Challenges in the Validation of Stability Sensitive Multiaxialy Loaded CFRP Structures

DFG Workshop

Inauguration of the new Multiaxial Test Rigs at TU Braunschweig and Hamburg University of Technology

3 May 2012, TU Hamburg Harburg

Richard Degenhardt

DLR, Institute of Composite Structures and Adaptive Systems

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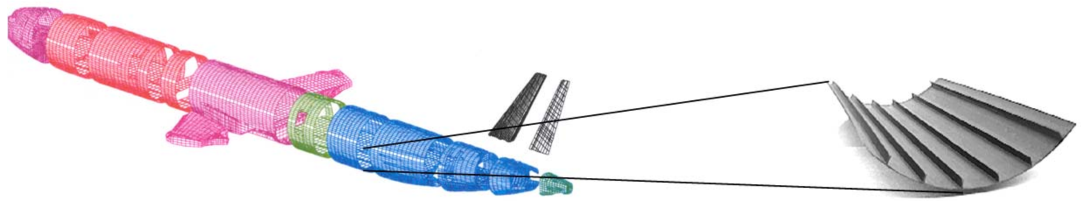
Content

- Introduction
- DLR Institute of Composite Structures and Adaptive Systems
- Comparison: Stiffened and unstiffened structures
- Examples
    - Aerospace



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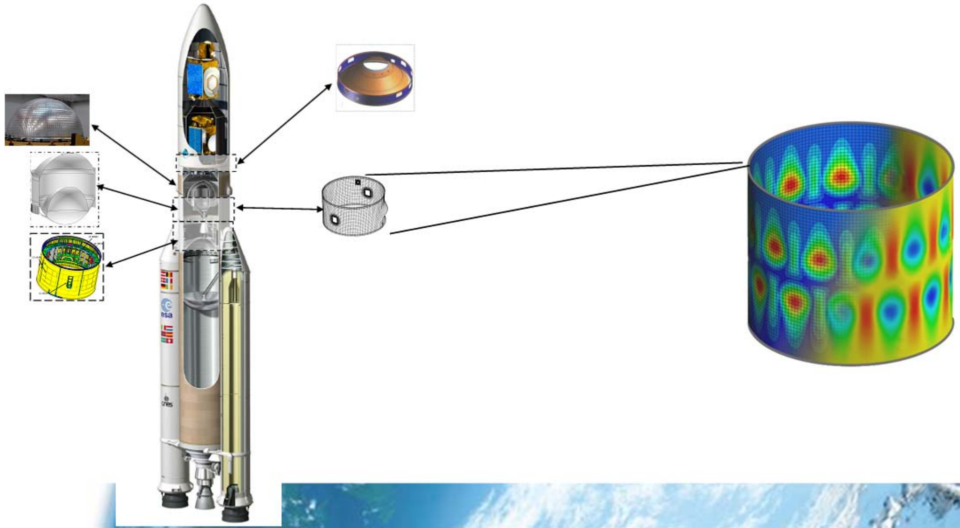

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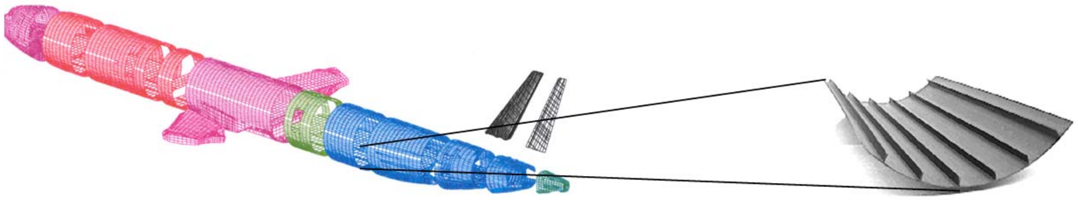

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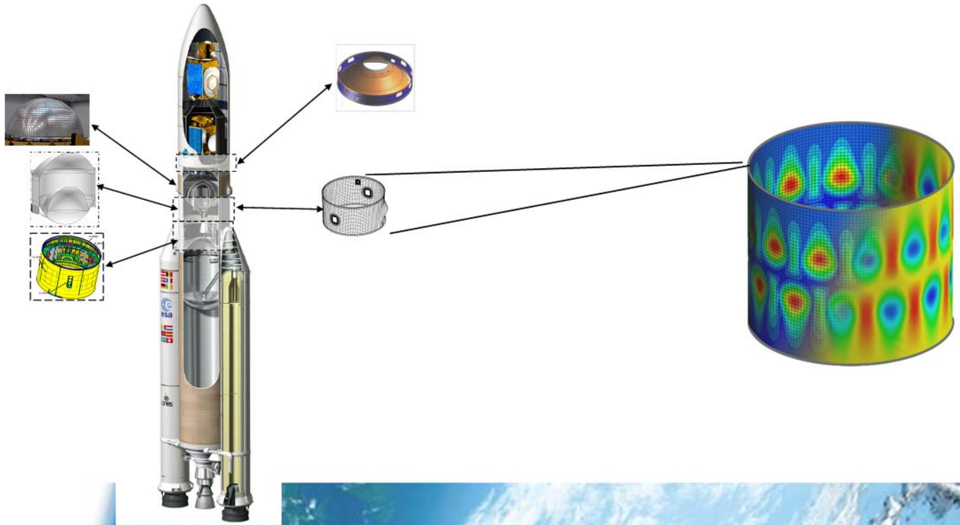

Motivation

1 kg less structural weight means saving of ca. 3 tons fuel in 20 operating years (A340-300)

Quelle: Airbus

Introduction

- The use of new materials as CFRP is one way to reduce structural weight.
- CFRP is already used in different primary structures (e.g. aerospace), however, the potential of CFRP is currently not fully exploited.
- One reason is that the material is still not fully understood and corresponding design guidelines are missing.
- Need for:
    - Improved design concepts and simulation tools
    - Validation by experimental results
- For a comprehensive validation especially experiments of multiaxialy loaded structures are needed.

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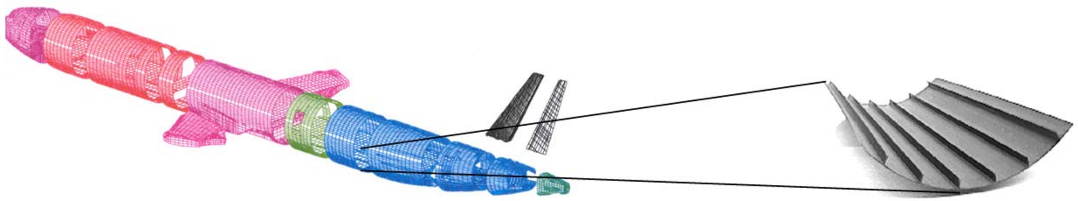

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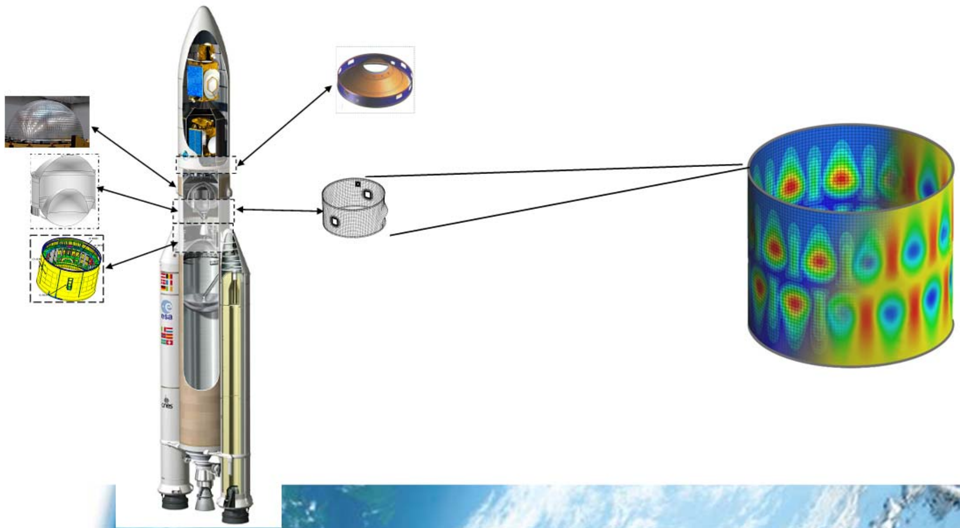

Institute of Composite Structures and Adaptive Systems

Director: Prof. Dr.-Ing. M. Wiedemann

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

Our research serves the improvement of:

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

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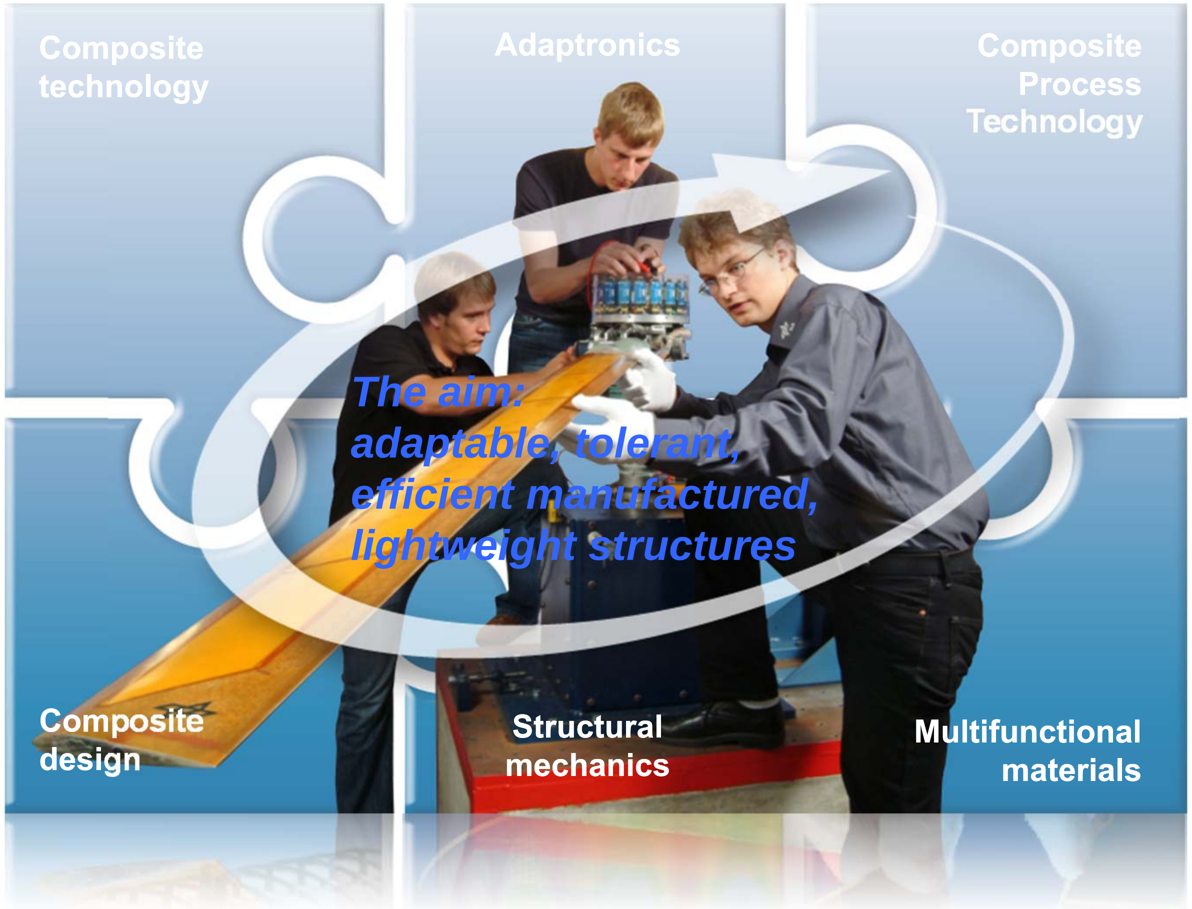
Our Professional Competences – Bricks of the
Process Chain of High Performance Lightweight Structures

We orient ourselves along the entire process chain for building adaptable, efficient manufactured, lightweight structures.

For excellent results in the basic research and industrial application.



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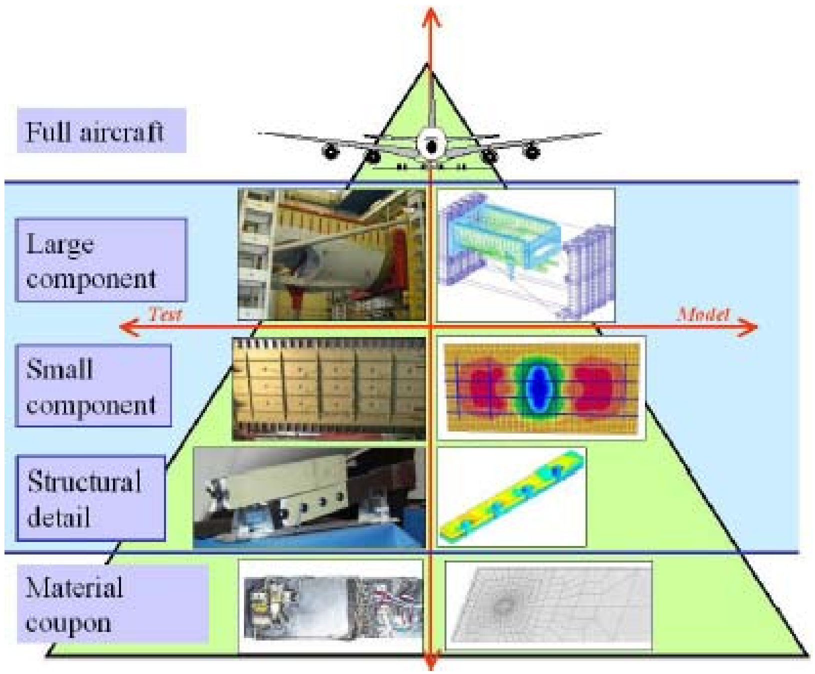
Structural Mechanics – Motto

Experimental Methods

- Efficient testing facilities
- Qualification of structural concepts
- Validation („Validation Experiments“)



Numerical Methods

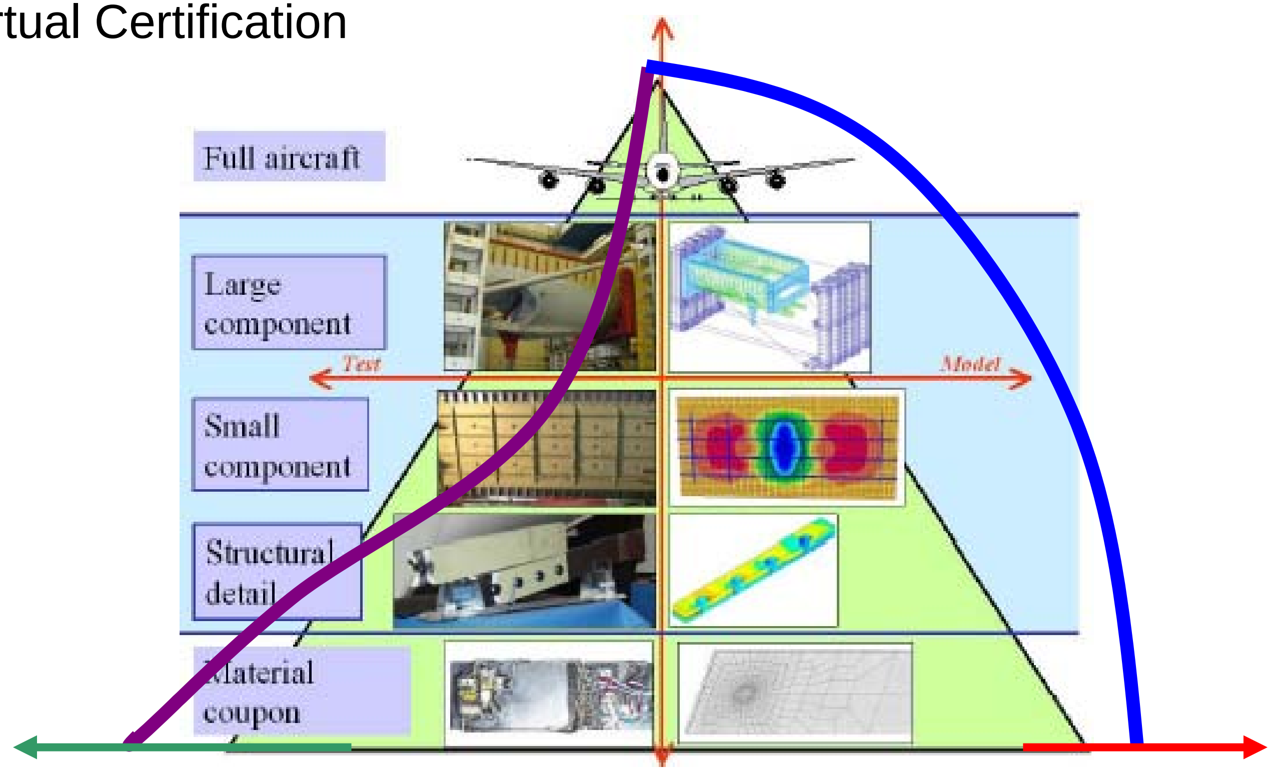
- Fast Design Tools
- Virtual Structures
- Structural Exploitation

From the phenomenon via modelling to simulation- and testing tools

Structural Mechanics – Computational Goals

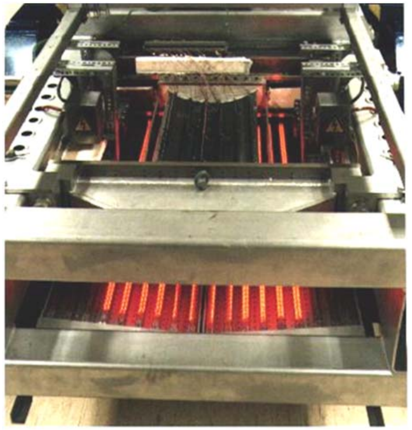
… to modify the shape of the pyramid …

- Virtual Tests
- Virtual Structures
- Virtual Certification

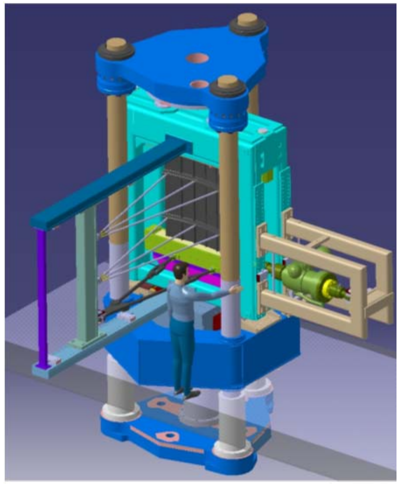


Experimental Testing Facilities (extract)

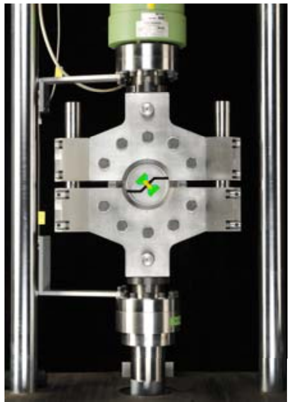
Thermex
(Thermo-mechanical Test Facility)

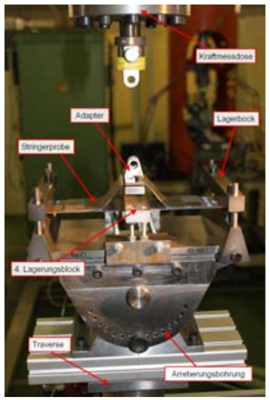


Buckling Test facility
(Compression and Shear)

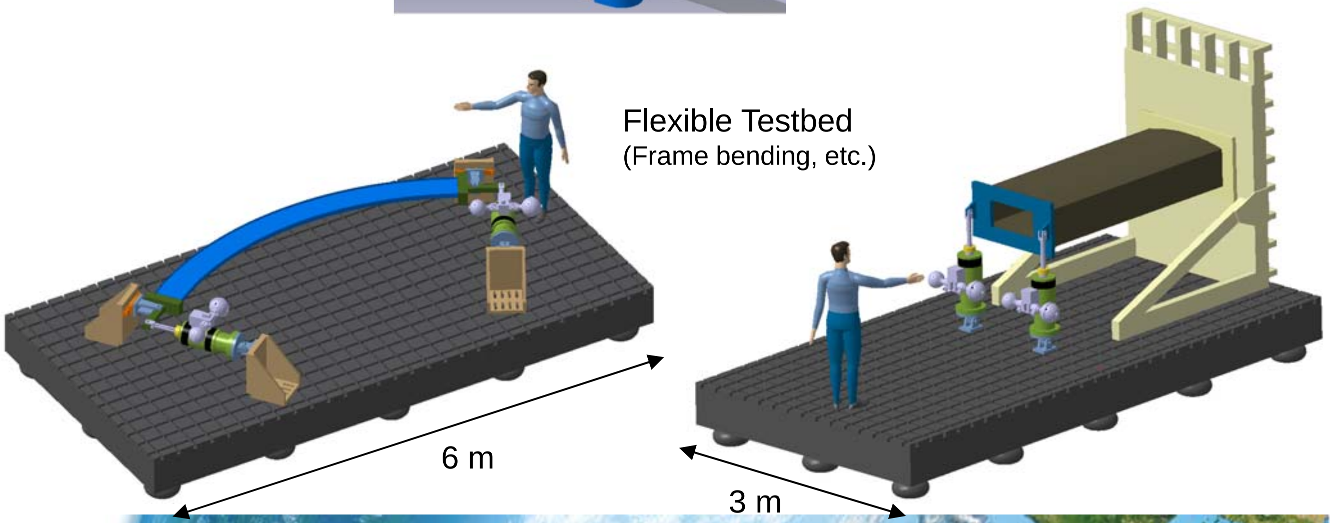


Subcomponent Tests





Flexible Testbed
(Frame bending, etc.)



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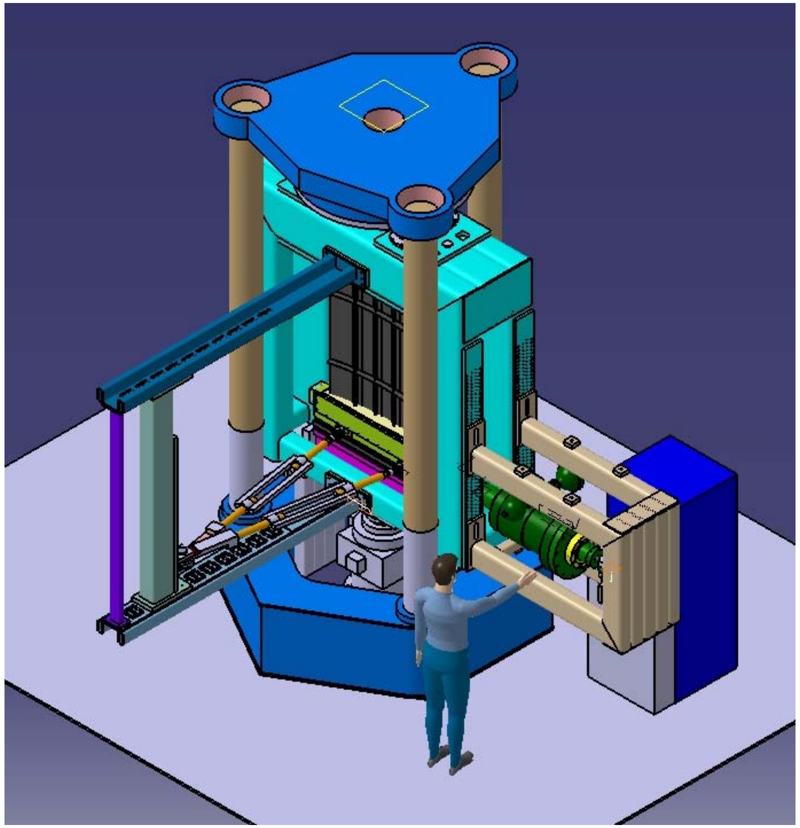
Stability and Buckling – Experimental Testing

- DLR buckling test facility for stability testing under shear and axial compression



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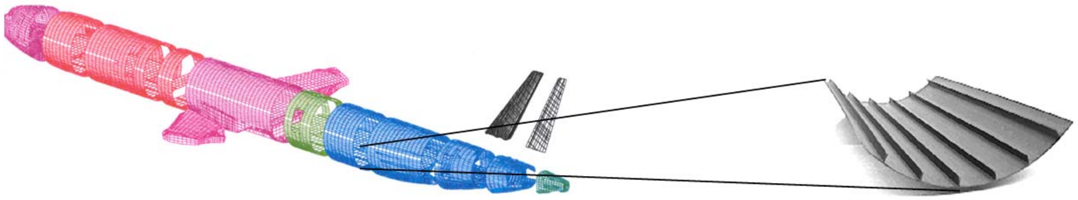

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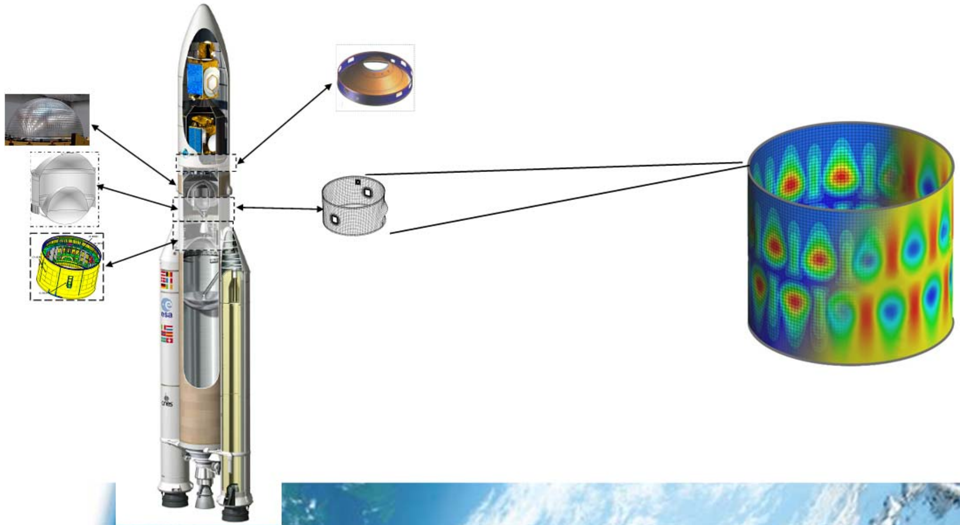

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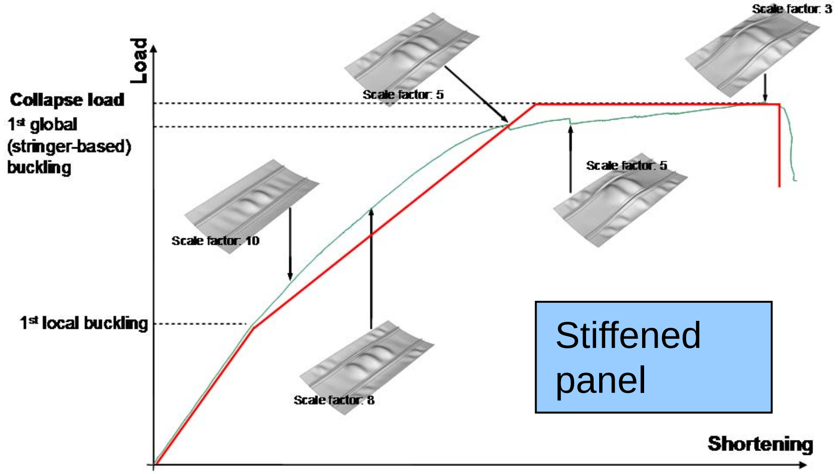
Comparison: Stiffened and unstiffened structures

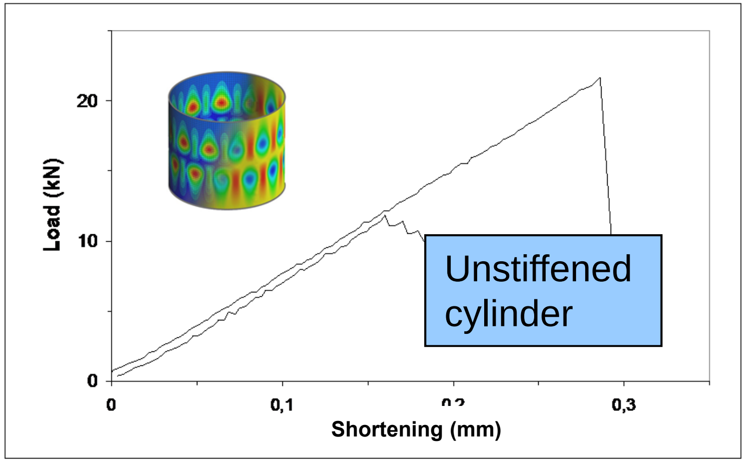
Light weight structures endangered by buckling can be divided into the following two groups:

Stiffened structures:



- Maximum load > first buckling load
- Postbuckling area is exploited for design
- Design load less dependent of imperfections

Unstiffened structures:



- Maximum load = first buckling load
- No exploitable postbuckling area
- Design load highly dependent on imperfections

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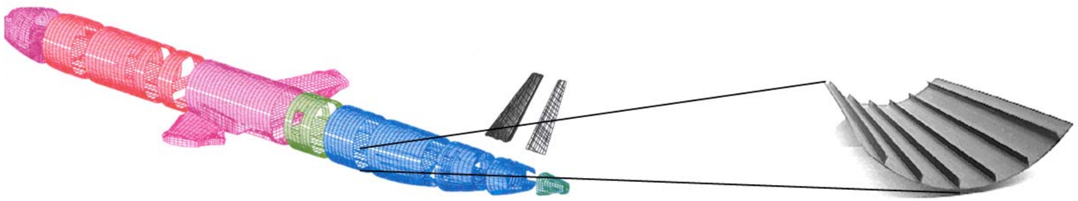

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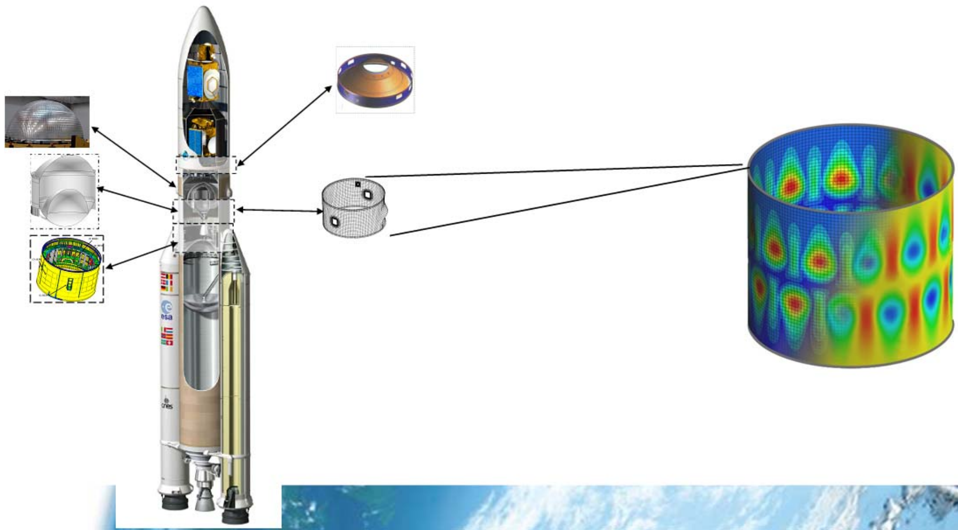

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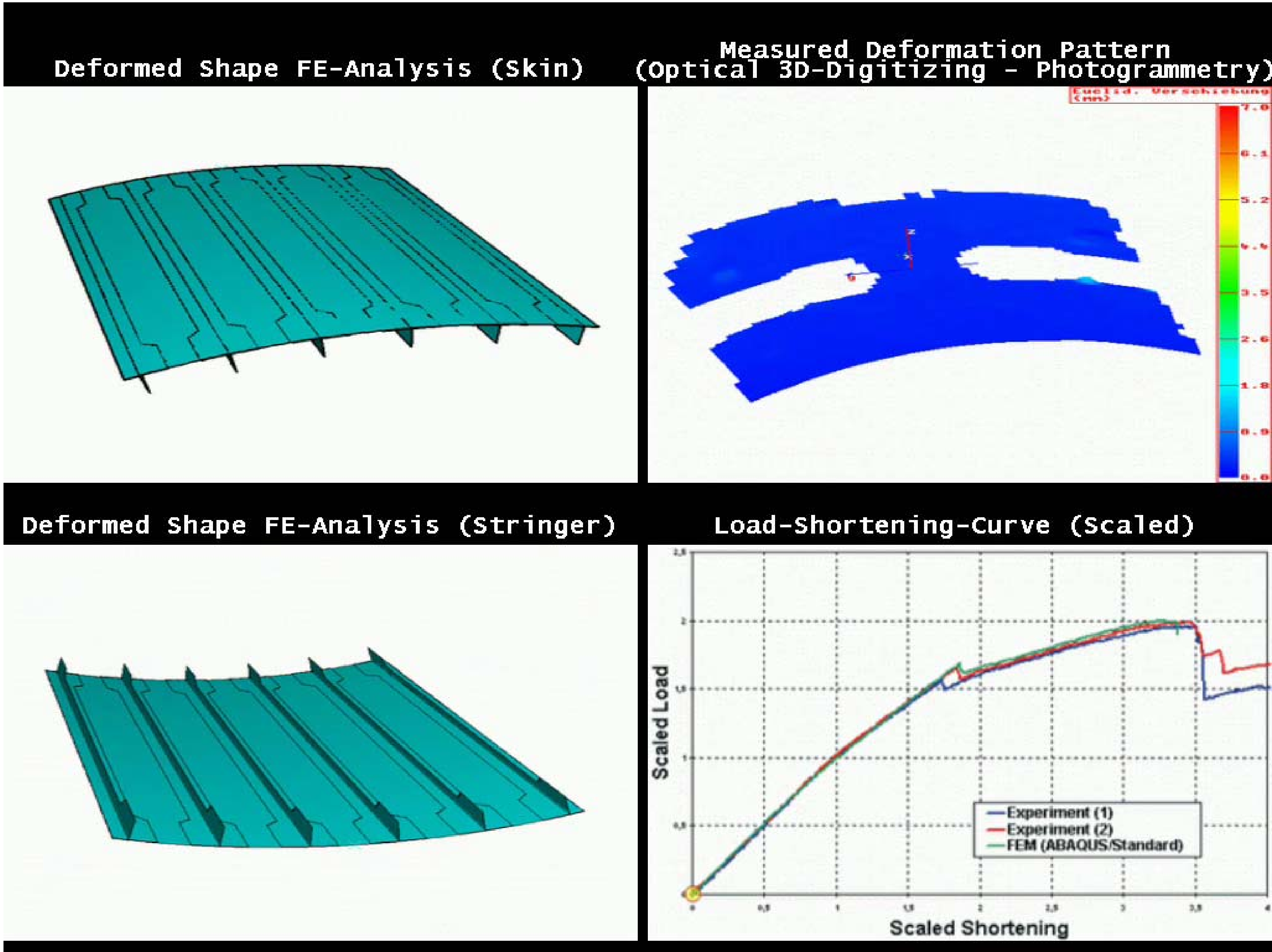
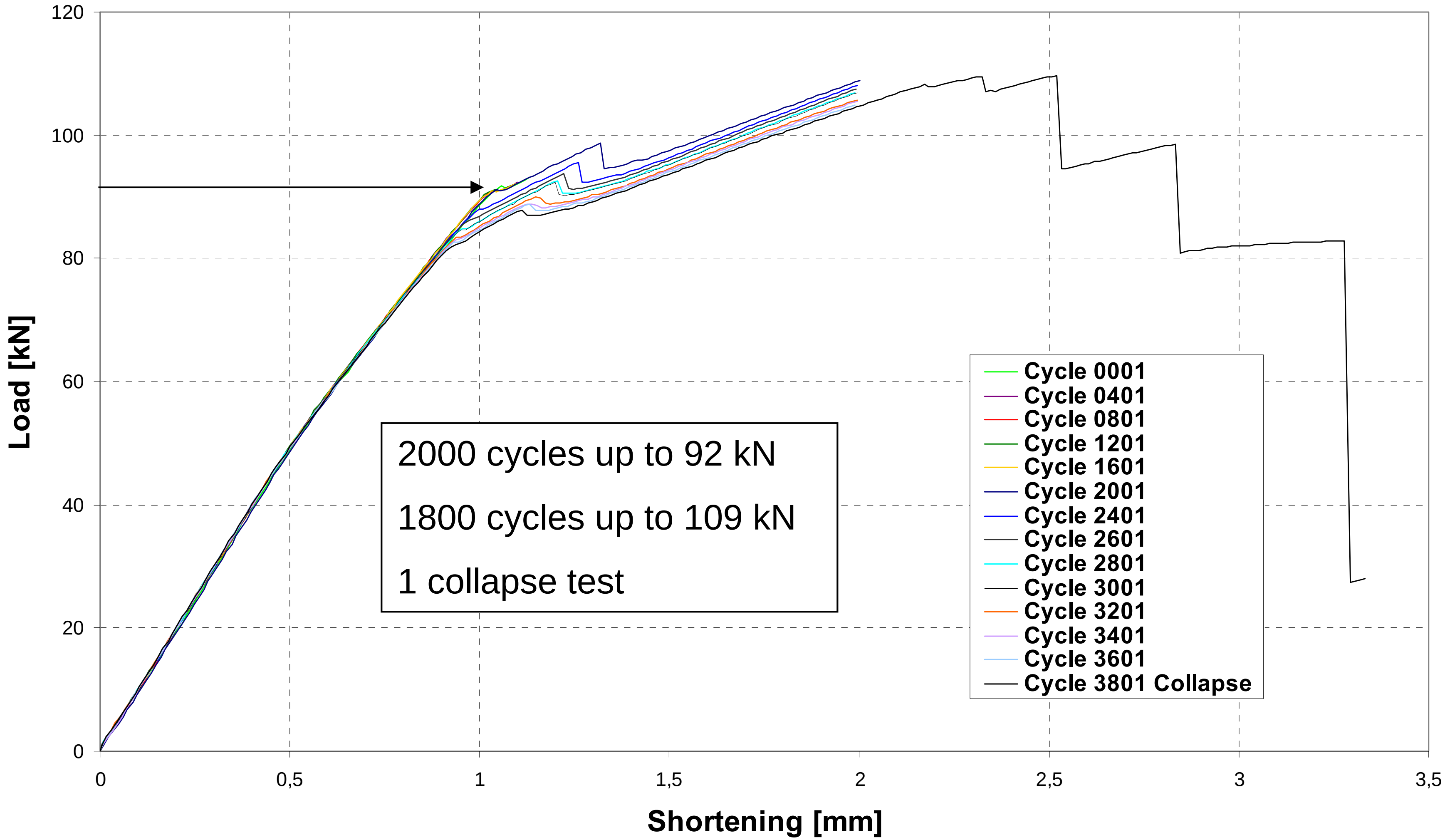
Axially loaded CFRP panel



Cyclic test – Load shortening curves



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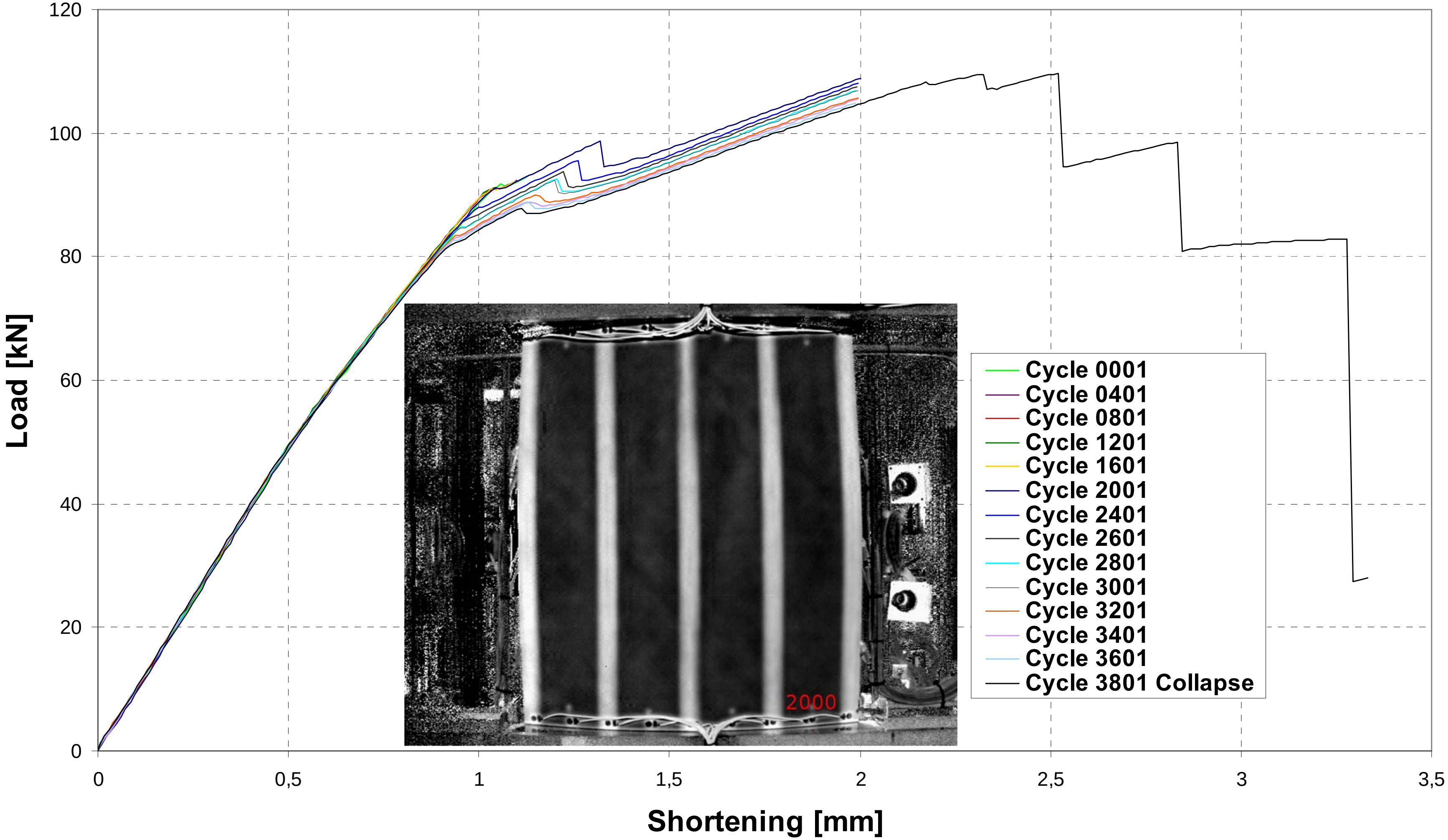
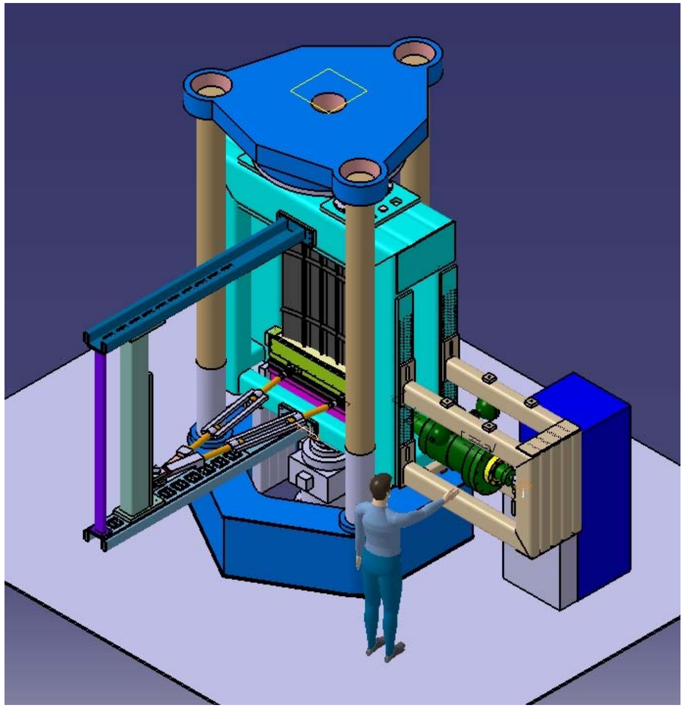
Cyclic test – Load shortening curves



Next steps

- Development of fast simulation concepts including axial compression and shear.
- Testing by combined axial compression and shear.



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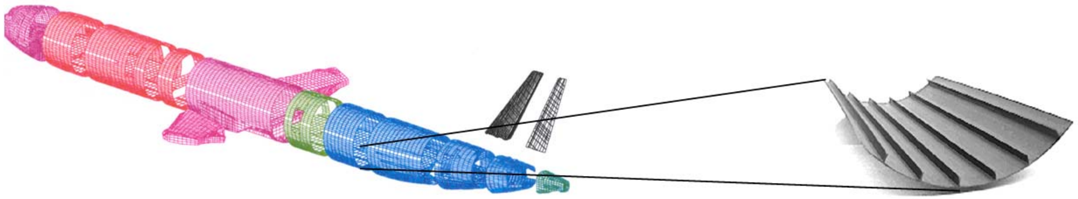

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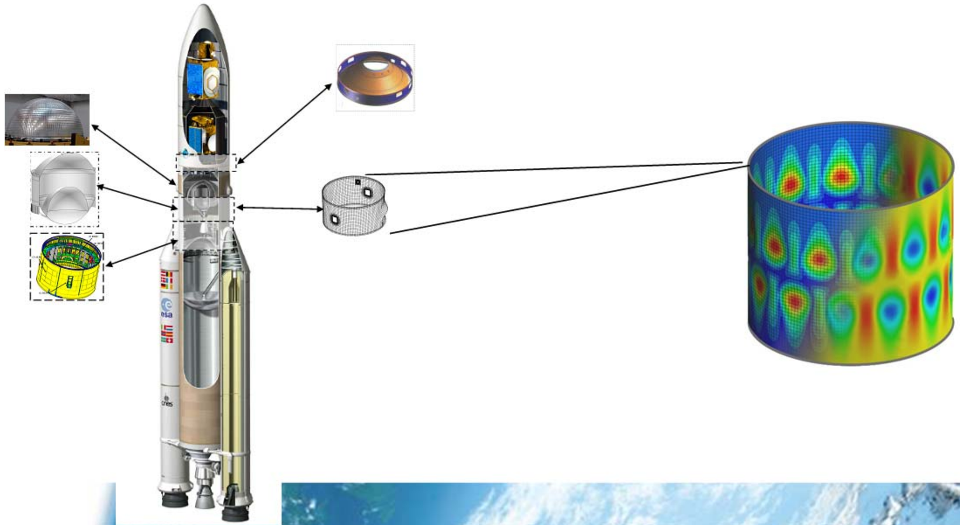

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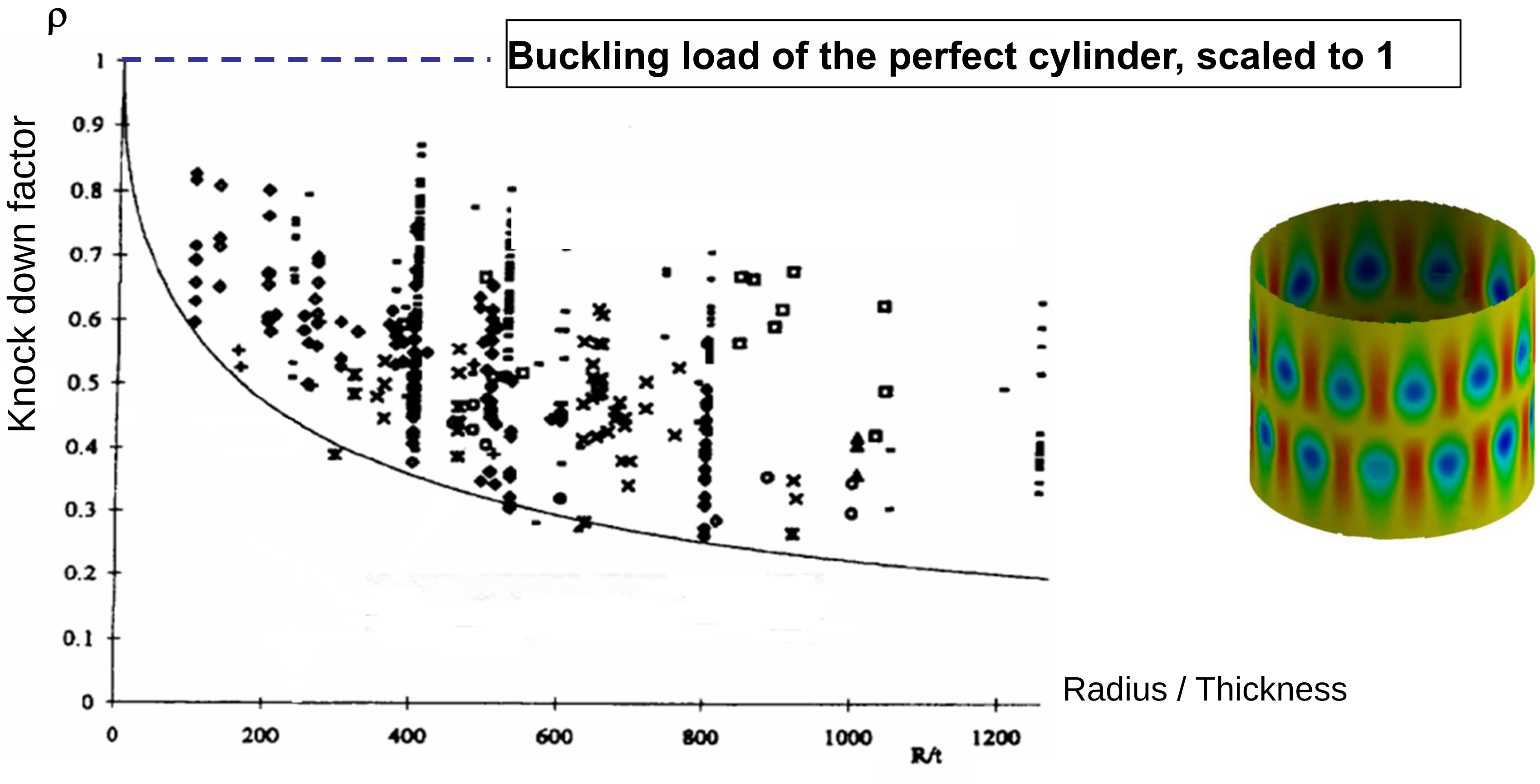
State-of-the-art: NASA-SP 8007 design guideline



- Valid for metallic structures
- No guidelines for composites structures

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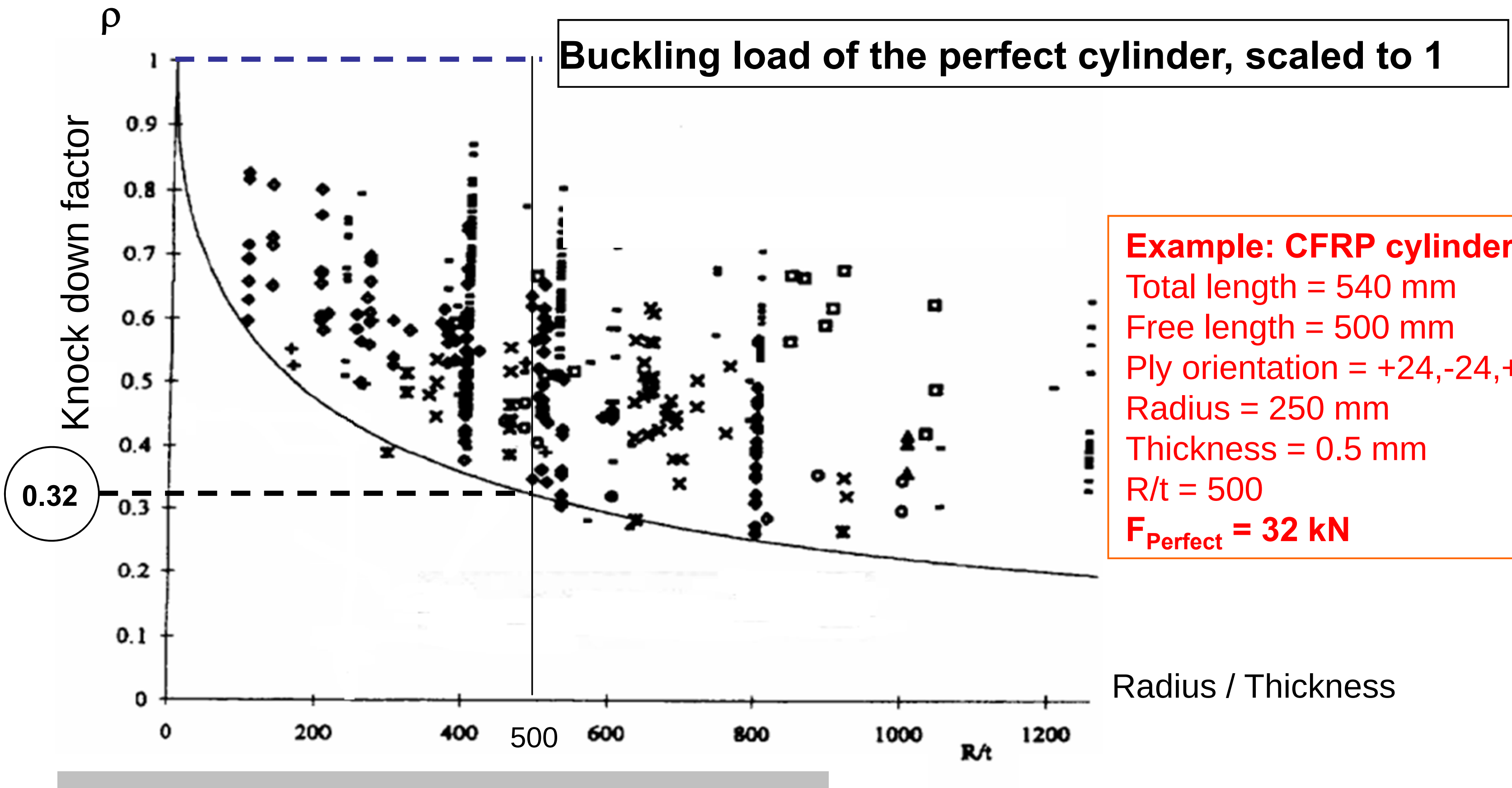
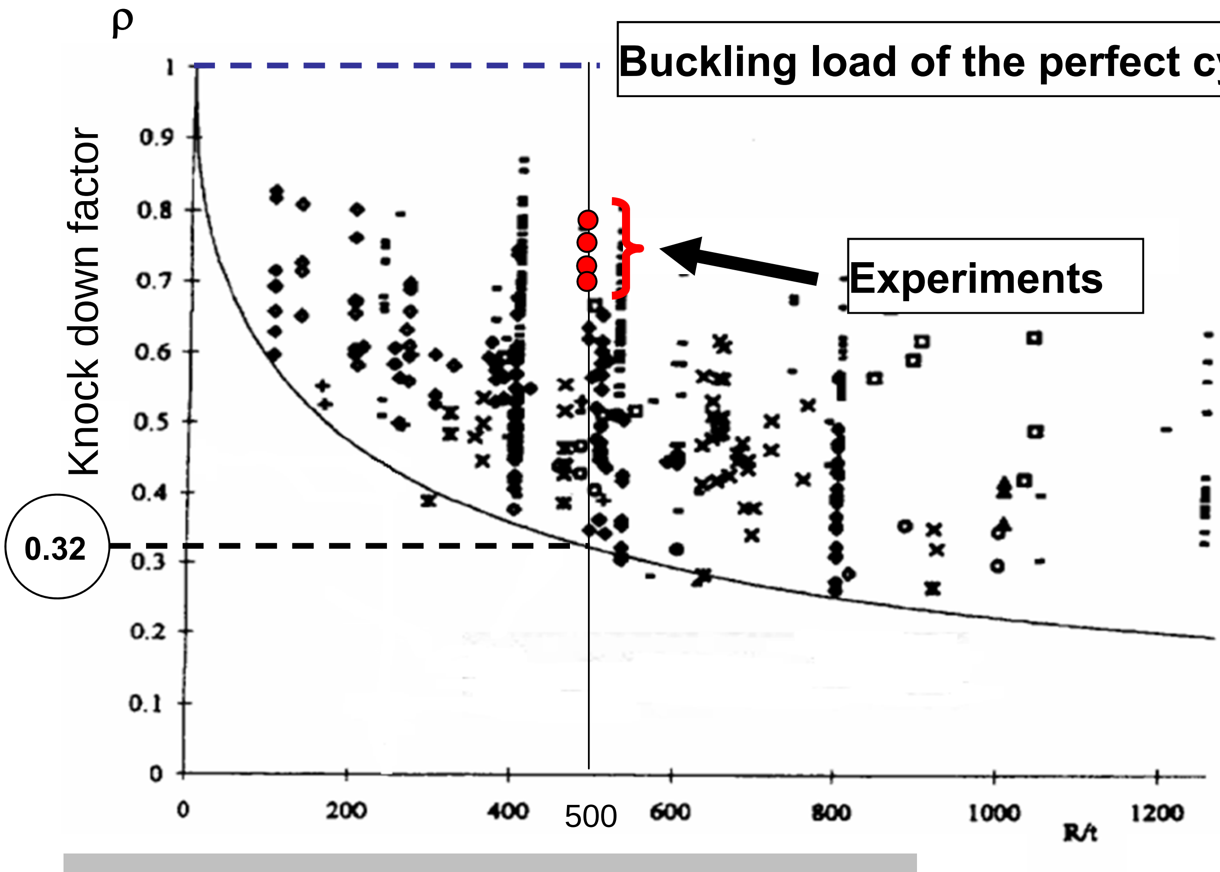
NASA-SP 8007 - Example



Example: CFRP cylinder
Total length = 540 mm
Free length = 500 mm
Ply orientation = +24,-24,+41,-41
Radius = 250 mm
Thickness = 0.5 mm
R/t = 500
$F_{Perfect}$ = 32 kN

$F_{Design\ load}$ = $F_{Perfect}$ * ρ_{NASA}
$F_{Design\ load}$ = **32** * **0.32** = 10.2 kN

NASA-SP 8007 - Example



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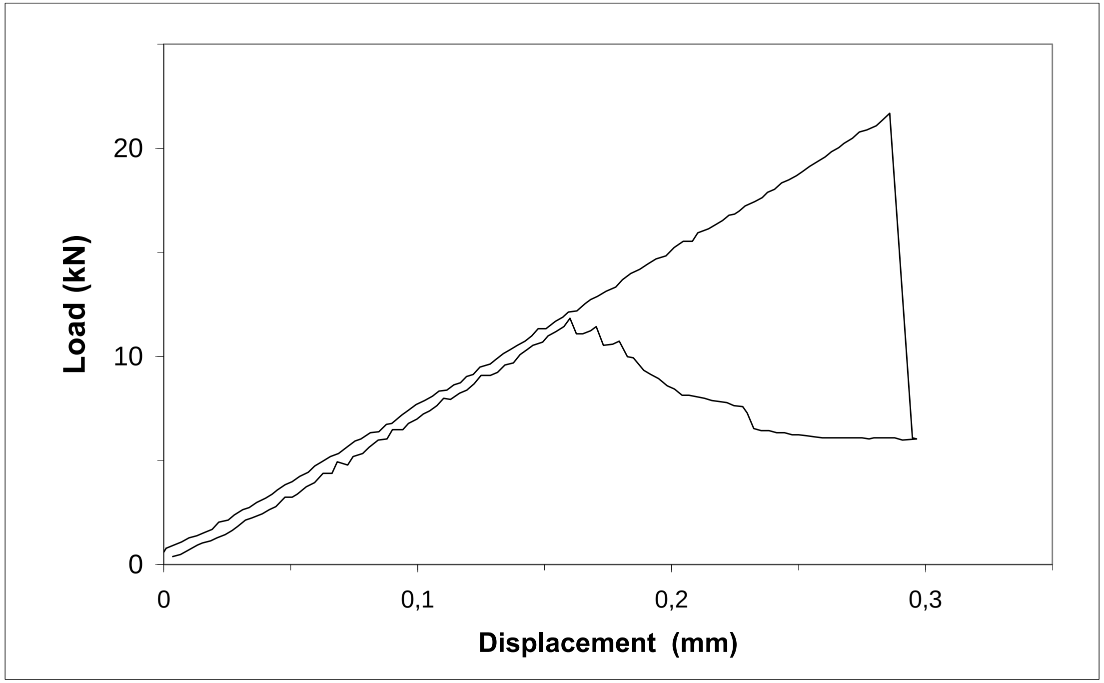
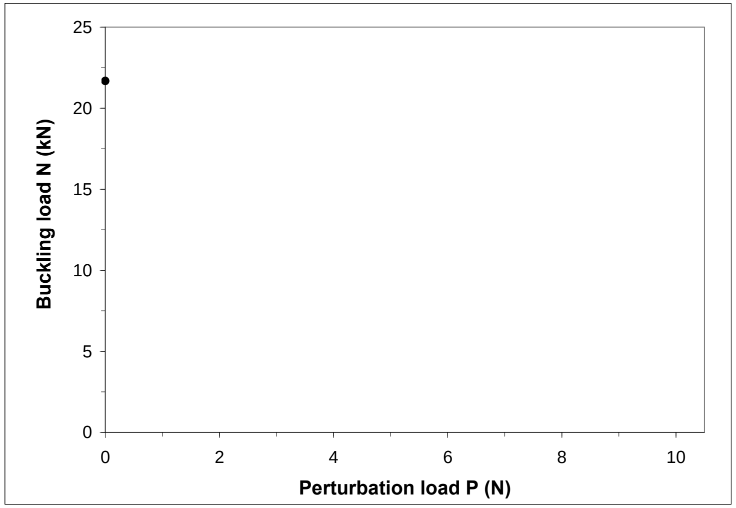
Single Perturbation Load Concept (SPLC)





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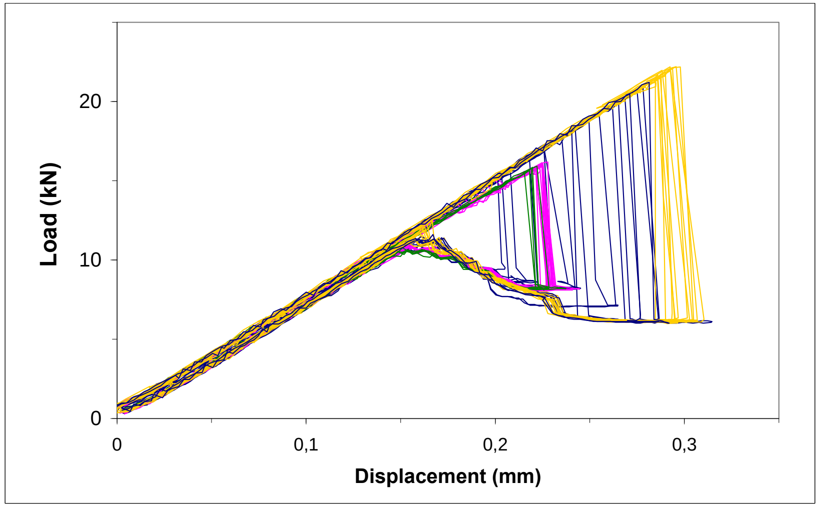

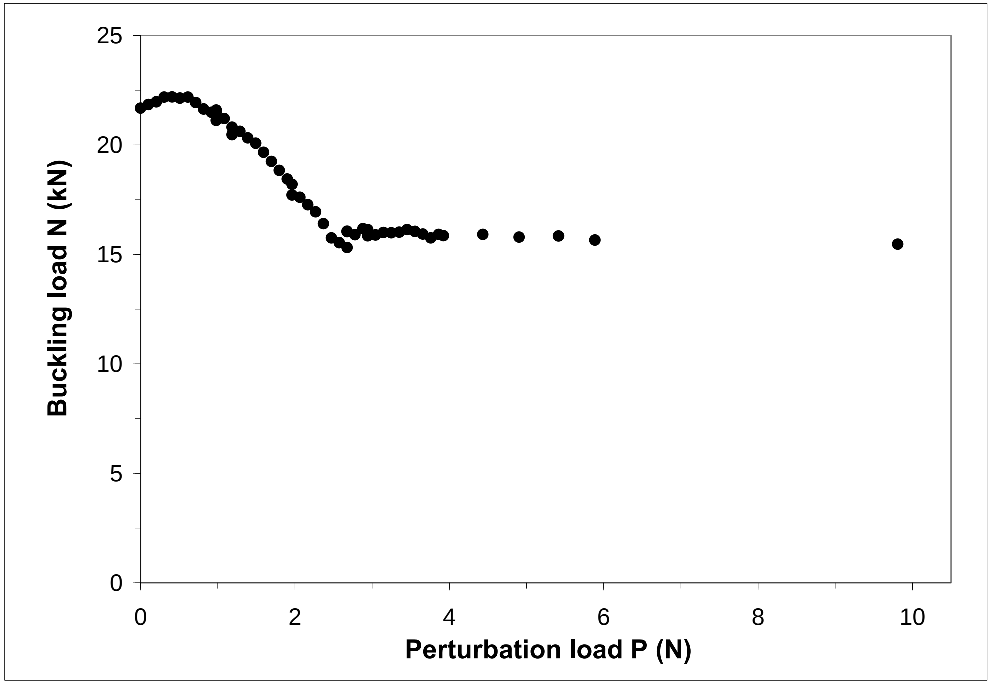

- Each dot marks one test
- Unexpected horizontal curve progression

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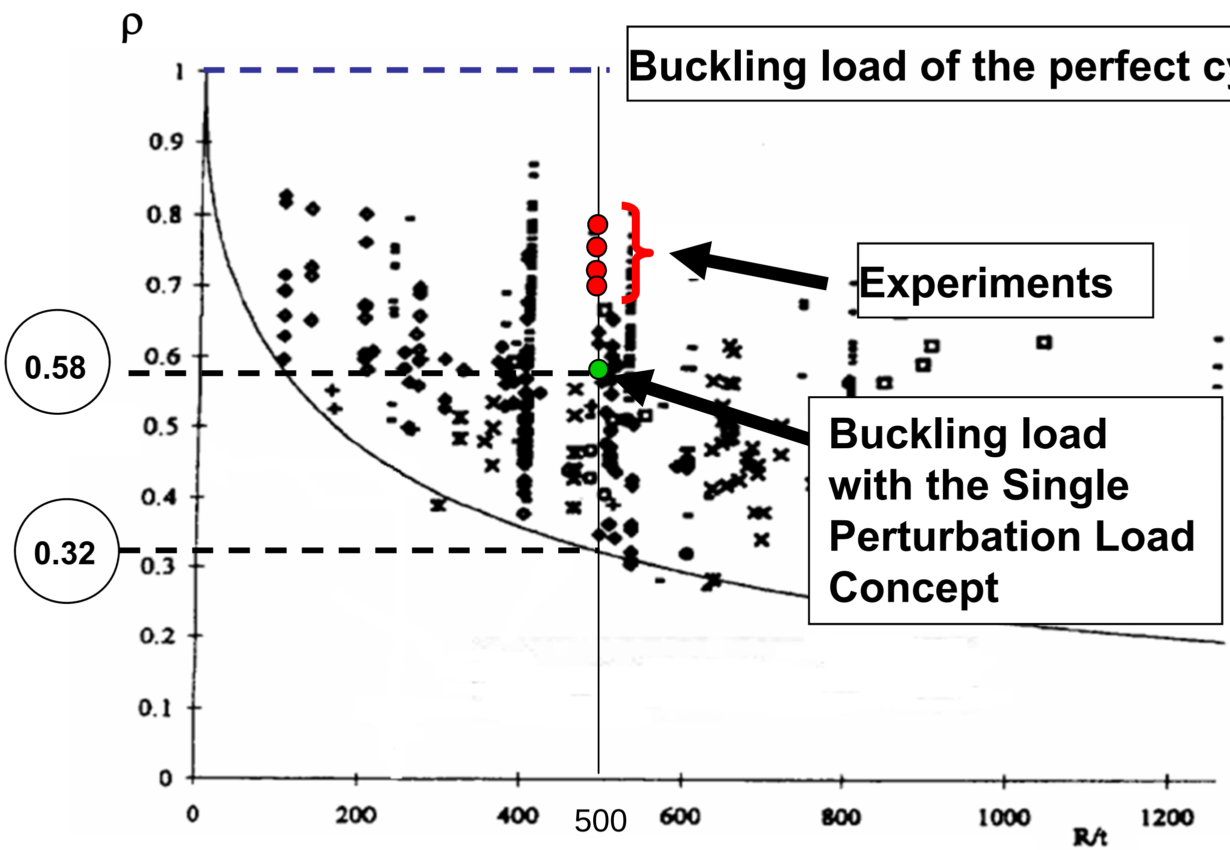
NASA-SP 8007 - Example



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Thickness = 0.5 mm
R/t = 500
$\mathbf{F_{Perfect} = 32\ kN}$

$F_{Design\ load} = F_{Perfect} * \rho_{NASA}$

$F_{Design\ load} = 32 * 0.32 = 10.2\ kN$

$F_{Design\ load} = F_{Perfect} * \rho_{SPLC}$

$F_{Design\ load} = 32 * 0.58 = 18.5\ kN$

Next steps

- Development of new design concept (DESICOS)
- Testing by combined axial compression and internal pressure.

Conclusions

- Future activities are going to exploit the reserve capacities of new materials more and more.
- New design concepts are developed.
- For a comprehensive validation especially experiments of multiaxialy loaded structures are needed.

Stability and Buckling – Experimental Testing

DLR Buckling Test Facility
- Characteristics

Parameter	Value
max. panel radius (extendable)	2300 mm
min. panel radius	1550 mm
max. panel length	1400 mm
max. panel width	1200 mm
max. axial force, (extendable)	380 kN, (1 MN)
max. shear force, (extendable)	210 kN, (500 kN)
max. shear stroke	100mm
max. axial stroke	40mm

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