DIGITAL X

# Automated sizing process of a complete aircraft structure for the usage within a MDO process

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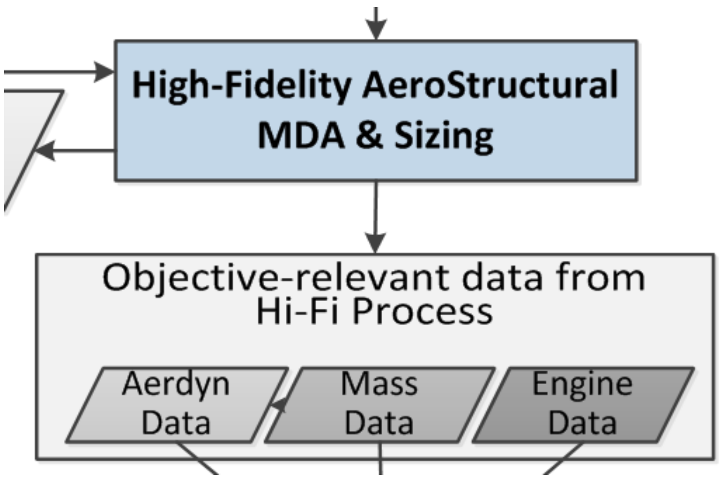
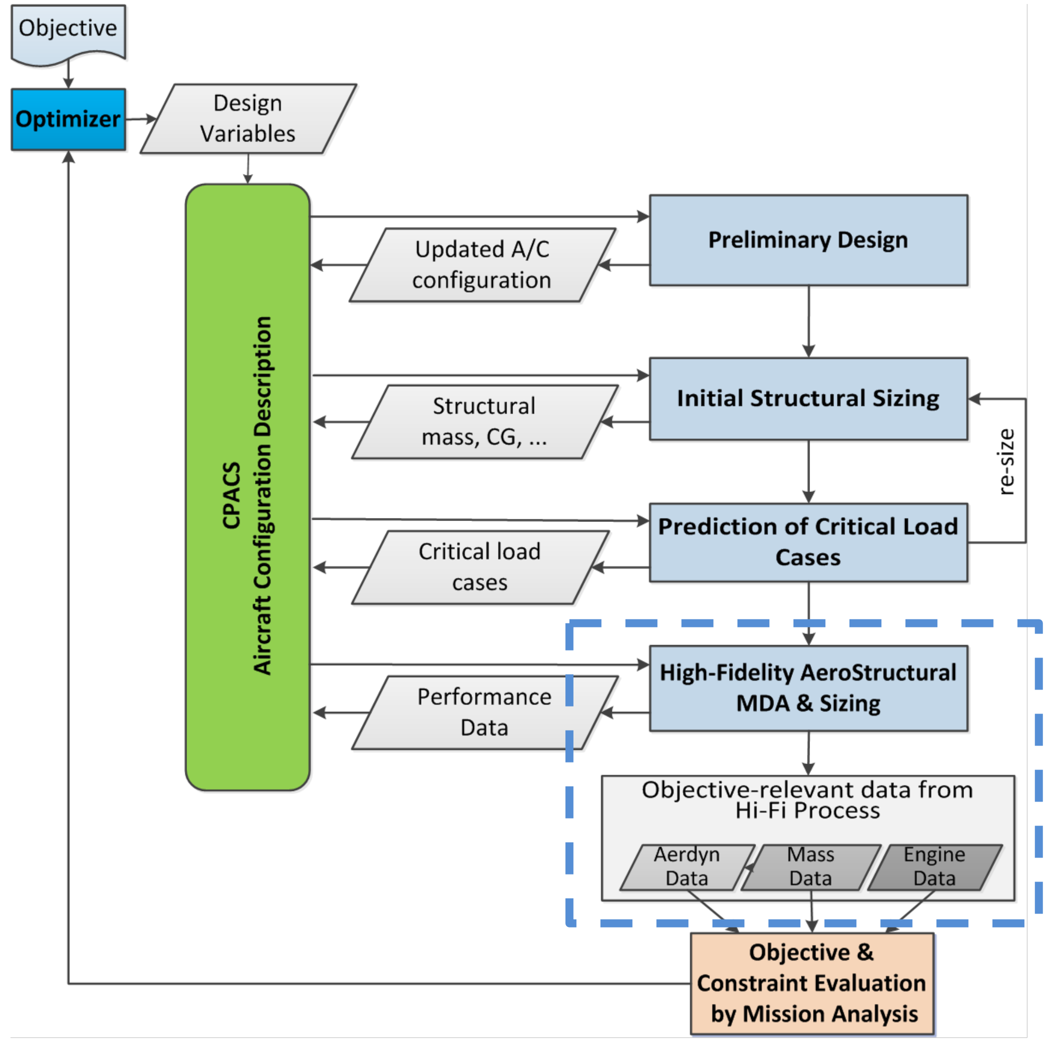
# Introduction

## Motivation:

Estimation of aircraft structural mass change due to changes of the aircraft configuration



# Structural Sizing

- Way forward to obtain aircraft structural mass:
  - Geometrical data
  - Structure definition
  - FE Model generation
  - Coupling of fuselage and wings
  - Loads
  - Static sizing process

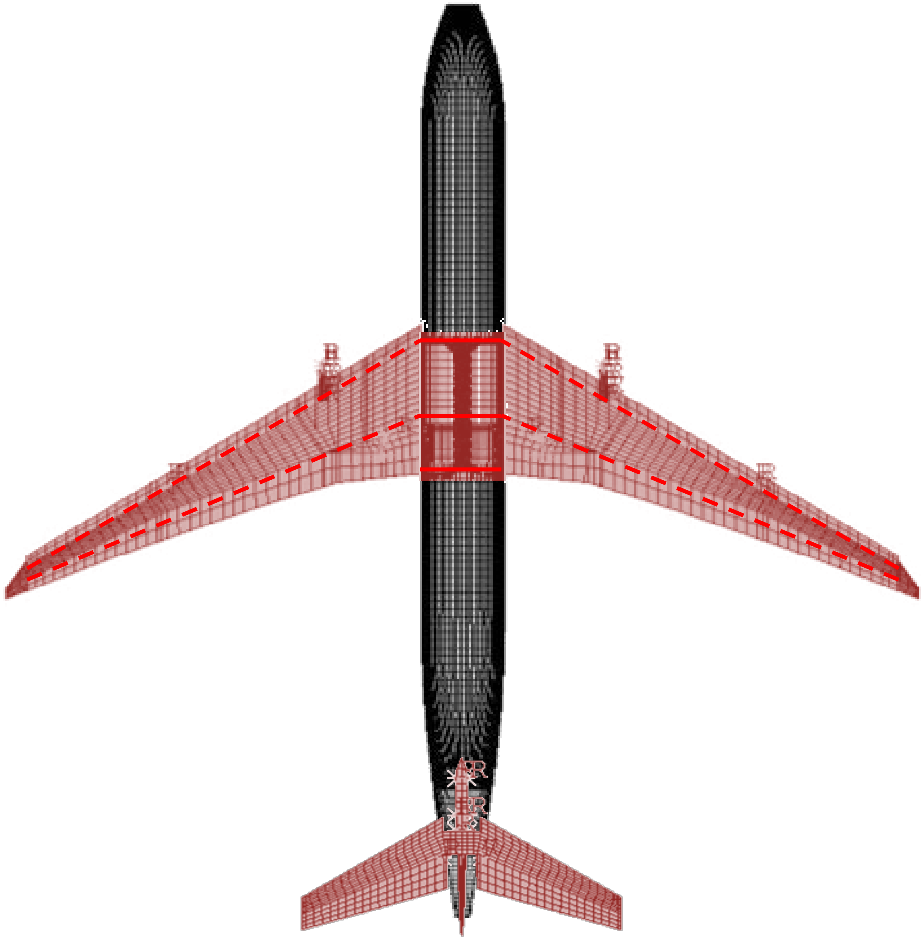
    → Aircraft structural mass!

- Side effects
  - Efficiency, efficiency, efficiency!

# Fuselage Structure Definition

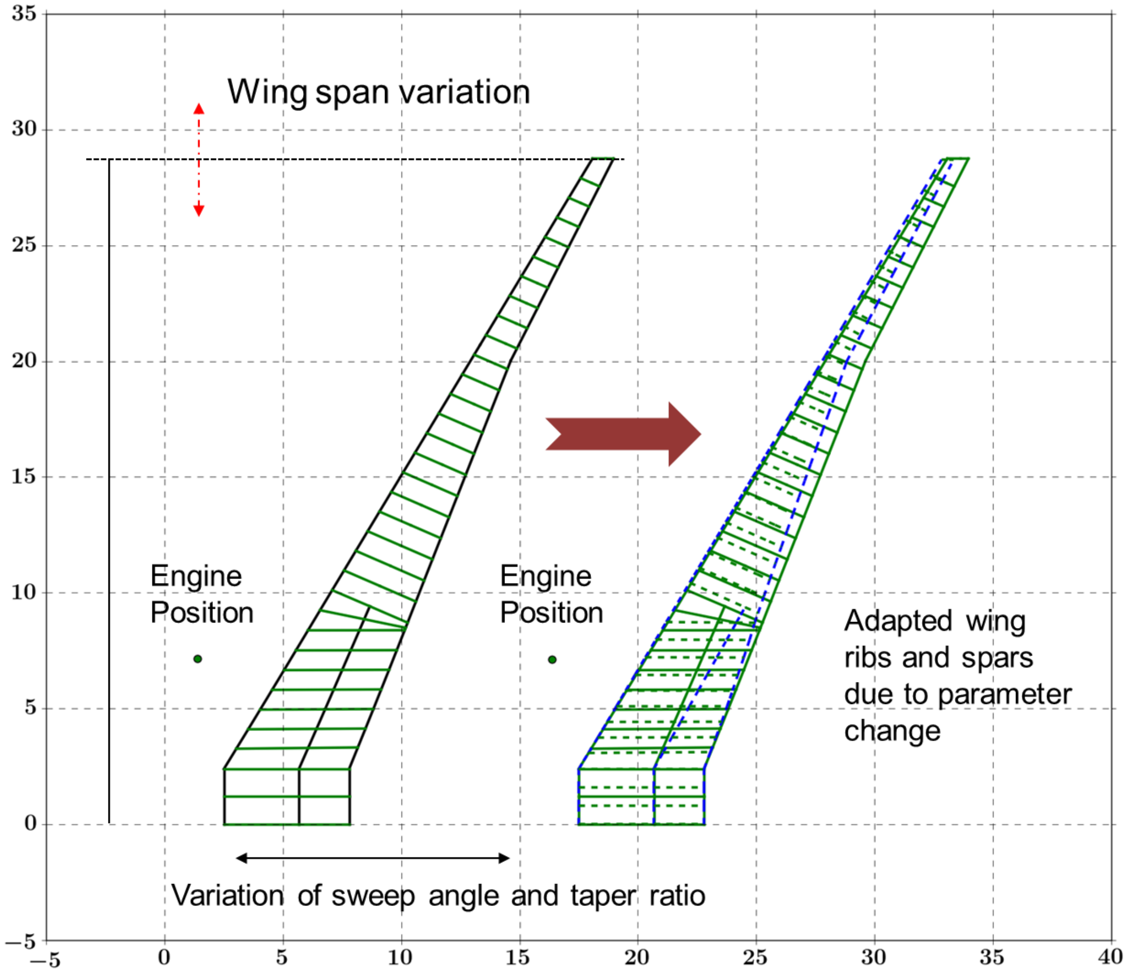
- Fuselage geometry stays the same – why does fuselage structure need adaption at all?
    - Wing geometry and position subject to optimization
    - Wing spar positions may change
    - Tailplane positions may change

    → Structural coupling of fuselage and wing requires fuselage structure definition update!



Adaption of fuselage structure definition

# Wing Structure Definition




Adaption of wing structure definition

- Adjustment of system ribs (for landing gear, engine, flaps) during optimization due to outer wing shape parameter change
- Automated generation of ribs within wing if no information is given in dataset

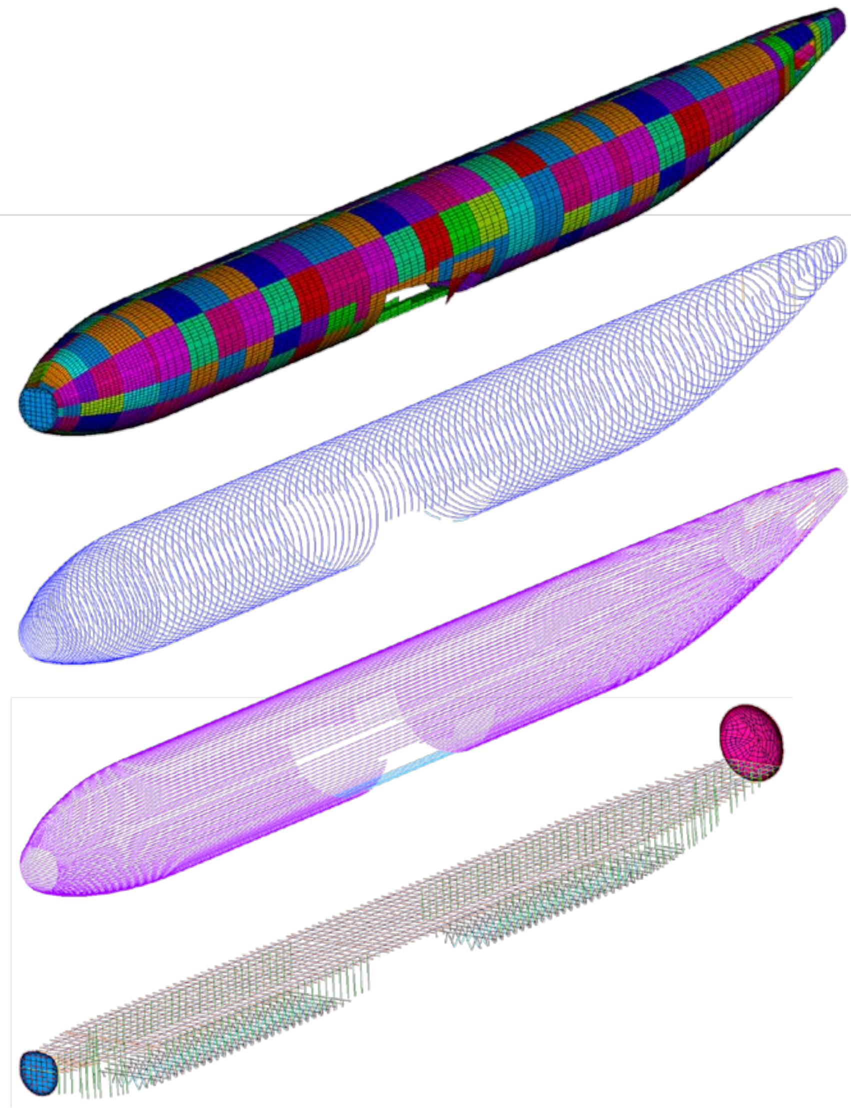
# Fuselage Model Generator

- Automated generation of fully parameterized fuselage models based on CPACS input

- Basic features:
    - Skin panels (shells)
    - Reinforcements (beams)
    - Floors (beams)
    - Bulkheads (shells and beams)

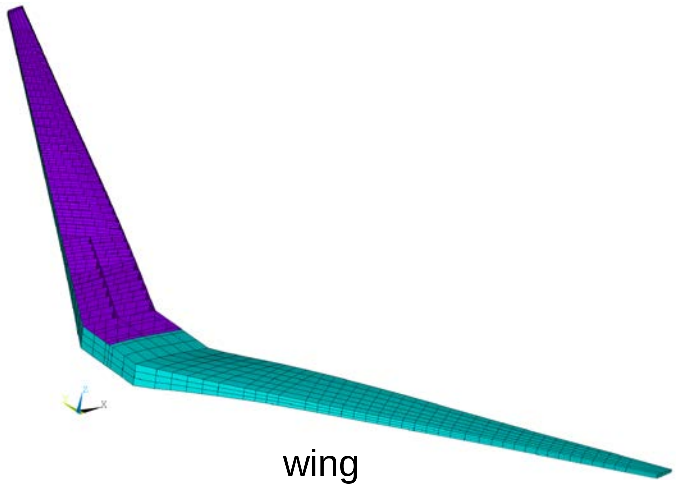
- Detailed coupling regions

- Based on Python and ANSYS APDL
- Sizing tool: SBOT+

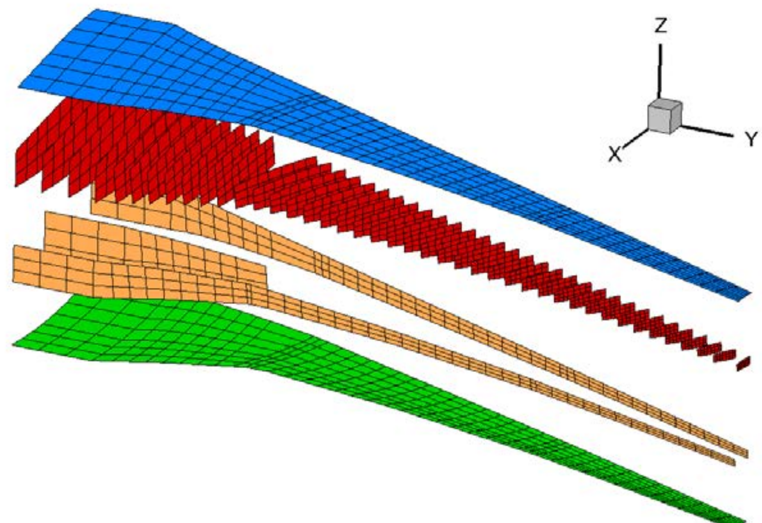


# Wing Model Generator

- Automated generation of fully parameterized wing and empennage models based on CPACS input
- Basic features:
  - upper/lower skin, spars, ribs (shells)
  - wing stiffener (as beam and smeared skin layer)
- Additional features integrated:
  - engine, landing gear, flaps, secondary masses
- Interfaces to FE solver: ANSYS, Nastran
- Interface to sizing tools: SBOT and HyperSizer



wing

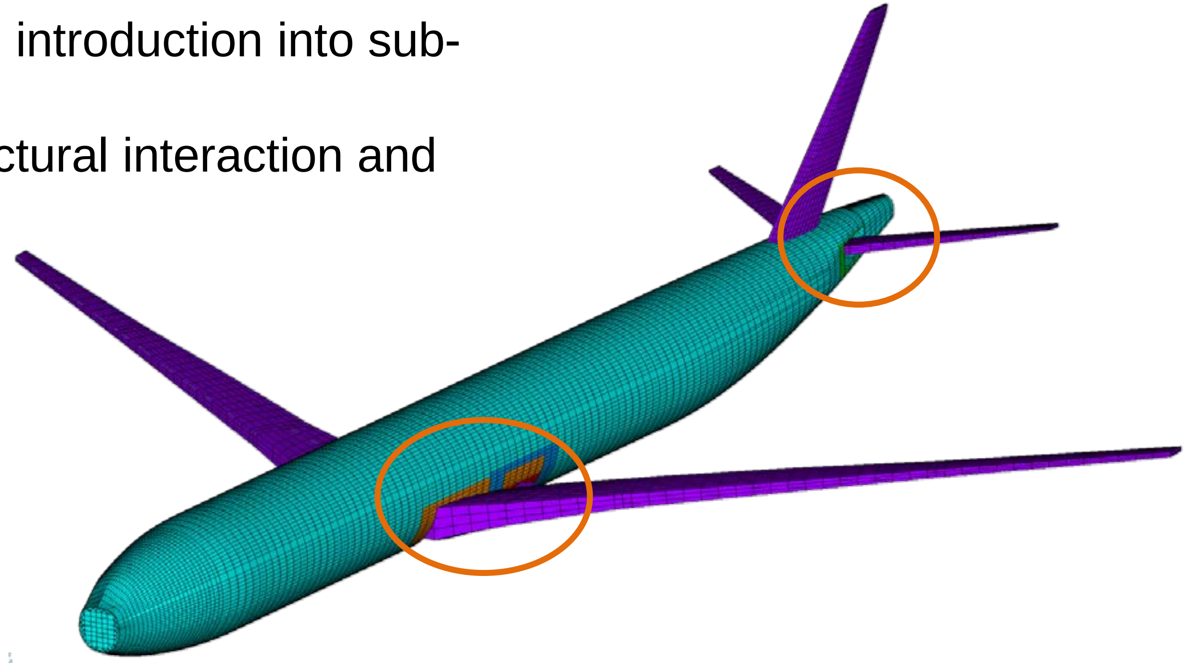



structural components of wing

# Coupling of Fuselage and Wings

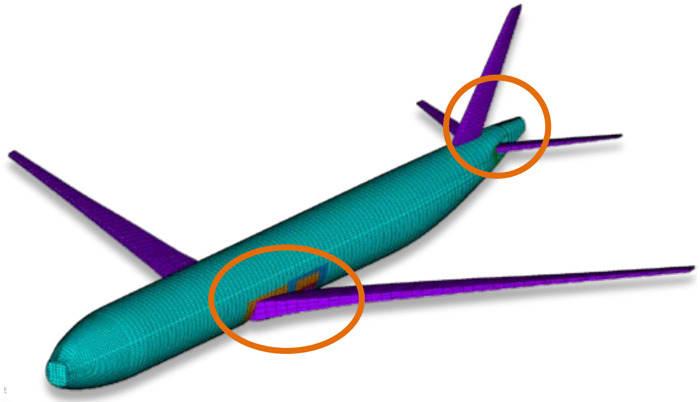
- Fully **automated** coupling of sub-models using consolidated interfaces

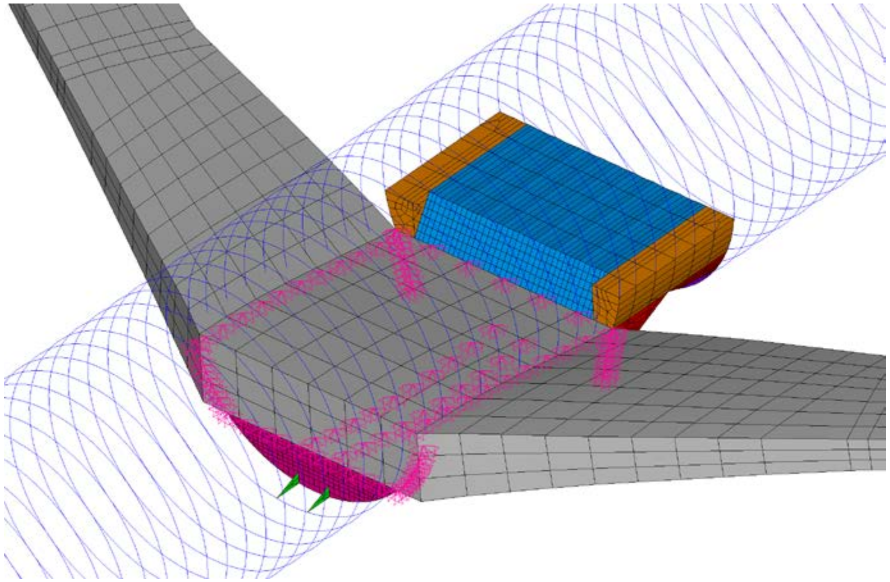
- Benefit:
  - improved load introduction into sub-models
  - improved structural interaction and sizing results

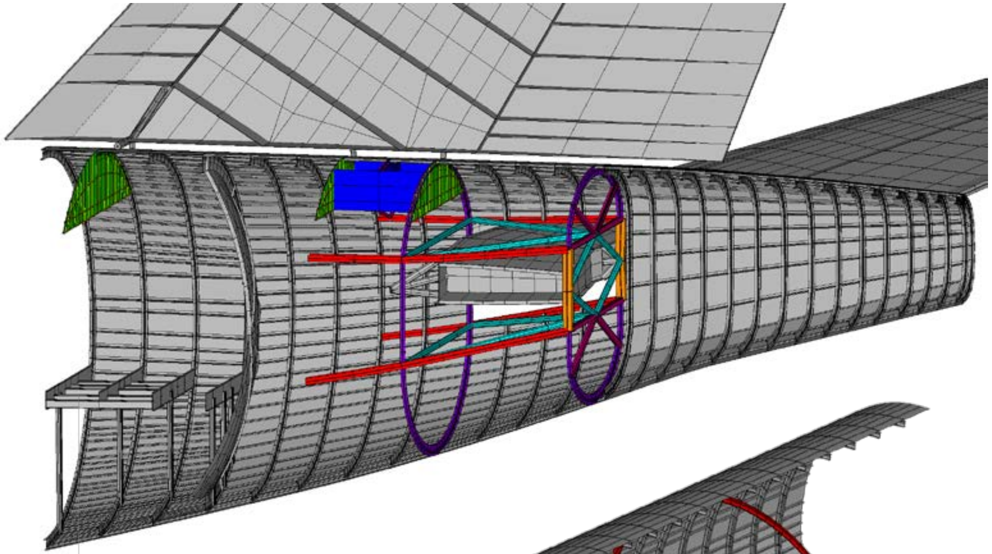


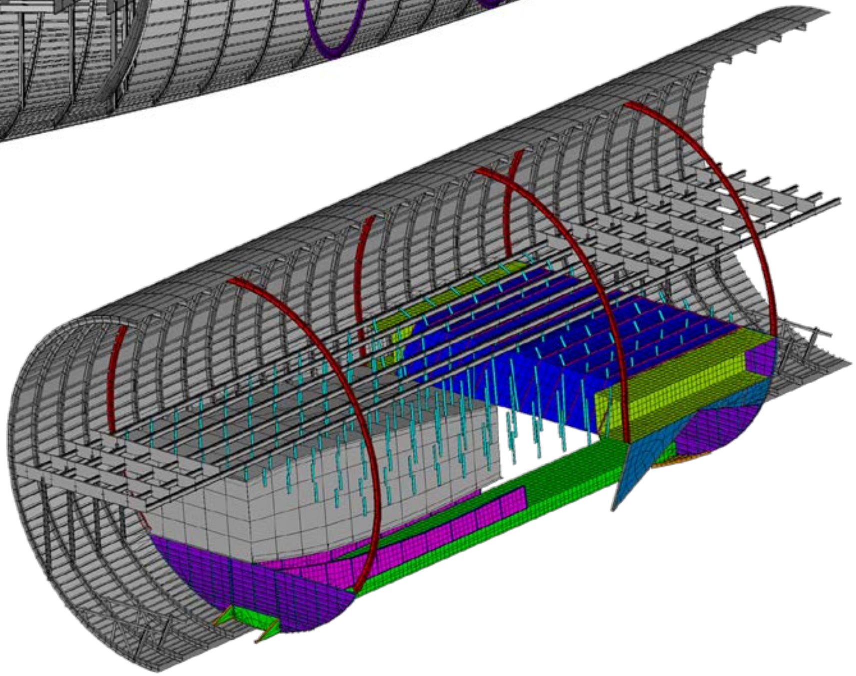
Coupling of sub-models

# Coupling of Fuselage and Wings







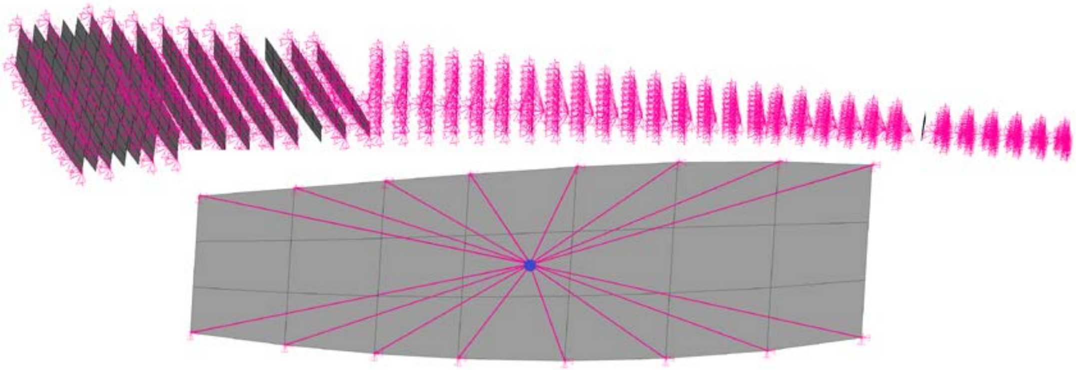


# Transmission of SMT Loads into Structure

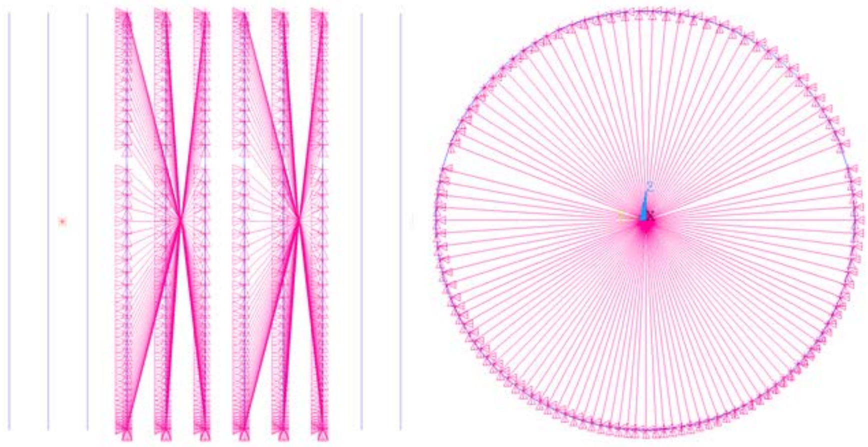
- SMT (shear, moment, torque) loads provided on loads reference axis points from preceding loads process

- Loads transmitted into structure via rigid body elements

- (Pressure loads on surface nodes, usage: mission analysis)

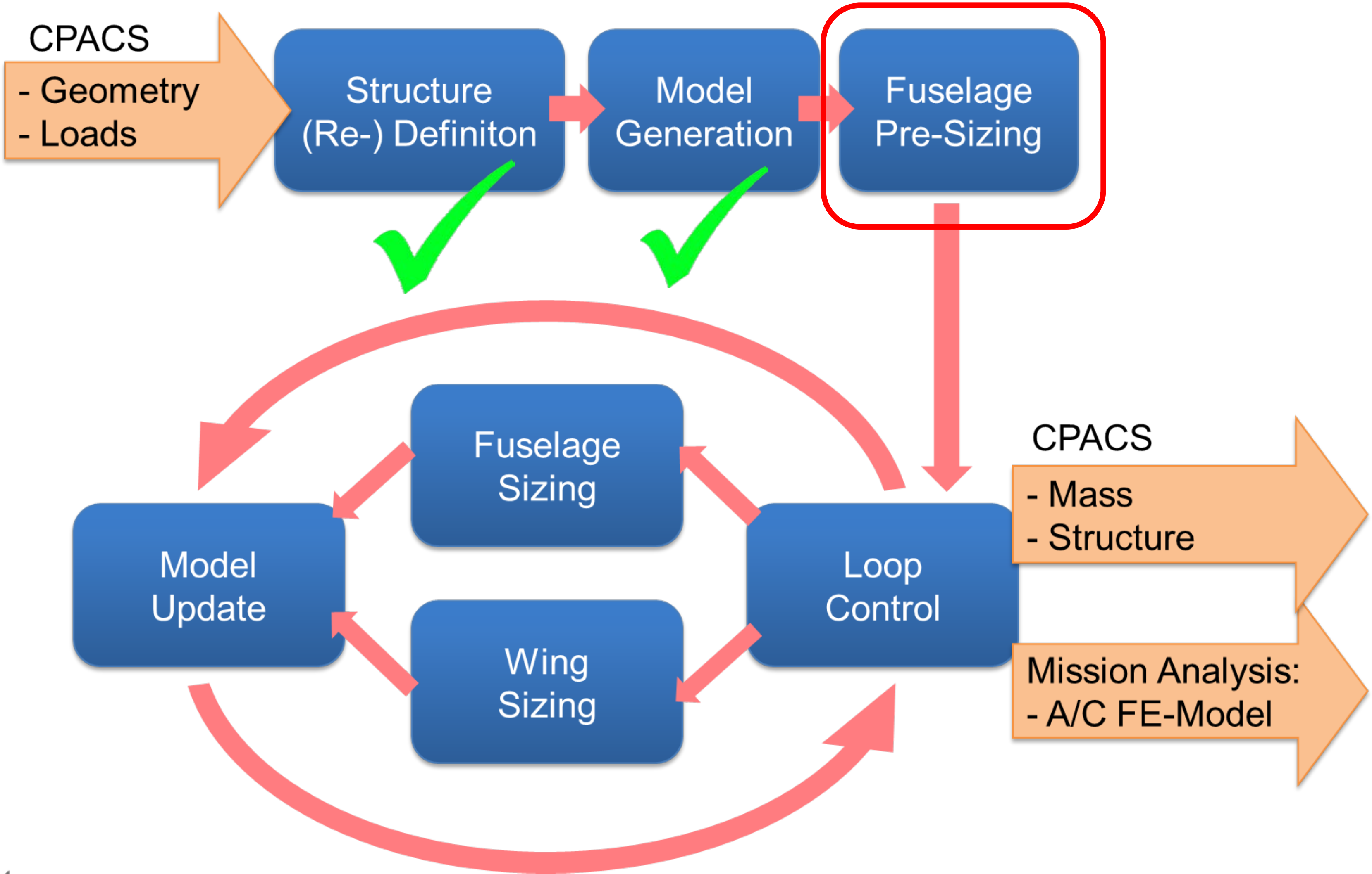


Load transmission into wing ribs



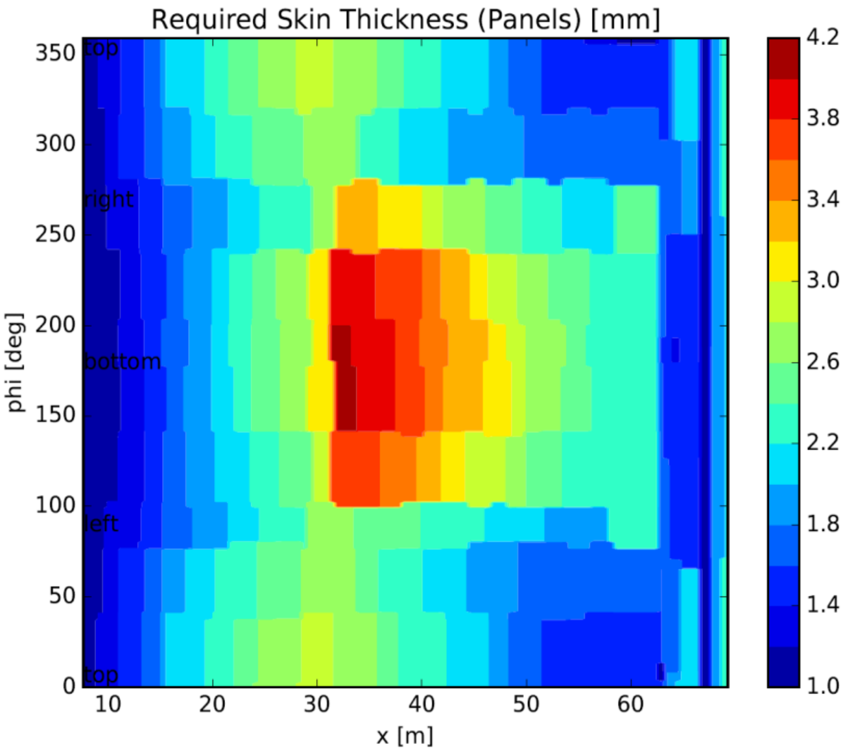
Load transmission into fuselage frames

# Static Structural Sizing - Process



# Static Structural Sizing – Efficiency

- Analytical fuselage pre-sizing
    - Very fast but not suited for complex geometry:
      → use numerical sizing!
    - Improve start values of skin panels: reduce iteration number
    - Selection of critical fuselage load cases: reduce iteration time



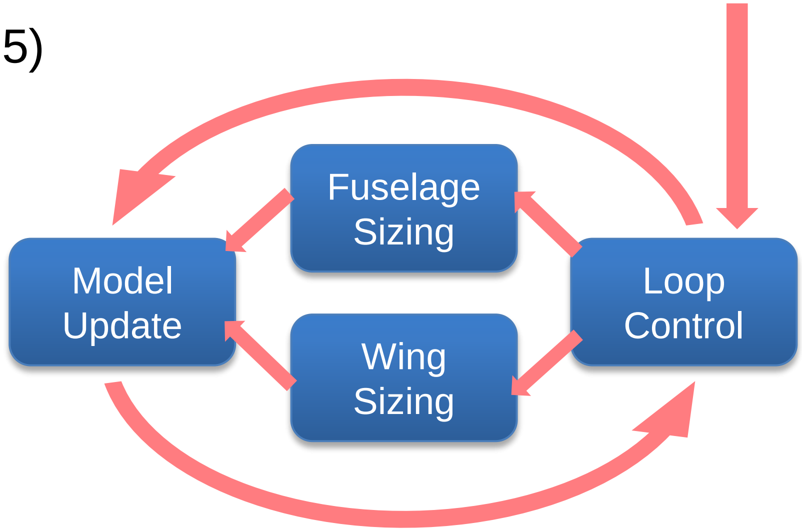

Exemplary fuselage panel thickness result from analytical fuselage pre-sizing

# Static Structural Sizing Loop

- Used configuration: long range XRF1
- Isotropic materials (e.g. aluminum 2024/7075)

- Fully Stressed Design approach

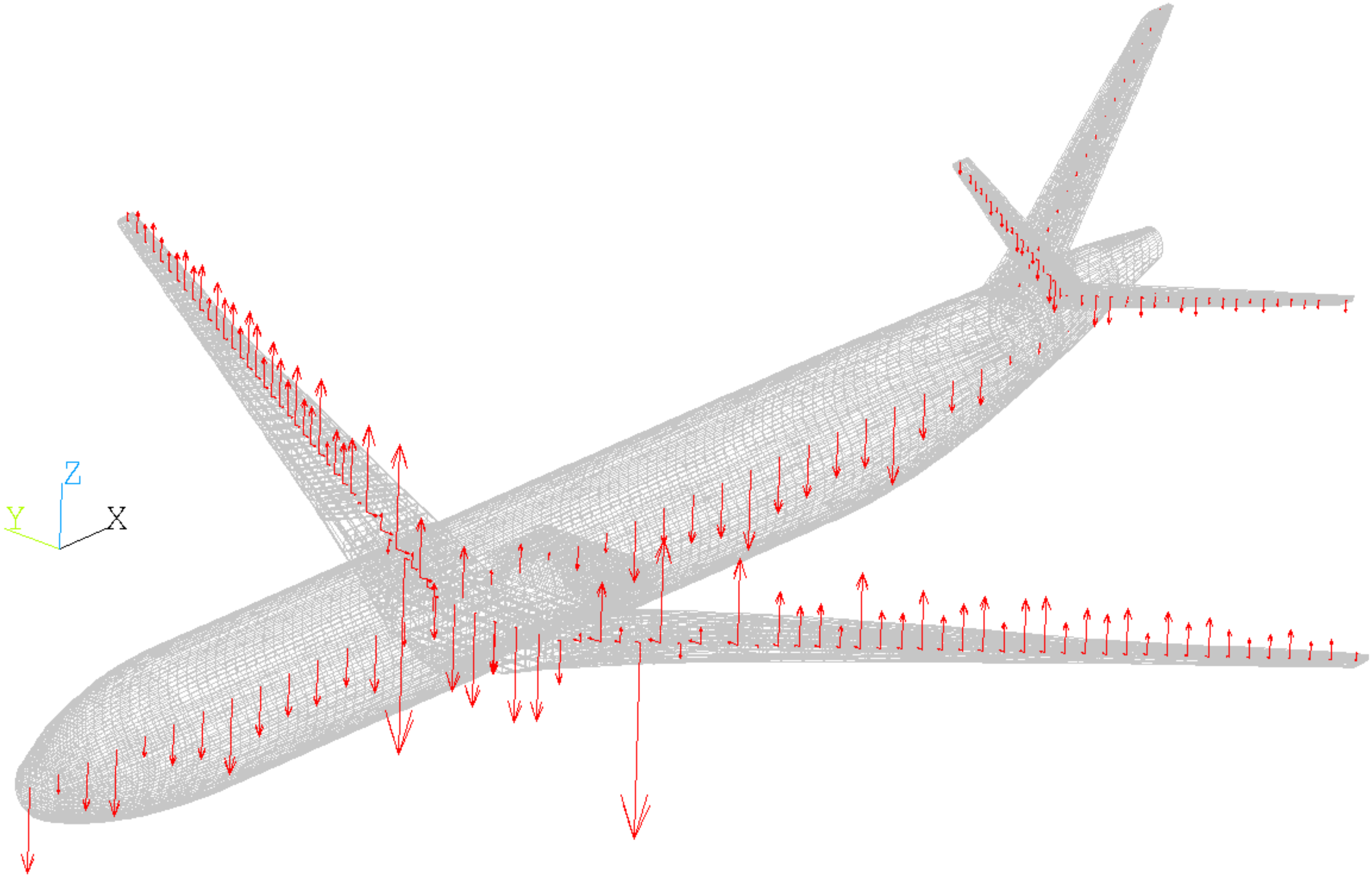
- Failure criteria for isotropic materials:
  - Strength (Von-Mises Stress)
  - Stability (HSB local skin buckling)



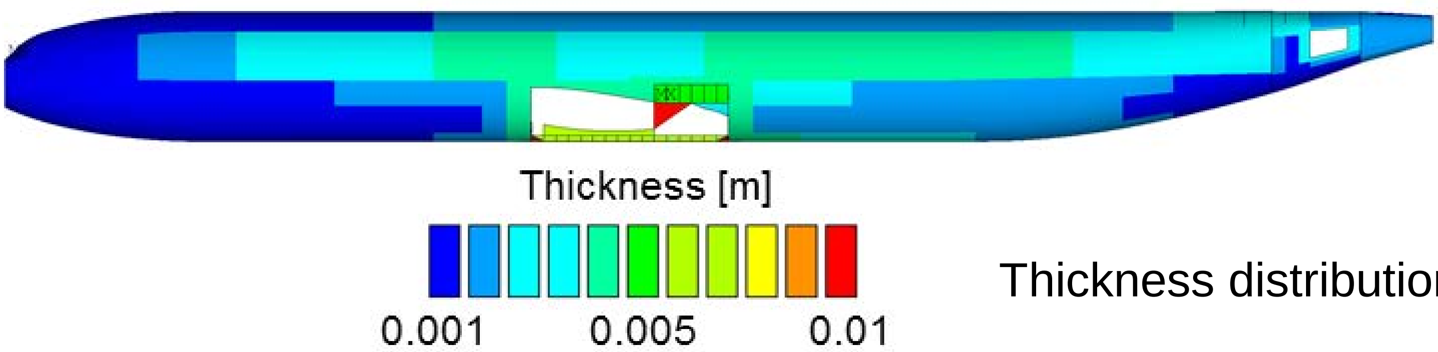

- Convergence criteria:
  - total aircraft mass difference <100 kg for two consecutive sizing iterations

- Input from Loads process:
  - Typically 50-60 critical SMT load cases including Maneuver and Gust loads

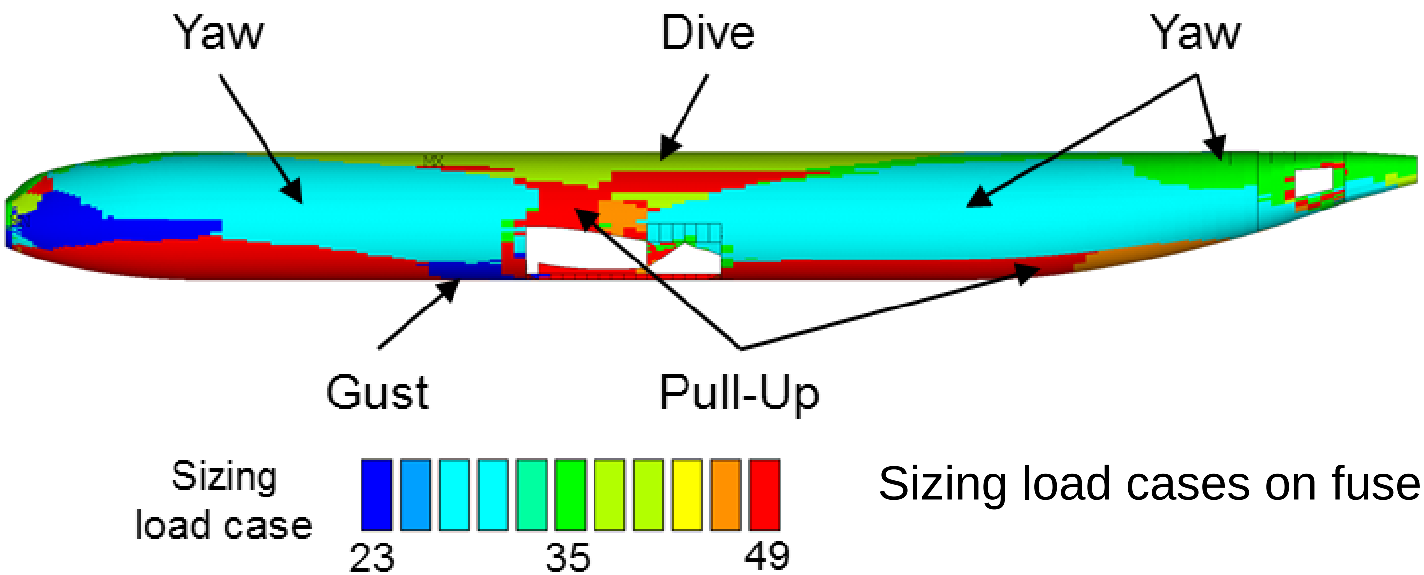
# Examplary 2.5g maneuver load case



# Static Structural Sizing - Results

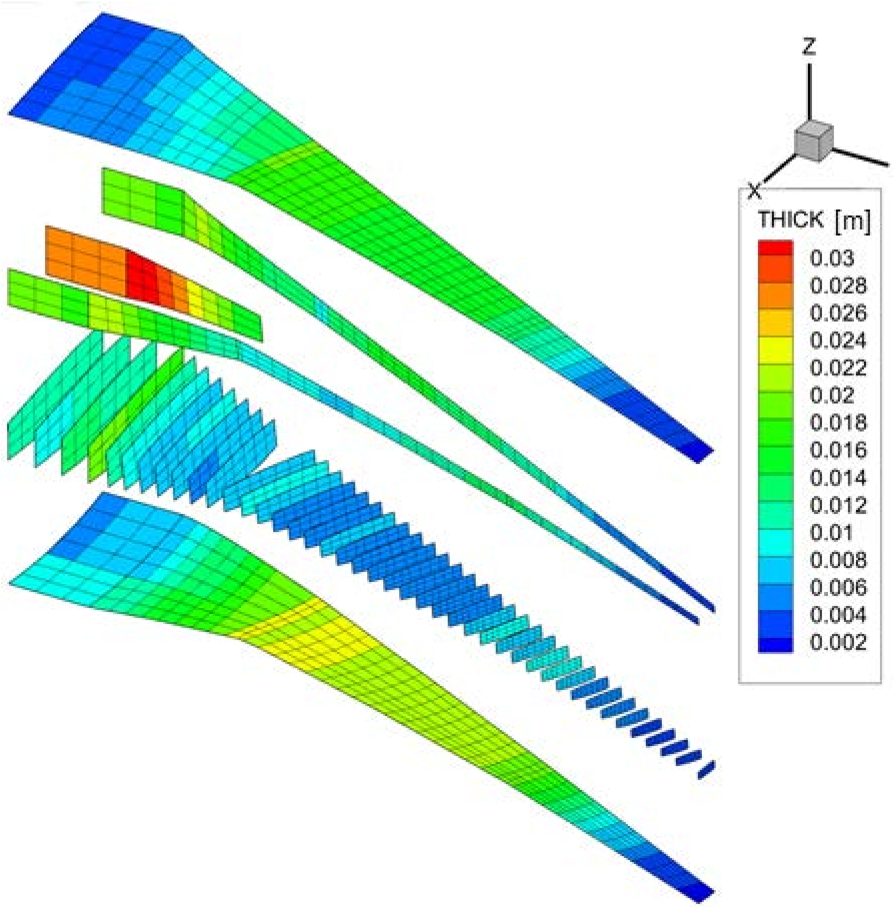



Thickness distribution

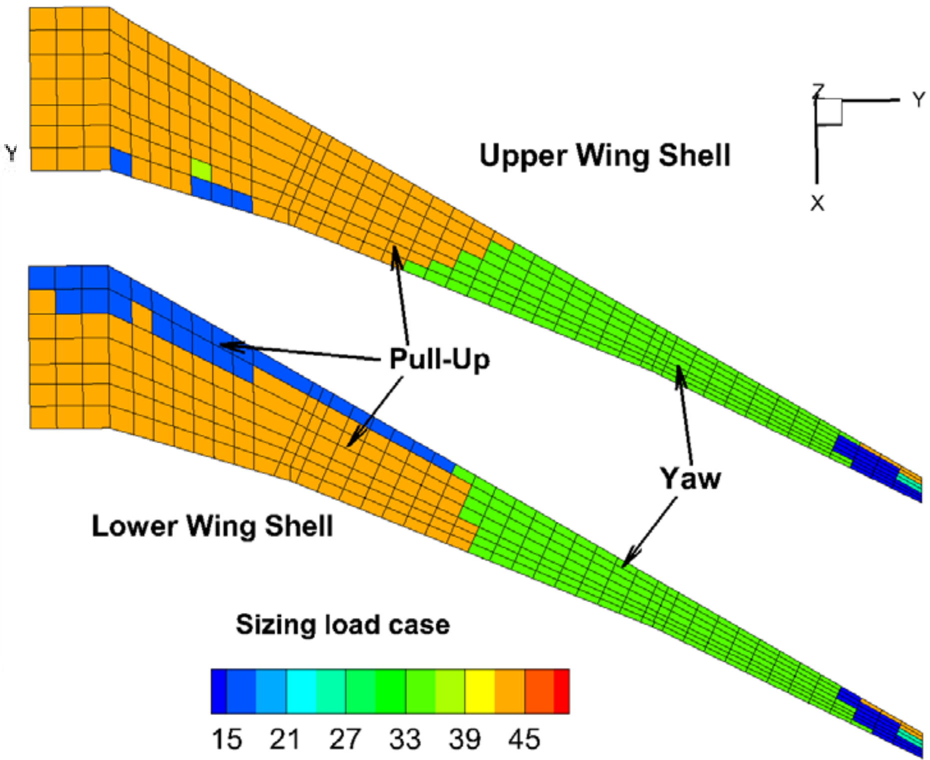



Sizing load cases on fuselage

# Static Structural Sizing - Results

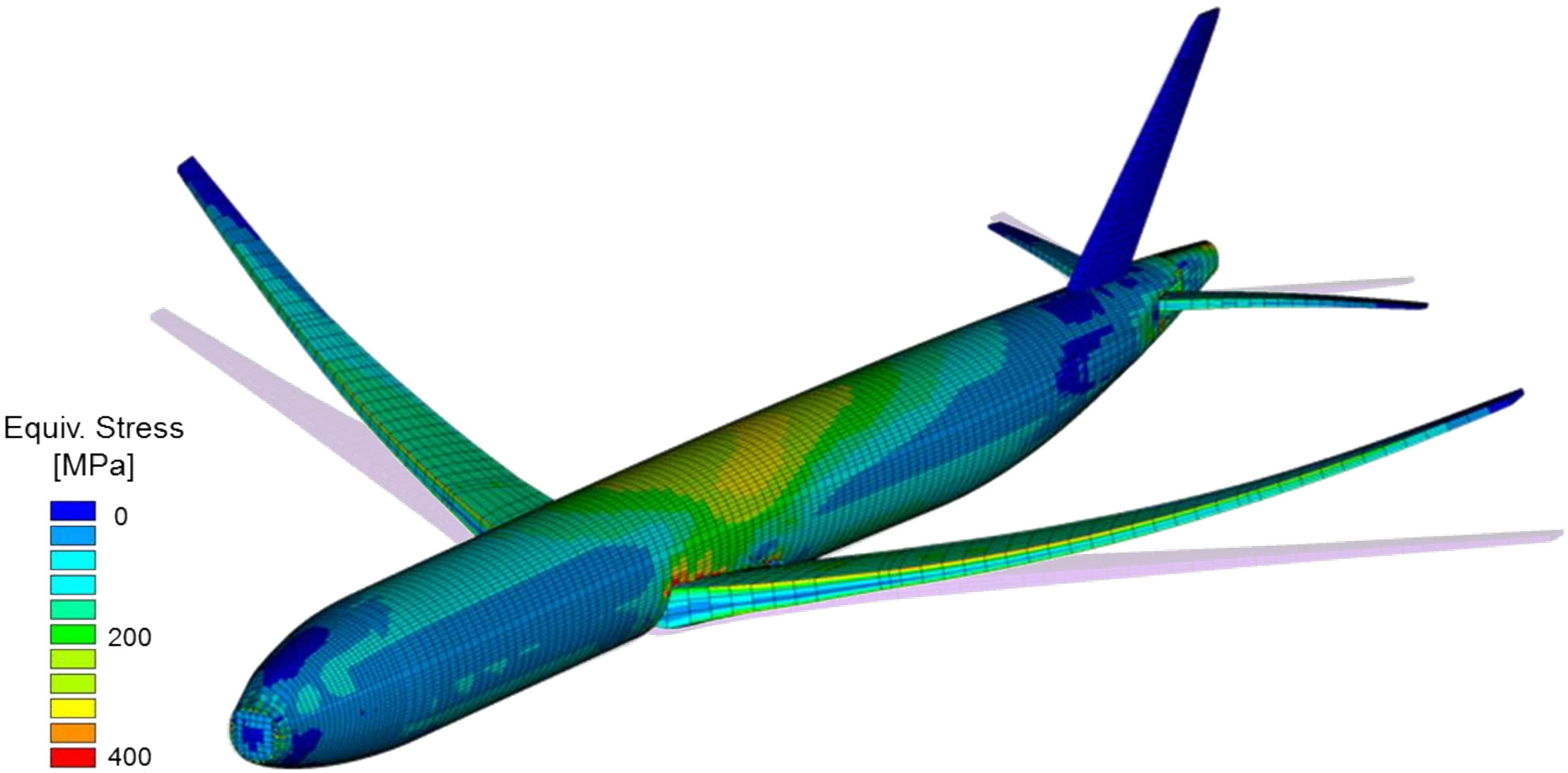



Thickness distribution




Sizing load cases on wing shell

# Static Structural Sizing - Results

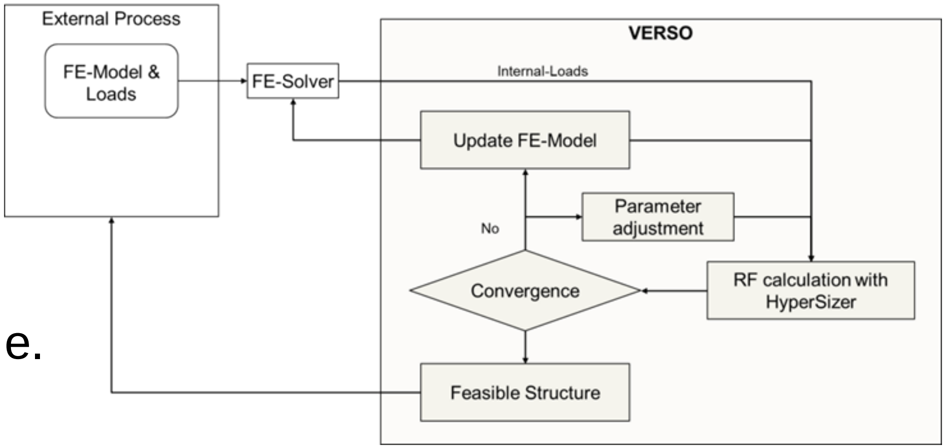


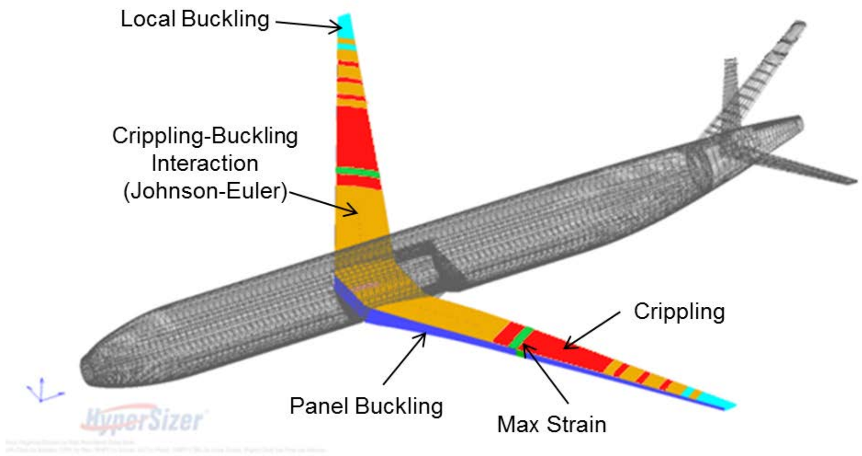

Equivalent stress distribution on a sized aircraft, 2.5 g pull up maneuver

Final Mass of sized aircraft: ~ 40t

# Development of an Environment for Composite Sizing & Optimization

- Consideration of composites
- Optimization of
  - Structural design concepts
  - Structural concept parameters (i.e. stringer height, pitch, …)
  - Material
- Parameter adjustment process to ensure compatibility to adjacent structural elements
- Efficient smeared composites approach for analysis
- Transformation of smeared composites into discrete layups



# Structural Sizing – Summary and Achievements

- Providing structural mass update to MDO process requires:
  - Adapt structure definition to geometry variation
  - Create and couple FE models
  - Apply given loads on aircraft model
  - Perform structural sizing
  - **Be fast!**

- Achievements:
  - Development of a cross-institute, fully automated, full aircraft, static structural sizing process for isotropic materials (used in MDO process)
  - Development of a fully automated environment for composite sizing and optimization
- Outlook
  - More detailed structure modelling (e.g. wing manholes)
  - Advanced failure criteria

# Vielen Dank für ihre Aufmerksamkeit!

# Fragen?