

# Curved Fuselage Panel Test

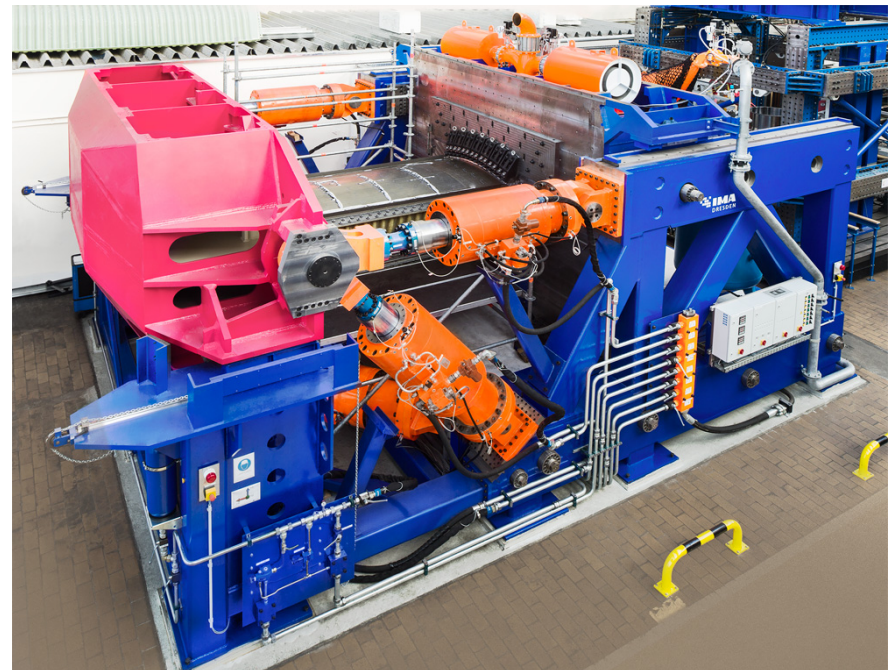
## Door Surround Structure



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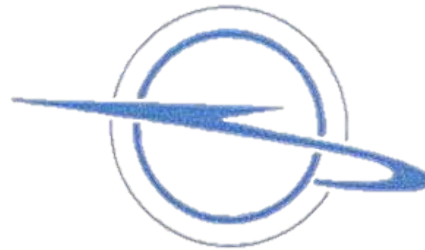
- EU – research project MAAXIMUS
- Main Partners for testing
  - Airbus Operations
  - Airbus Helicopters (Door)
- Work share
  - FE → Airbus
  - Testing → IMA

- **IMA Dresden**
- Overview Curved Panel Test
- Baseline
- Adaptations to enable Door Surround Structure Tests
- Load Determination
- Test Performance



1954 - 1961

VEB Flugzeugwerke  
Dresden



1961 - 1989

Institute for Lightweight  
Construction





# IMA Today

- Engineering Services for Research & Development
- Management-Buy-out 1993
- 100% Private Enterprise
- 100% Independent



Test Design

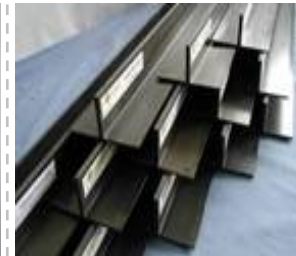
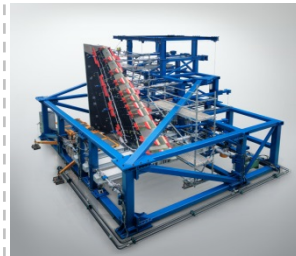
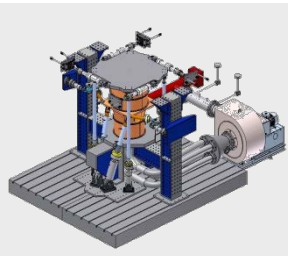
Simulation

Test

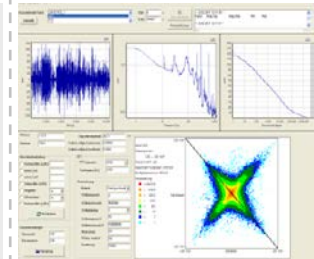
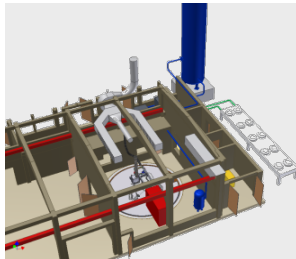
Product-Improvement

Services  
On-Site Service

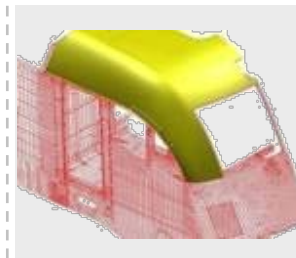
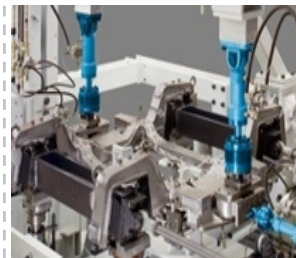
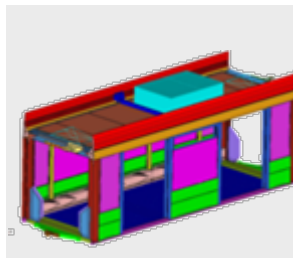
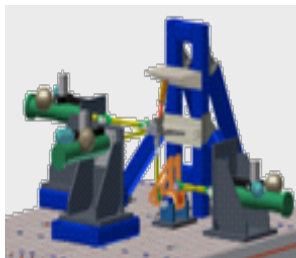
Aerospace



Automotive

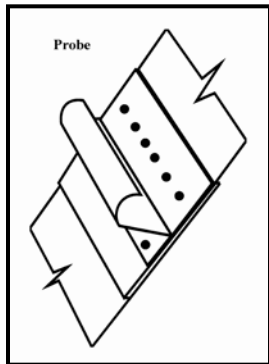


Railway

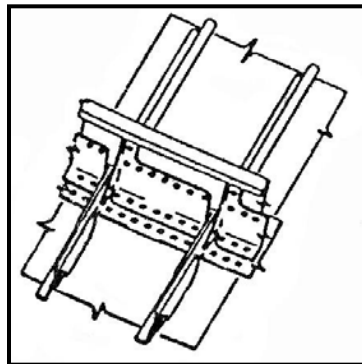


- IMA Dresden
- **Overview Curved Panel Test**
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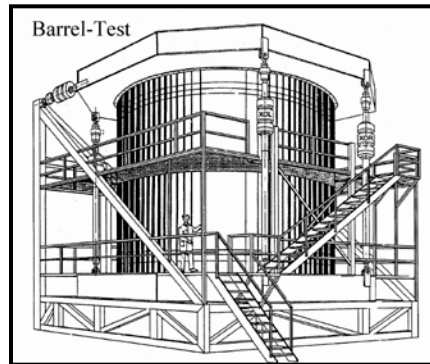
# Overview



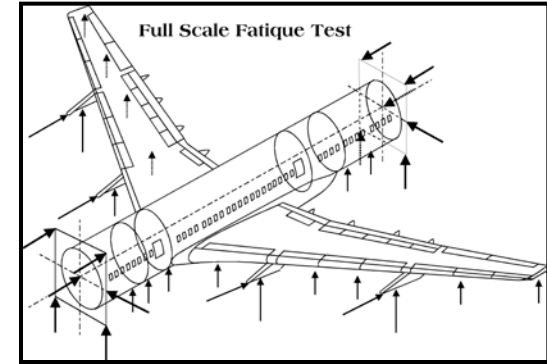
Coupon test



Panel test

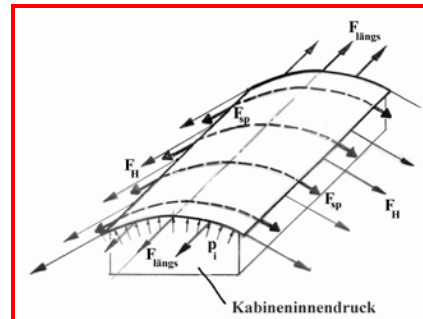


Barrel test



Full scale fatigue test

- Test of complete fuselage structure
- Specimen with stringer and frames



- Complex loading program with
  - Internal pressure
  - Longitudinal force
  - Shear

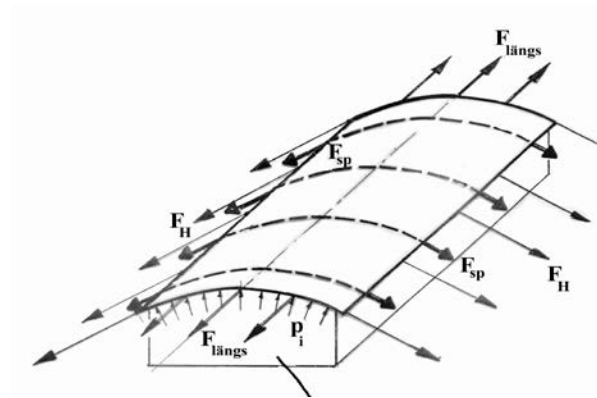
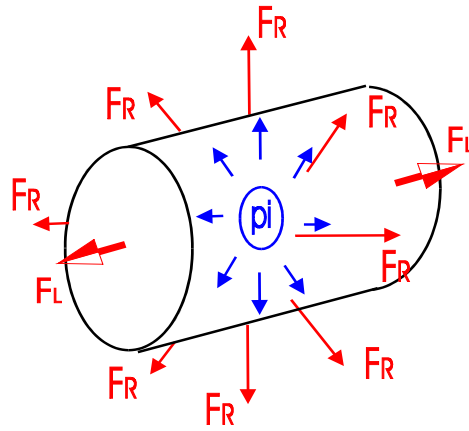
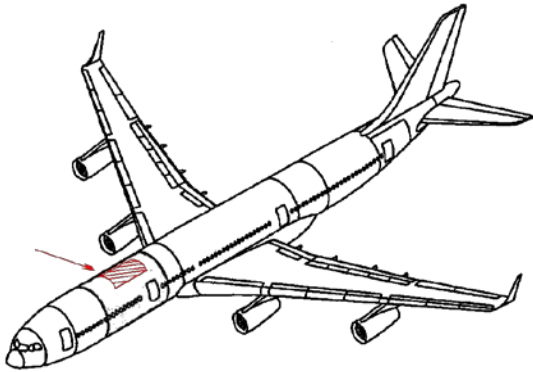
**Cost and expense**

**Technical significance**





# Overview

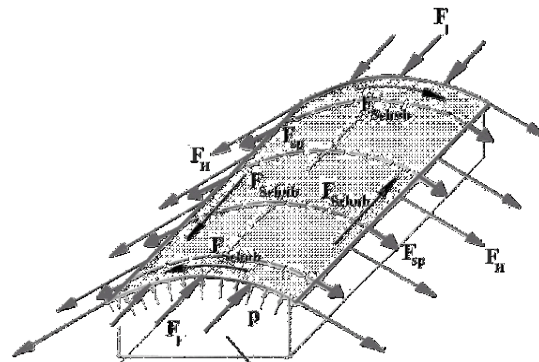
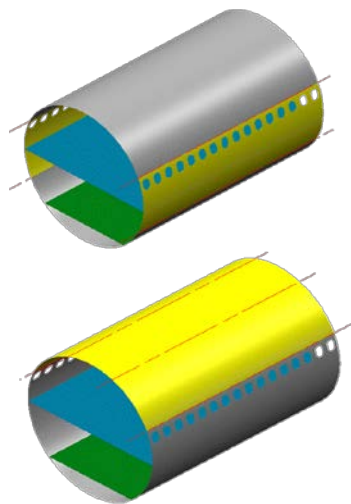


- IMA Dresden
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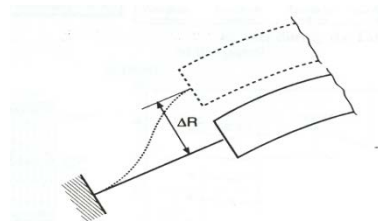
# Test Principle: Floating Panel

## Load condition

- Internal pressure
- Tension via longitudinal force
- Shear



pressure cabin

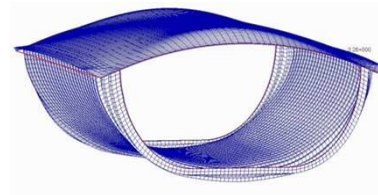
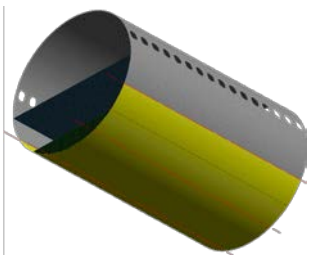
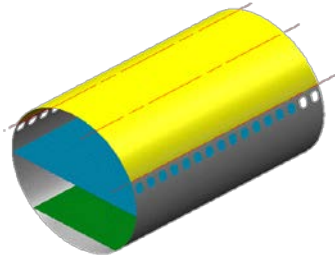
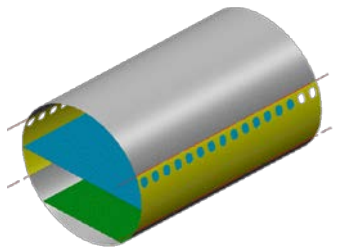


Radial "Floating"

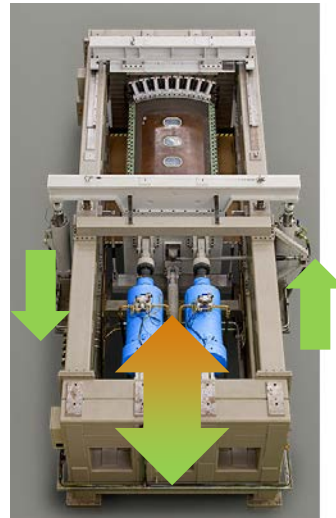
# Test Principle: Closed Cross Section

## Load condition

- Internal pressure
- Tension / Compression via longitudinal force
- Shear



pressure tube



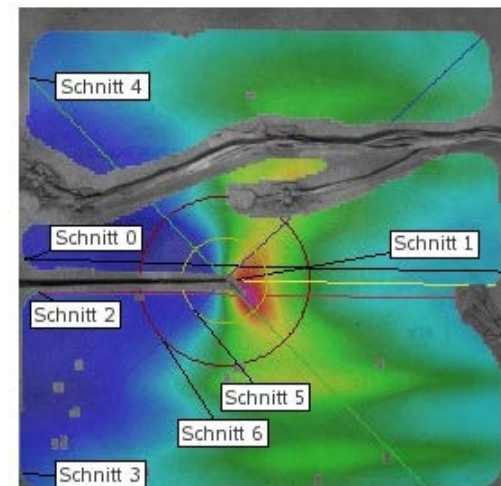
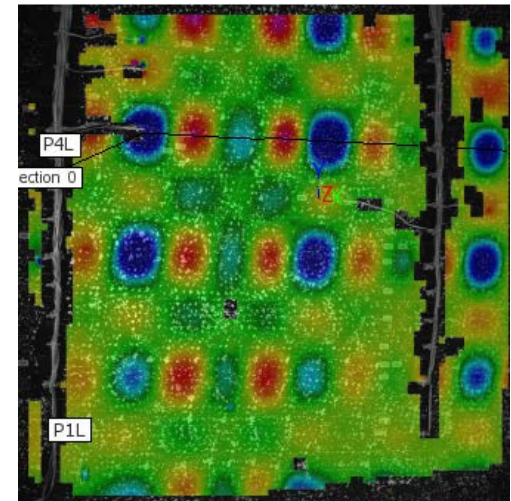
# Baseline Summary

## Target of Loading

- Equally distributed stresses
- Large, undisturbed field of investigation

## Target of Tests

- Compare different design principles
- Validate FE models





- IMA Dresden
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- Test Performance

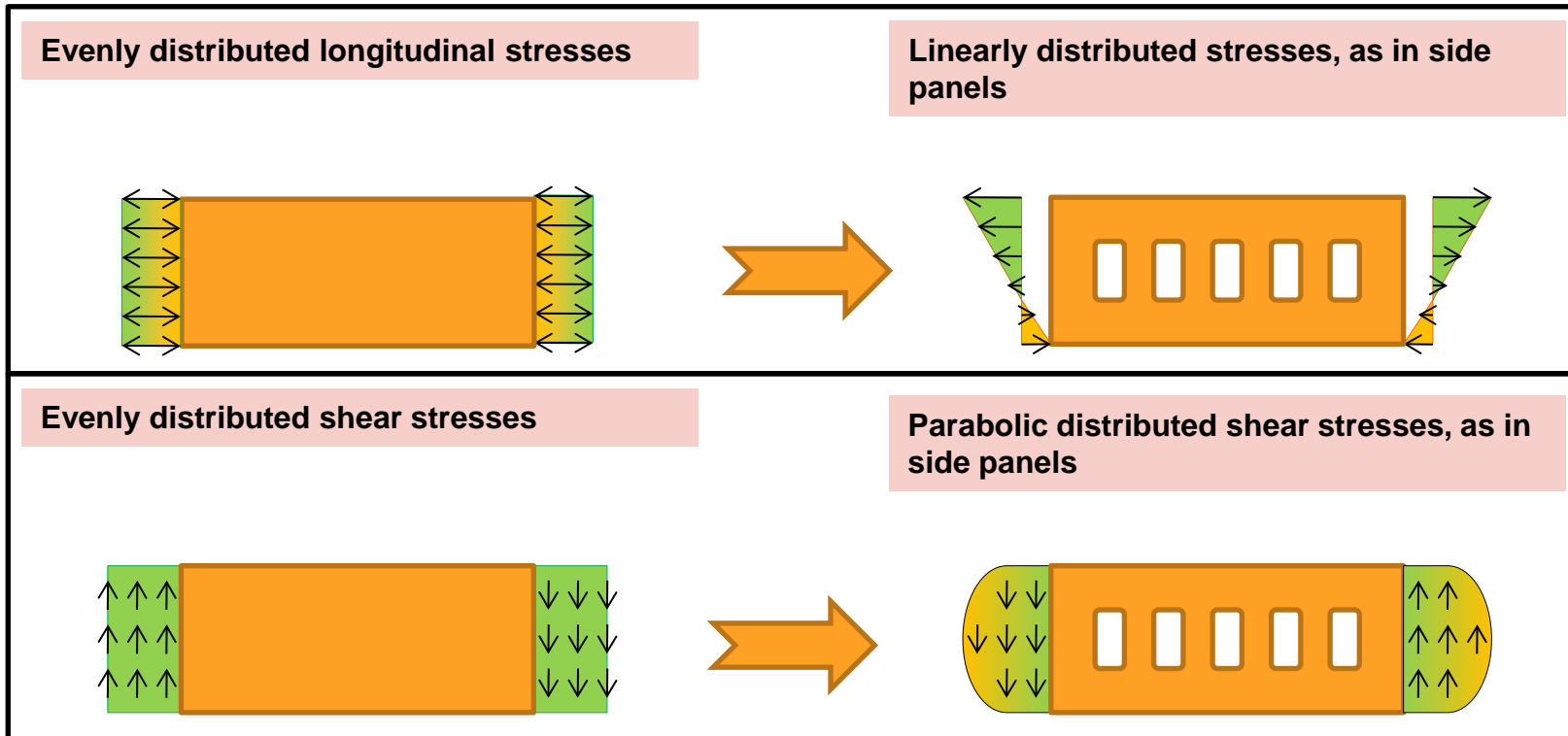
# Adaptations of Mechanical Loads

## Target of Loading

- Stress distribution as in an aircraft fuselage

## Target of Tests

- Validate large structures
- (Validate FE models)



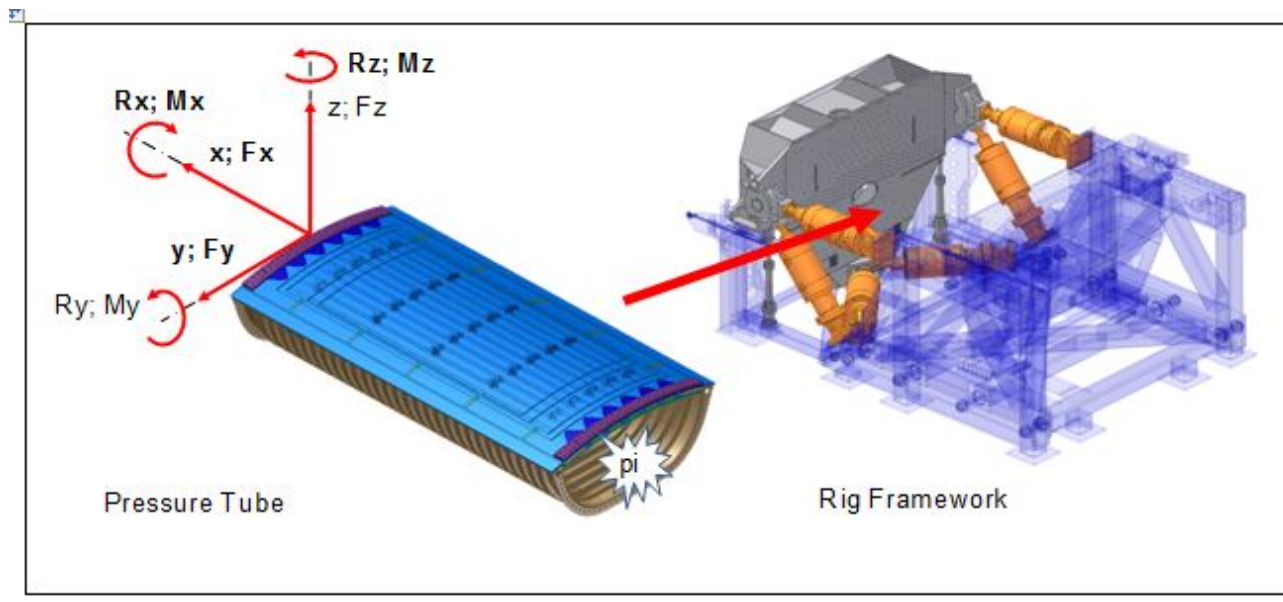
# Adaptations of Mechanical Loads

## Target of Loading

- Stress distribution as in an aircraft fuselage

## Target of Tests

- Validate large structures
- (Validate FE models)



Pressure tube in a 6 DOF Test Rig

# Adaptations of Mechanical Loads

## Introduction of Out of Plane Loads

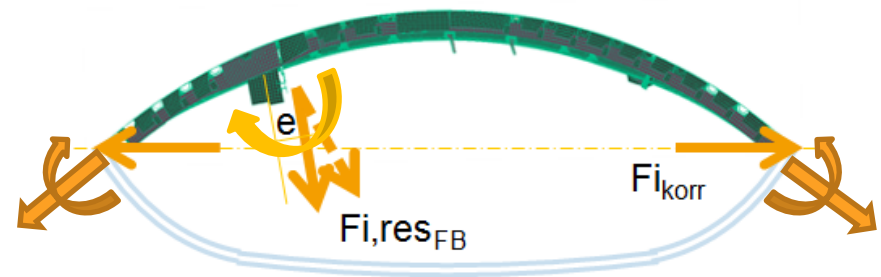
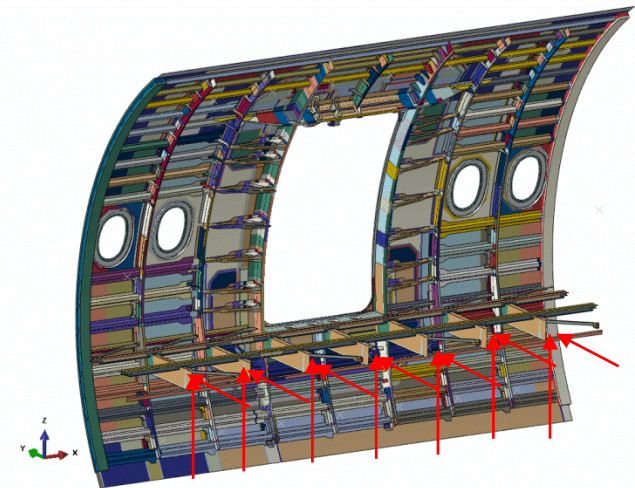
- Active Frame Bending
- Floor Loads

## Questions

- What load components are necessary?
- What simplifications are possible?

## Possible Loads

- Floor beam loads ( $F_y$ ,  $M_x$ ,  $M_y$ ,  $M_z$ ,  $F_x$ ,  $F_z$ )
  - 7 Floor beam connections
  - 6 DOF each
  - → 42 Control channels
- Frame Loads ( $M_x$ ,  $F_{\phi i}$ )
  - 14 Frame Ends
  - 2 Load Components each
  - → 28 Control channels
- Skin Spreaders ( $F_{H,i}$ )
  - Diverse groupings



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# Determination of Mechanical Loads

## Baseline for Optimisation

- Simulated load cases (LC) at Barrel
- Simulated unitary loads ( $F_{i,0}$ ) at rig model

$$\bar{\varepsilon}_{ref,LC} = FE_{Barrel}(LC)$$

$$\bar{\varepsilon}_{i,0} = FE_{Rig}(F_{i,0})$$

## Optimisation Run

- Assumed Configuration of Rig  
→ Conditions for Optimisation
- Optimisation of load factors for unitary loads taking into account all reference points

$$F_x = 0$$

$$F_y = F_z$$

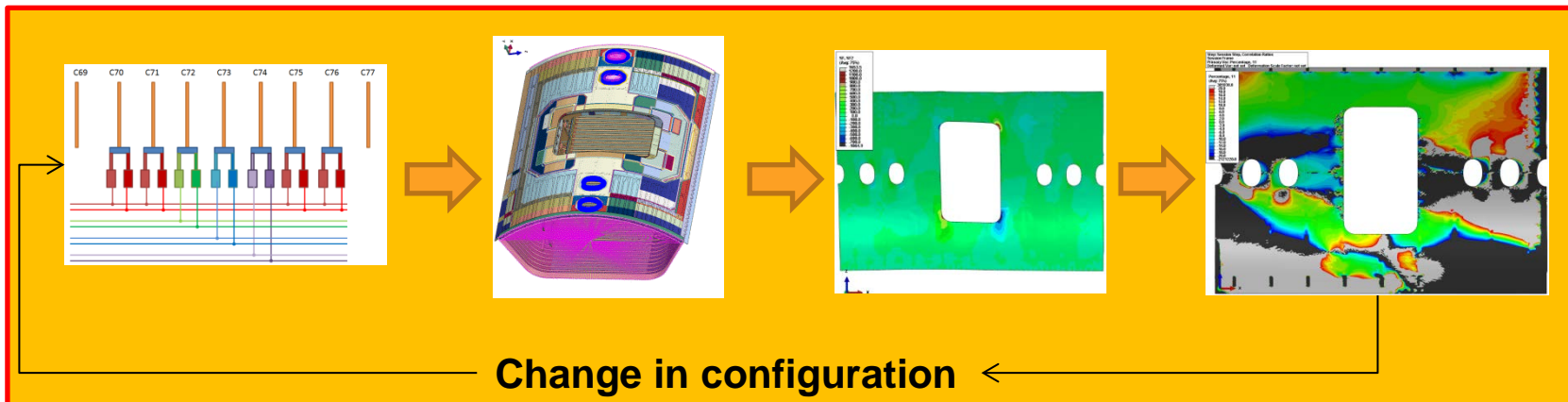
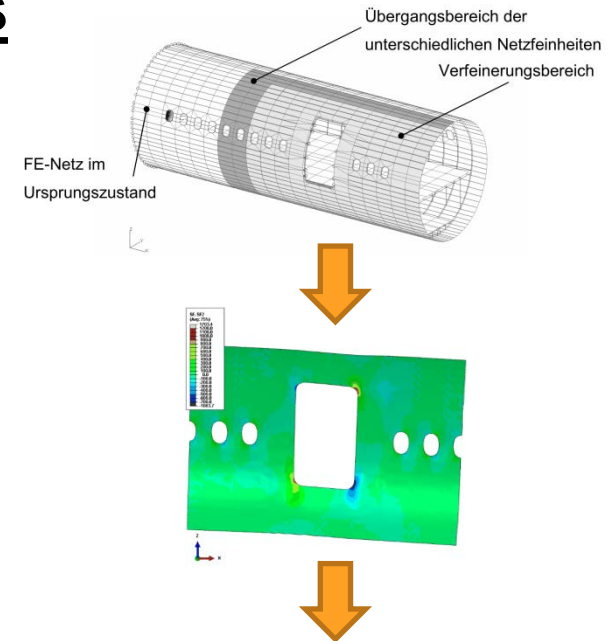
$$\sum \left( \bar{\varepsilon}_{ref,LC} - a_{i,LC} \bar{\varepsilon}_{i,0} \right)^2 \rightarrow Min$$

$$F_{i,LC} = a_{i,LC} \cdot F_{i,0}$$

# Determination of Mechanical Loads

## Iterative Approach

- Determination of strains and flows at panel edges from barrel model (reference)
- Assumption of boundary conditions for panel test set-up
- Analysis of FE model with assumed boundary conditions
- Comparison to reference

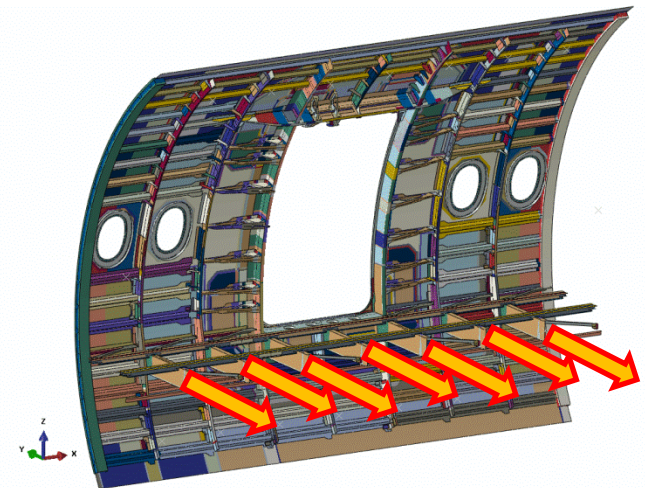


# Determination of Mechanical Loads

## Influences on configuration selection / evaluation

- Comparison of optimised loads with loads in the reference model
- Differences of loads at similar parts, e.g. floor beams

$$F_{i,LC} \approx F_{ref,LC}$$



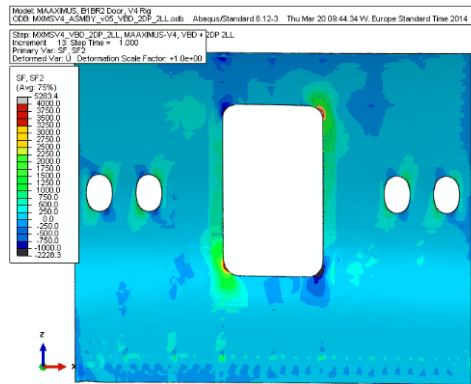
- Meaningfulness of optimisation results, e.g. skin spreader forces
- Can appropriate load introduction interfaces be designed / built?
- Minimisation of control channel number

$$\sum F_{H,i} \approx p_{ii} \cdot R \cdot l \cdot \cos\left(\frac{\alpha}{2}\right)$$

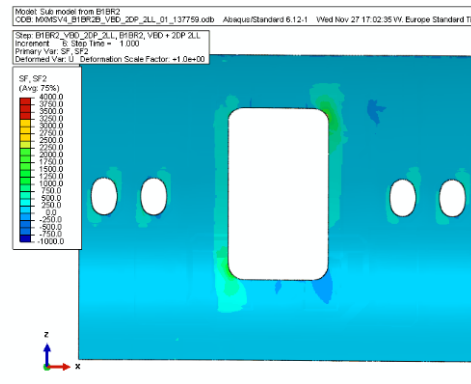
# Determination of Mechanical Loads

## Comparison of Results

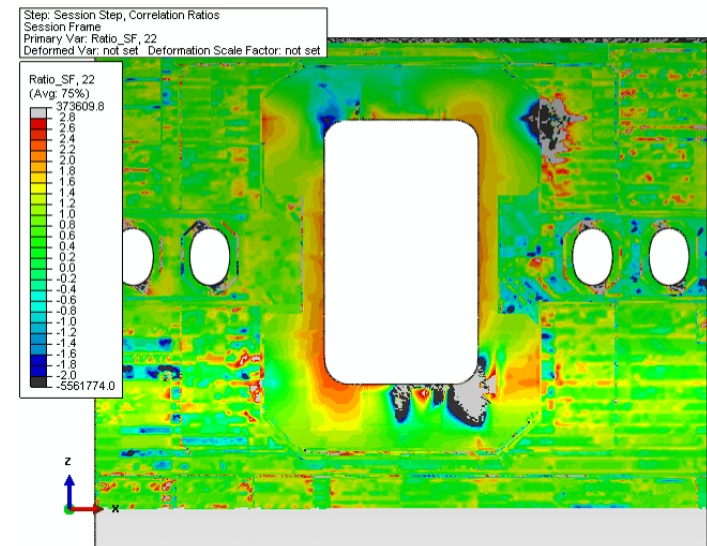
- Qualitative comparison, strains



Rig model



Barrel model

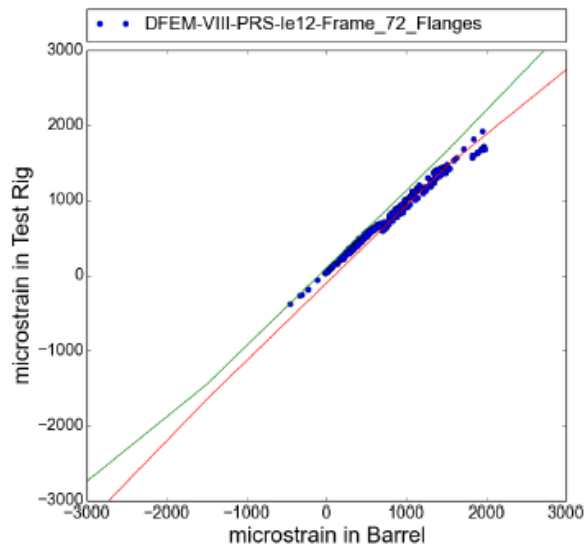


Relative Deviation

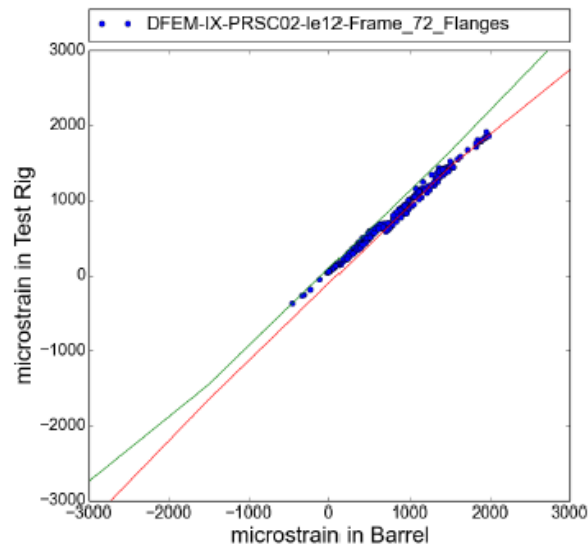
# Determination of Mechanical Loads

## Comparison of Results

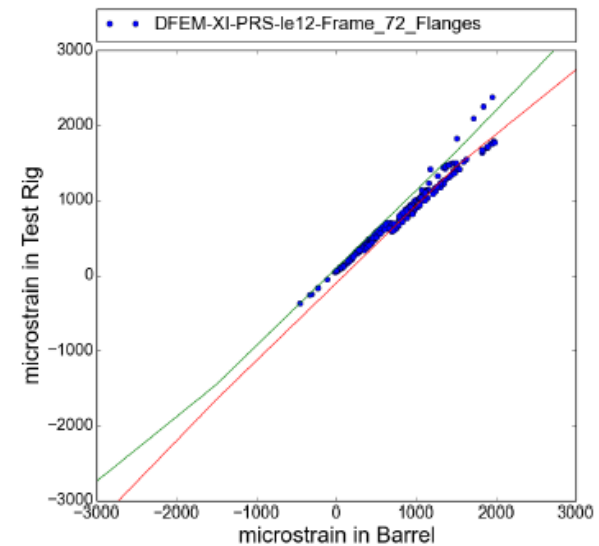
- Quantitative comparison, strains



**Config 1**



**Config 2**



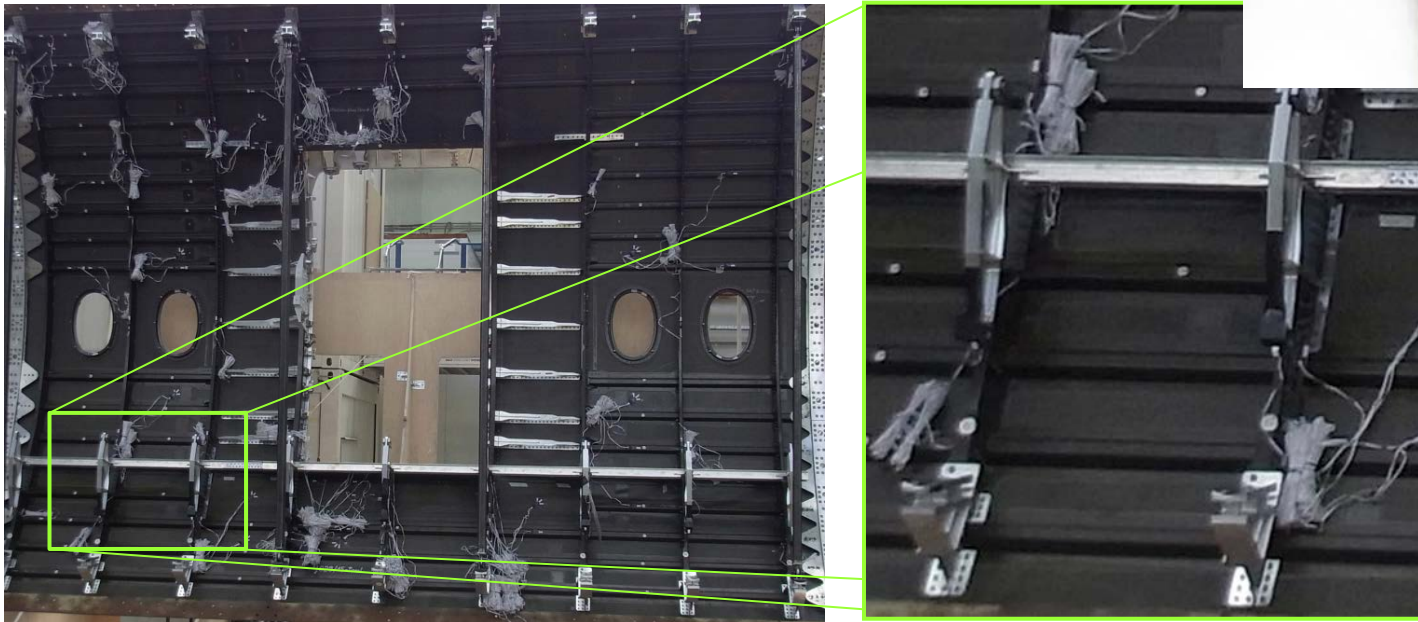
**Config 3**



## Determination of Mechanical Loads

### Resulting Configuration

- Floor beam: bending moment + axial load
- Frame ends: different control modes for bending moments
- Total: 49 load introduction elements
- No. of control channels: 25

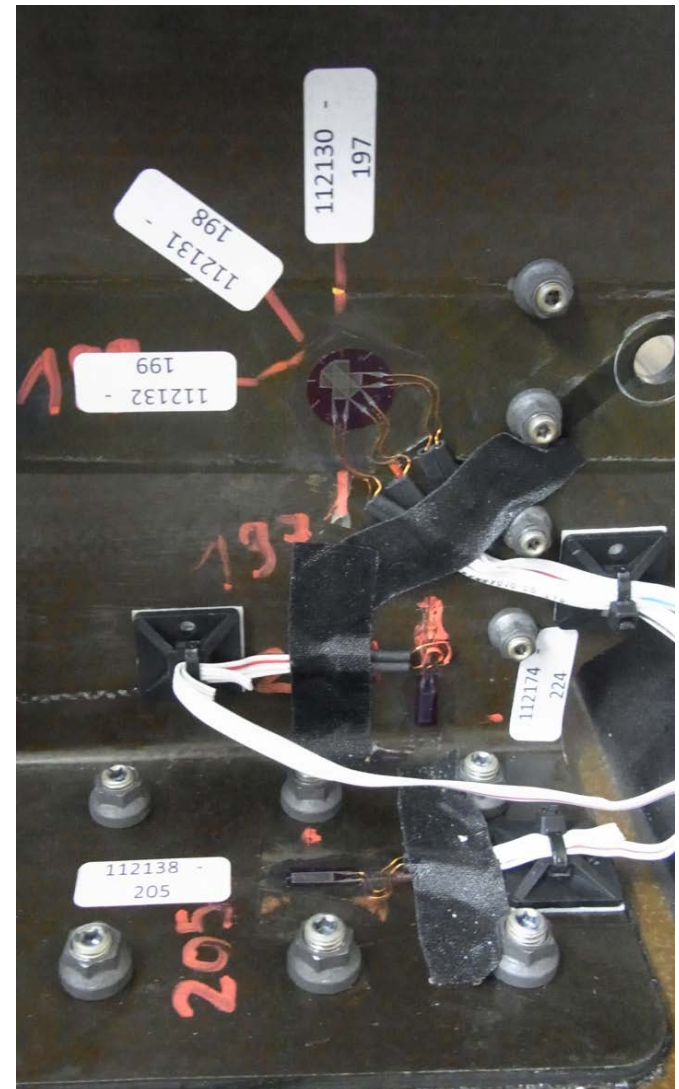


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- **Test Performance**

# Test Performance

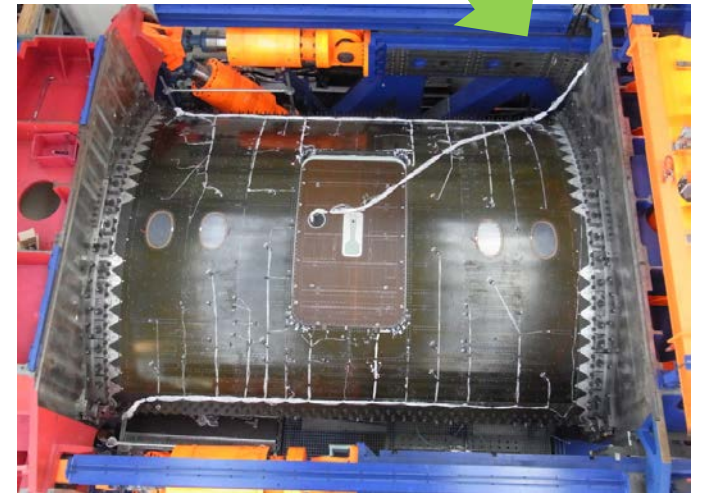
## Specimen Instrumentation

- 800 strain gauge channels
- 14 instrumented door stops
- PONTOS Pattern
- ARAMIS Pattern



# Test Performance

## Specimen Installation

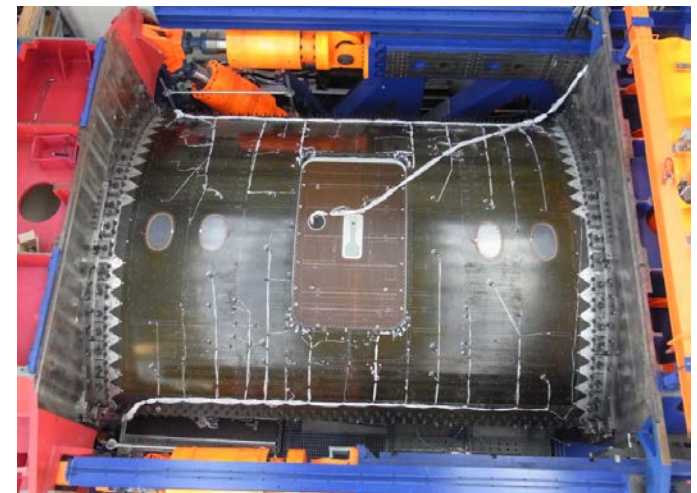
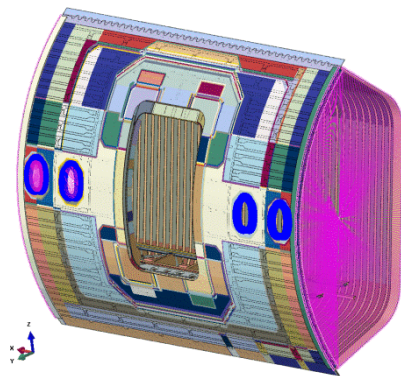




# Test Performance

## Load Application

- General behaviour – unitary loads
- 3 load cases as example
  - 1 DP (pressurisation of fuselage)
  - VBD (Vertical Bending Down)
  - LBL (Lateral Bending Left)
  
- Comparison FE Prediction – Rig Measurement



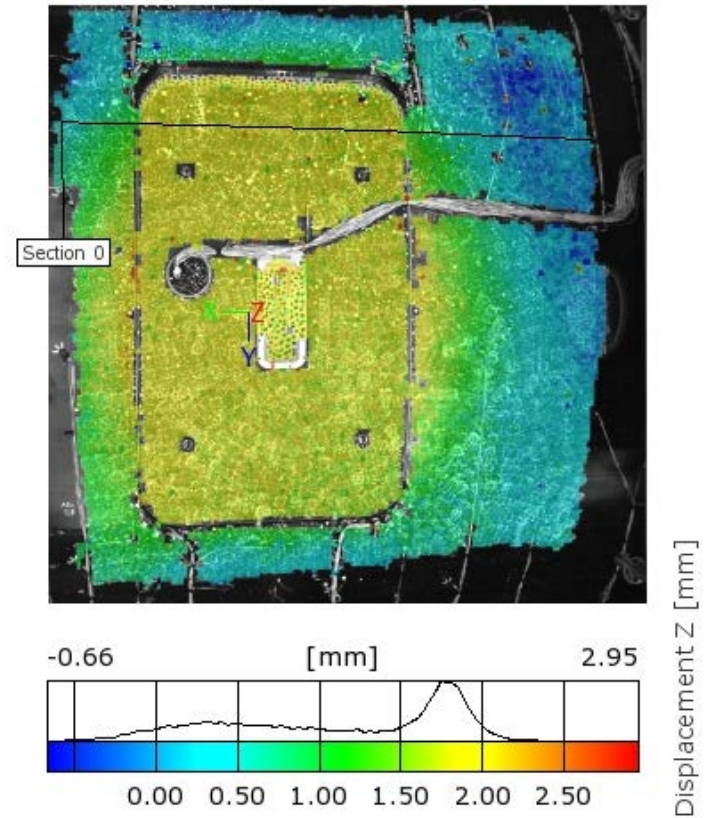
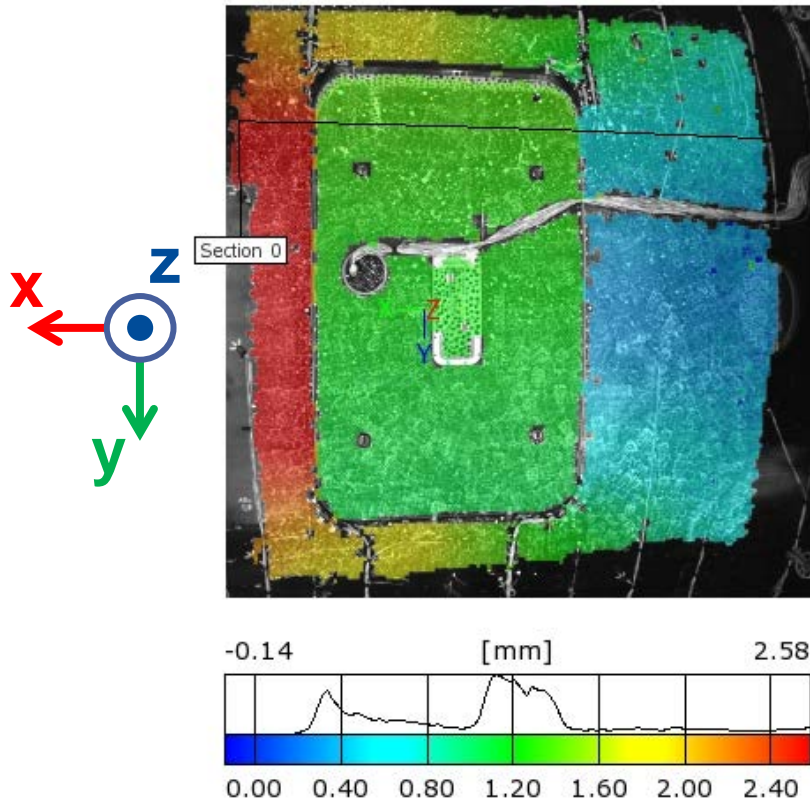


# Test Performance

## General Behaviour

Load level (Dx Dy Dz Mx): 1 x x x

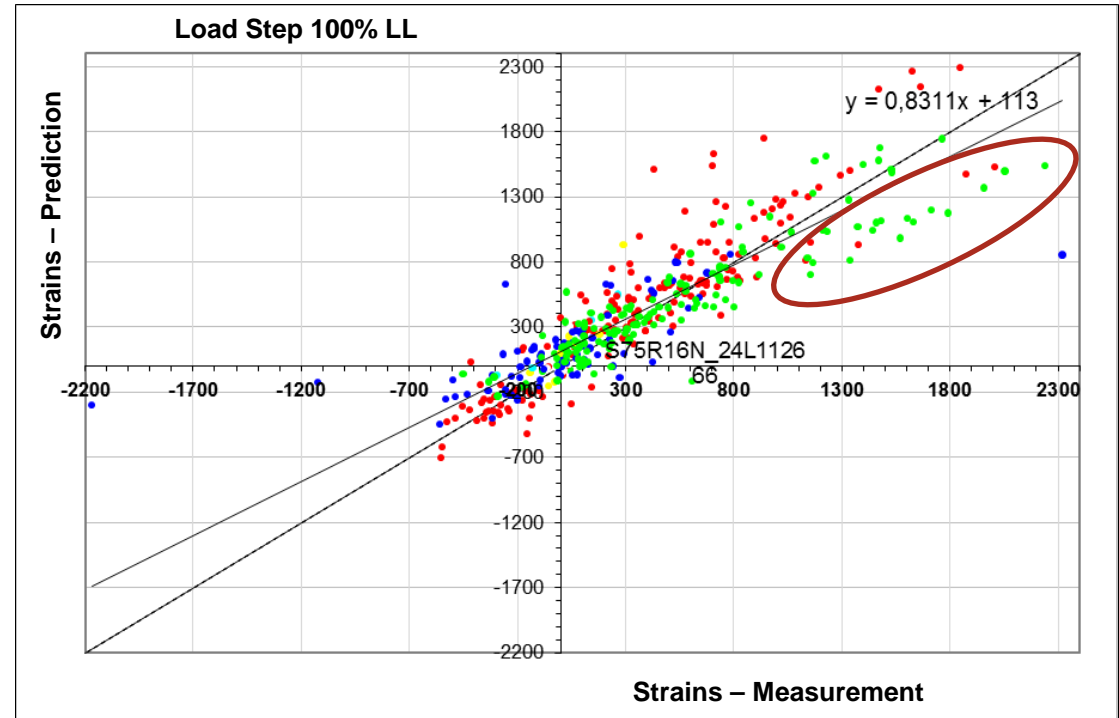
Load level (Dx Dy Dz Mx): 1 x x x



# Test Performance

## Load Case 1 $\Delta p$

- Strains underestimated in general, esp. door corners

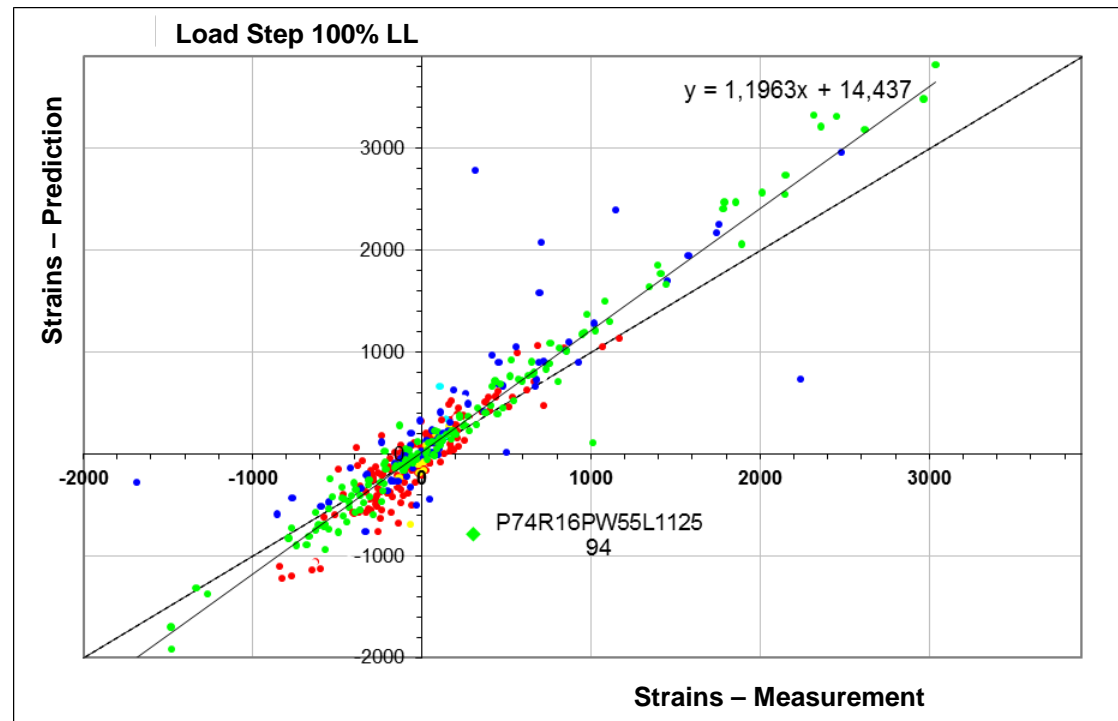


red: Frame  
green: Skin  
blue: Stringer

# Test Performance

## Load Case VBD

- Strains overestimated in general

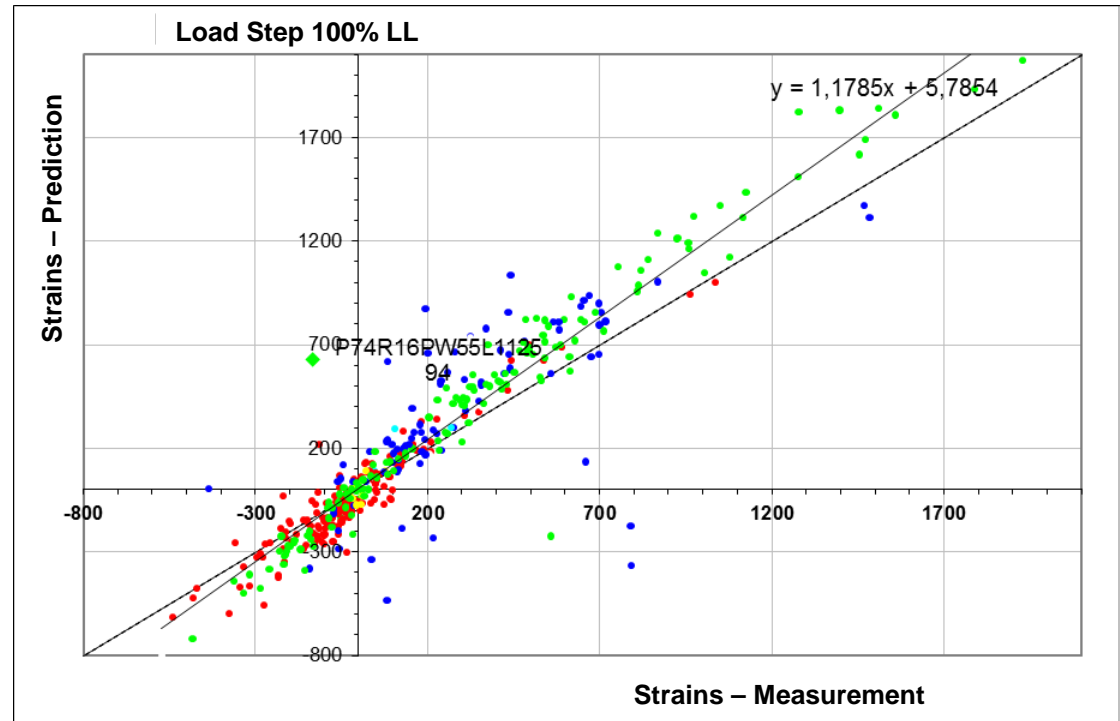


red: Frame  
green: Skin  
blue: Stringer

# Test Performance

## Load Case LBL

- Strains overestimated in general



red: Frame  
green: Skin  
blue: Stringer

# Conclusion

## Test Concept

- Concept with out of plane loads can be realised in general
- Overall Displacements of Specimen are as expected
- Load determination / application has to be improved

## Load Determination

- Concept with optimisation works in general, but should be tweaked towards a “statically equivalent loads”-approach
  - Needs a limited number of load cases
  - Limited number of strain comparison points recommended
- Adjustments to loads are needed during test commissioning

## Next Steps

- Fatigue testing of complex loaded curved fuselage panel

## Contact

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