TOWARDS THE VALIDATION OF MANUFACTURING SIMULATIONS BY MEANS OF DIGITAL TWINS: CONCEPTION, IMPLEMENTATION AND DATA ACQUISITION FOR A COMPOSITE AIRCRAFT MOVEABLE MANUFACTURING PROCESS

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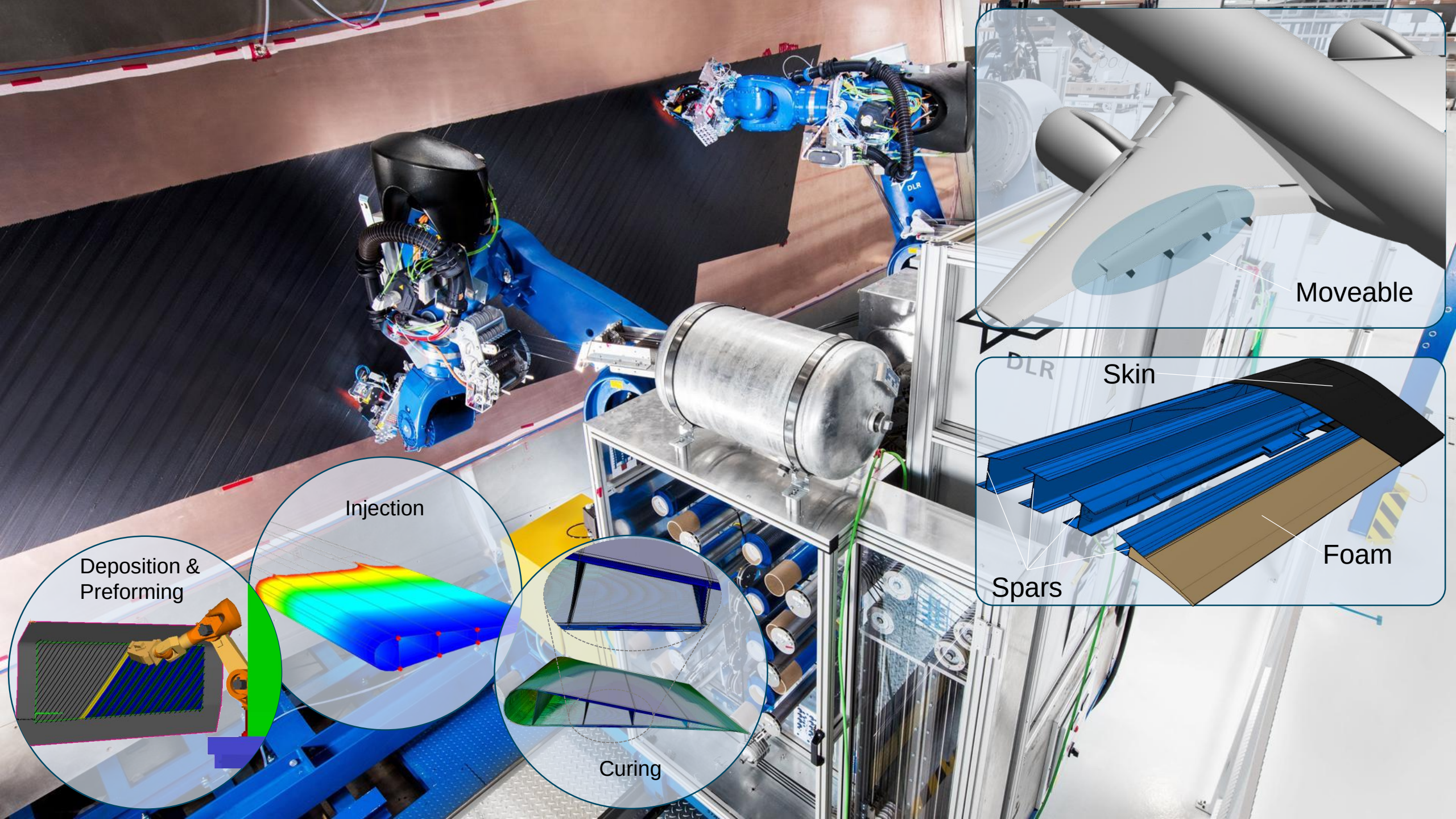
Deutscher Luft- und Raumfahrtkongress

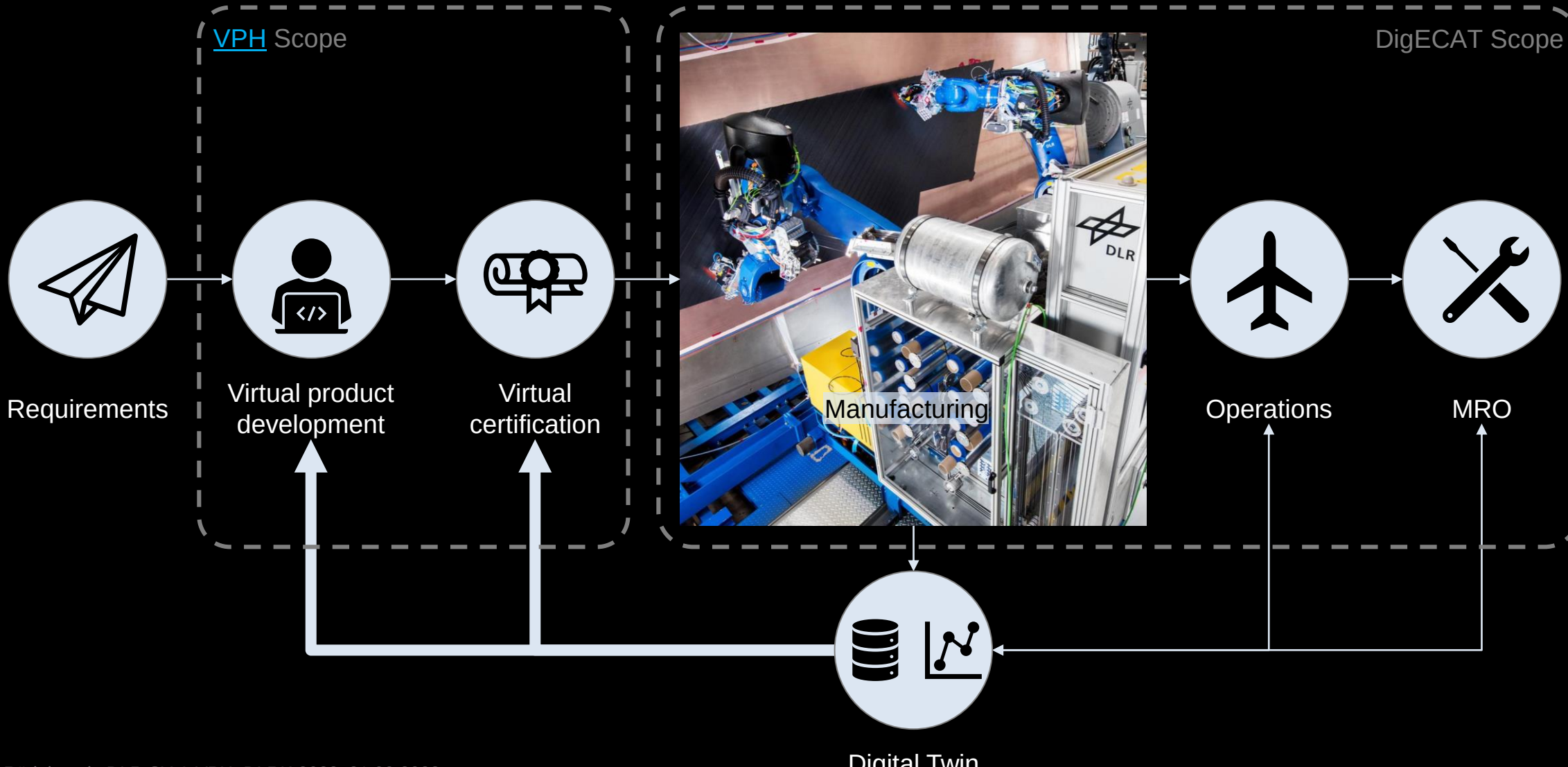
21.09.2023, Stuttgart

DLR


Moveable
Skin
Foam
Spars
Injection
Deposition &
Preforming
Curing

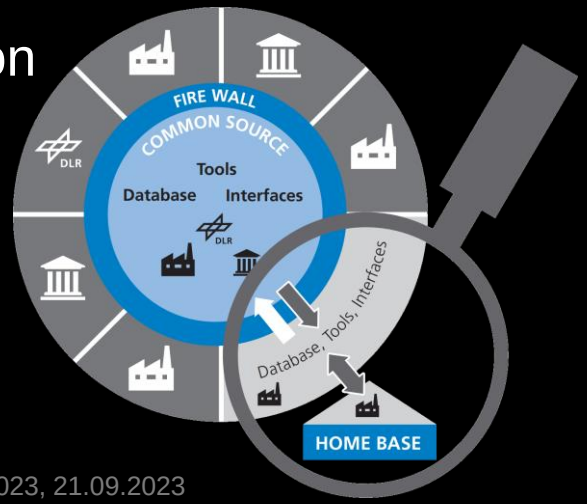
Context

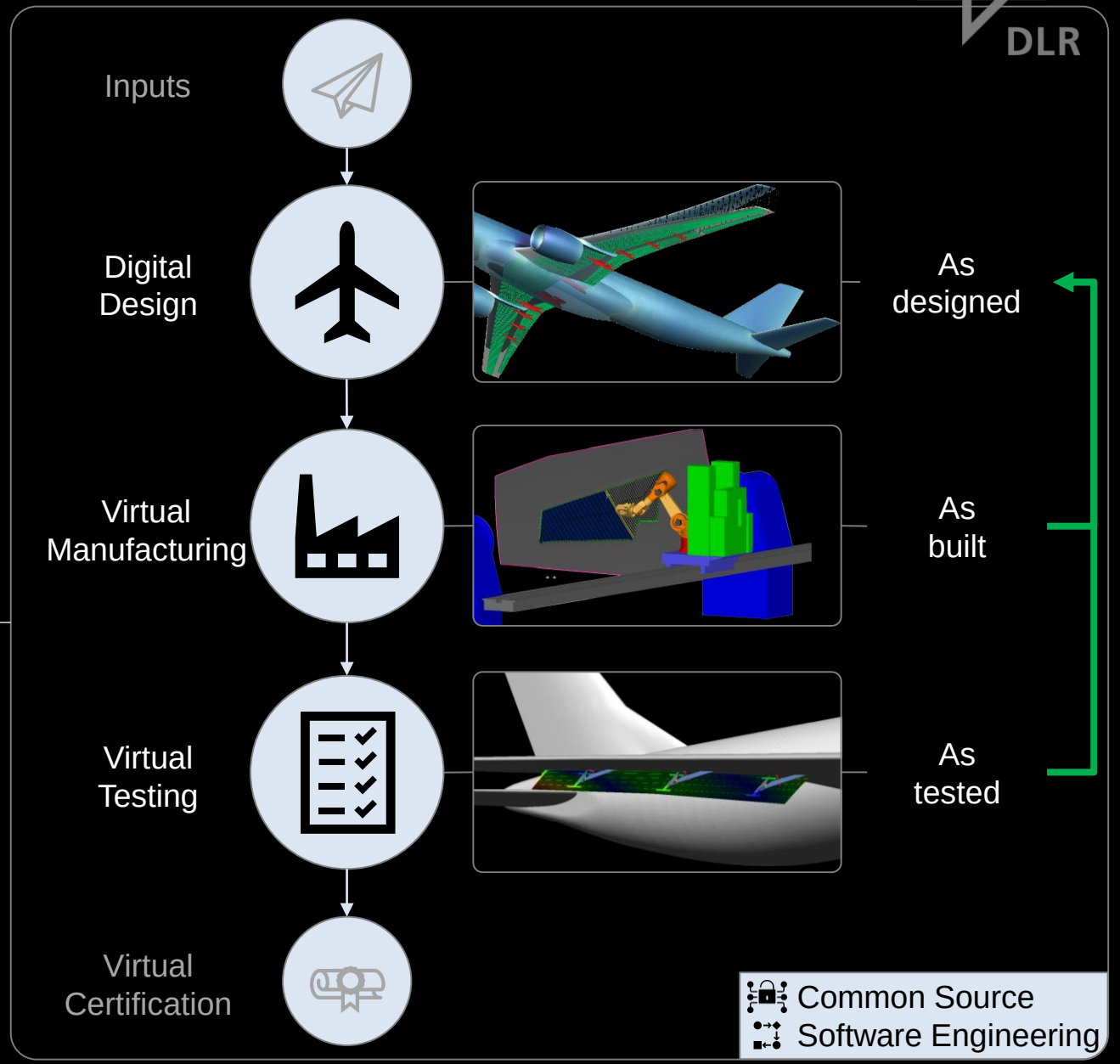
Product lifecycle



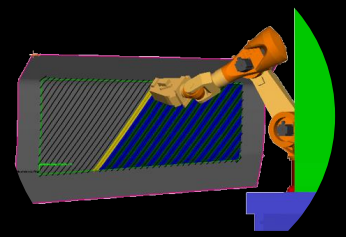
VPH

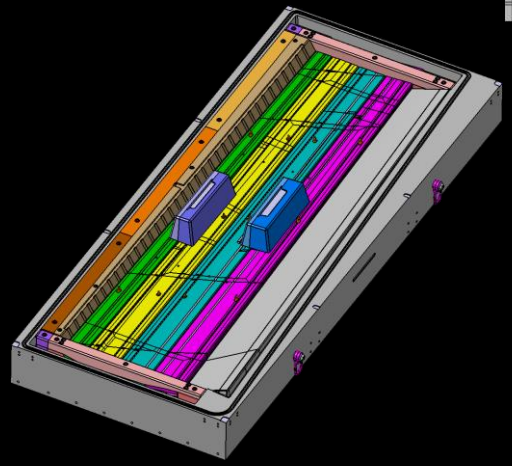
- Task
  - Integration & test center in Bremen
  - For virtual simulation & certification components & technologies
  - Integration in overall aircraft
- Approach:
  Digital end2end process
  - Technical
  - IT, collaboration & data

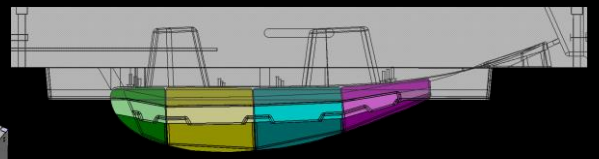




- Verification & validation approach:
- Validation requirements
  - Measure
  - Prepare
  - Manufacture
  - Store & evaluate
  - Simulate
- Use case





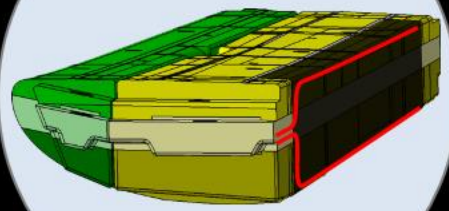


[1]

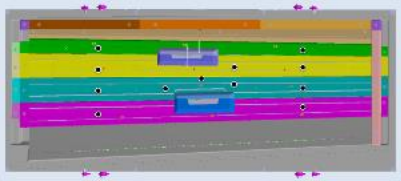
- Steps & entities
- Positions
  - Mold
  - Product
- With AIRBUS
- Types:
- > 80 sensors

Degree of cure

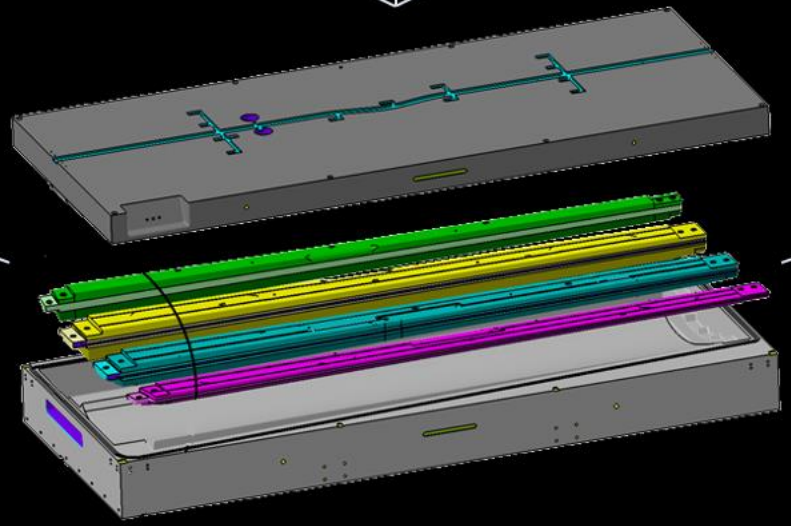
Flow front



Strain

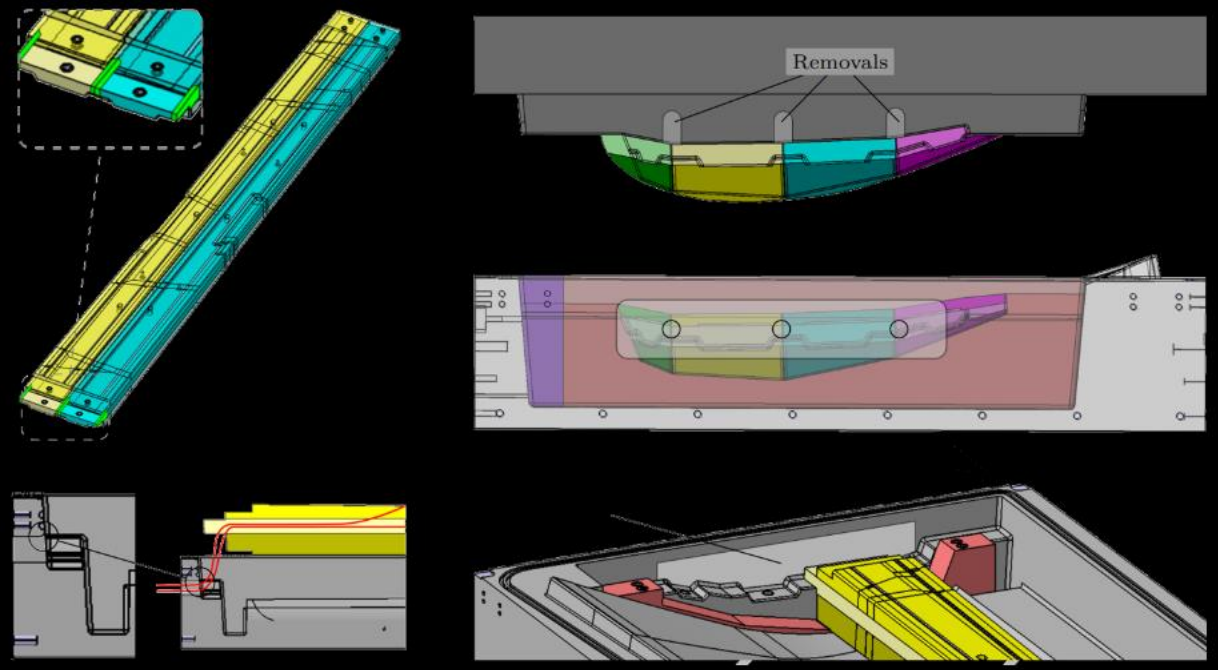


Temperature

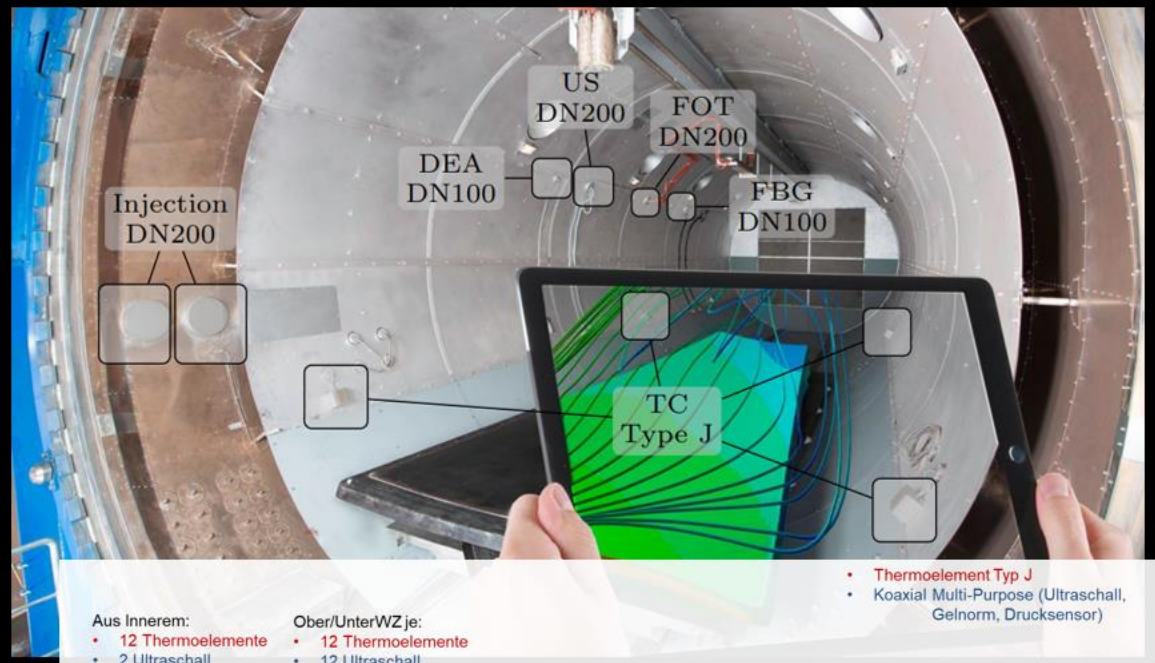


Pressure

- Mold



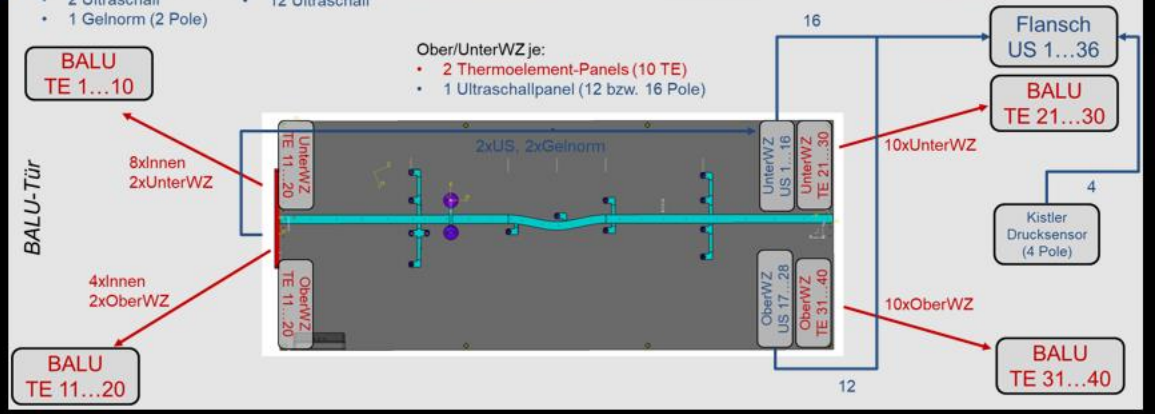
- Autoclave



- Thermoelement Typ J
- Koaxial Multi-Purpose (Ultraschall, Gelnorm, Drucksensor)

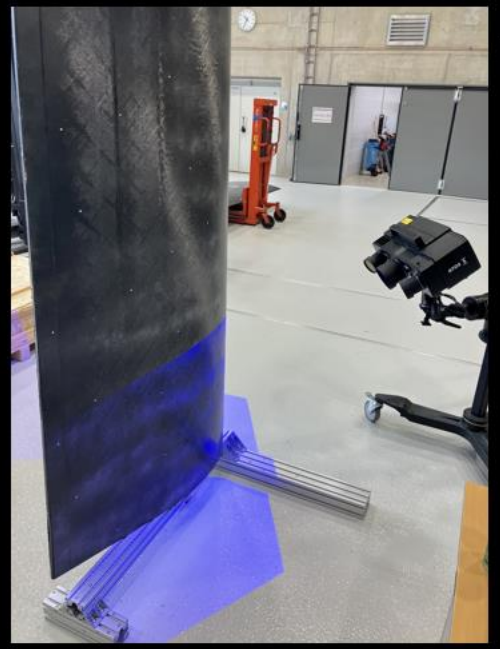
Aus Innerem:
- 12 Thermoelemente
- 2 Ultraschall
- 1 Gelnorm (2 Pole)

Ober/UnterWZ je:
- 12 Thermoelemente
- 12 Ultraschall

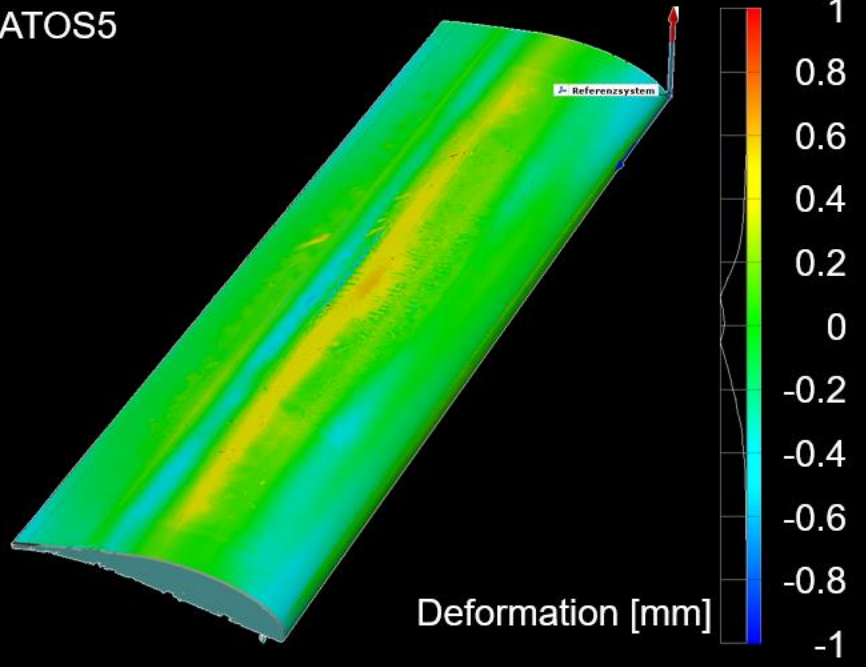


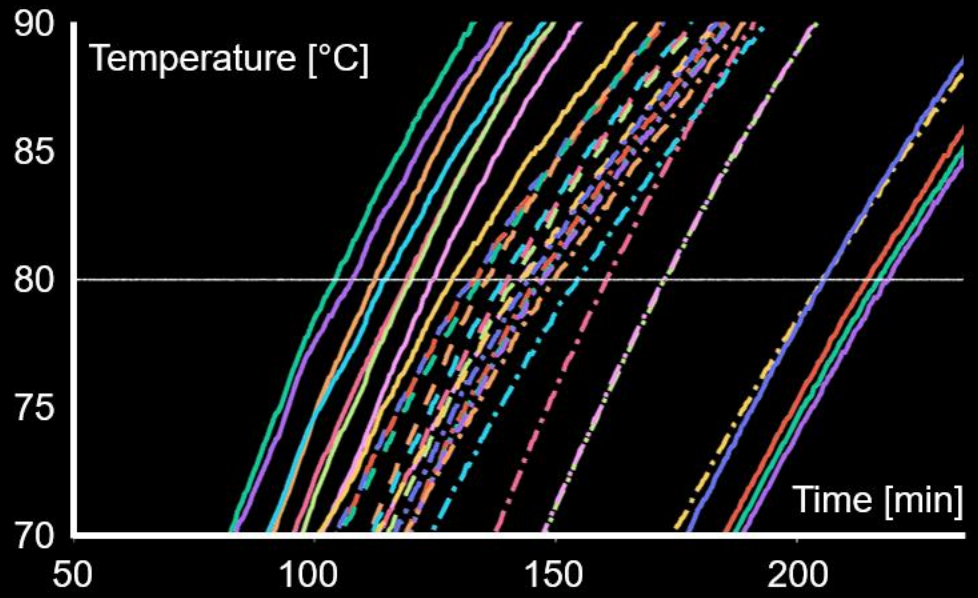
Finale Werkzeugausrüstung und Sensorintegration im Autoklav

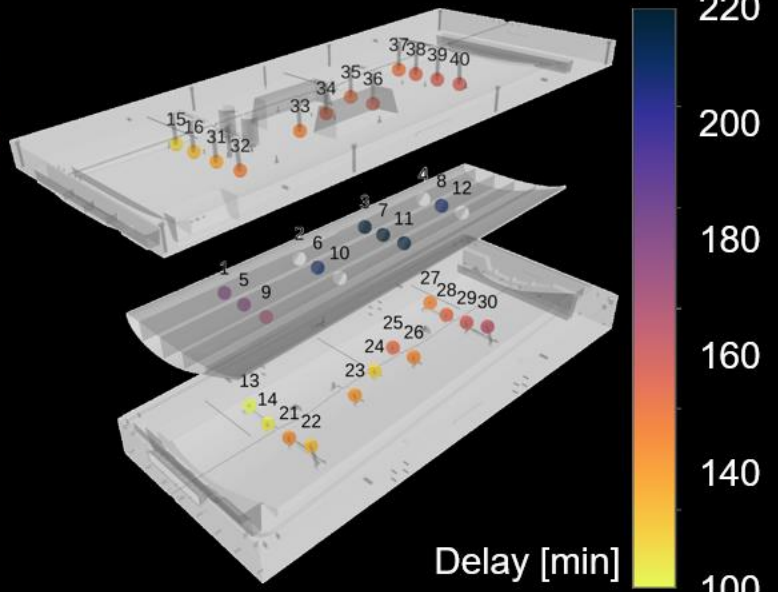
- Additional measurements
- Data management: shepard [2]
- Multiple sources & digital twins
- Added values: Evaluations



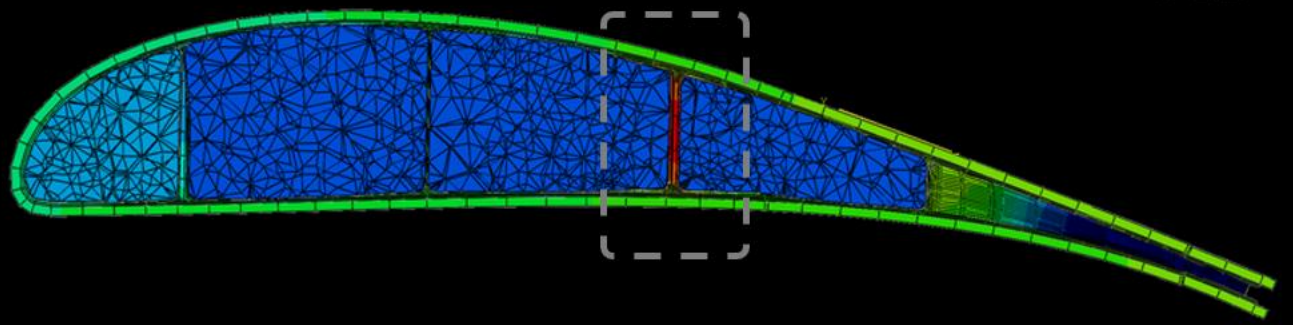
ATOS5



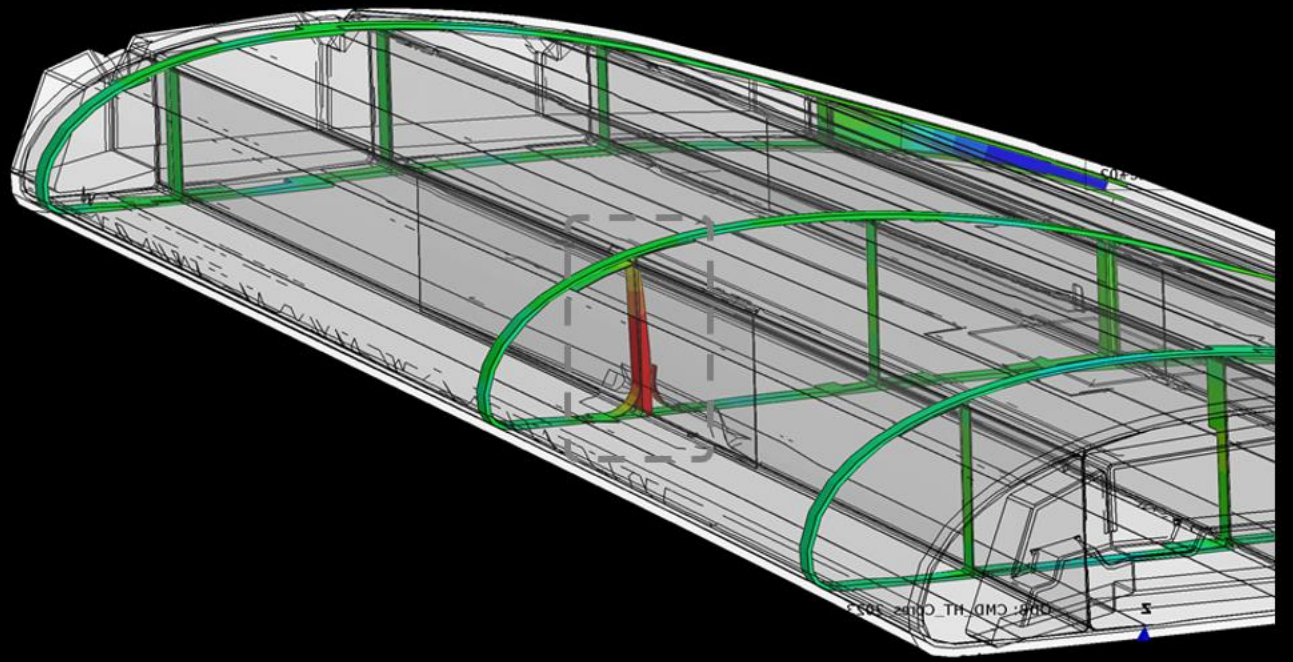


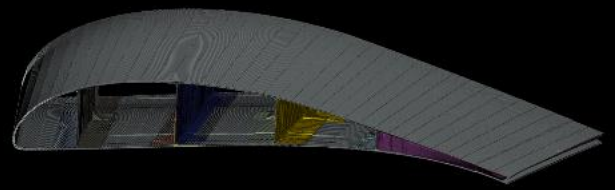


- Abaqus FEM model with anisotropic viscoelastic UMATs
- Standard cycle:
  - Hot spots due to exothermal reaction
  - Structure probably damaged



Nodal temperature
Max: 249°C

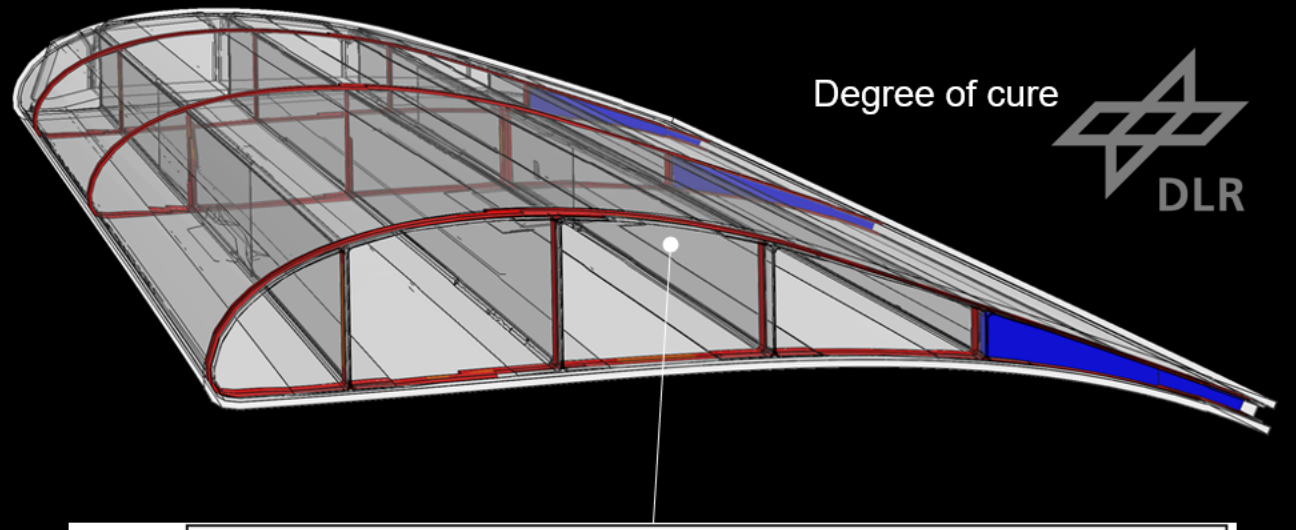


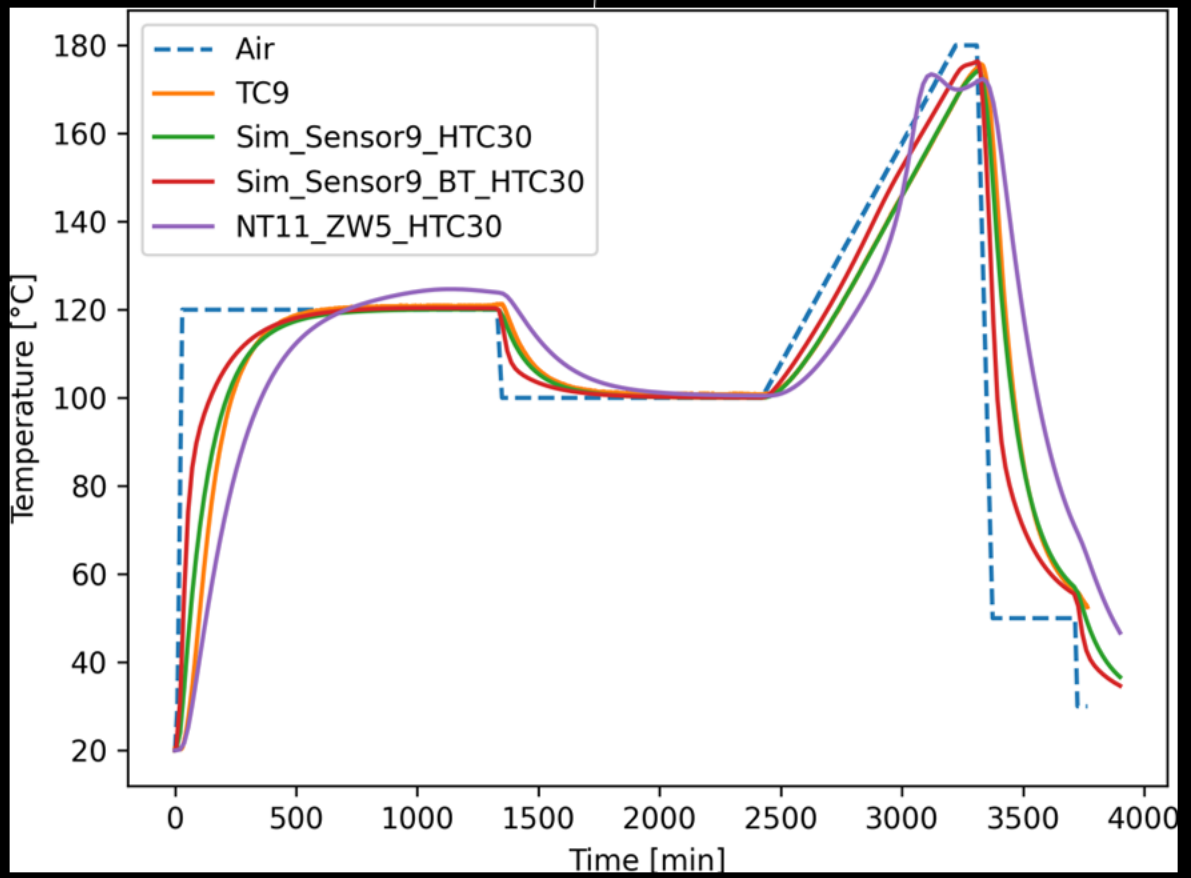


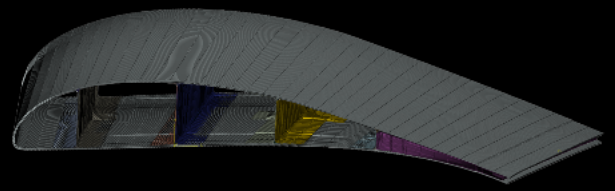
Simulate

Process simulation

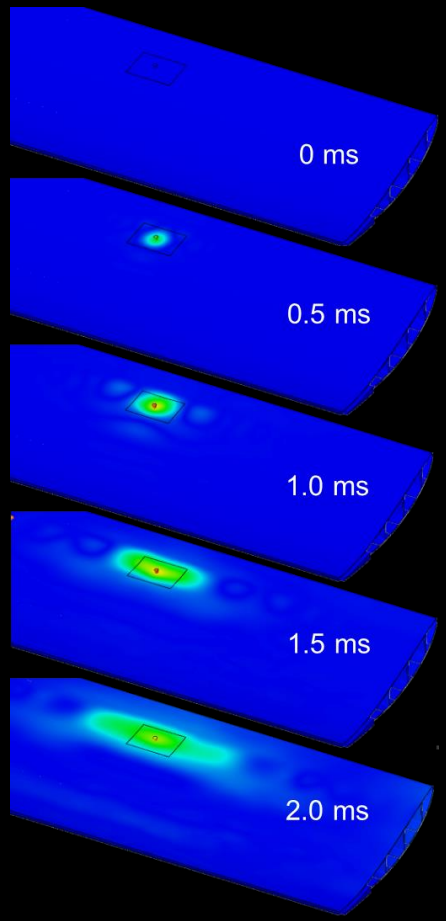
- Abaqus FEM model with anisotropic viscoelastic UMATs
- Standard cycle:
  - Hot spots due to exothermal reaction
  - Structure probably damaged
- Long cycle:
  - Degree of cure: ~91%
  - Tg ~167°C
  - Very good agreement



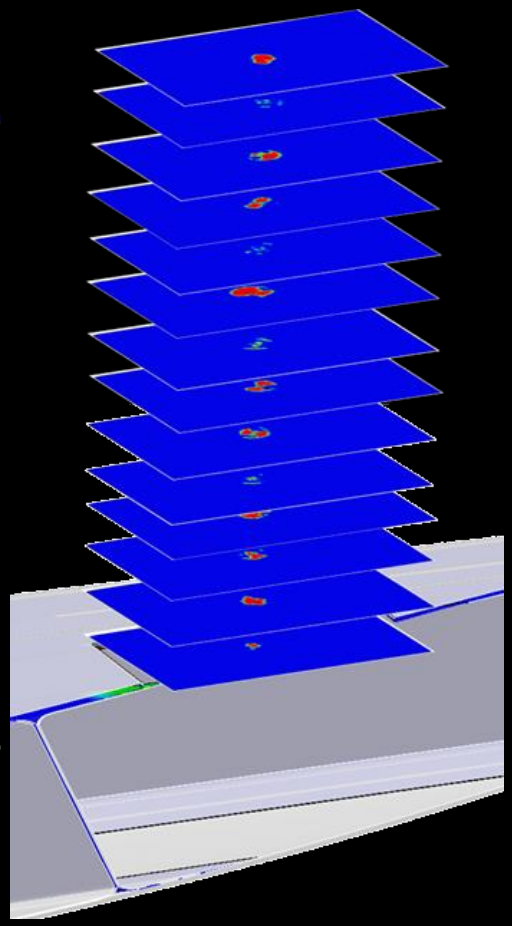




- Digital twin valuable asset in virtual certification validation
  - Added values
  - Edge computing
- Requires a lot of DLR skill set
- Manufacturing planning & provenance information [3]
- Measurement data valuable input for testing
- Uncertainty quantification & robustness analysis pending



Deformation



Damage

Damage tolerance testing

THANK YOU FOR YOUR ATTENTION

Contact

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(1) ASME: Standard for Verification and Validation in Computational Solid Mechanics, V V 10 - 2019

(2) Tobias Haase, Roland Dr. Glück, Patrick Kaufmann, and Mark Willmeroth. shepard - storage for heterogeneous product and research data. Technical report, Deutsches Zentrum für Luft- und Raumfahrt e.V., July 2021. URL https://elib.dlr.de/143136/

(3) Frank Dressel and Alen Doko. Common source & provenance at virtual product house. In Deutscher Luft- und Raumfahrtkongress 2021. Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal-Oberth e.V., 2021. doi: https://doi.org/10.25967/550061. URL https://elib.dlr.de/144515/

Topic:	Towards the validation of manufacturing simulations by means of digital twins: conception, implementation and data acquisition for a composite aircraft moveable manufacturing process
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