Lightweight Design

“Potential and material-specific challenges”

Fraunhofer LBF

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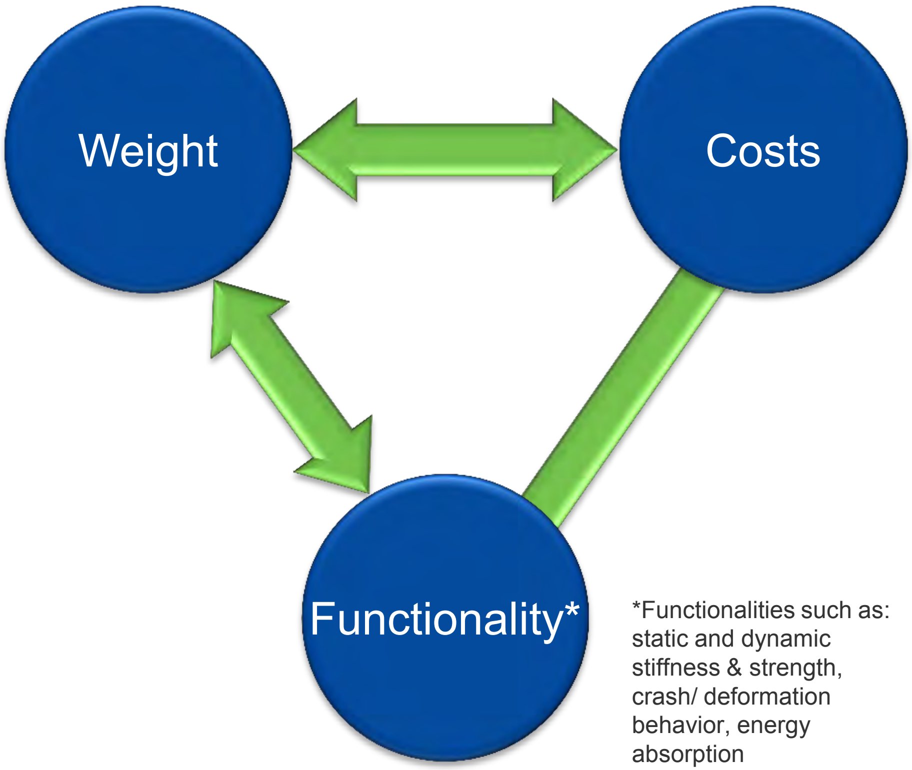
This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

RawMaterials Connecting matters

LightRight Materials for Lightweight Design

Lightweight design

Compromise between weight, functionality and cost



*Functionalities such as: static and dynamic stiffness & strength, crash/ deformation behavior, energy absorption

Aim: Weight minimization whilst meeting requirements for stiffness-stability, vibration characteristics and operational stability

Note: The acceptability of costs depends on the individual case:

- Automobile industry: 0 … 5€/kg
- Aviation industry: 0 … 100€/kg
- Aerospace industry: 0 … 1000€/kg

Lightweight design requires consideration of multiple parameters

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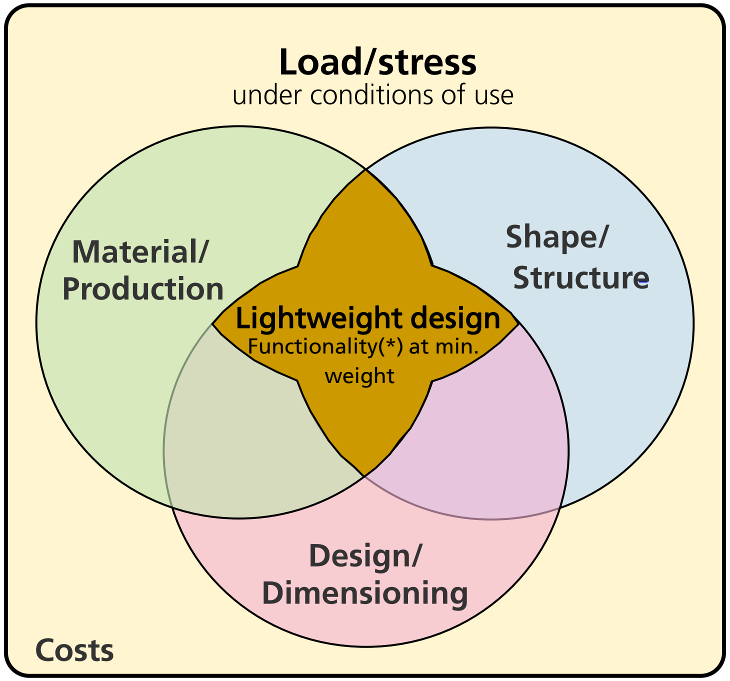
Lightweight design
is multidisciplinary!

Operational stability

Materials	**Design**
Technology/ Production	**Requirements**
Economics	**Shape/structure**



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Lightweight design is multidisciplinary and has a wide range of objectives

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Lightweight design requires space

Bearing strength and stiffness

$RS = W_{bx} / W_{bMS}$

$W_b = \pi \cdot s \cdot r_m^2$

$$RLC = \frac{(R_p \cdot W_b \cdot \eta)_x}{(R_p \cdot W_b \cdot \eta)_{MS}}$$

($\eta<1$ for buckling)

	Standard material	High strength Material	High strength Material
Tensile strength MPa	**220**	**500**	**500**
Diameter mm	**80**	**80**	**100**
thickness mm	**2,0**	**1,0**	**1,0**
Bearing strength for bending*	**1**	**1**	**1,42**
Relative stiffness (RS)	**1**	**0,52**	**1**
Relative weight	**1**	**0,5**	**0,6**

(*) RLC, buckling considered

> *It is clear from this that*
> *higher strength materials require more space for comparable stiffness*

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Materials for Lightweight Design

Lightweight design

Approaches for lightweight design in the development process

Identification of the objective → **Adaptation of requirements**

Adaptation of the shape to the flow of force (design)
→ Design: "Bionic Design"
→ **Adaptation of design**

Adaptation of the materials To the flow force (material selection)
→ Design: "Bionic hybrid design"
→ **Adaptation of materials**

The ideal material and ideal shape are linked to each other by the flow of forces

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Lightweight design

Approaches for lightweight design

Adaptation of the requirements:

Material-savings by adapting and/or lowering the requirements on components, e.g. precise knowledge of the loads, load distribution, load set type, etc.

Adaptation of the design or shape:

Adaptation of geometric parameters having a large effect on the resulting load/stress for uniform utilization of the structural strength. Reduction of unloaded regions via clear force flow pathways.

Adaptation of materials:

Substitution of a material having high structural weight by another material having higher specific properties (high quality index).

Adaptation of joints/production:

Utilization of other joining and production technologies in order to lower the number of additional elements and enhance material utilization in individual structural regions (high function-integration, change from differential to integrating construction methods).

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Lightweight design

Example of adaptation of the design / construction method

- **Main structural component (e.g. fuselage)**
  - **Framework system**
    - Metal
    - FRP
    - Mixed metal/FRP
    - …
  - **Beam with spar system**
    - Metal
    - FRP
    - Mixed metal/FRP
    - …
  - **Stringer system**
    - Metal
    - FRP
    - Mixed metal/FRP
    - …
  - **Skin system**
    - Metal
    - FRP
    - Mixed metal/FRP
    - …

Construction elements

Longitudinal stays
Posts
Diagonal stays
Cross bars
Tensioning straps
Stringers
Ribs
Skin

The construction method and choice of material influence the shape and production

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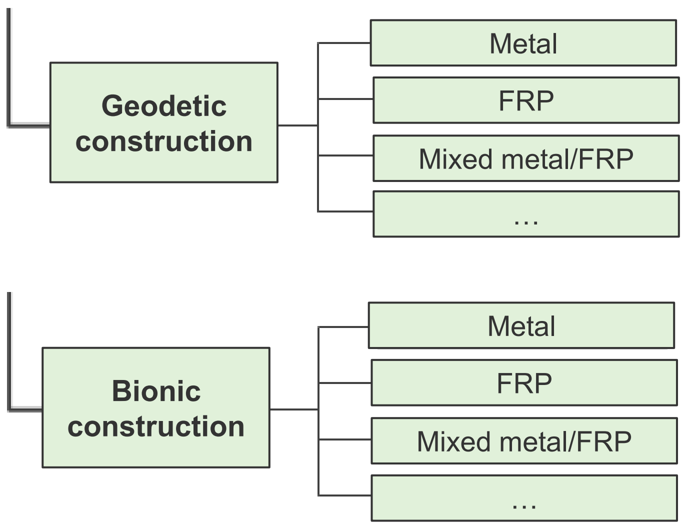
Lightweight design

Example of adaptation of the design / construction method

Special shape

New!



Bionic construction methods utilize principles of biological systems

The construction method and choice of material influence the shape and production

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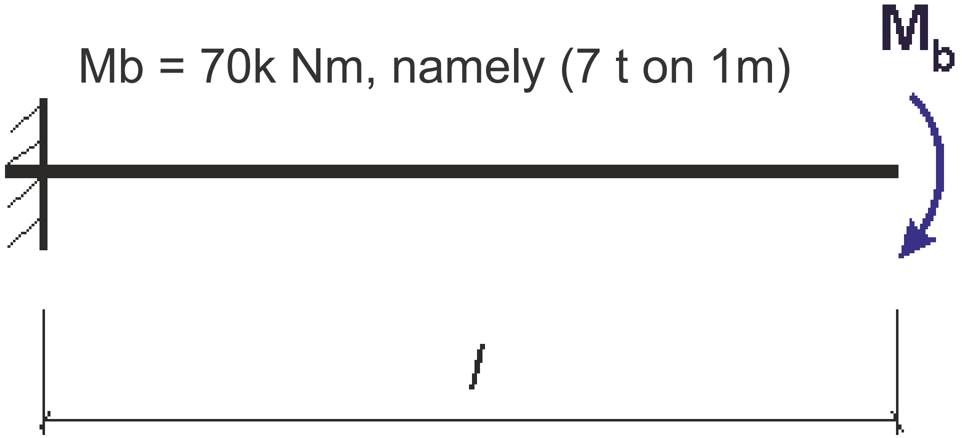
Lightweight design

Example – Differences between the construction methods?

Function – Realization of a fuselage with a ∅ of 94 cm and aerodynamic paneling

Load case - bending

Mb = 70k Nm, namely (7 t on 1m)



Summary:

Function 1 – Bearing the loads

Function 2 – Aerodynamic paneling with a smooth surface

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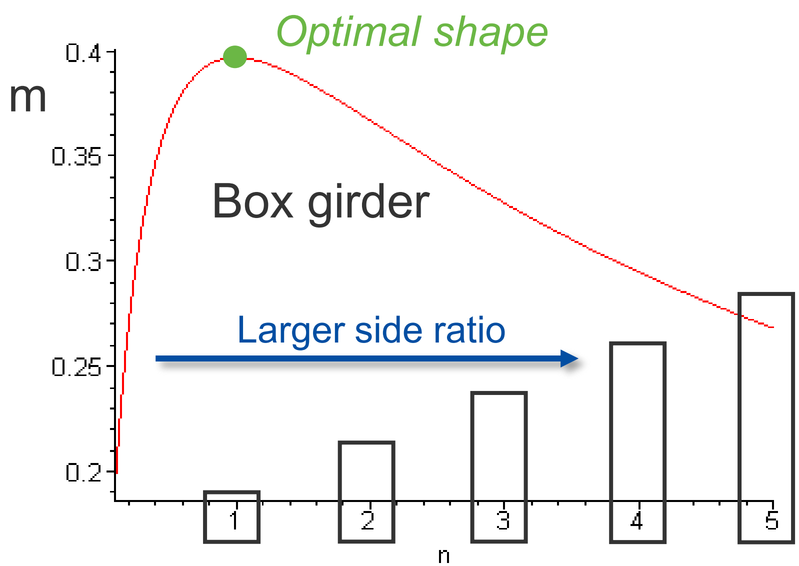
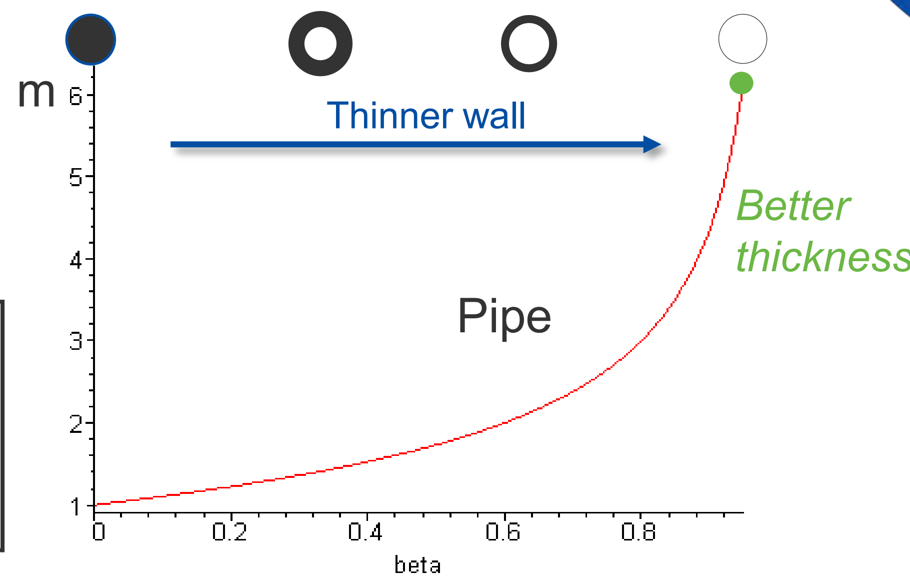
Adaptation of the design

Effect of the shape on the weight (Example: torsional stiffness)





Material Shape

$$\frac{\sqrt[3]{G}}{\rho} * \sqrt[3]{\frac{n^2}{(n+1)^4} * \sqrt[3]{\frac{1}{t^2}}} \quad n = \frac{Height\ h}{Width\ b}$$

$$\frac{\sqrt{G}}{\rho} * \sqrt{\frac{1+\beta}{1-\beta}} \quad \beta = \frac{d_i^2}{d_a^2}$$

→ Lightweight design requires an optimal shape (adaptation of the design)
→ Lightweight design requires thin walls

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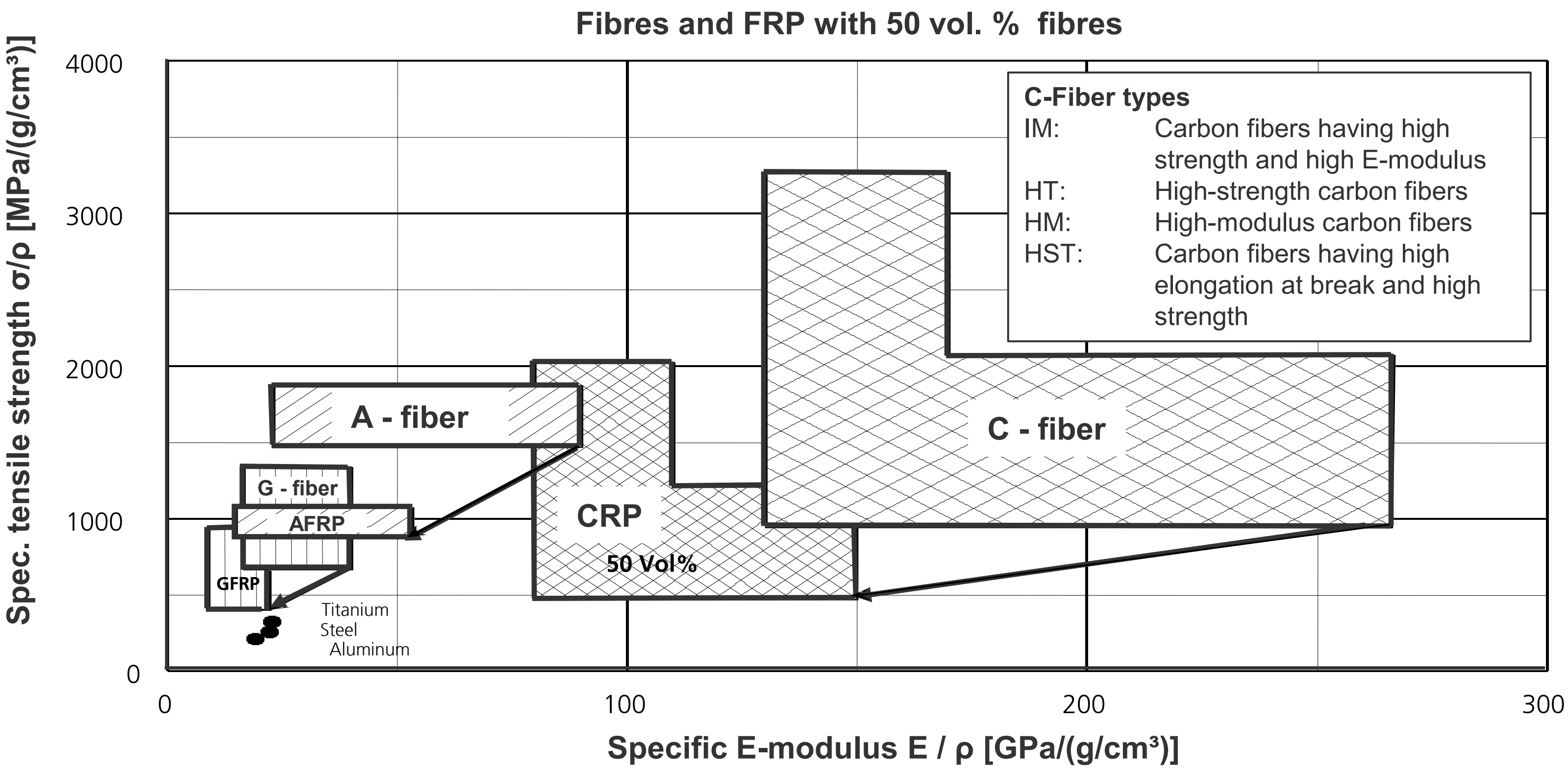
Adaptation of materials
for structural components



Materials play a big part in lightweight design!

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Lightweight design

Approaches for lightweight design

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Fiber reinforced plastics

Diverse material combinations

Overview of fiber reinforced plastics (FRPs)

	Glass fiber (GF) Carbon fiber (CF) Aramide fiber (AF) Natural fiber (NF)…		
Thermoset or thermoplastic matrix	Short fibers $l_{Fiber} \leq 1mm$	Long fibers $l_{Fiber} \leq 50mm$	Endless fibers $l_{Fiber} > 50mm$

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Adaptation of materials for lightweight design

Isotropic vs. Anisotropic

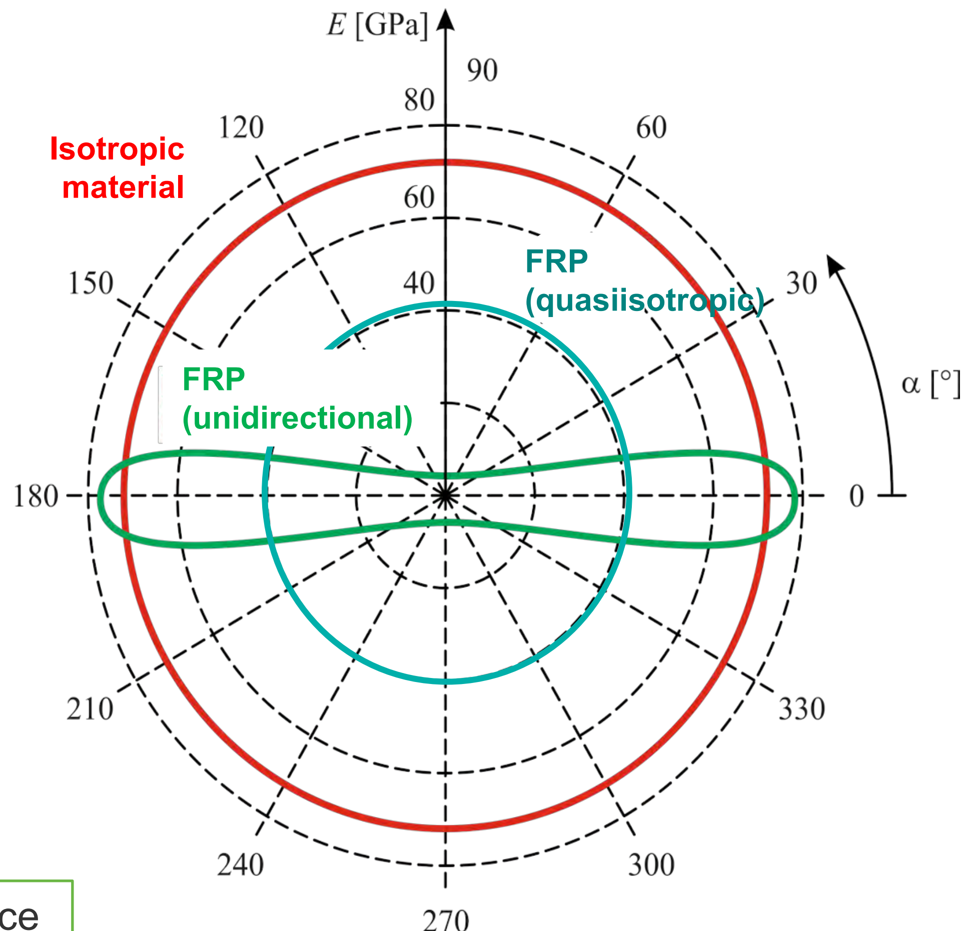
Isotropic *loads*

Isotropic materials

Anisotropic loads

Anisotropic materials

The right material in the right place



Direction-dependent stiffness

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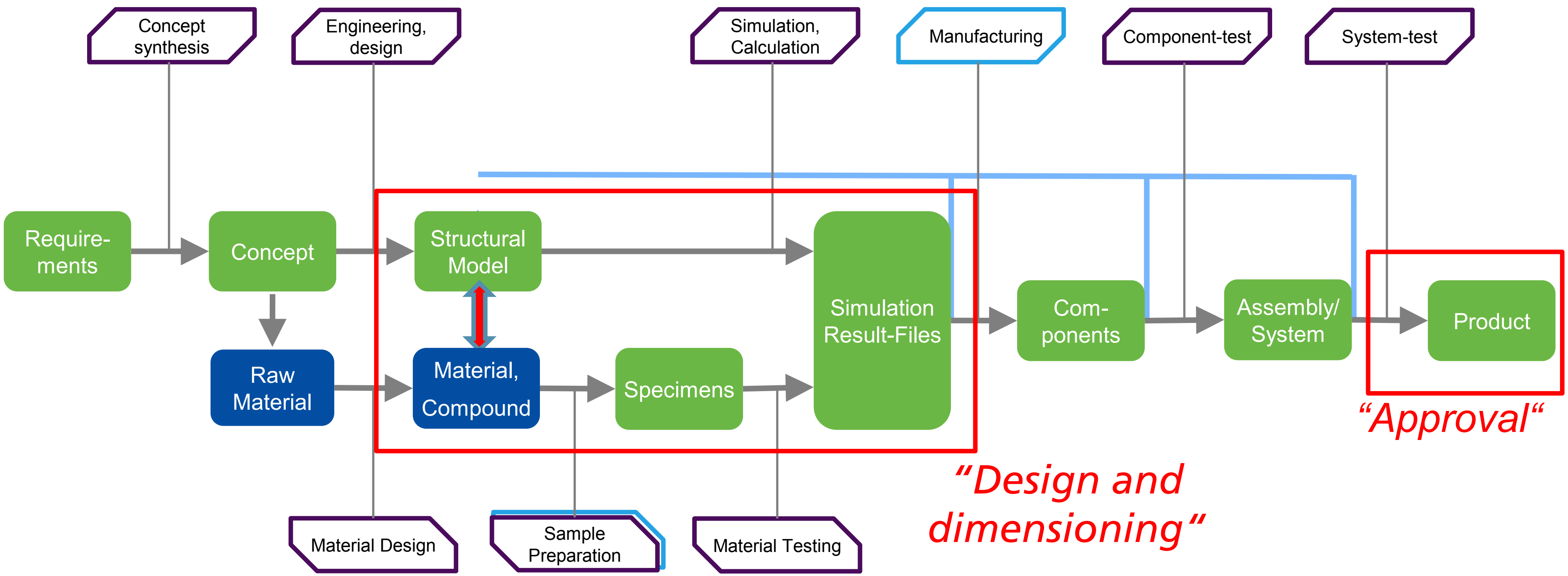
Design

in the product development process



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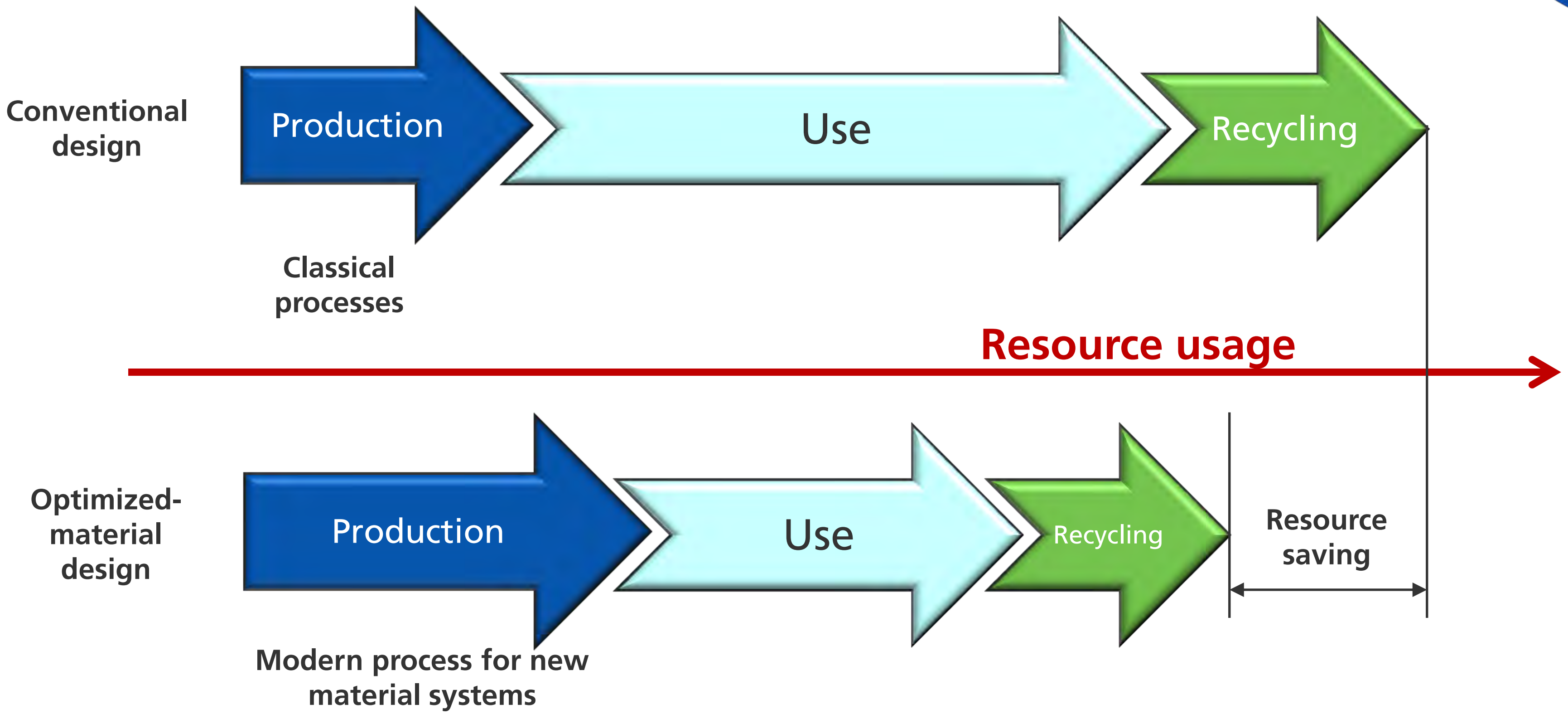
Lightweight design and the complete life cycle

Design, materials, production, use, recycling…



Intelligent lightweight design leads to resource saving over the whole life cycle

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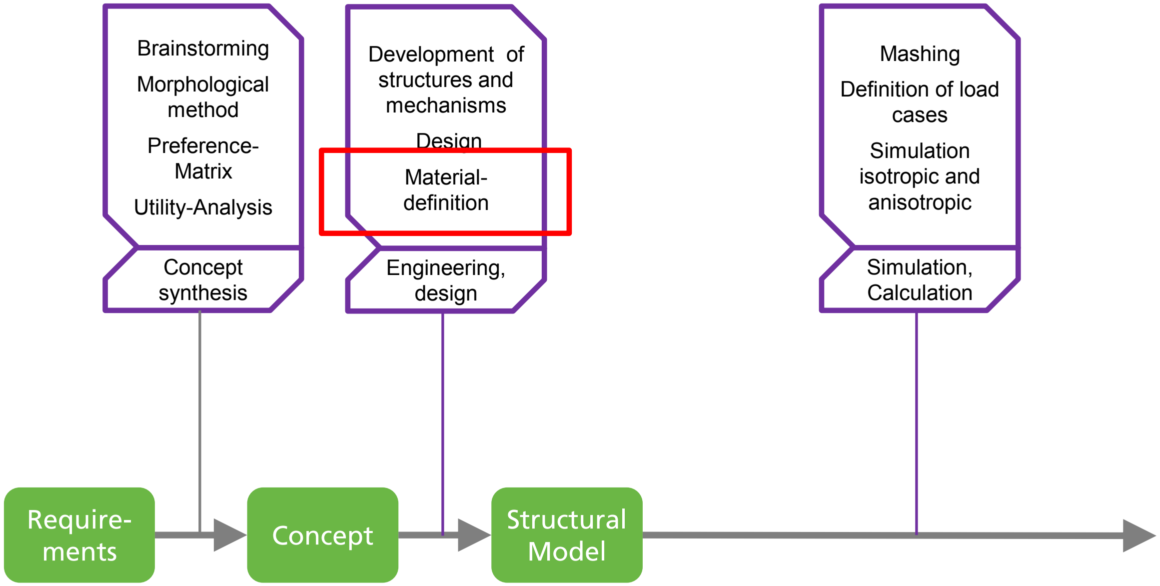
Leichtbau

über den gesamten Lebenszyklus



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THANK YOU
FOR YOUR ATTENTION!

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