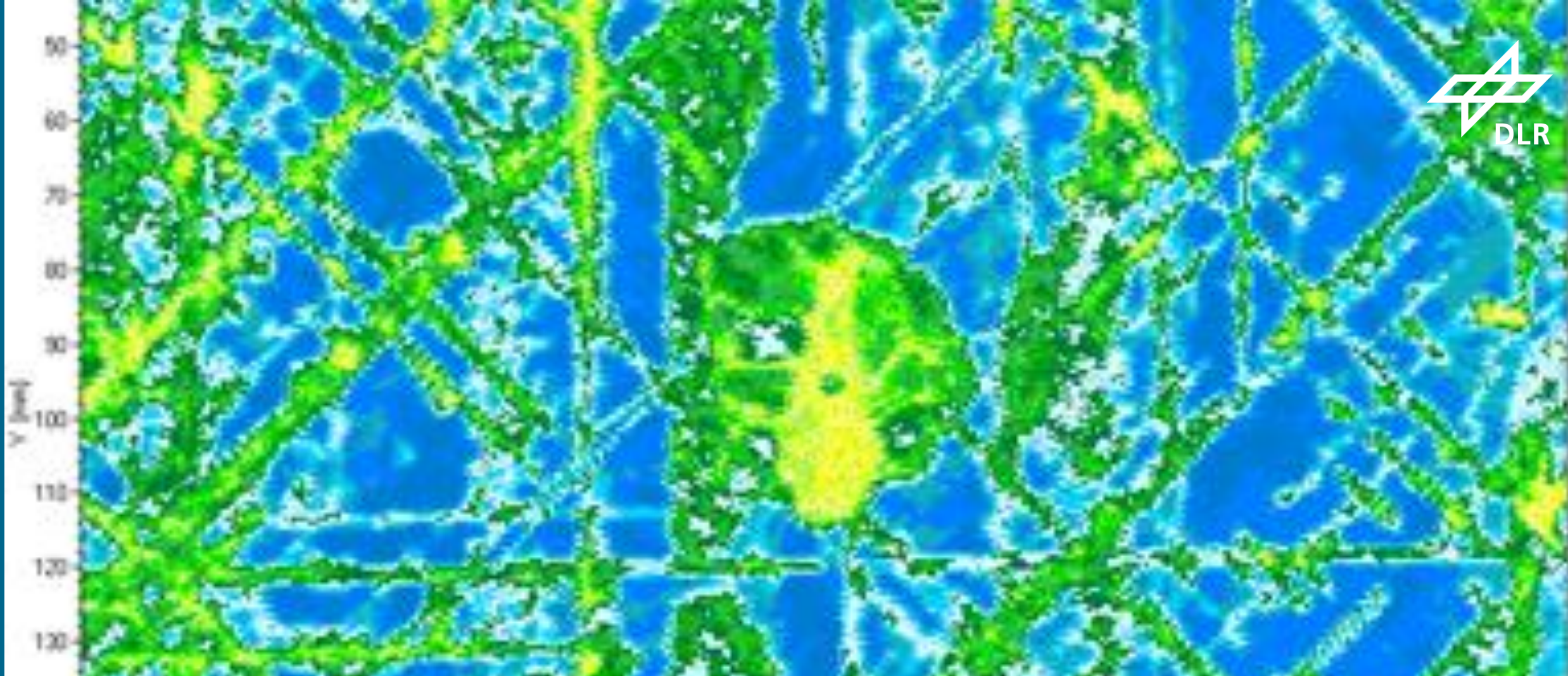
(b) Span-wise integration concept



(c) Chord-wise positions for one side



(d) Span-wise test



VIRTUAL TESTING VALIDATION

Virtual Manufacturing

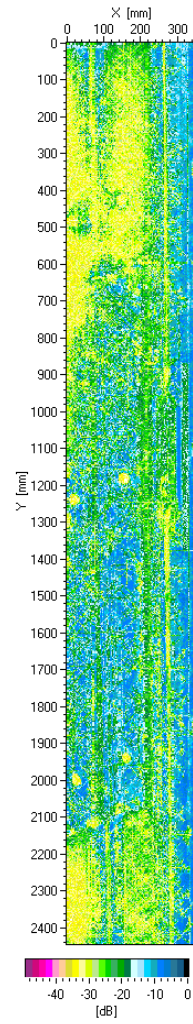
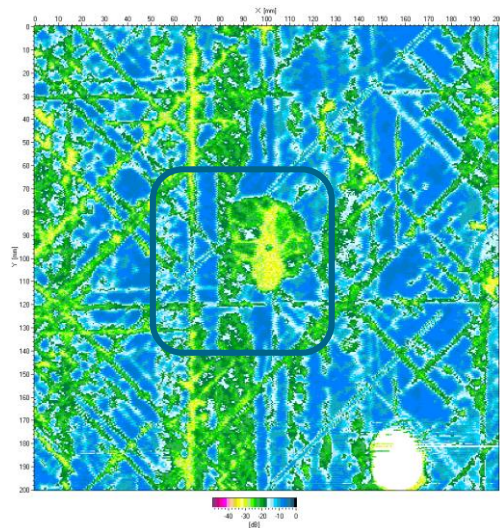
Validation data

- Fringe Projection with ATOS 5

→ ±0.4mm to CAD

- Ultrasonic Scan

→ Inhomogeneous Infusion

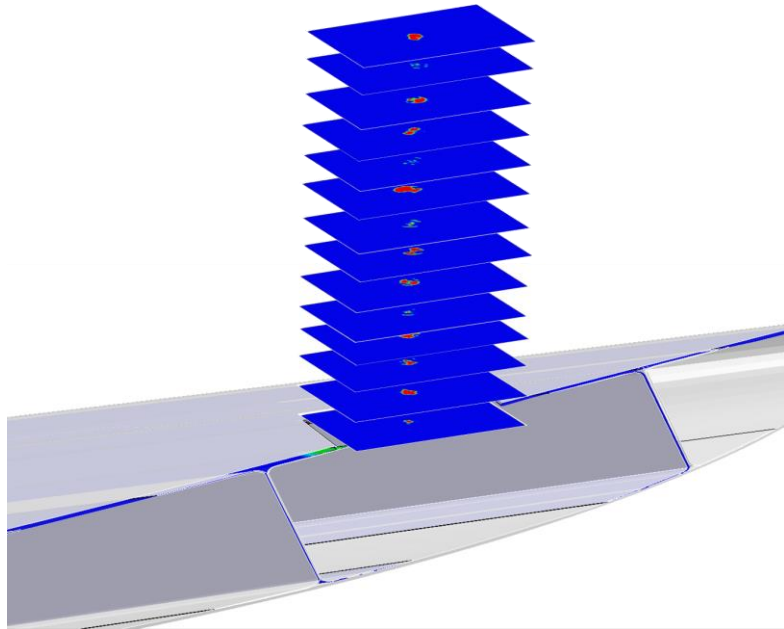


Virtual Testing

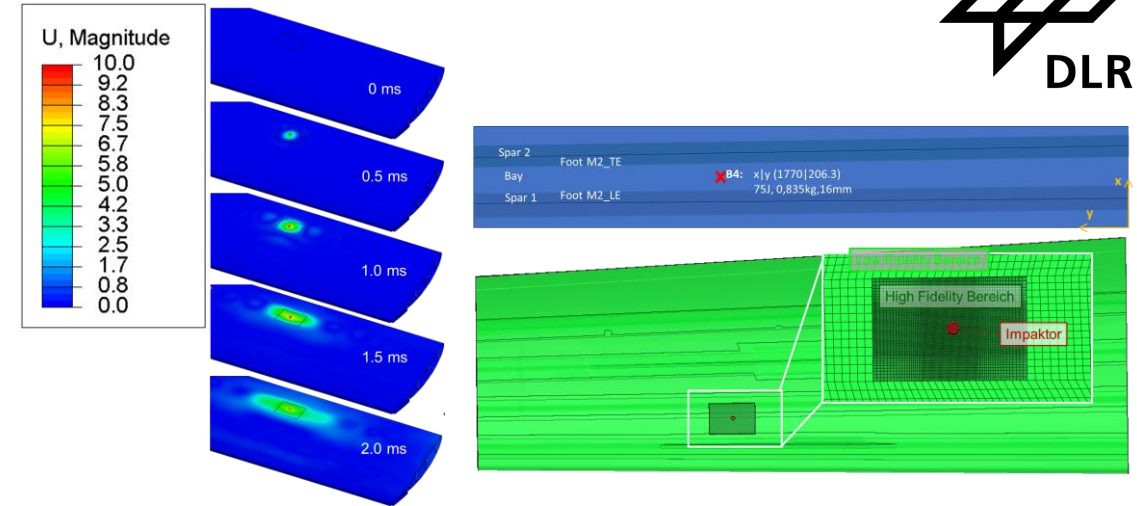
Damage Tolerance

Impact Simulation (Hail and Foreign Objects):

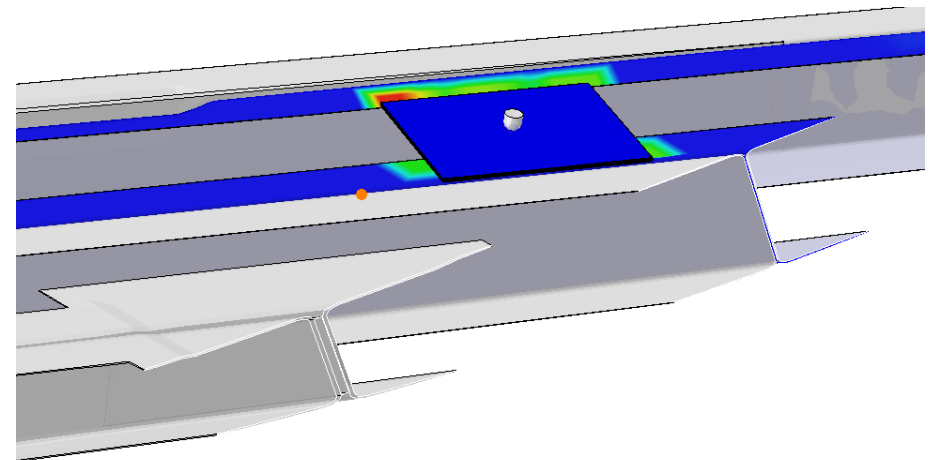
- Analysis on structural level to consider structural particularities due to stiffeners
- Integration of high-fidelity analysis methods
- Evaluation of resulting local and global damages



→ Local delamination at impact position



Time history for integrated high-fidelity analysis method



→ Global damage in surrounding stiffener areas

Virtual Testing

Damage Tolerance

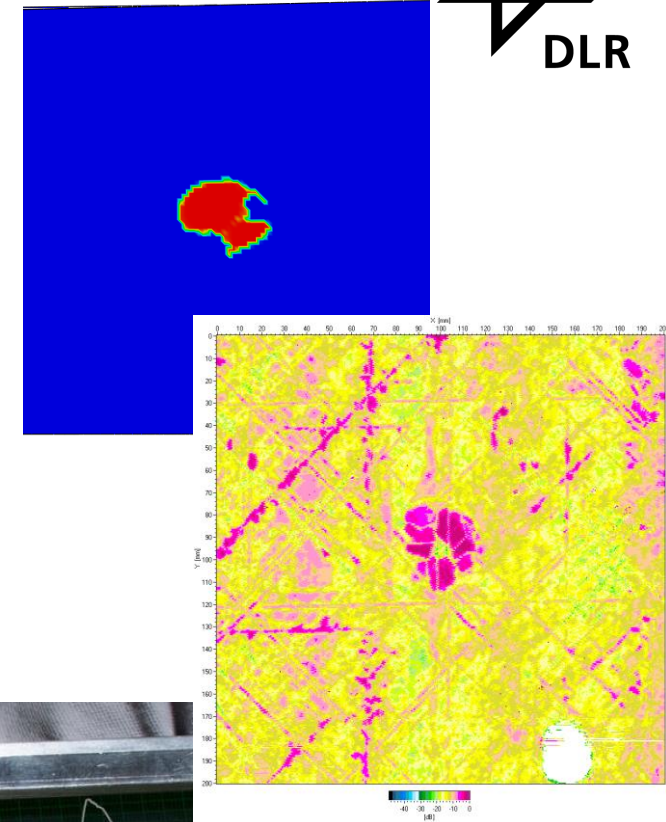


Realistic impact testing with mobile gas gun:

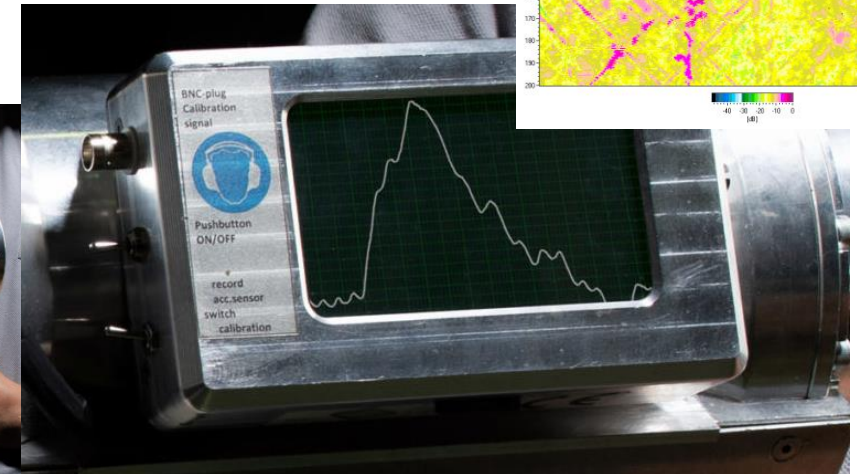
→ Target: BVID (40...110J)

→ Representative component elasticity

- Simulated Hail impact
- Simulation of FOD (Foreign Object Damage)



Contact-Force-Time history





CONCLUSION

Conclusion



Opportunity → Continuous Improvement

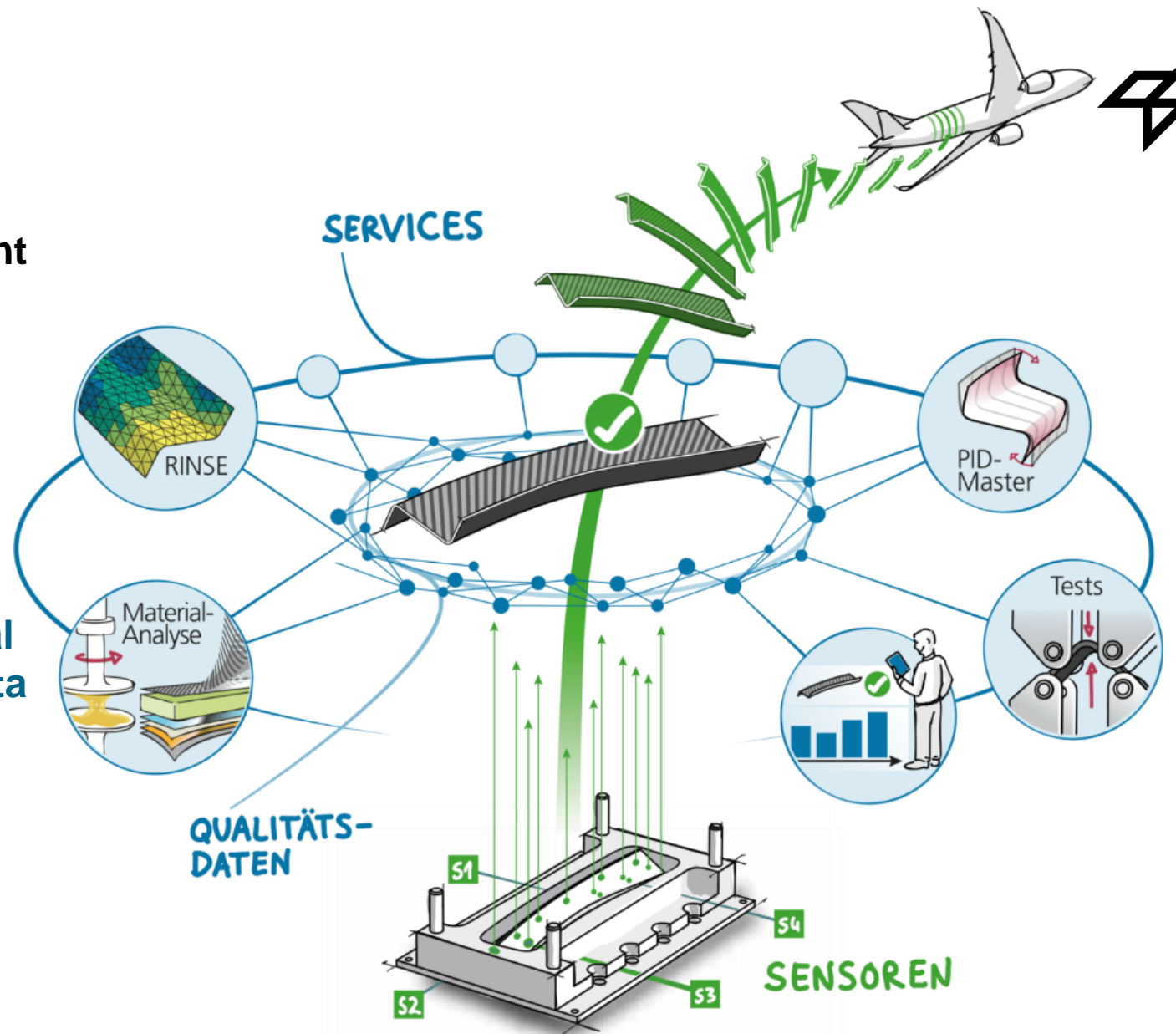
- Reduced process times
- Lower quality fluctuations
- Reduced scrap
- Knowledge management
- In line Quality Assurance

→ **Virtual certification of each individual component based on real quality data**

Challenge

- Handling of more complex scenarios
- Data acquisition and fusion approach
- Analyses algorithms

→ **Benefit and Effort need to be balanced**



Thank you for your attention!

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Funding:

Dieses Vorhaben wurde aus Mitteln des Europäischen Fonds für regionale Entwicklung (EFRE) gefördert.

This project was funded through European Regional Development Fund.



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