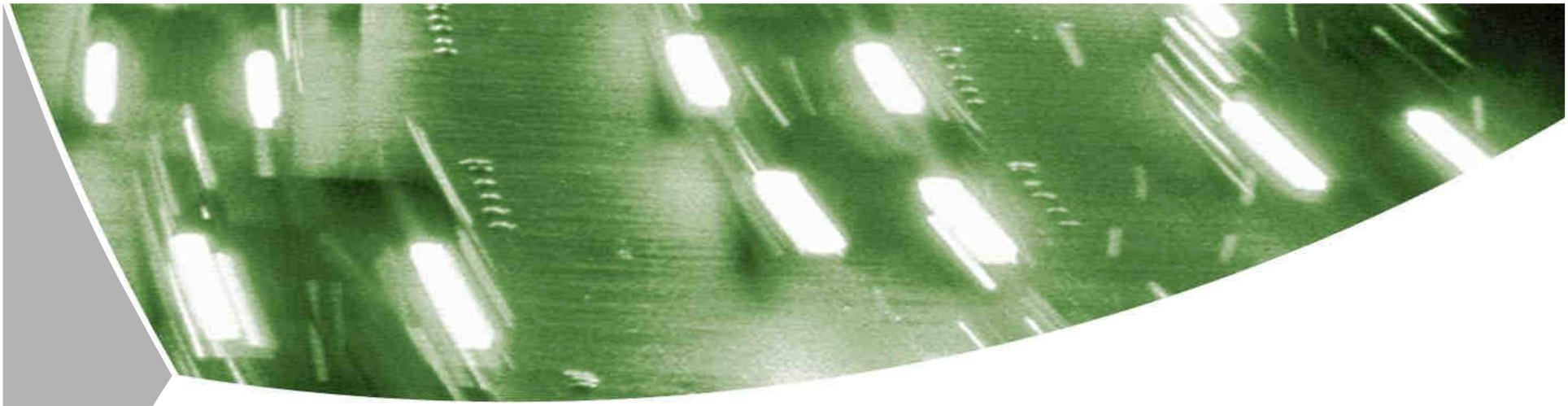


COMPOSITES Forum, Lightweight Structure,
15. September 2010

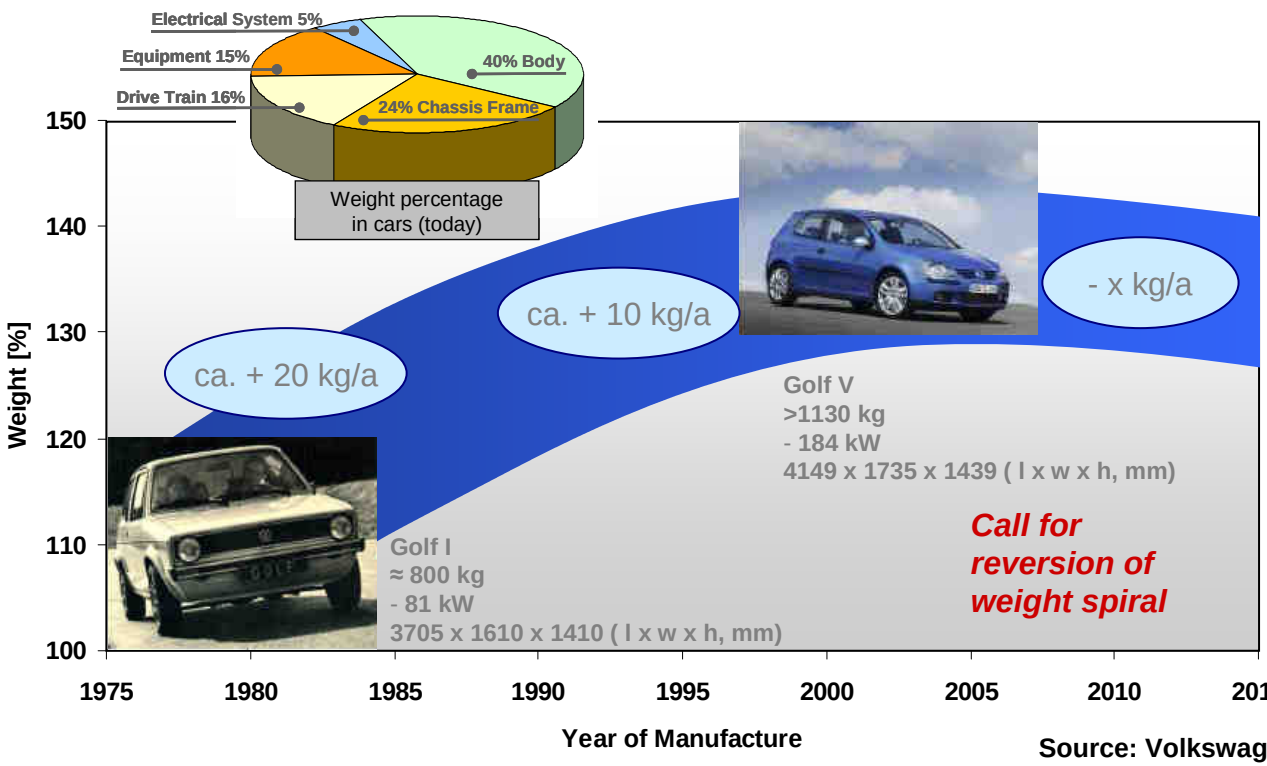
Crash Relevant Composite Vehicle Structures in the DLR Vehicle Concept NFS

Arne Stahl, Dr. Christian Hühne, Gerhard Kopp

Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Institute of Composite Structures and Adaptive Systems

Lightweight Design – Motivation



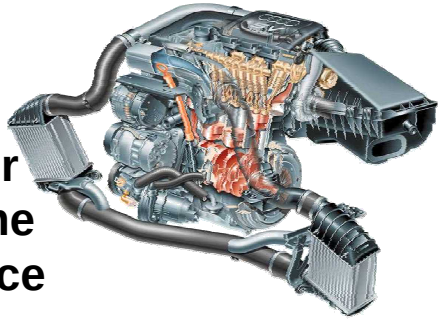
lightweight design - motivation

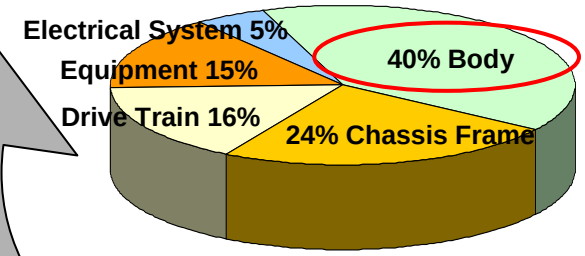
- reduction of pollutant emission
- increased driving comfort
- compliance of the law
- optimised efficiency weight
- optimised axle load distribution
- compensation of battery weight
- increase in equipment components and safety without extra weight

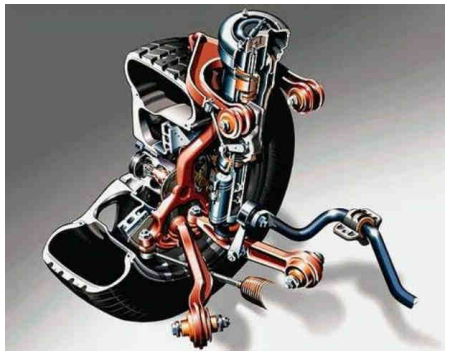
Lightweight Design – Weight Potentials and Weight Spiral

Mass reduction of BIW

Smaller, lighter engine for same car performance







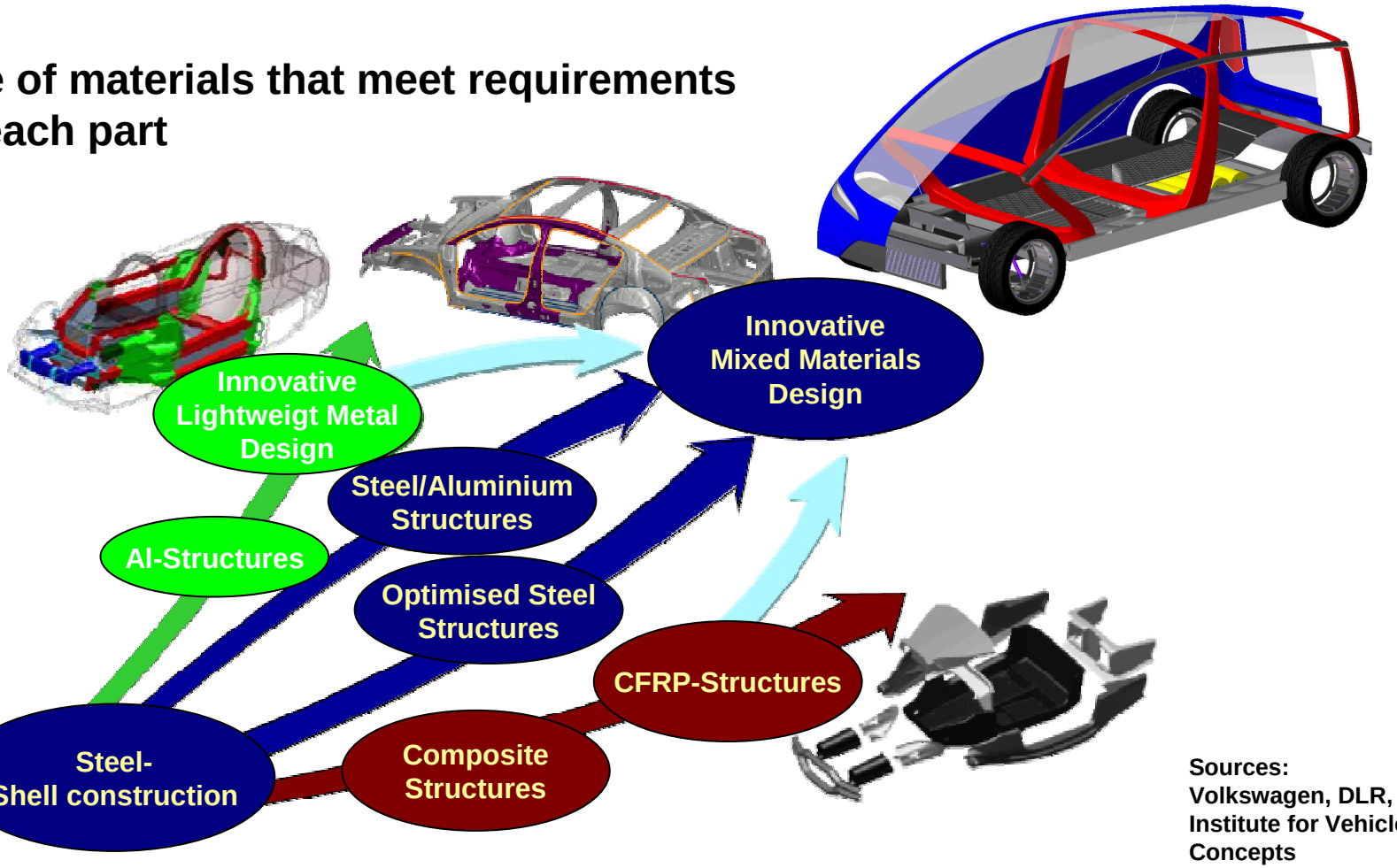
Smaller suspension, brakes and drivetrain

Less fuel consumption: smaller tank for same range

Source: Volkswagen, Bertrandt

Lightweight Design – Material Approaches for Weight Reduction

Use of materials that meet requirements of each part



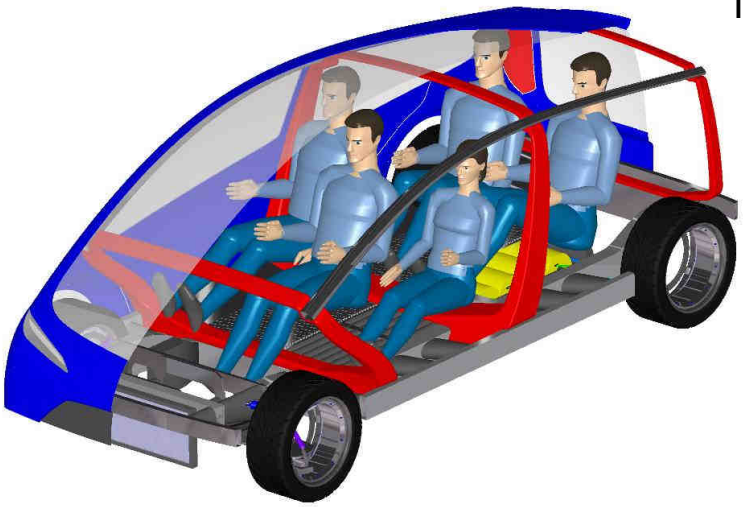
Sources:
Volkswagen, DLR, Institute for Vehicle Concepts

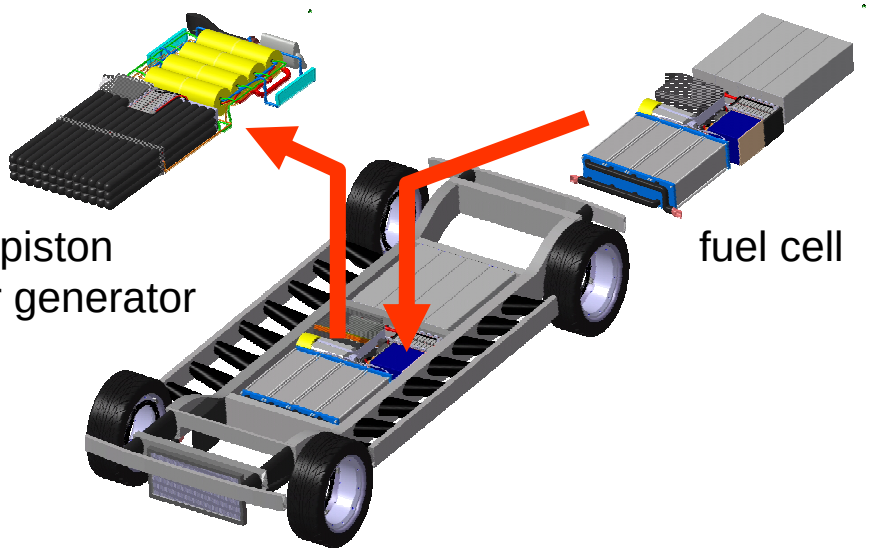
Lightweight Design – Innovative Rib and Space Frame Design

Objectives of the multi material vehicle concept

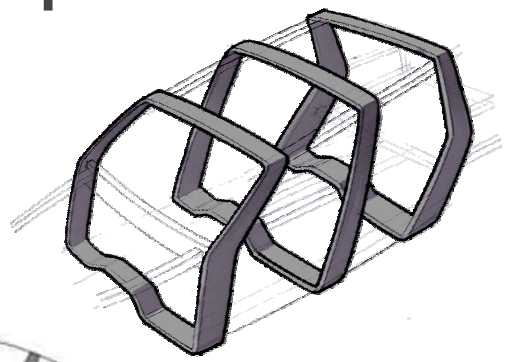
Ground-breaking improvements for

- Weight reduction
- Enhanced safety
- Innovative modular strategies





Lightweight Design – Innovative Rib and Space Frame Design



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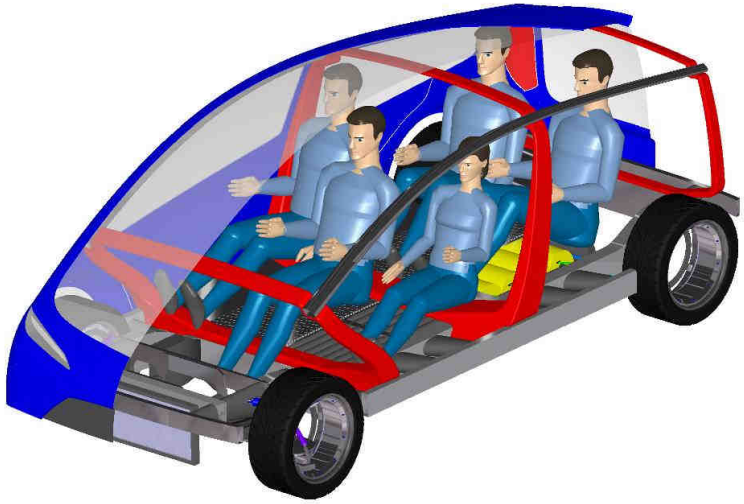
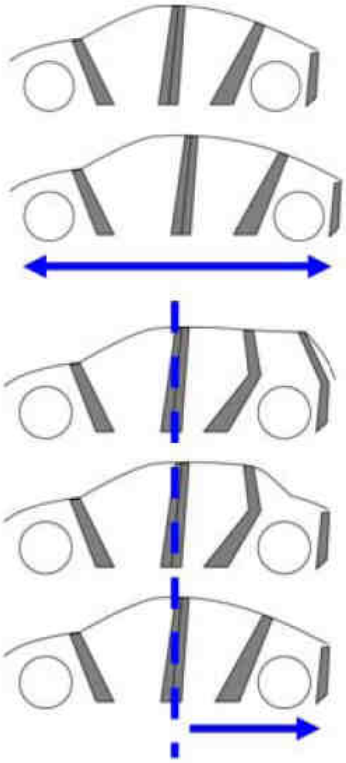
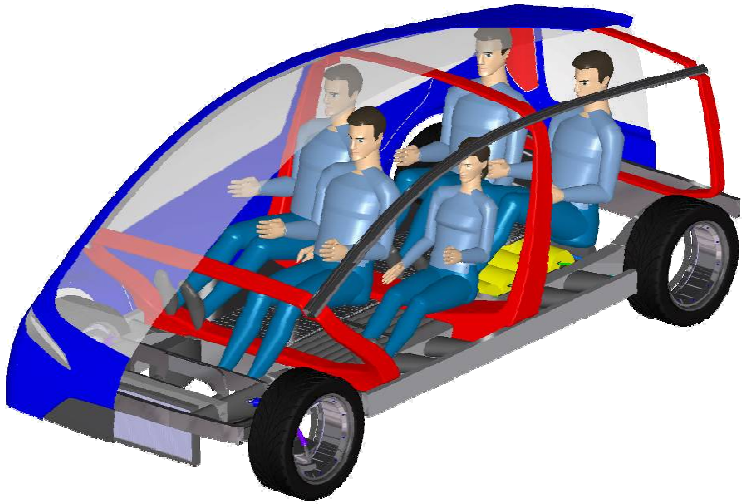




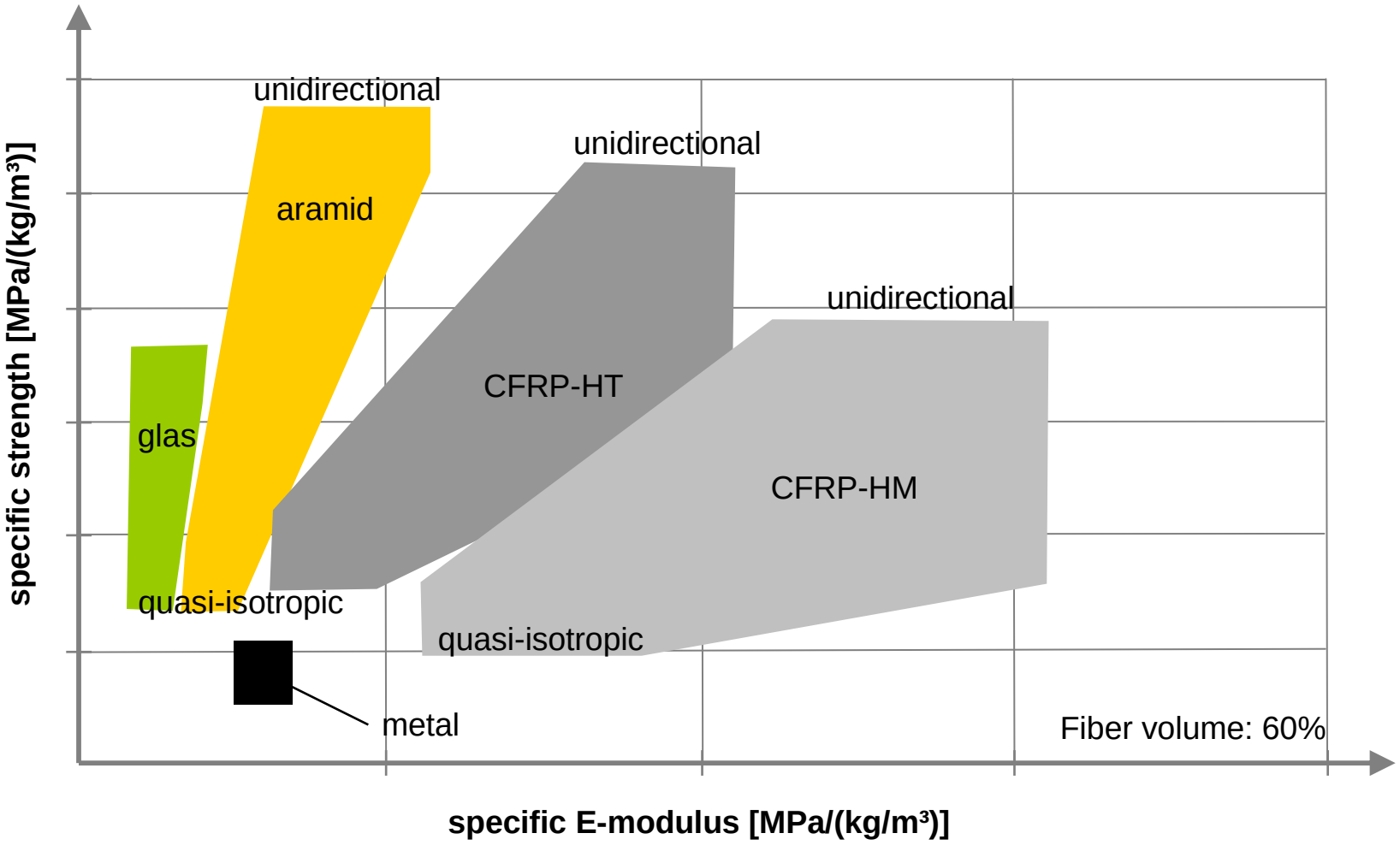
B-Frame as Central Component

Design of the B-frame as a crash relevant part made of CFRP incorporating the following requirements:

- Non-deformable passenger cabin during side impact
  - low intrusion into cabin
- Compliance with safety values for acceleration of passengers during side impact



Composites – Properties under Static Load



Composites – Properties under Dynamic Load

Experiment: dynamic load in axial direction of a crash cone

(a) CFRP **(b) Metal**

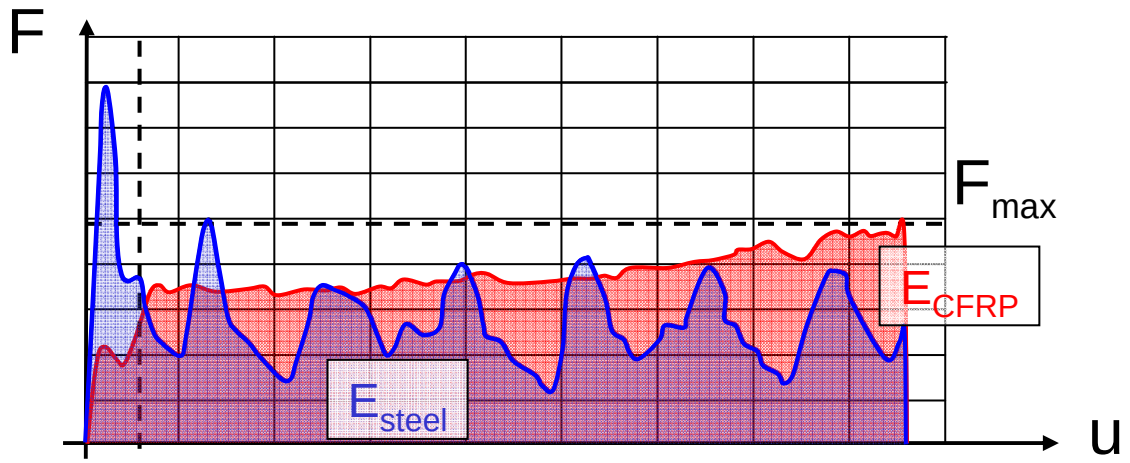
Composites – Properties under Dynamic Load

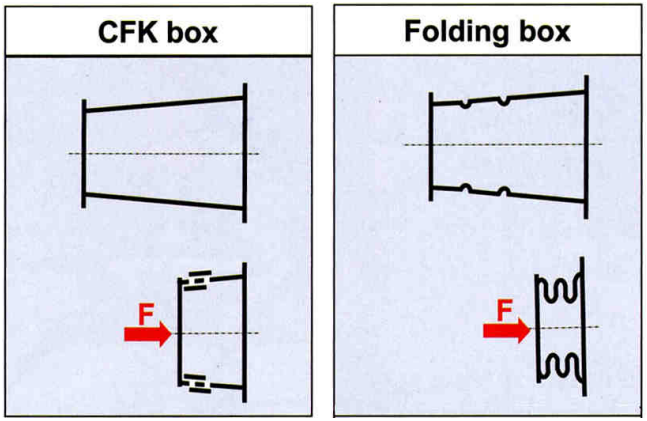
Experiment: dynamic load in axial direction of a crash cone

(a) CFRP **(b) Metal**

Active Principles: Energy Dissipation

Crash cone under dynamic load in axial direction





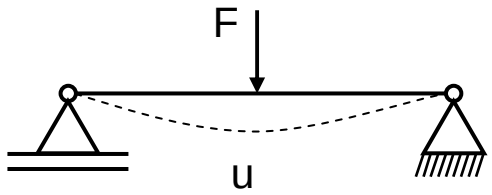
With load in fiber direction:

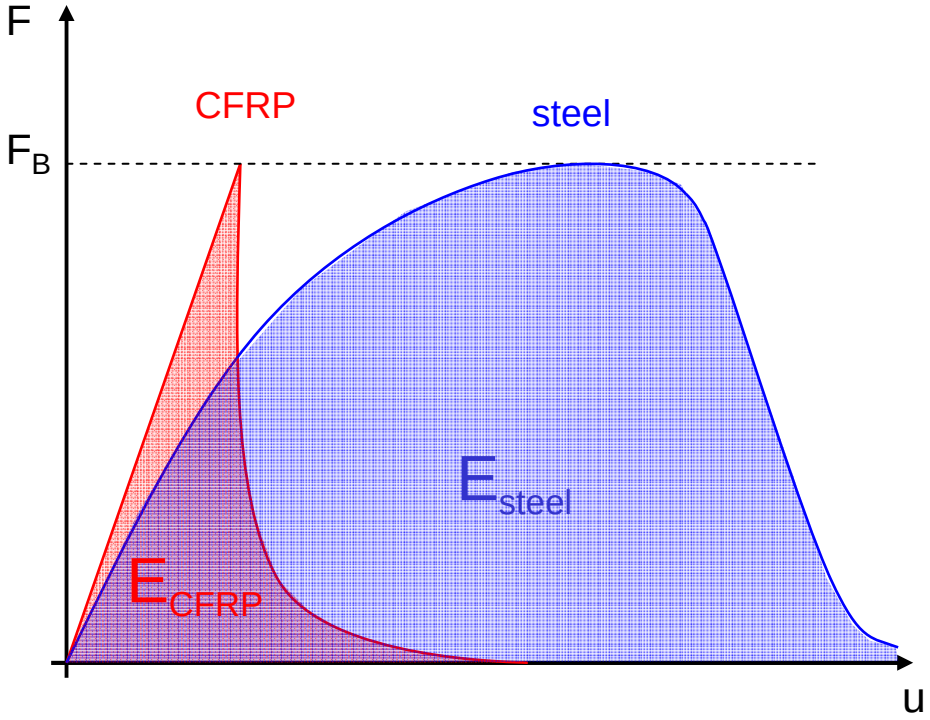
$E_{CFRP} > E_{steel}$

Source: Stauber, Vollrath, Plastics in Automotive Engineering

Active Principles: Energy Dissipation

3-point-bending under dynamic load
(until failure, same ultimate load)



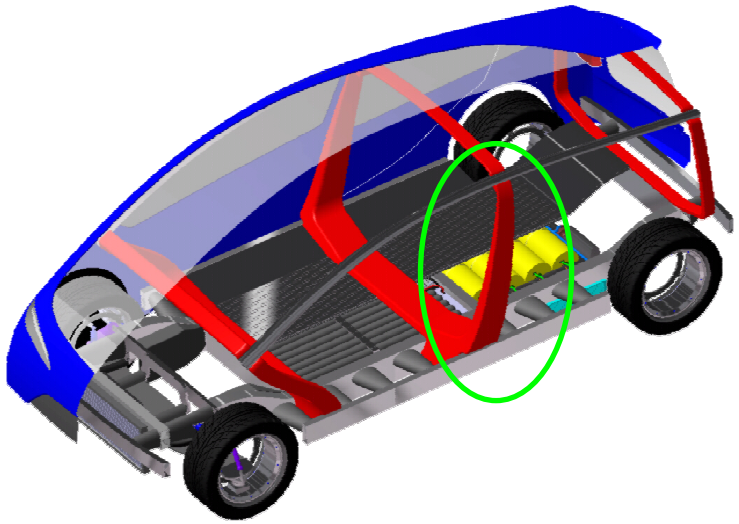


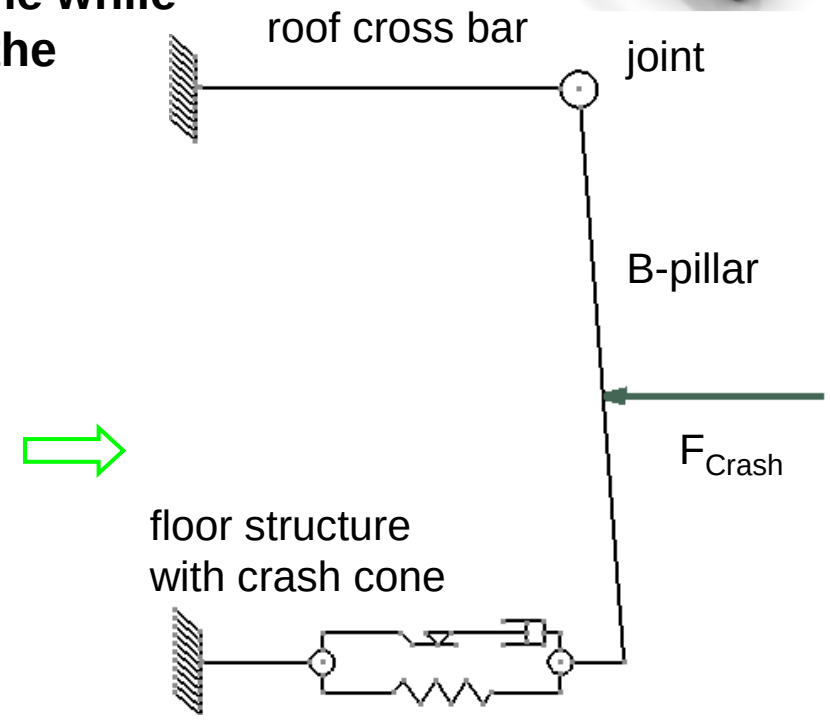
With load orthogonal to fiber direction:

$E_{CFRP} < E_{steel}$

Mechanical Analogous Model of Frame during Side Impact

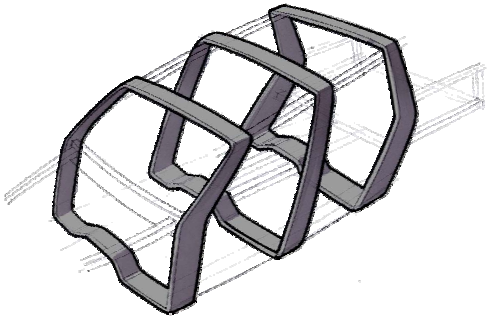
- **Basic idea: firm B-pillar with a deformable joint at the roof post and “high performance crash absorption” underneath the front seats**
- **Minimum deformation of the frame while dissipating maximum energy in the crash cones**

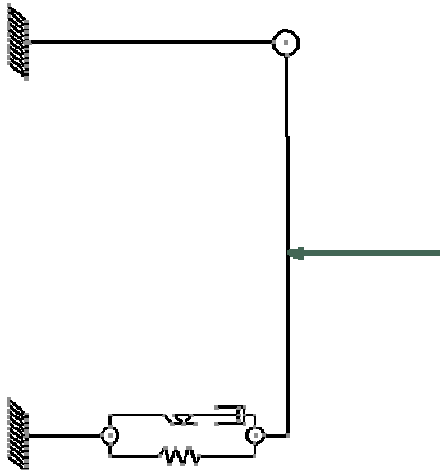




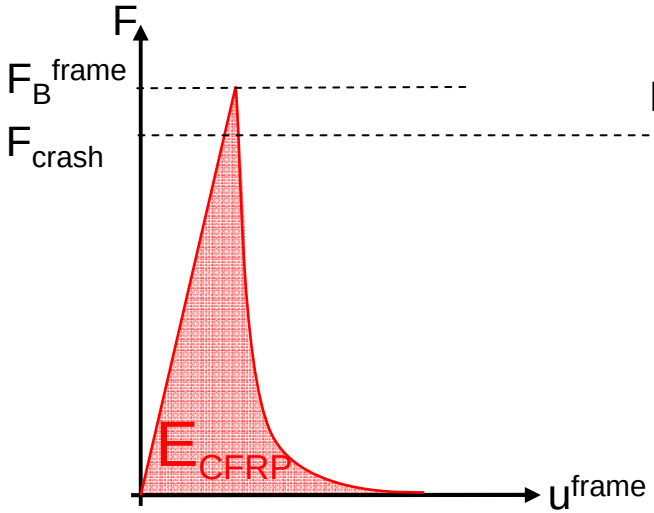
Mechanical Principle of Frame During Side Impact

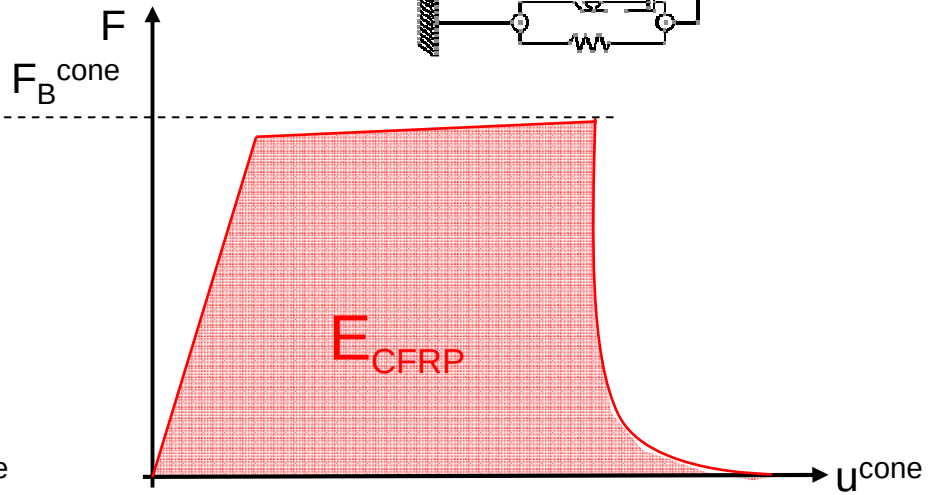
- **Mechanical analogous model of the closed ringframe**



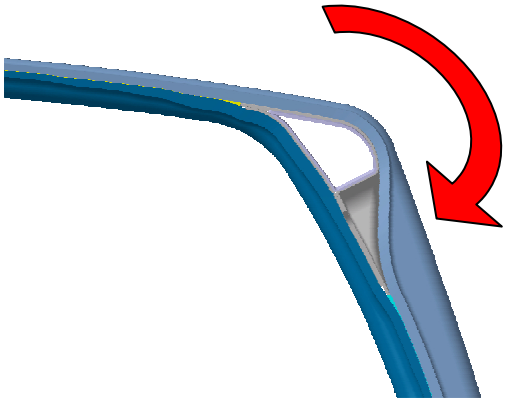


- **Energy dissipation**





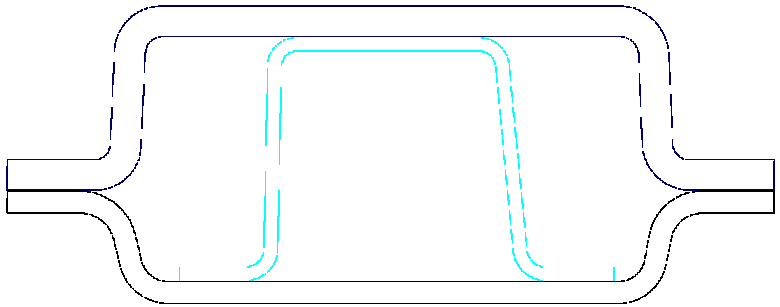
Functional Principle of CFRP-Ringframe



Joint:

- Area around roof post is designed as a flexible joint to allow the pillar pivoting around the roof post

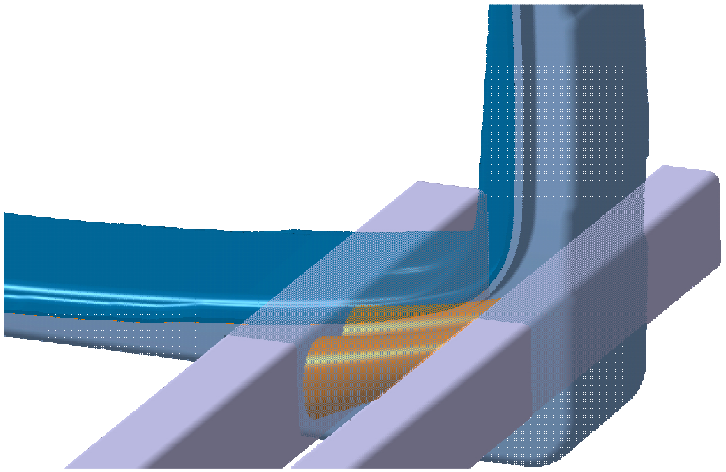
Functional Principle of CFRP-Ringframe



B-pillar:

- The cross section of the B-pillar is designed to have maximum stiffness and stability to keep structure intact and to ensure the best protection of the passengers.

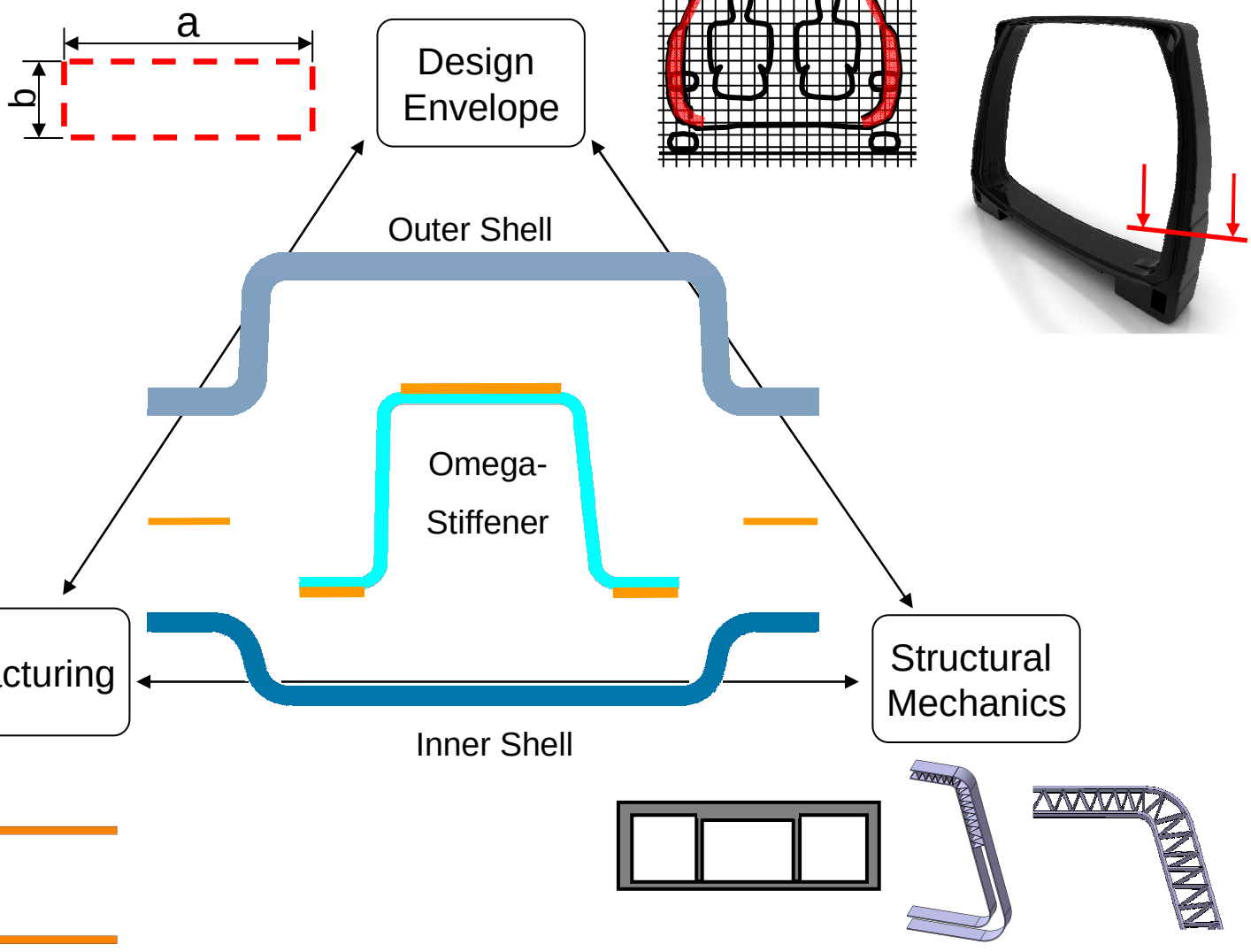
Functional Principle of CFRP-Ringframe



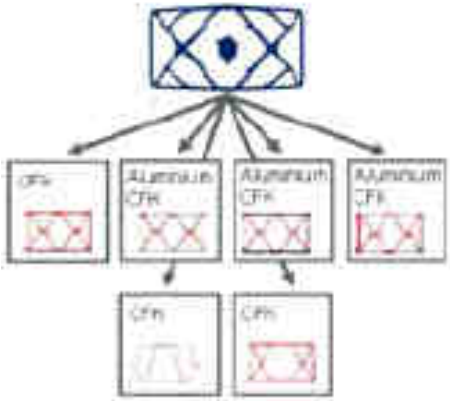
Crash cones:

- Crash cones are integrated in the floor structure of the frame
- Crash cones fail at a specific load level and dissipate energy constantly

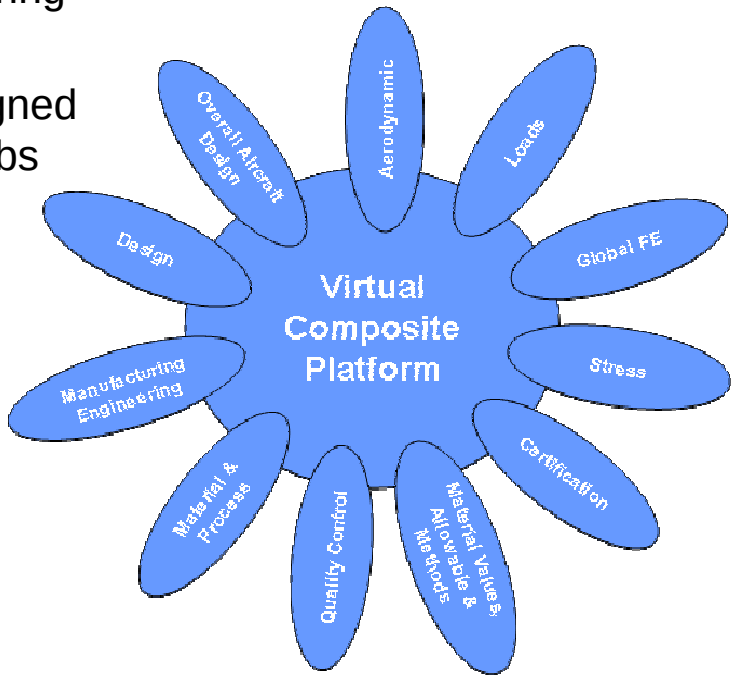
Design Process



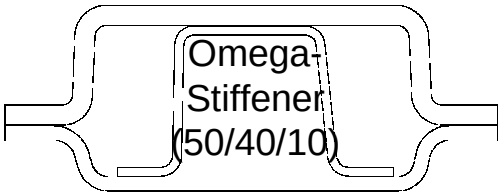
Design Process



- **Preliminary Design**
  - Analytic approach for preliminary determination of wallthickness
    - Outer shell: higher wallthickness due to force application and buckling stability
    - Inner shell: mainly tension forces during crash hence lower wallthickness
    - Omega stiffener: wallthickness designed to withstand local buckling of the webs
  - Topology optimization
  - Preliminary layup



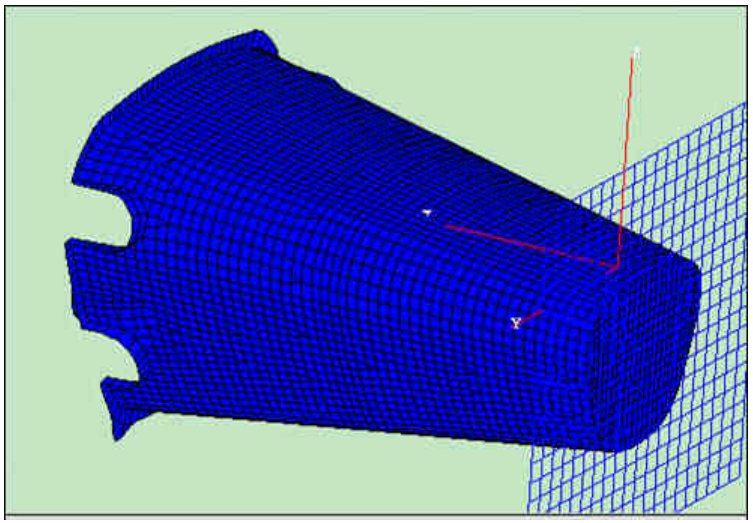
Outer shell: (65/25/10)

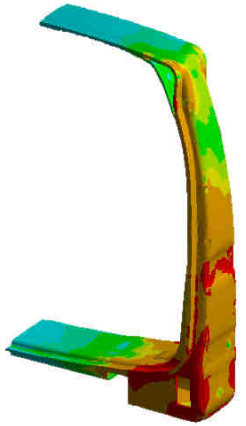


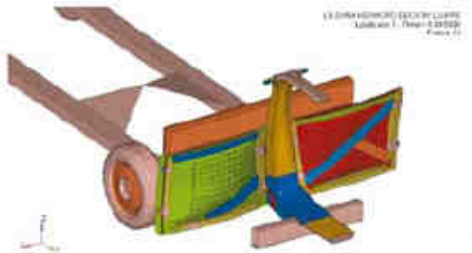
Inner shell (65/25/10)

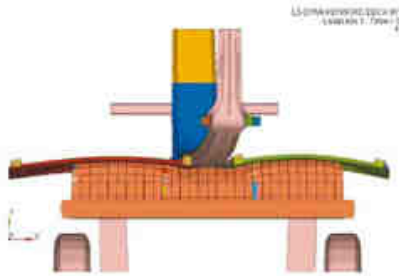
Design Process

- Preliminary Design
- **Dimensioning**
  - Static FEA-calculation
  - Dynamic crash calculation for determination of exact layup, fibre orientation and wallthickness



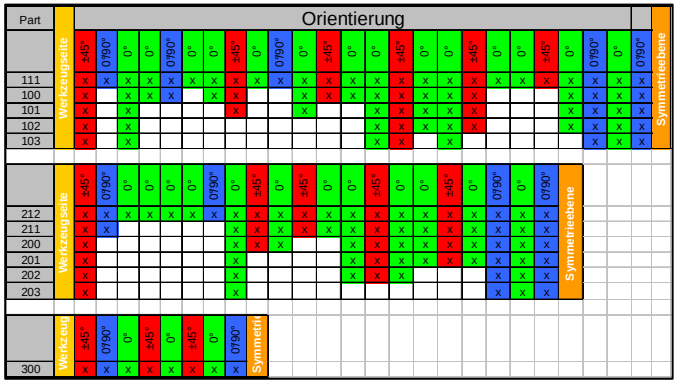


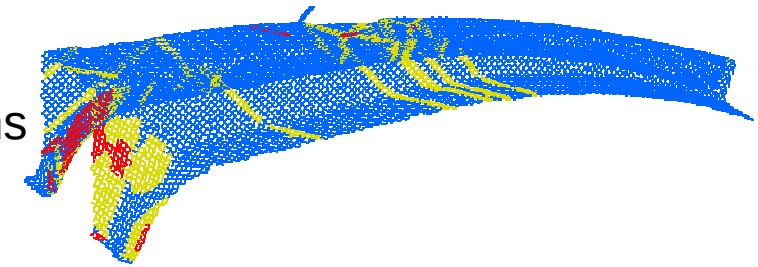


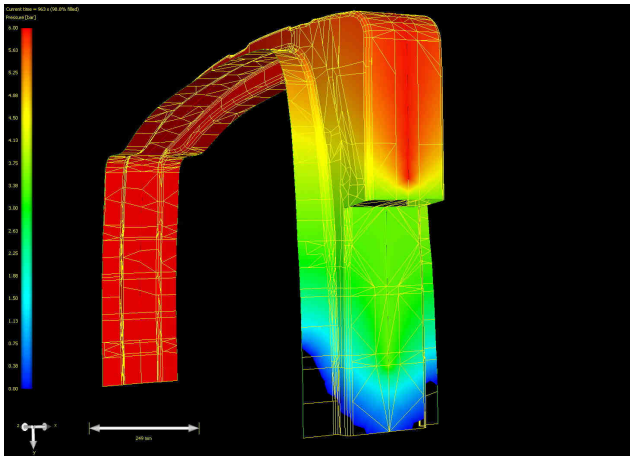


Design Process

- Preliminary Design
- Detailed Dimensioning
- **Detailed Design**
  - Geometry
  - Layup, Ply-Book
  - Draping simulation, flat patterns
  - Flow simulation
  - Tooling concepts

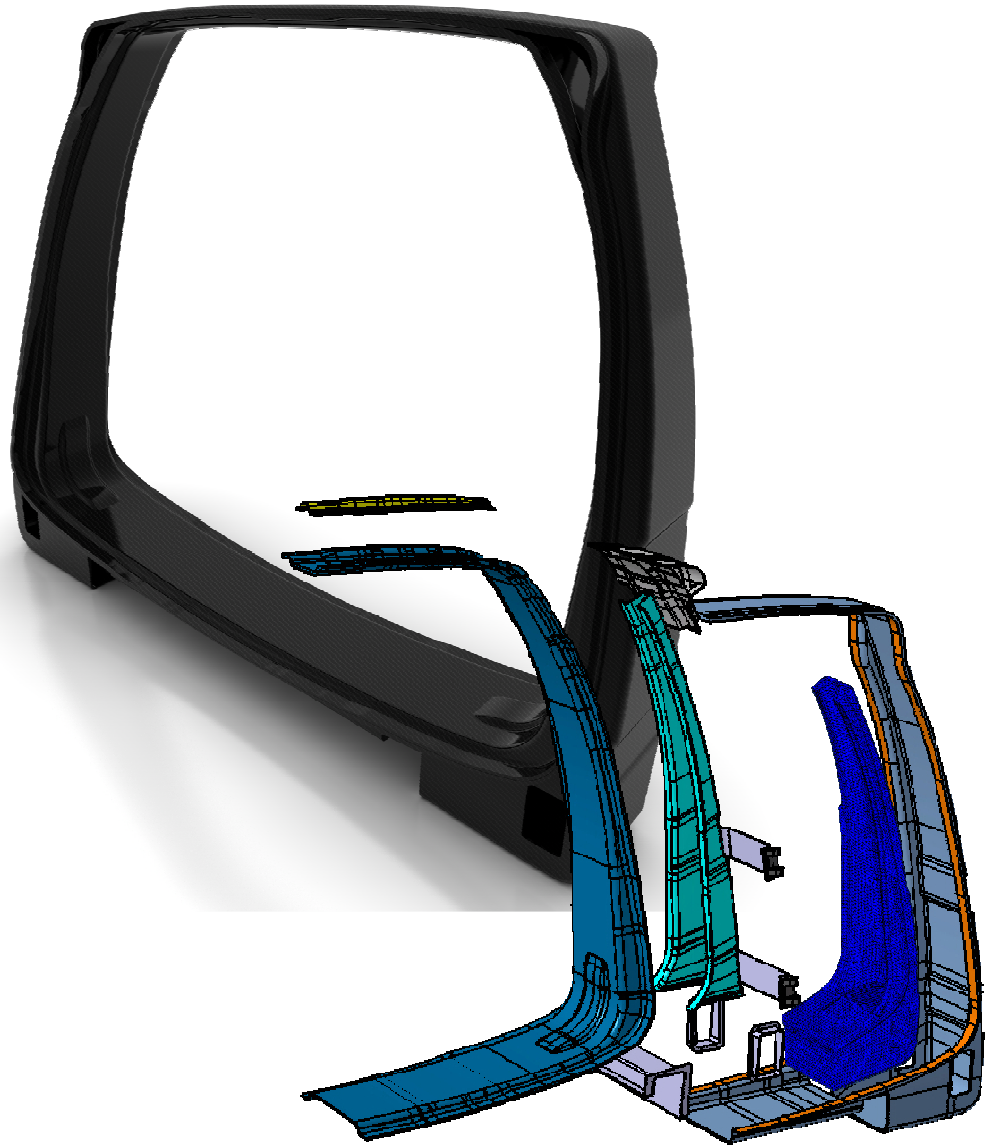






Manufacturing

- **Cutting**
- **Preforming**
- **Vacuum setup for SLI**
- **Autoclave configuration**
- **Injection**
- **Demoulding and trimming**
- **Bonding of components**



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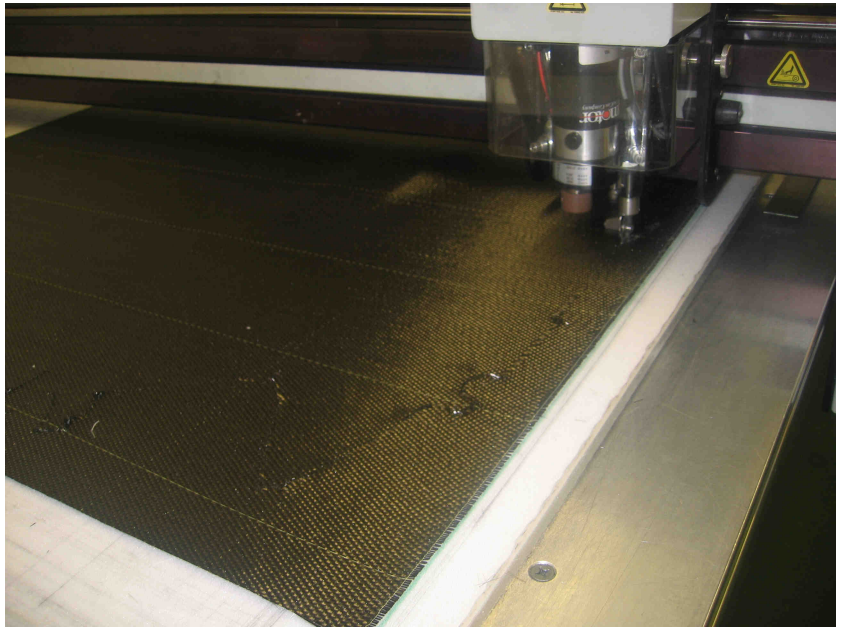

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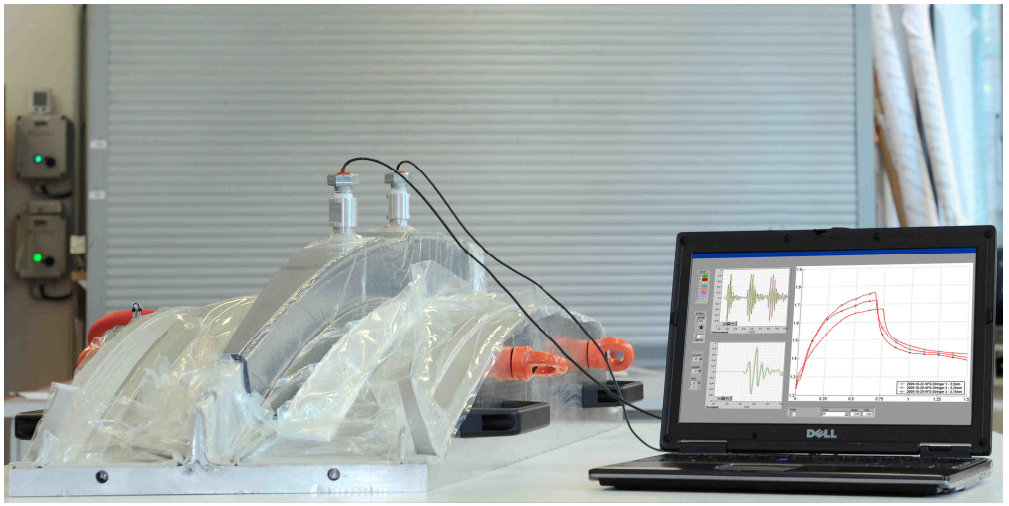

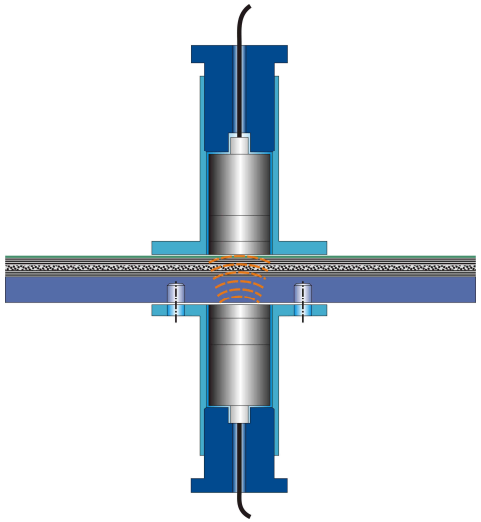

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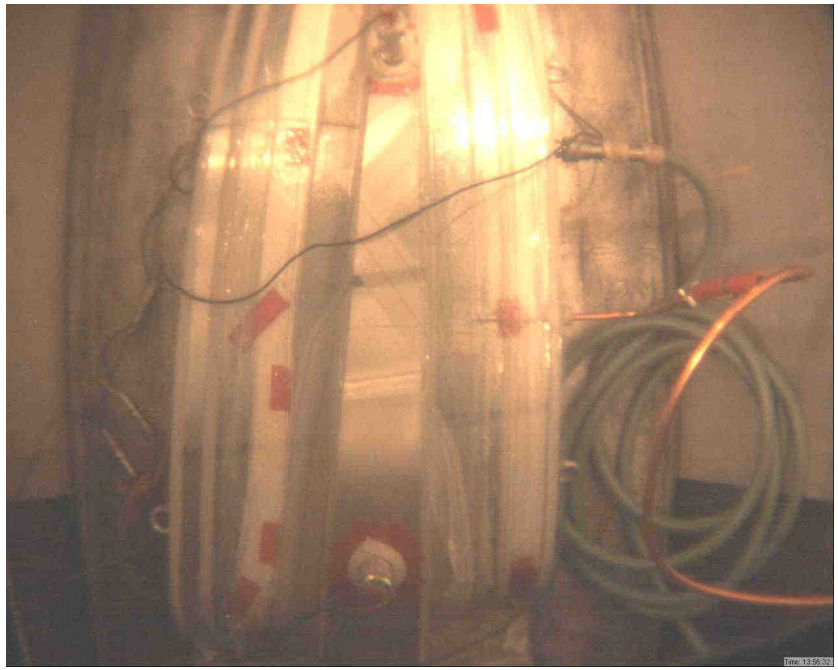

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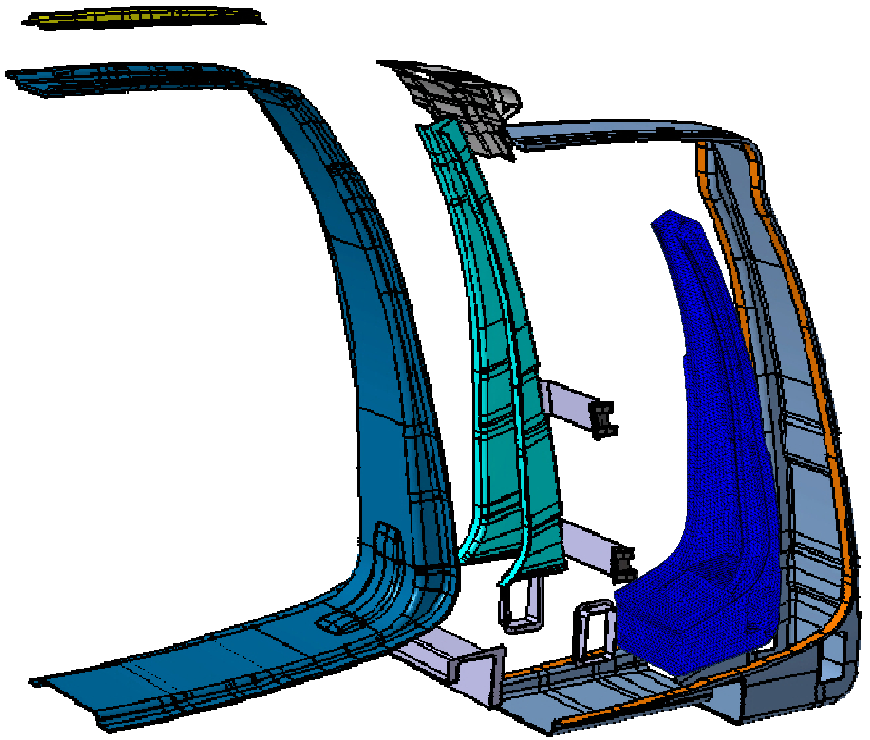
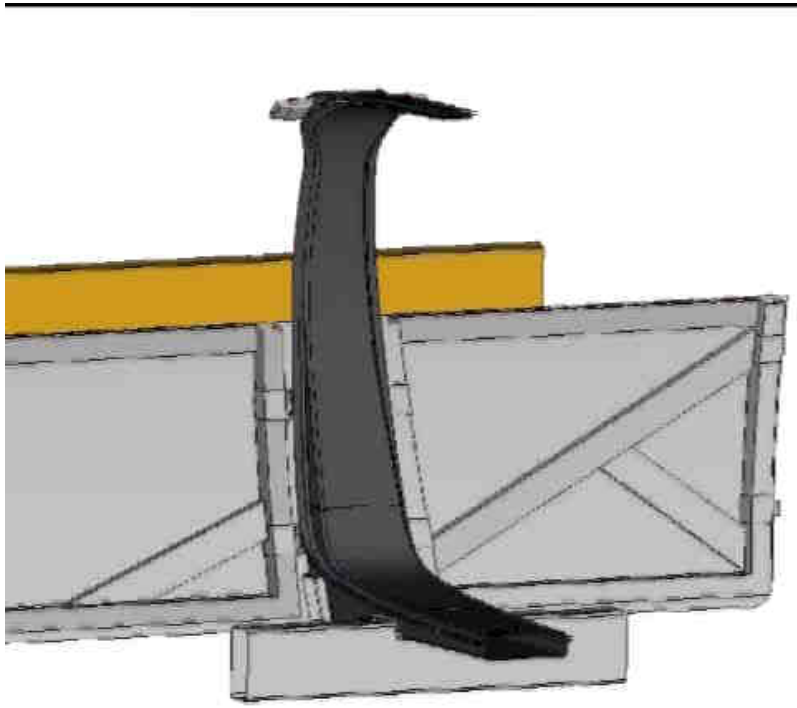


Crash test Euro NCAP / IIHS

Validation of simulation with experimental results

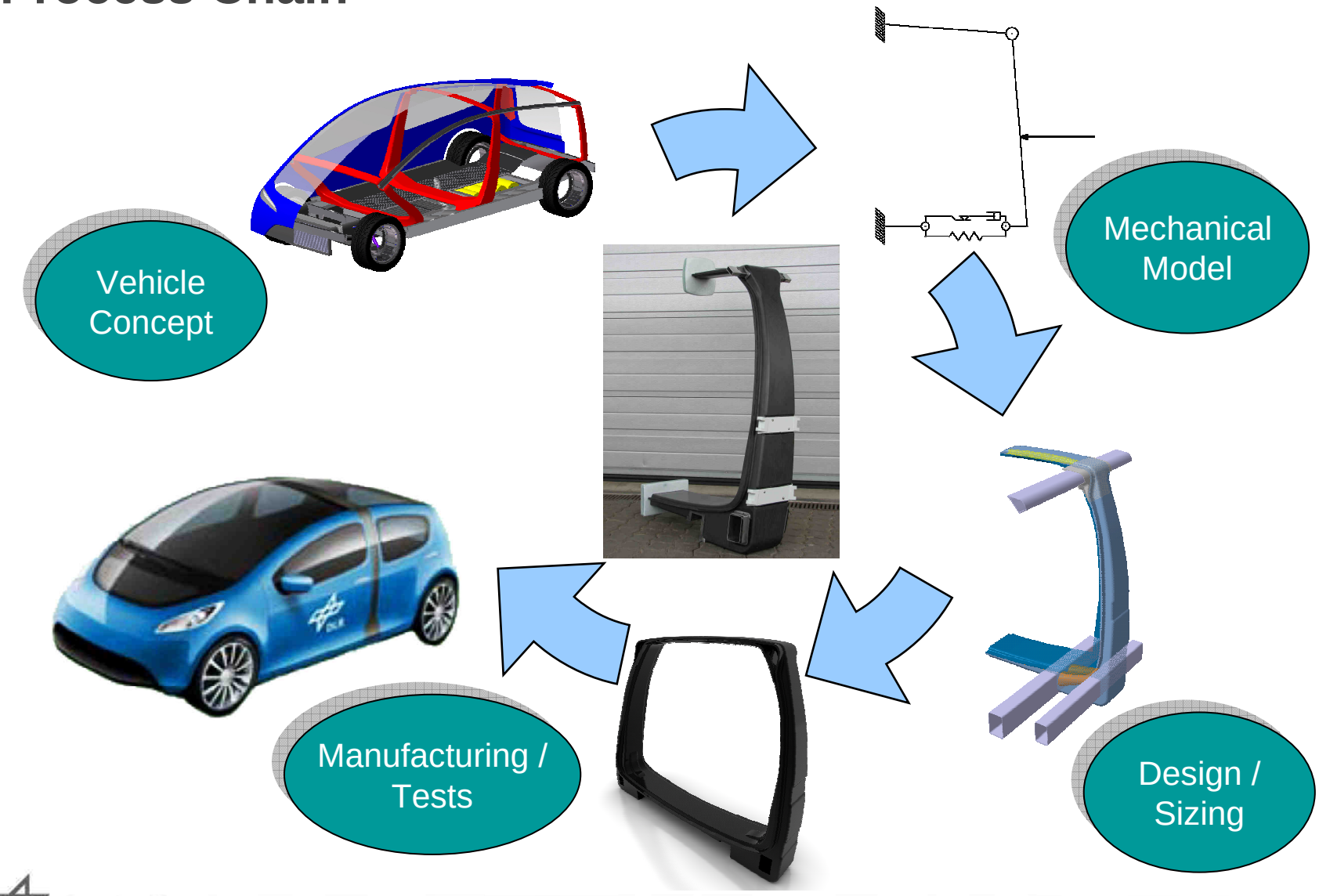
Simulation



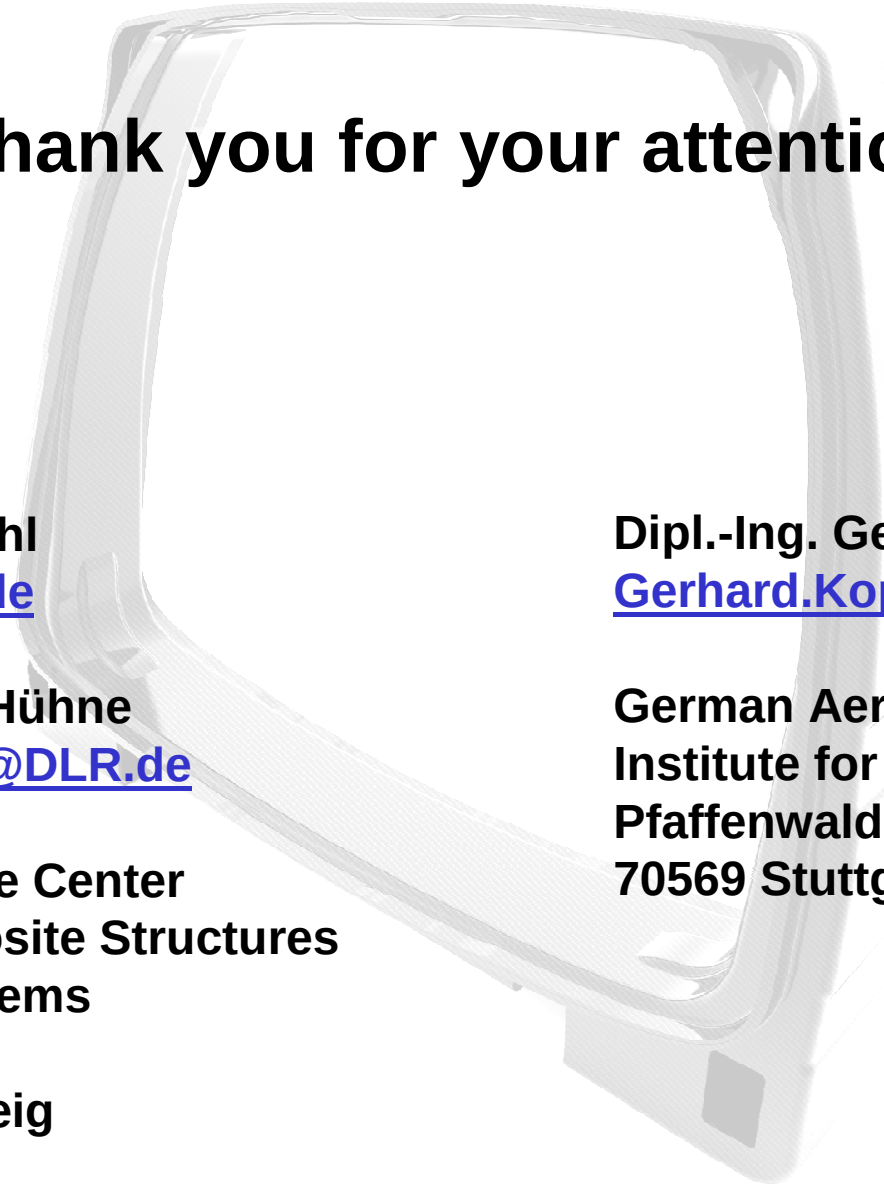
Crash test

Weight reduction - steel: 45 kg → composite: 29 kg

Process Chain



Thank you for your attention!



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