Structural Mechanic Aspects of CFRP Fuselage Structures

ESAComp User‘s Meeting 2007, April 24th – 25th,
„Advances in Design and Analysis of Composite Structures“

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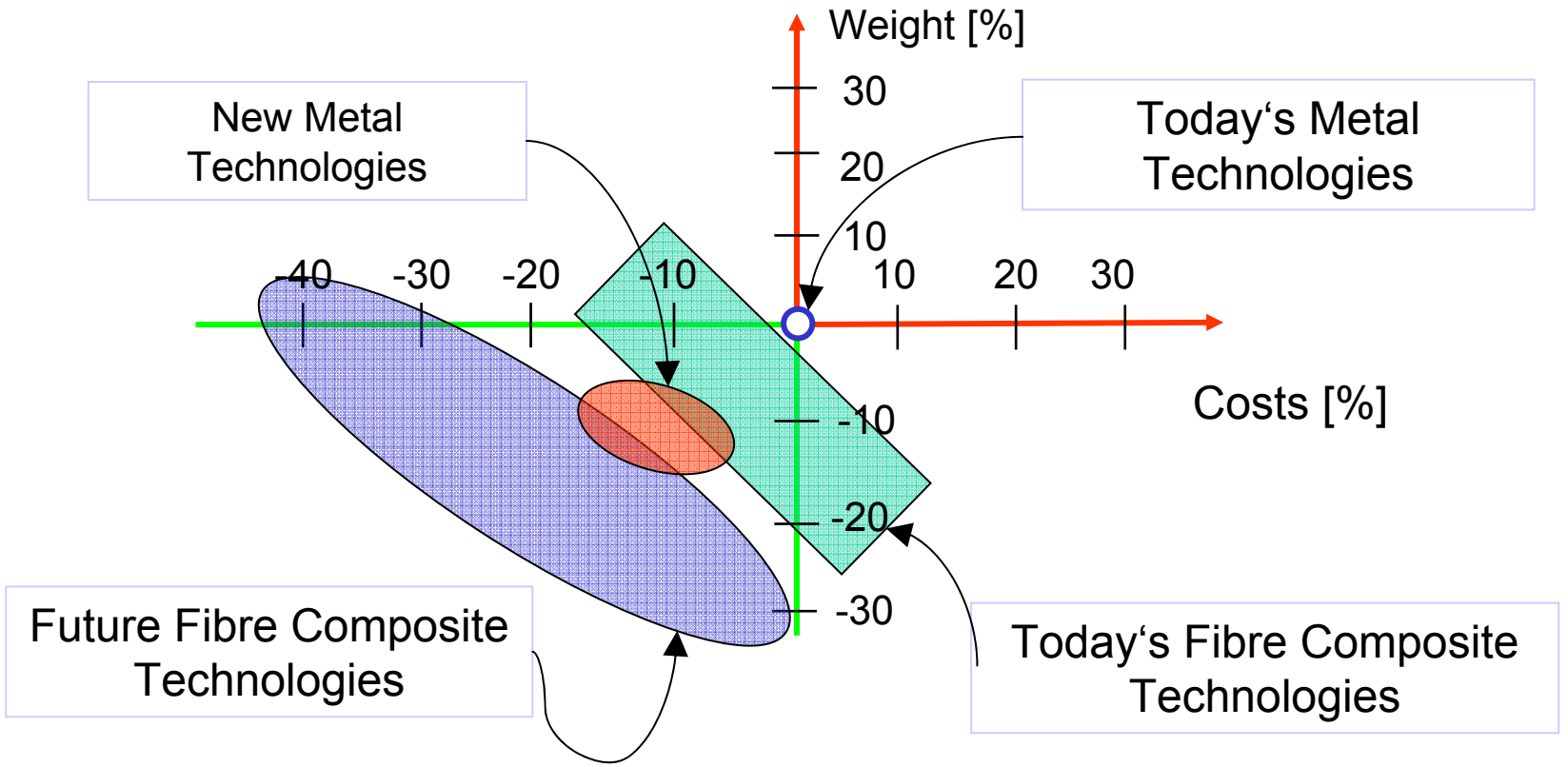
Overview

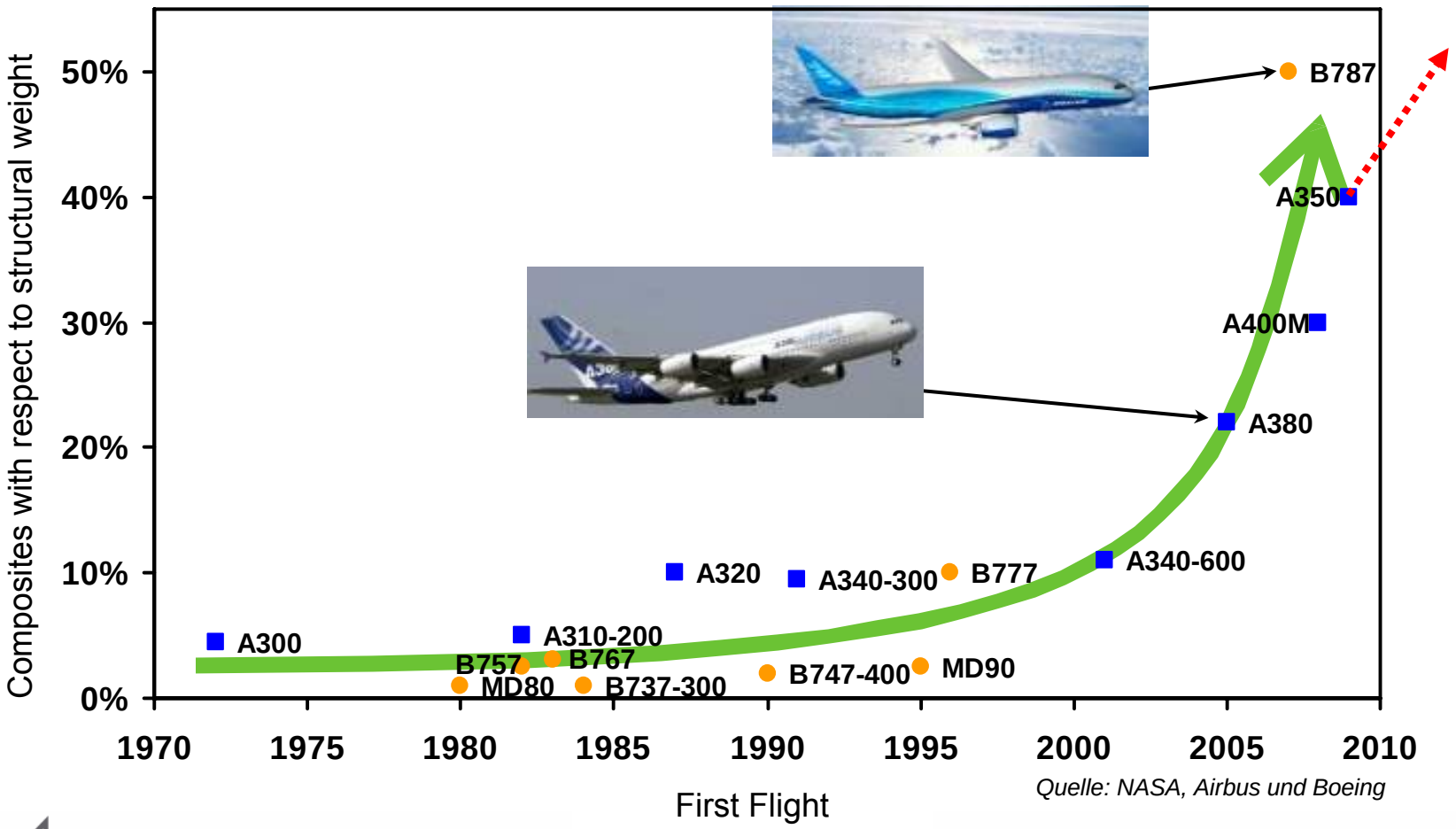
- Introduction
- Competences and Working Areas in Structural Mechanics at DLR
- Validation
- Experimental Methods
- Non-Destructive Testing (NDT)
- Virtual Testing
- Global-Local Approach
- Fast Tools for Design
- Structural Health Monitoring (SHM)
- Summary and Conclusions

Challenges and Motivation for High-Performance Lightweight Structures



Targets: Weight Reduction → Cost Reduction → Saving of Resources

Utilization of Composites – A Steep Slope



Quelle: NASA, Airbus und Boeing

Competences and Working Areas in Structural Mechanics

Health Monitoring

Validation and Qualification

Virtual Testing

Modelling and Simulation of whole Life Cycle

Simulation Based Design

Deformation, Stress and Failure Analysis

Stability Analysis

Damage Tolerance

Thermal Analysis

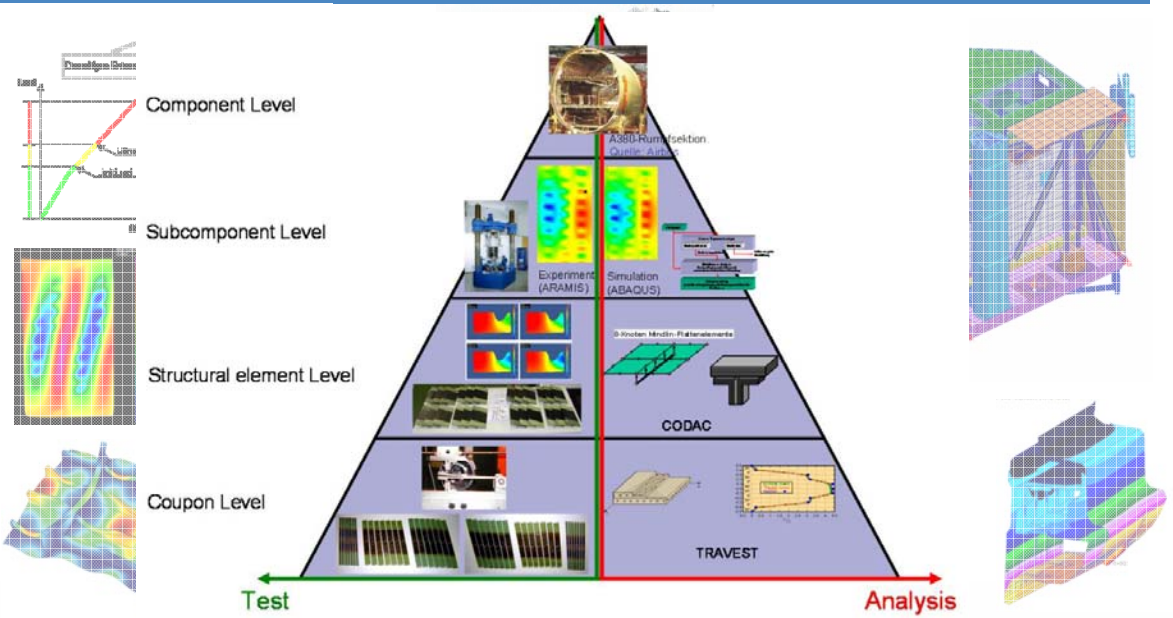
NDT/SHM

Validation

Experimental Structural Analysis (EXSACOM)

Competences

Working Areas

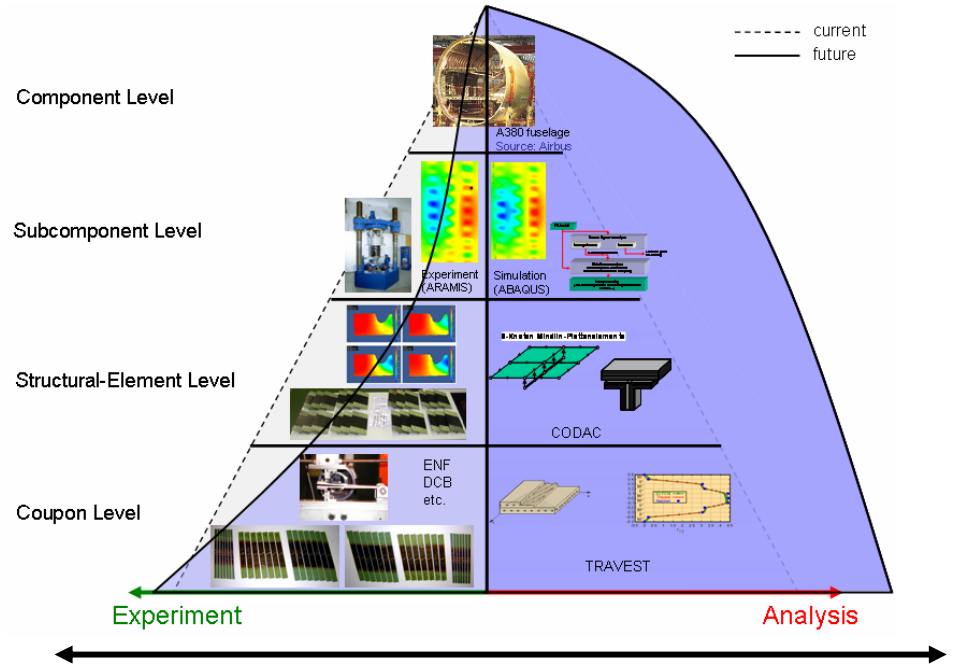


Spectrum of Working Areas

Health Monitoring | Validation and Qualification | Virtual Testing | Modelling and Simulation of whole Life Cycle | Simulation Based Design

Experimental Methods

- **Efficient testing facilities**
- **Qualifikation of structural concepts**
- **Structural Health Monitoring (SHM)**



Numerical Methods

- **Fast Design Tools**
- **Virtual Structures**
- **Structural Exploitation**

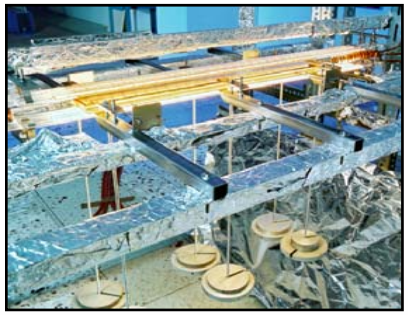
Validation

There is an industrial need of validated analysis tools

- Deformation, Stress and Failure Analysis
- Stability Analysis
- Damage Tolerance
- Thermal Analysis
- NDT/SHM
- Validation
- Experimental Structural Analysis (EXSACOM)

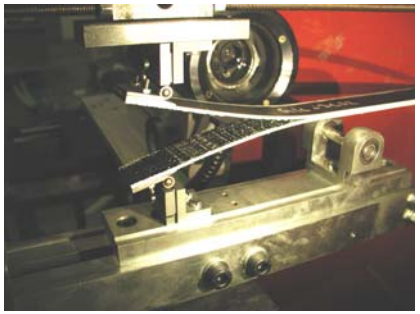
Validation
„Solve the right equations“

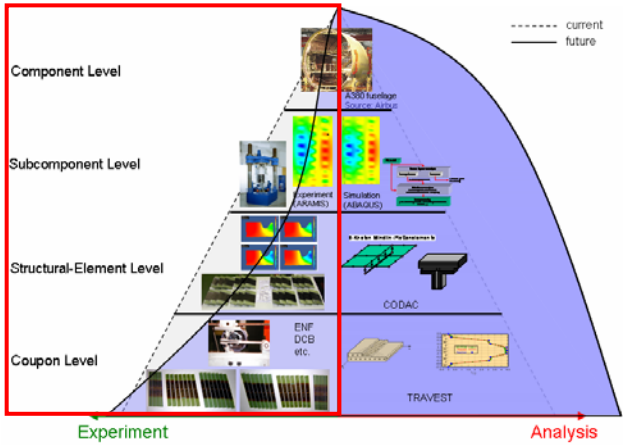
Experimental Structural Analysis
(Test Field, Buckling Device, Thermex, Ultrasonic Facilities ARAMIS, …)



Experimental Methods

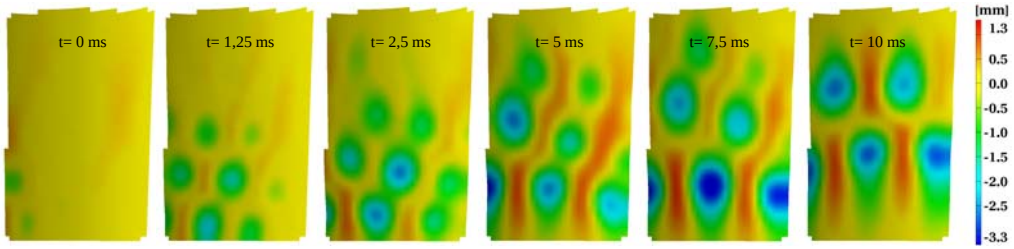
Characterization Exp.



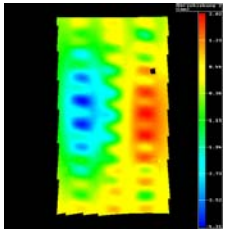


Qualification Exp.

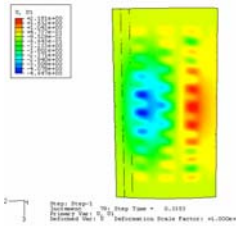
Phenomenological Experiment



Validation Experiment

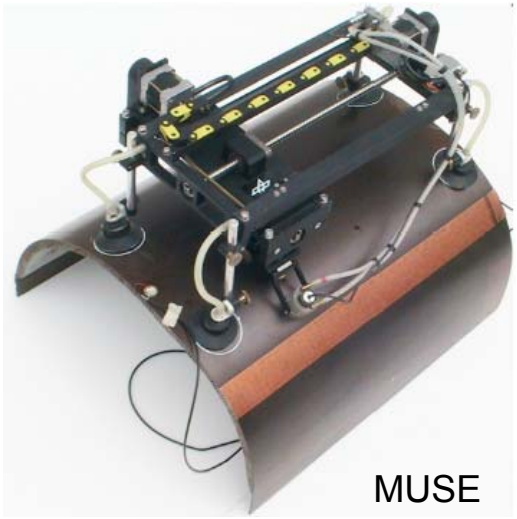


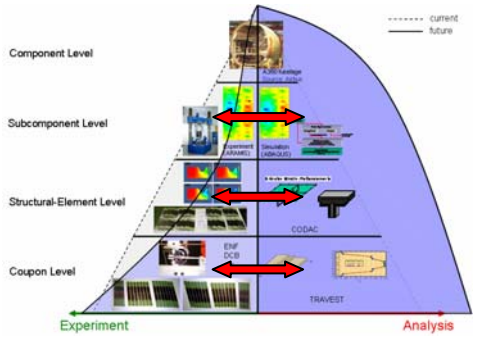
Experiment

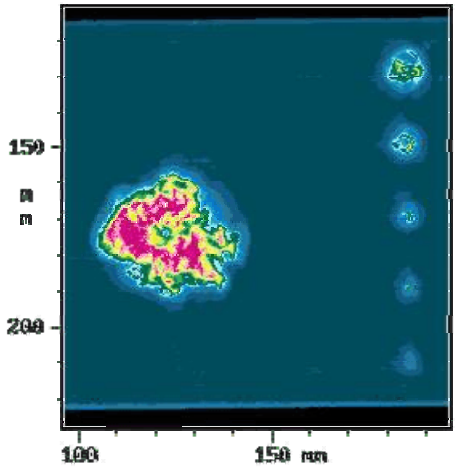


Nonl. FEM Analysis

Non-Destructive Testing (NDT)

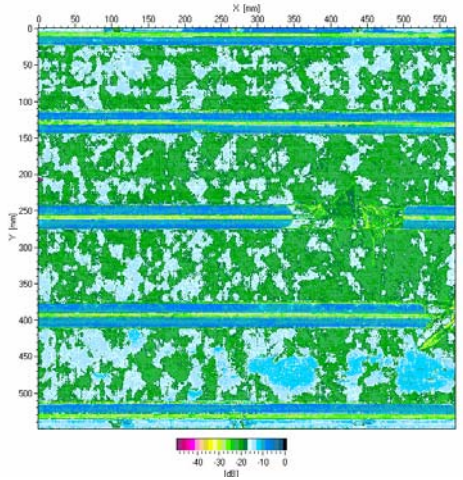






Working Areas:

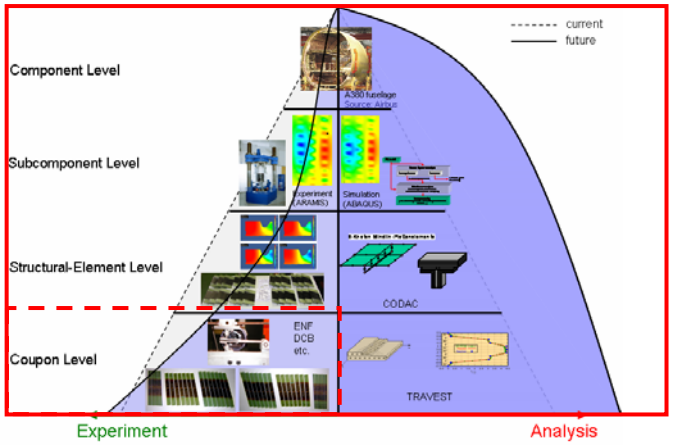
- Coupling by air
- Mobile System (MUSE)
- Detection of porosity

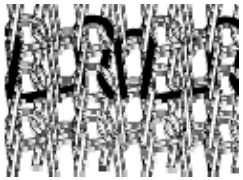


Damages after collapse of a stiffened panel

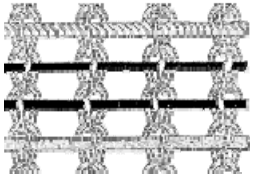
Increasing Number of Material Systems

Monolithic

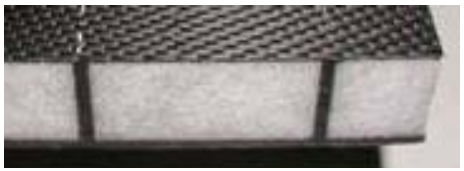


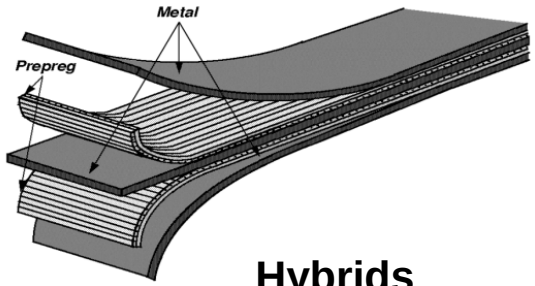


Textiles



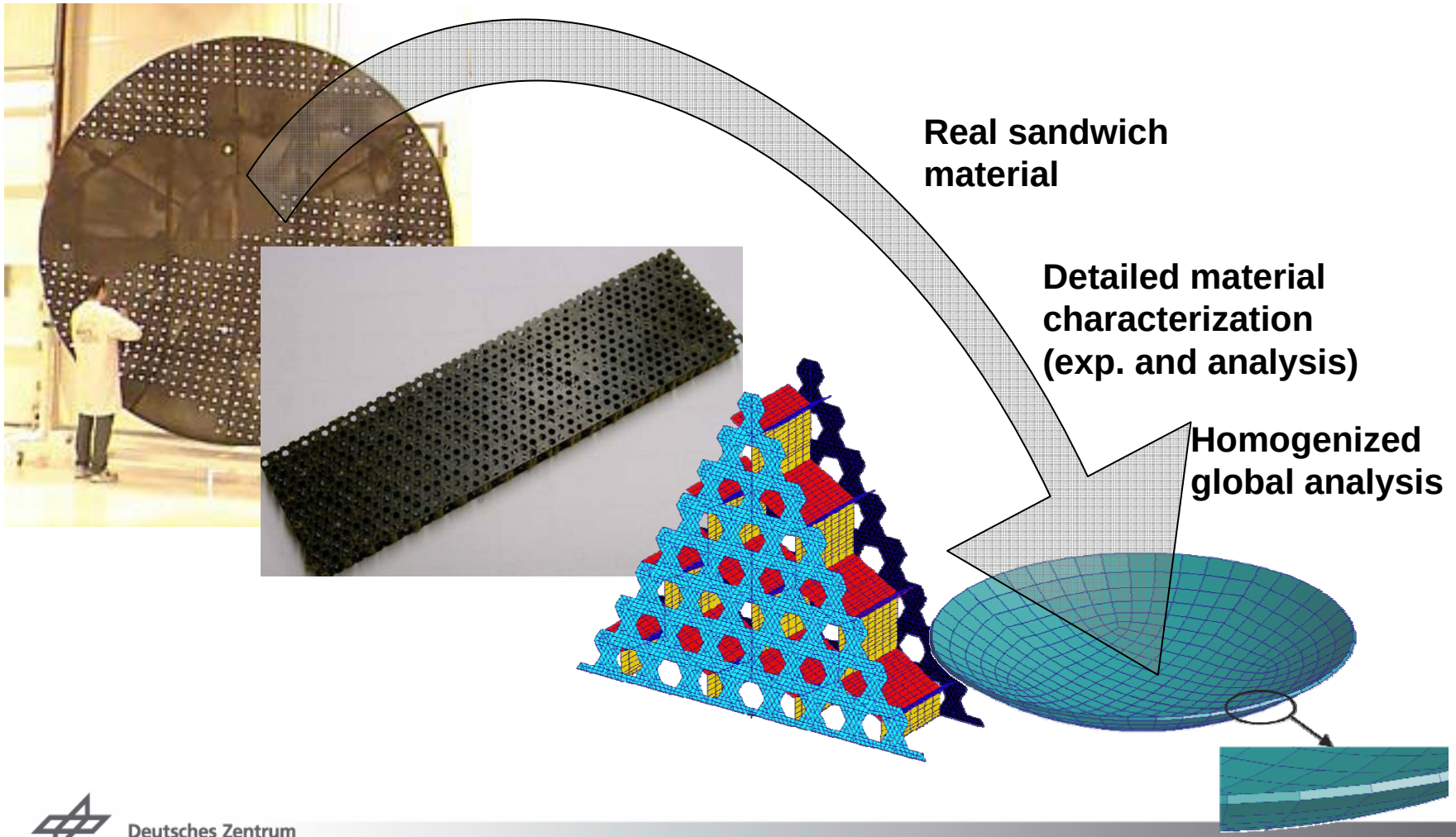
Sandwich





Hybrids

Antenna Structure Made of Perforated Sandwich

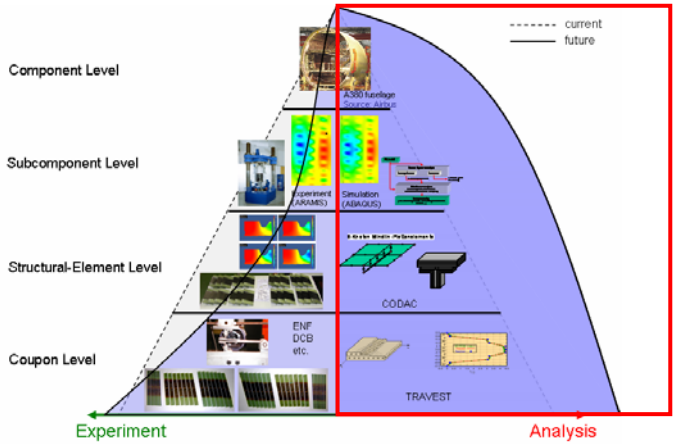


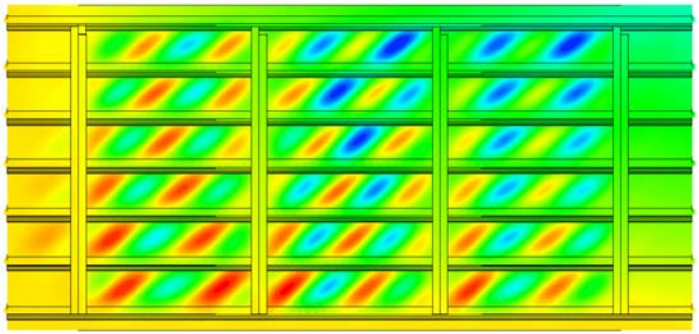
Virtual Testing

Set up of virtual test to:

Reduce time and cost intensive experiments
To optimize test set-up:

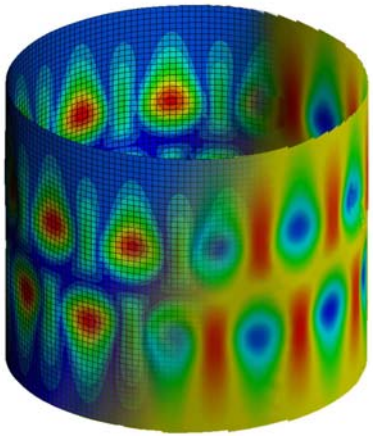
- “Validation” experiments
- „Pre-test“ analysis
- „First time right“





Shear loaded A340 panel

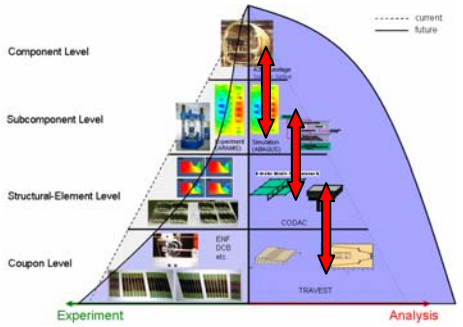
FEM



Full field exp. Measurement (ARAMIS)

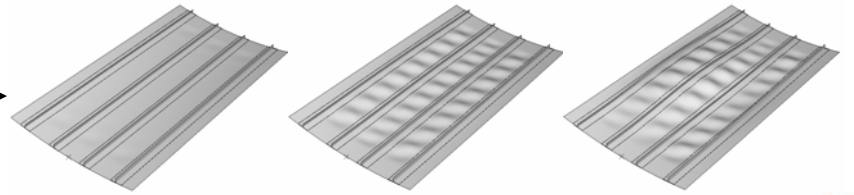
Axially loaded cylinder

Global-Local Approach (Submodeling)

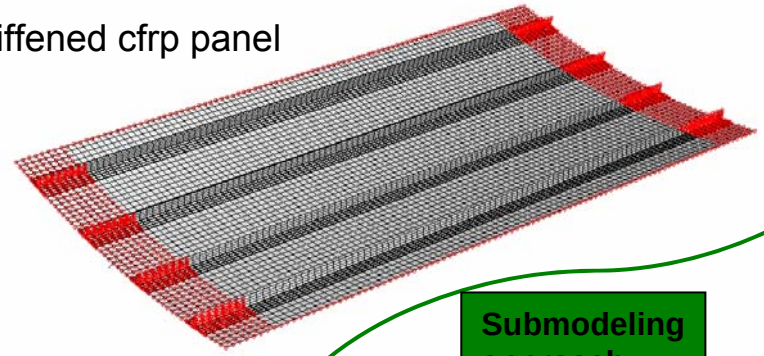


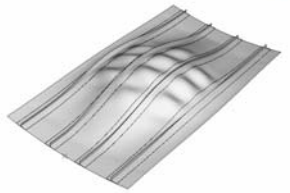
Matlab mesh generator
Global model

NI. FEM (ABAQUS)

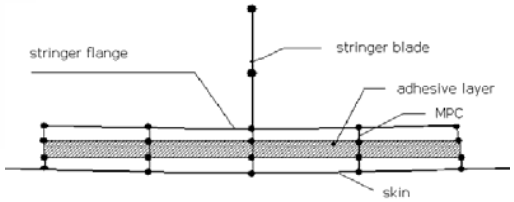


stiffened cfrp panel





Submodeling approach (ABAQUS)

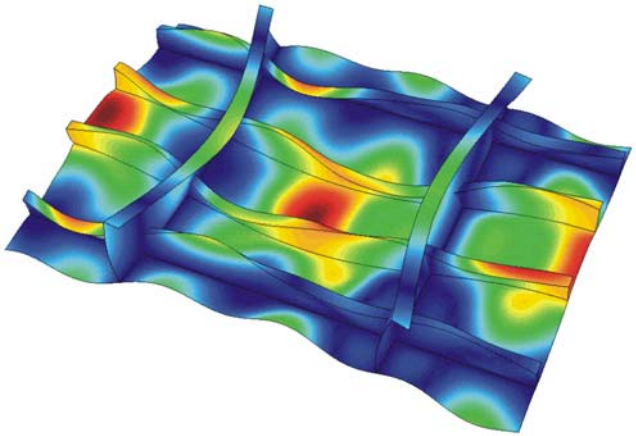


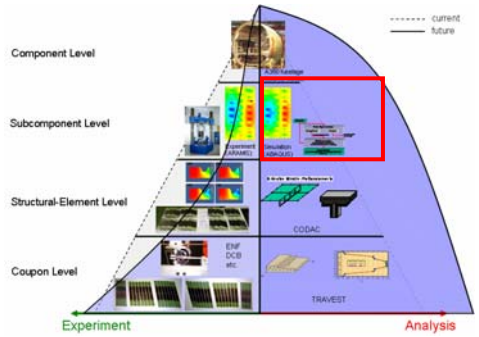
Python script to obtain simple stress based indication of critical areas in the stringer-skin interface

NI. FEMs ABAQUS + stress based failure criteria

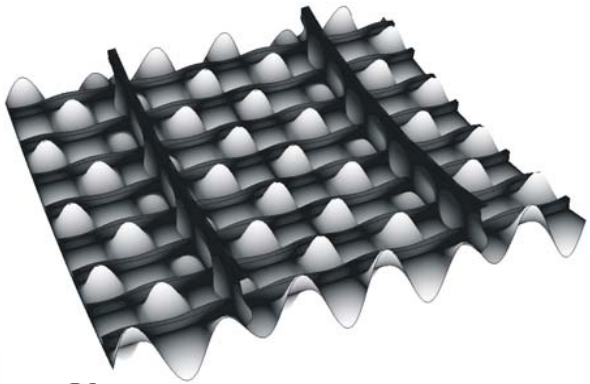
Matlab mesh generator
Local Models with focus
on the stringer-skin interface

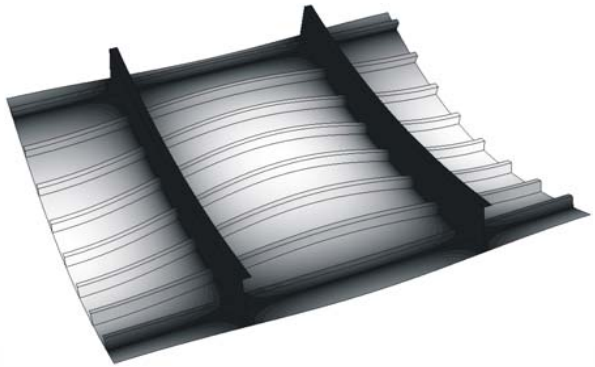
Fast Tools for Design – Stability Analysis

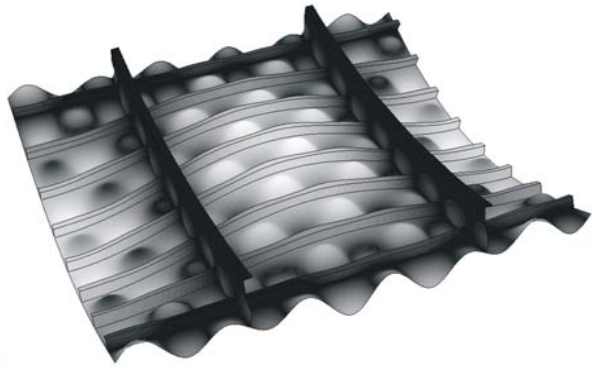




E.g. IBUCK: Semi-analytical design tool to simulate the buckling and post-buckling behaviour of stiffened panels

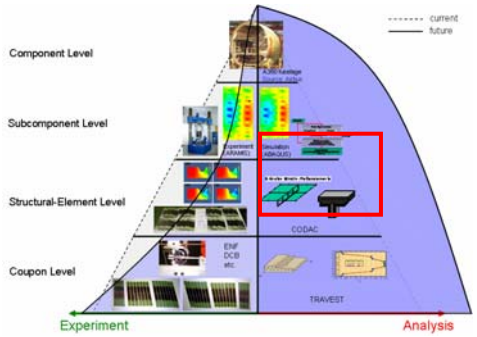




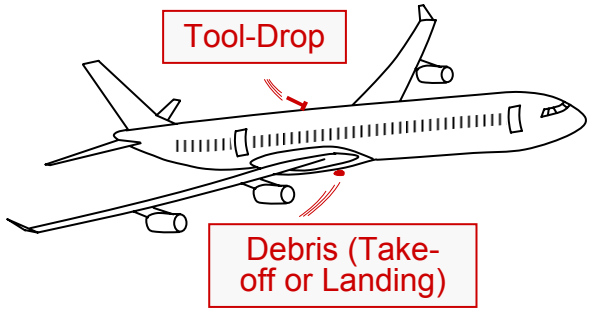


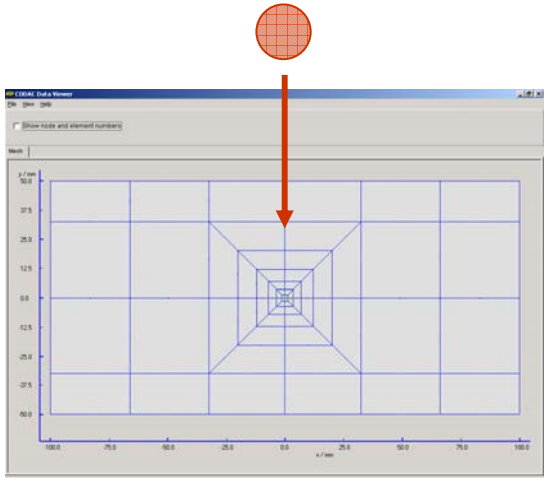
Fast Tools for Design – Impact (1)

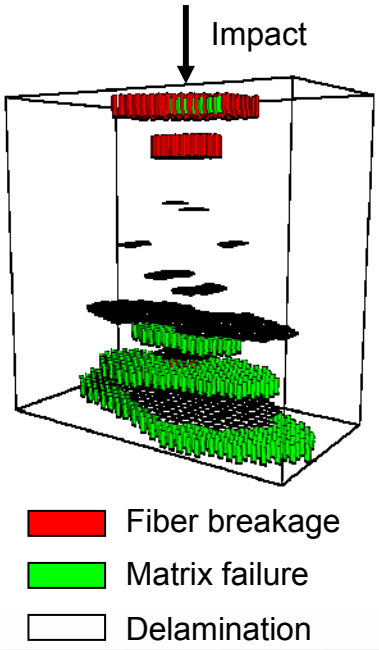
- **CODAC =** **Co**mposite **Da**mage Tolerance **A**nalysis **C**ode
- Analysis of impact damages and residual strength for composite structures
- Based on the FE-method



Low-velocity Impacts

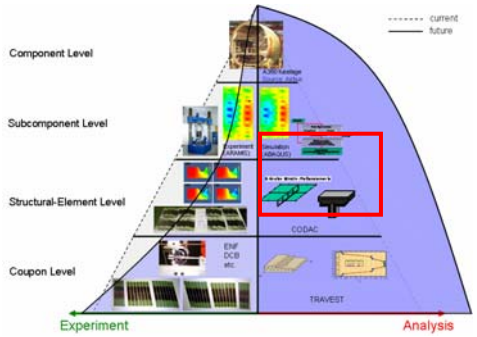


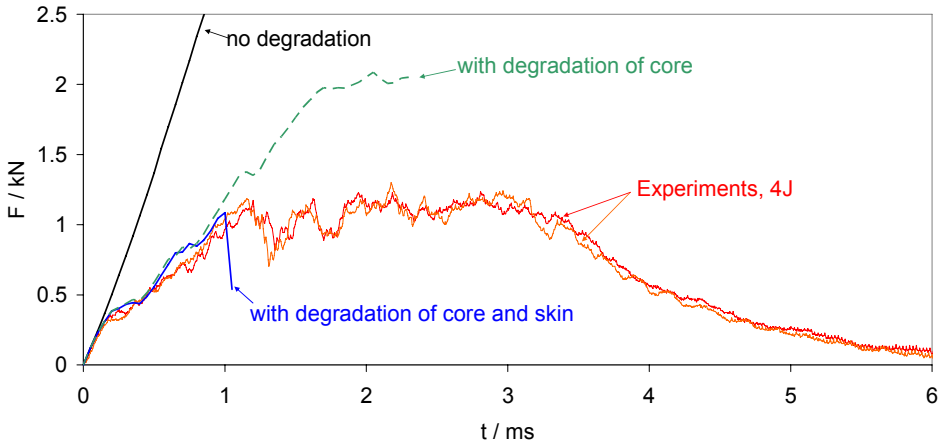


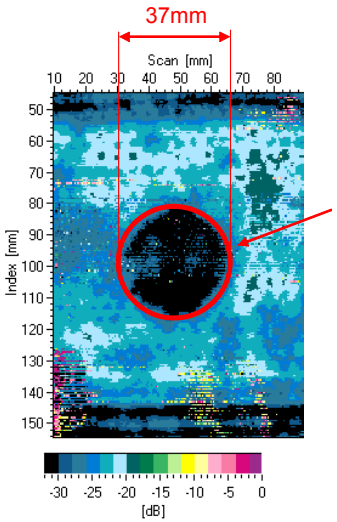


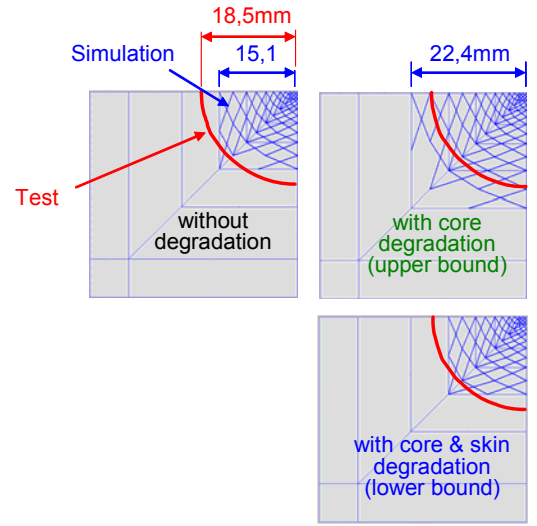
Fast Tools for Design – Impact (2)

- Impact simulation on composite sandwich panels
- Comparison of num. and exp. results show good results









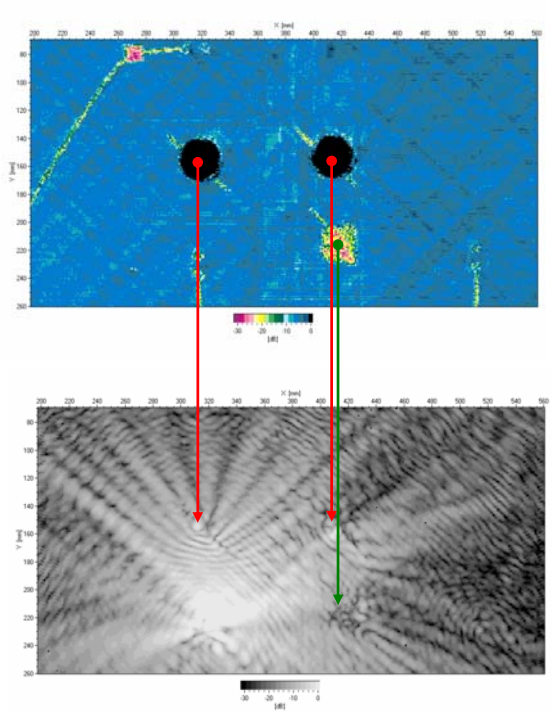
Structural Health Monitoring (SHM)

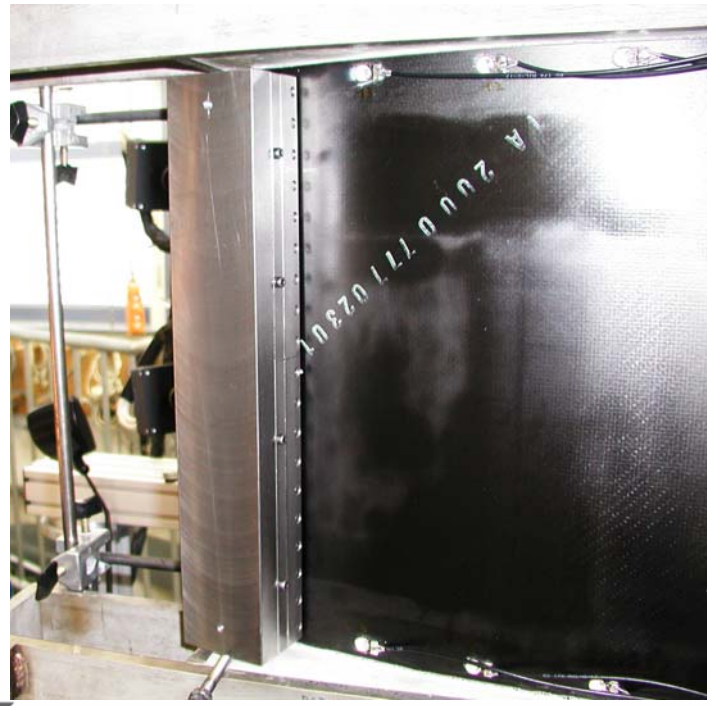
Objectives:

- Simplified inspection
- Continuous monitoring

Concepts:

Lamb-wave analyses





Summary and Conclusions

- **Brief insight into some relevant structural mechanic aspects for CFRP fuselage structures have been given.**

- **Validated analysis tools essential for save, efficient (cost and time) design**
  - State of the art experimental methods
  - State of the art NDT/SHM methods
  - State of the numerical methods

- **Global-Local (submodeling) approach can be used as an “elevator” up and down in the “Rouchon“ pyramid**

Thank you for your attention

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