CFRP
Status of Application in Airframe Structures and Future Development Process

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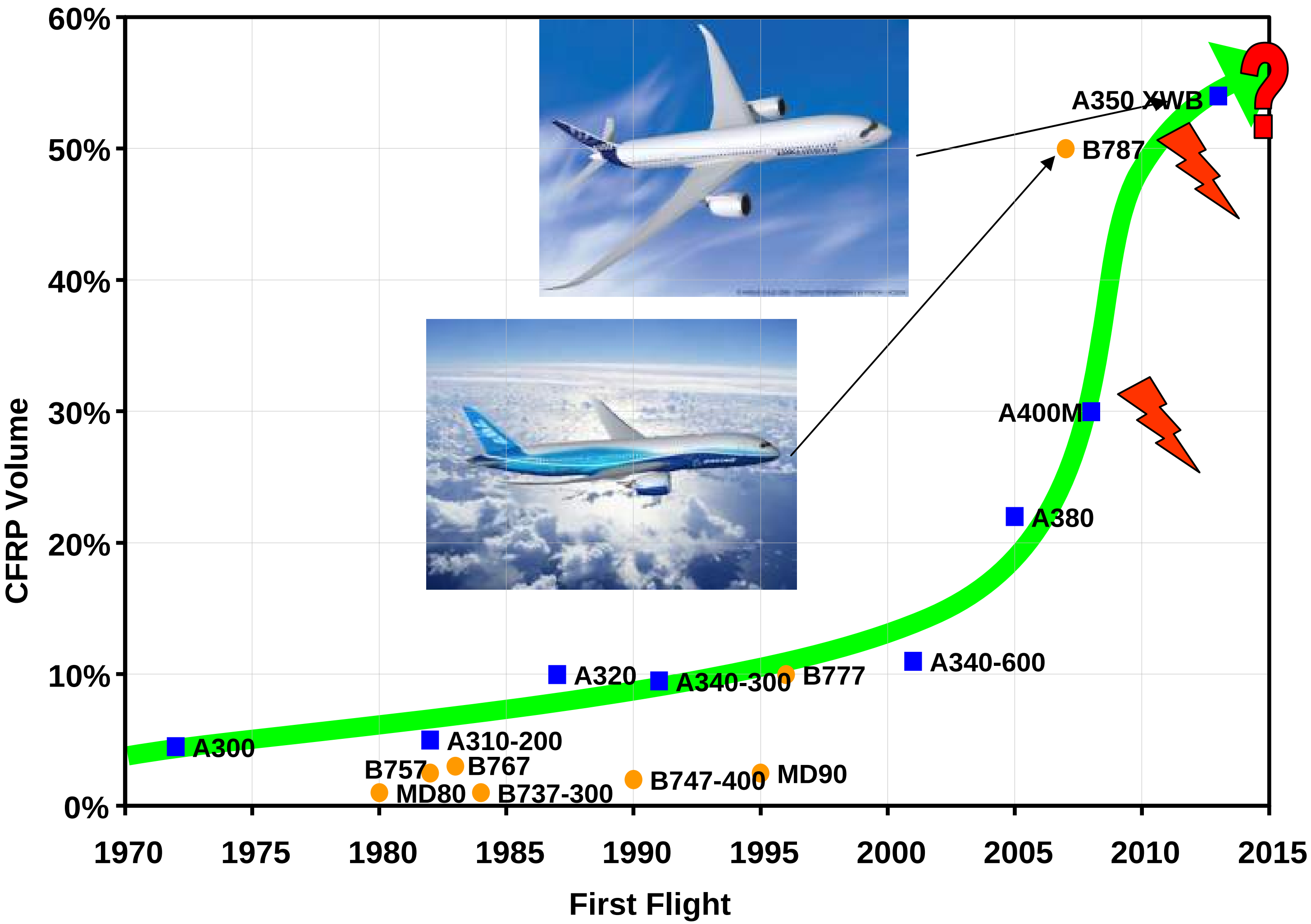
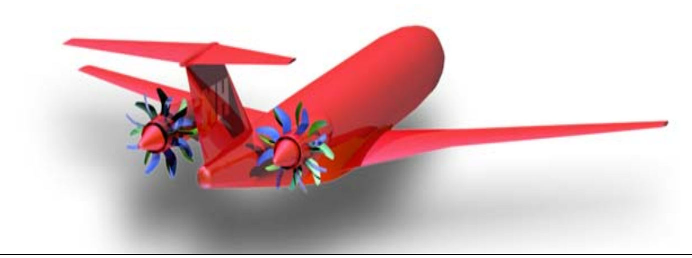
Institute of Composite Structures and Adaptive Systems

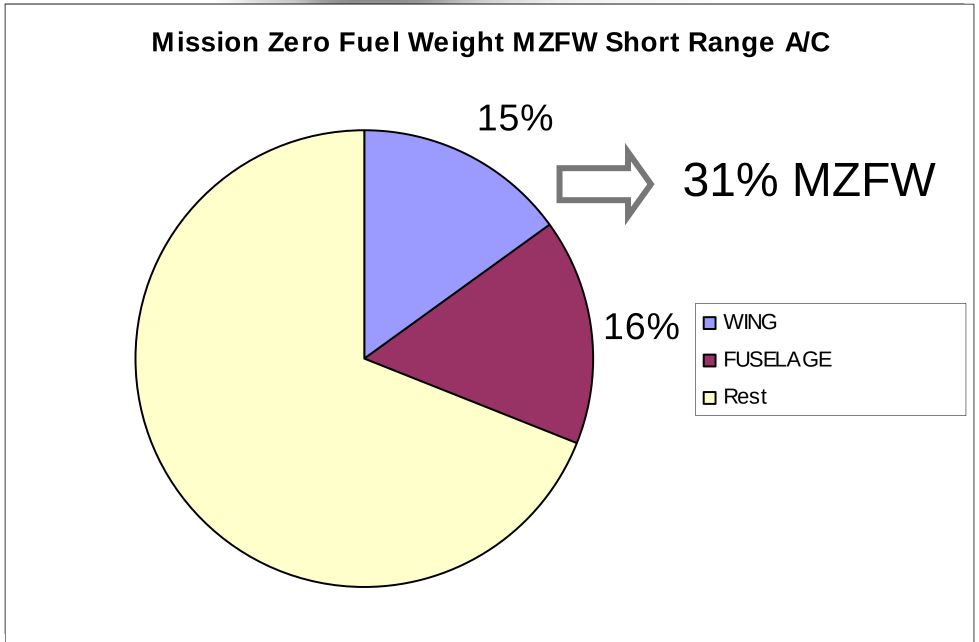
Evolution of CFRP Application



CFRP Potential in Airframe Structures

CO2-Reduction New Short Range Aircraft

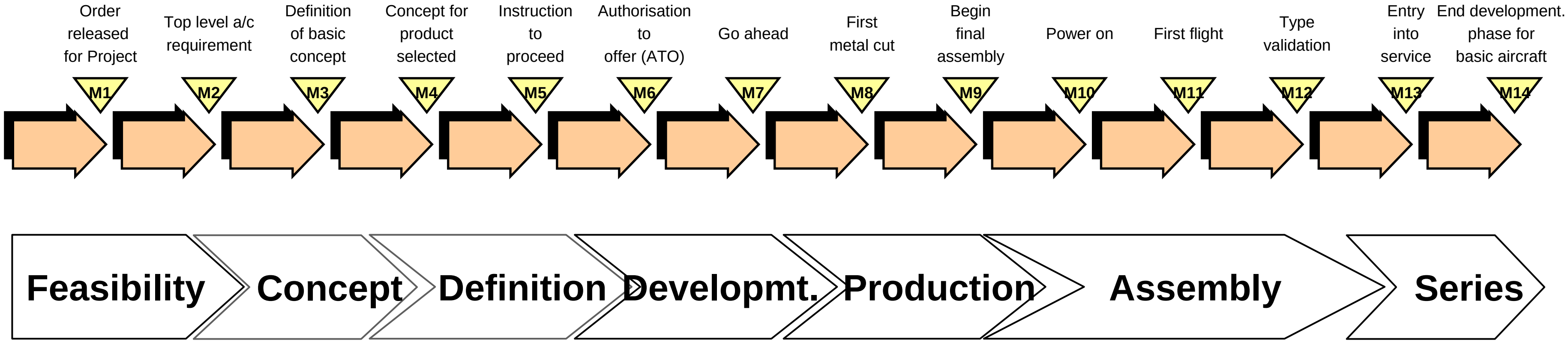




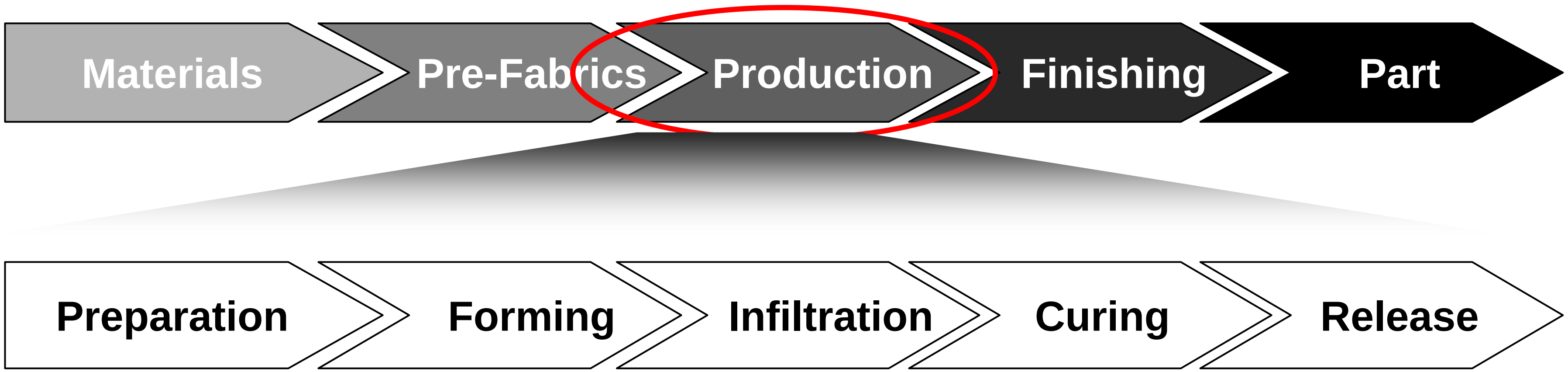
1) MTOW = Maximum Take Off Weight
2) Idle = not weight driven fuel consumption

- 80% Primary Structure
  - ~24,8% MZFW
- 60% potentially in CFRP
  - ~15% MZFW
- 20% Weight Reduction
  - \- 3% MZFW
- Show Ball ~3
  - up to -10% MTOW[1)]
- Idle[2)] for 500 nm mission
  - ~ 20% Fuel
- CO_2-Reduction
  - 0.8x10%=8%

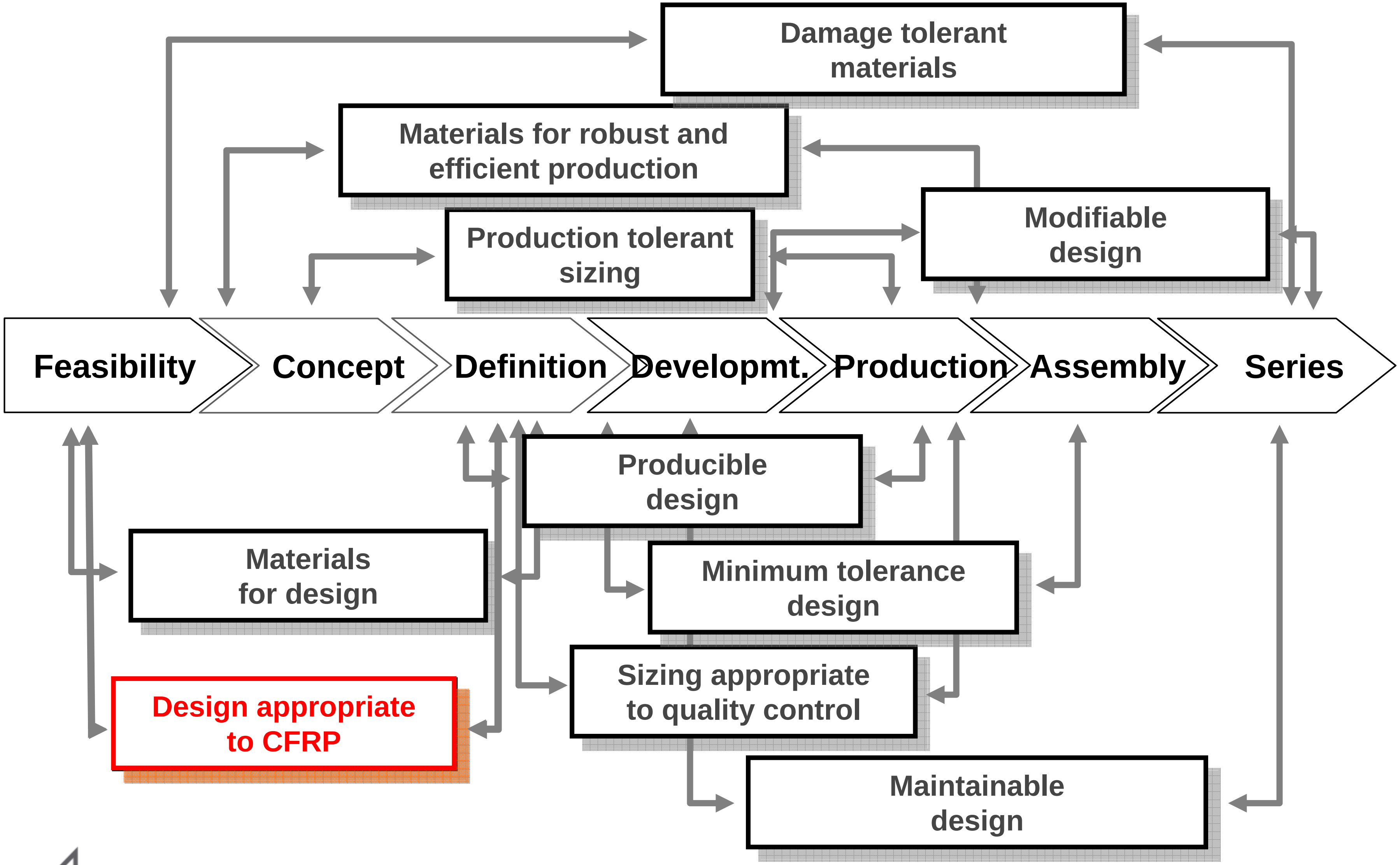
Airframe Development Process



CFRP Production Process Chain

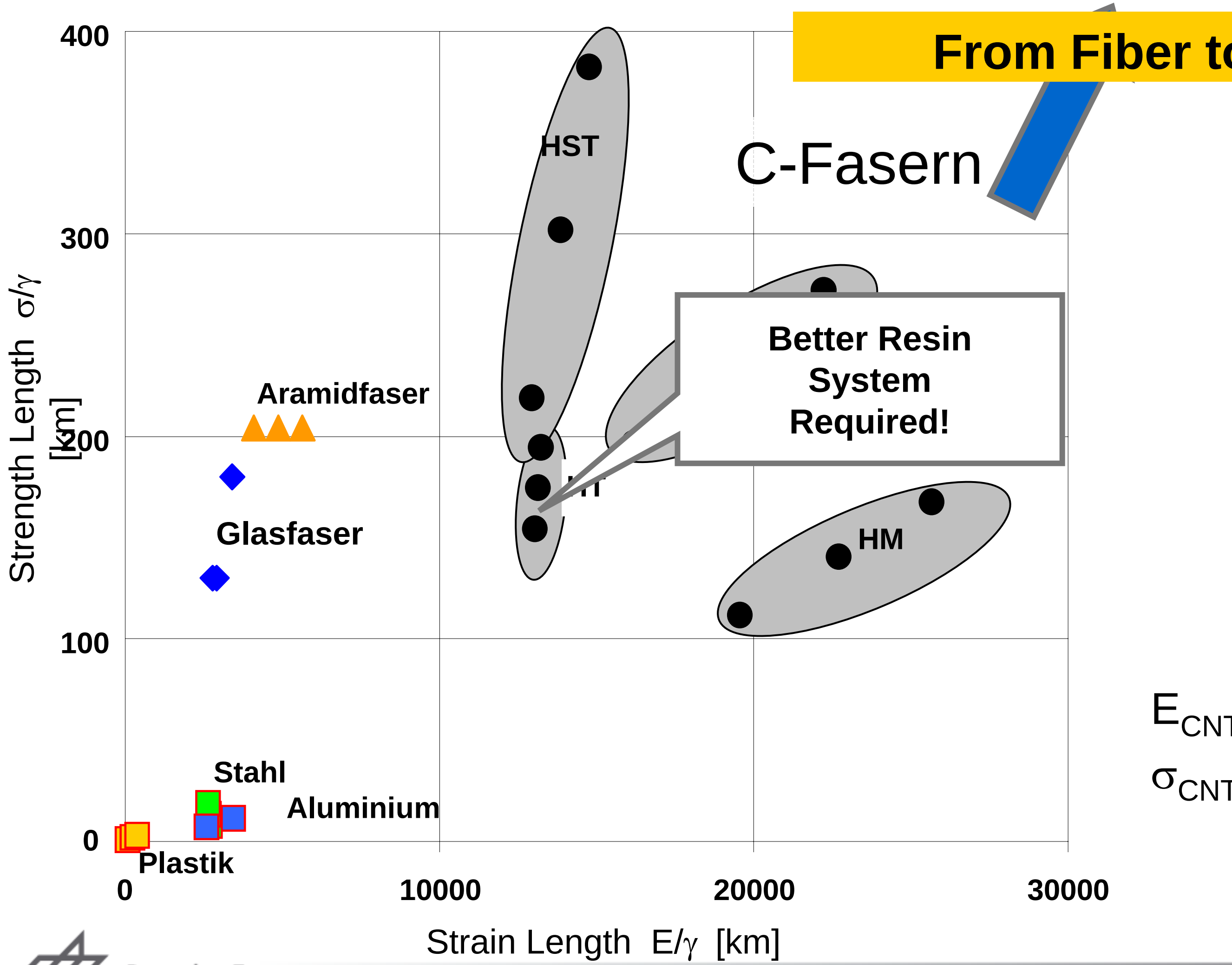


Examples of Dependencies in CFRP Structure Development

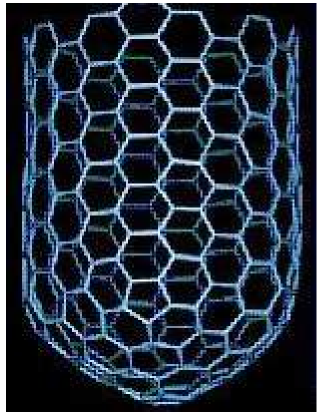


Design appropriate for CFRP

Fiber Strength and Strain Length compared to Metal Alloys



CNT

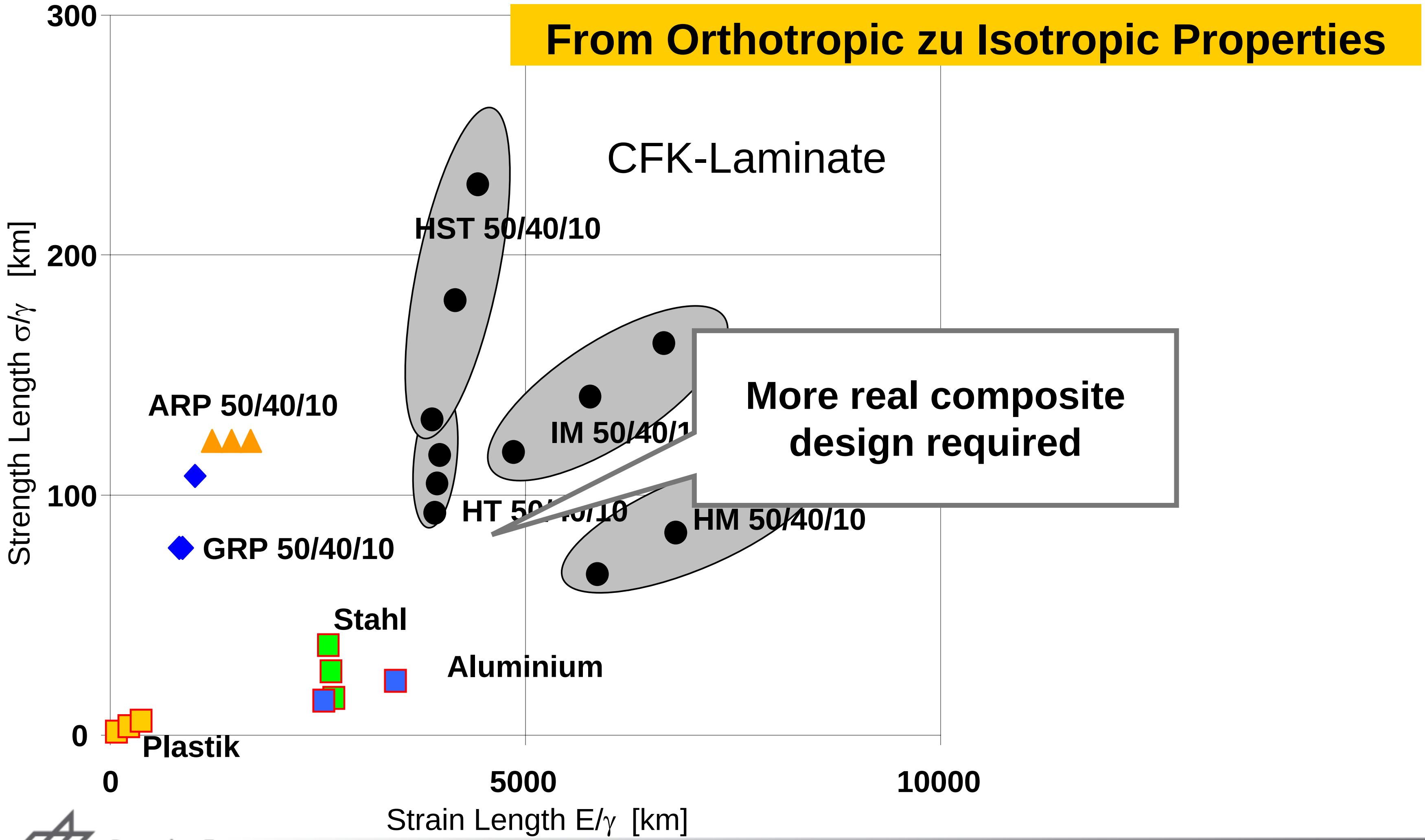


$E_{CNT} / \gamma_{CNT} > 64\,000$ km

$\sigma_{CNT} / \gamma_{CNT} > 3\,700$ km

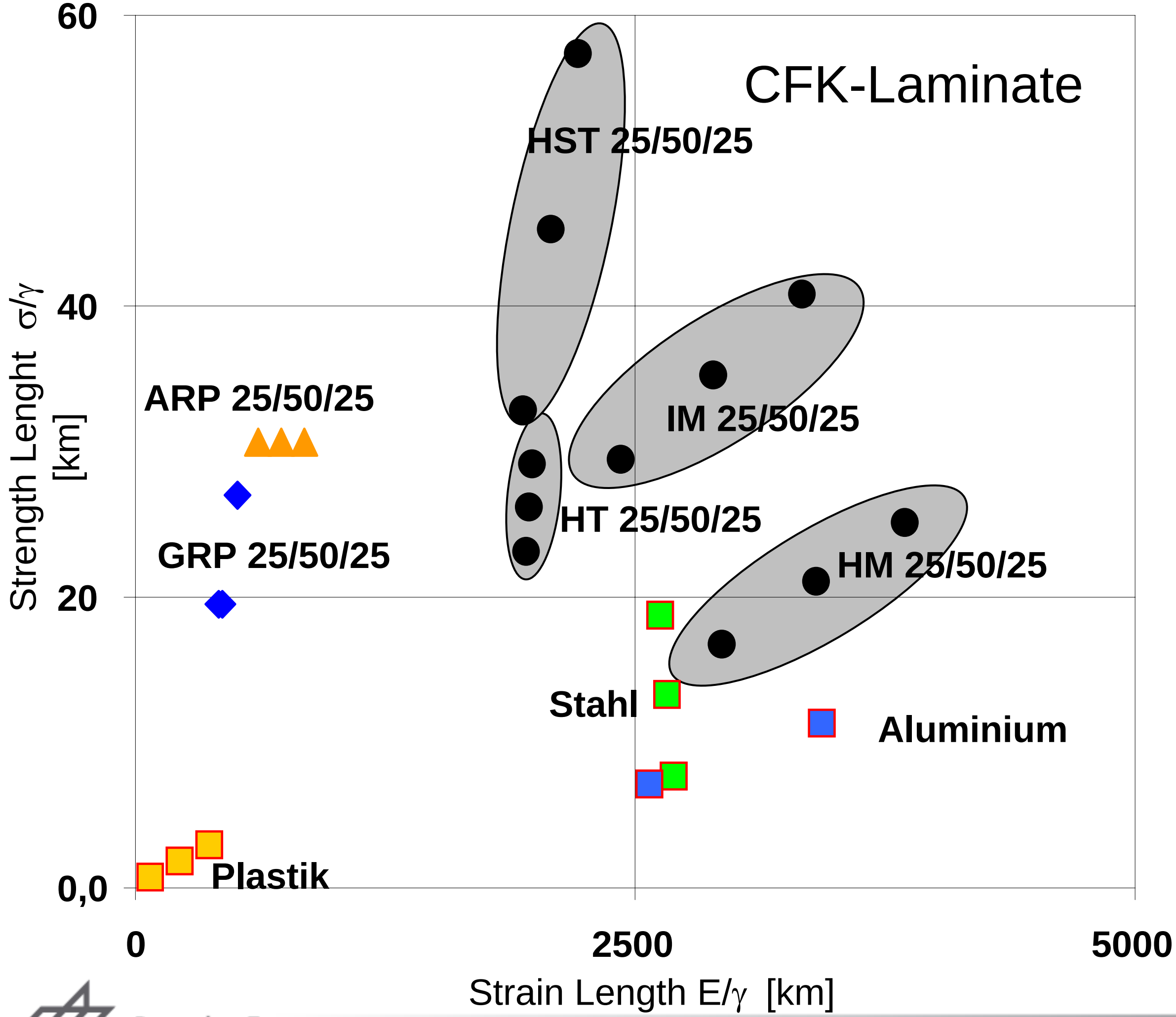
Design appropriate for CFRP

Laminate Strength and Strain Length compared to Metal Alloys



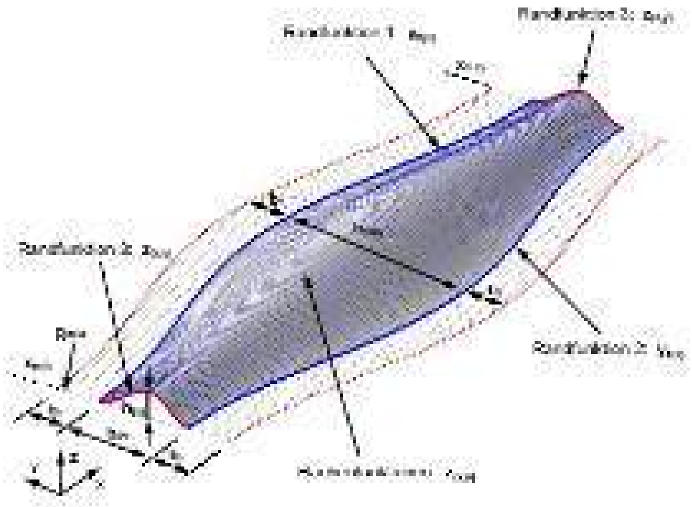
Design appropriate for CFRP

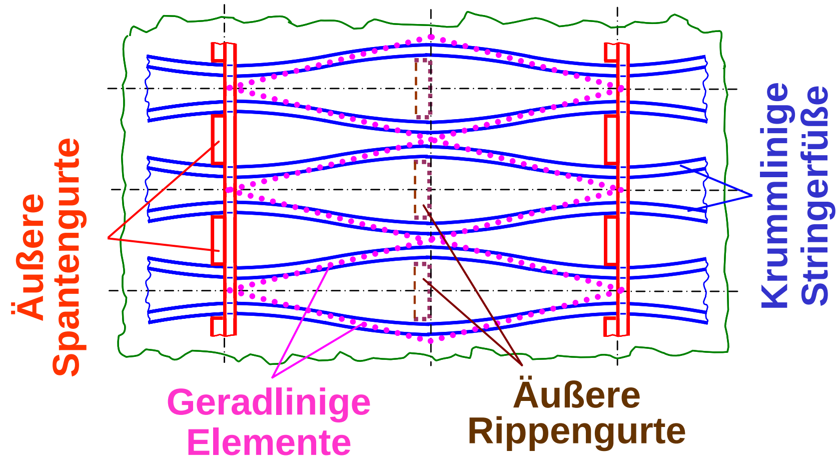
Isotropic Laminate Strength and Strain Length compared to Metal Alloys

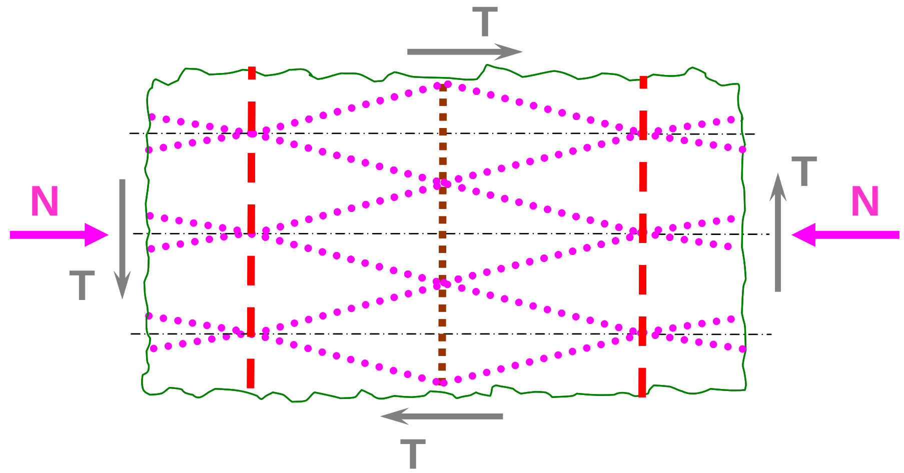


Design appropriate to CFRP

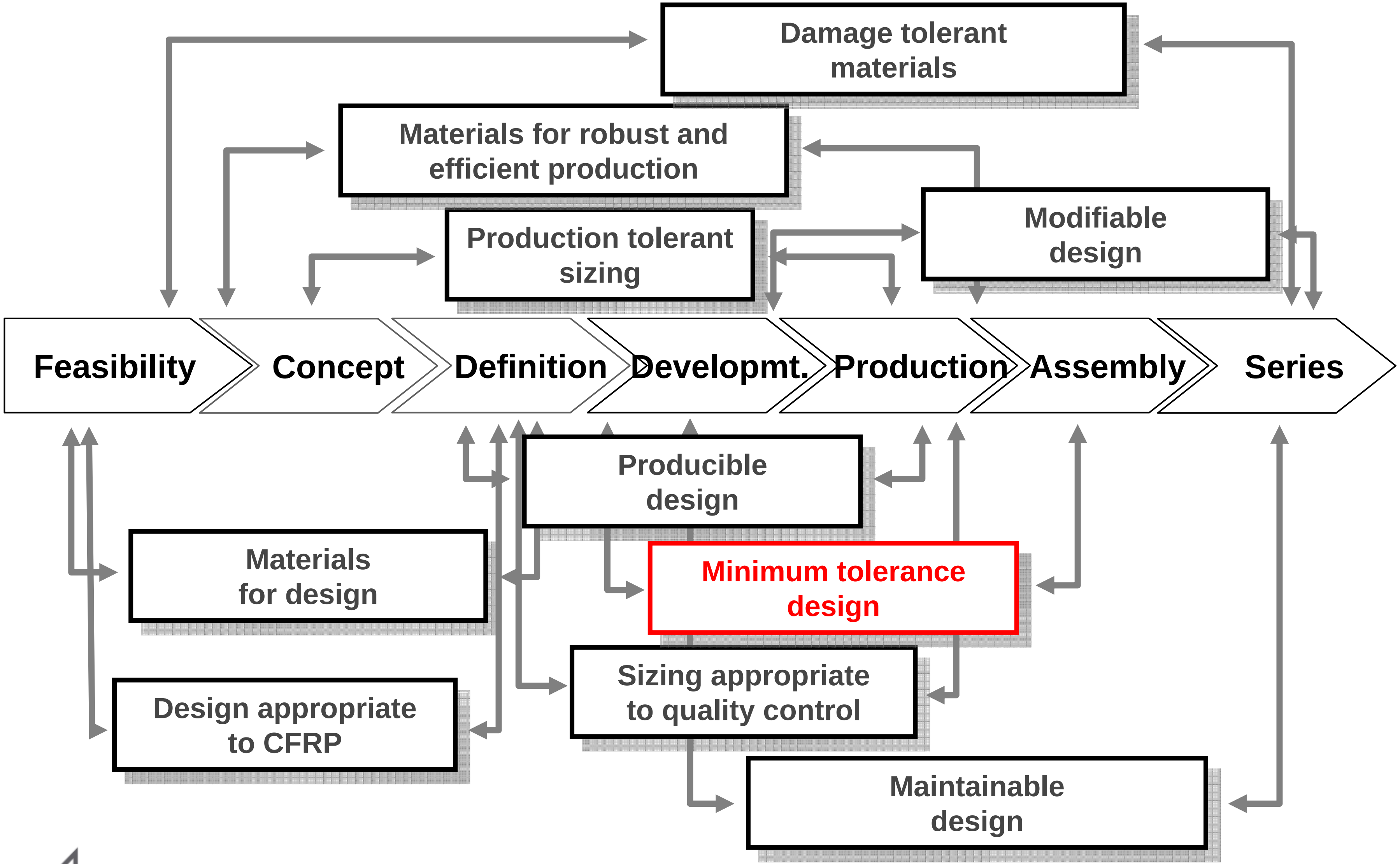
e.g. Semimonocoque-Panel with Double Curved Stringer





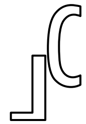


Examples of Dependencies in CFRP Structure Development



Minimum Tolerance Design

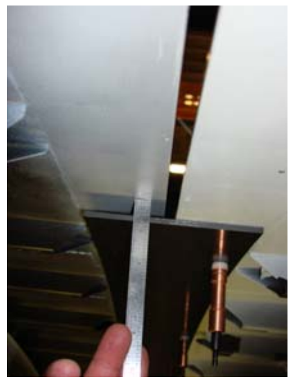
e.g. „Spring-In“ in LC frame – Requirements for Production



Actual process conditions lead to cost distribution of about 2/3 for frame production and 1/3 for frame assembly.

Typical cost drivers in production

→ **High failure rate due to unacceptable contour mismatch**
→ **High failure rate due to production problems (voids, laminate misalignment)**
→ **Material cost**
→ **Manual process, few automation**



Typical cost driver in assembly

→ **Fitting effort due to tolerance mismatch (Shim)**

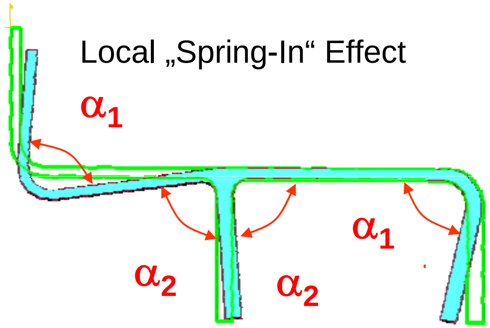
Main problem:
Proper consideration of „Spring-In“ effect in tolerance management

Minimum Tolerance Design

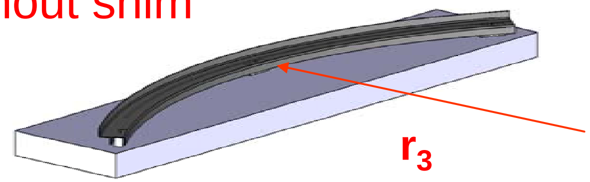
e.g. „Spring-In“ in LC frame – Challenge

Differences „as-designed“ versus „as-build“:

1) Change of radius in angles flange to web ($\Delta\alpha_1$, $\Delta\alpha_2$)
   → Bending load in flanges caused by assembly



2) Change of global frame radius (r_3)
   → Contour gaps which cannot be compensated without shim
   → No reference points for assembly possible



As-Designed according to tool measurement

α_{Soll1} = 90°

α_{Soll2} = 90°

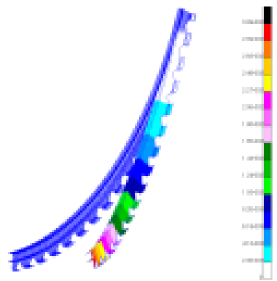
r_{Soll3} =1975mm

As-Built (average) according to measurement final frame (COFU I²)

α_1 = 88,75° ($\Delta\alpha_1$ =1,25°)

α_2 = 89,67° ($\Delta\alpha_2$ = 0,325°)

r_3 = 1963,5mm (Δr_3=11,5mm)



Minimum Tolerance Design

e.g. „Spring-In“ in LC frame – Theory

Spring-In

Eckwinkel θ

- Thermische Einflüsse (ca. 0,5%))*
  - Gelier-
  - Inkompatibler
- Chem. Einflüsse (ca. 0,2-0,7%)*
  - chemischer
- Sonstige Einflüsse (ca. 0-0,9%)*
  - Einfluss durch Laminataufbau (Unsymmetrie)
  - Werkzeug Einfluss
  - Einfluss durch Laminat-inhomogenität

$$\Delta\theta_{ges} = \Delta\theta_{thermisch} + \Delta\theta_{chemisch} = \theta \cdot \left(\left[\frac{(\alpha_t - \alpha_r)\cdot \Delta T}{(1+\alpha_r \cdot \Delta T)} \right] + \left[\frac{\phi_t - \phi_r}{1+\phi_r} \right] \right)$$

α_t: tangentialer Wärmedehnungskoeffizienten
α_r: radialer Wärmedehnungskoeffizienten
ϕ_r : radialer Laminatschwund und
ϕ_t : tangentialen Laminatschwund
ΔT: effektiv wirkende Temperaturdifferenz

Influences regarding Spring-In not yet fully evaluated

Optimized process and lay-up parameters may reduce impact

Verspannung der Preform | Spring In Unterdrückung | Verzerrung | radius

Gradient im Fasergehalt | Lokale Poren | Harznester | Ondulationen

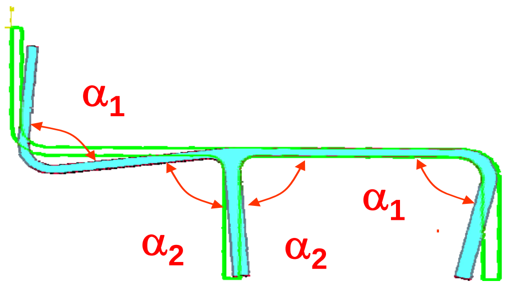
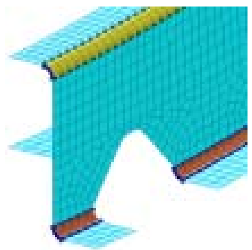
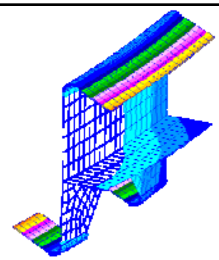
*(Nelson, 1989 S. 2410)
entspricht bei 90° Winkel
0,45°
0,18° bis 0,63°
0° bis 0,81°

Minimum Tolerance Design

e.g. „Spring-In“ in LC frame – Simulation

Analysis of „Spring-In“ deformation in the corner radii frame to web after introduction of the modified thermal expansion coefficients:

“As-Designed” in frame outer flange α_{Soll1}=90°, measured “As-Built” α_1=88,75°

	V2 T_{gel}=180°C	V7 T_{gel}=110°C	
2D + 3D simulation of the radii	α_{1s}=88,75°	α_{1s}=89,39°	 

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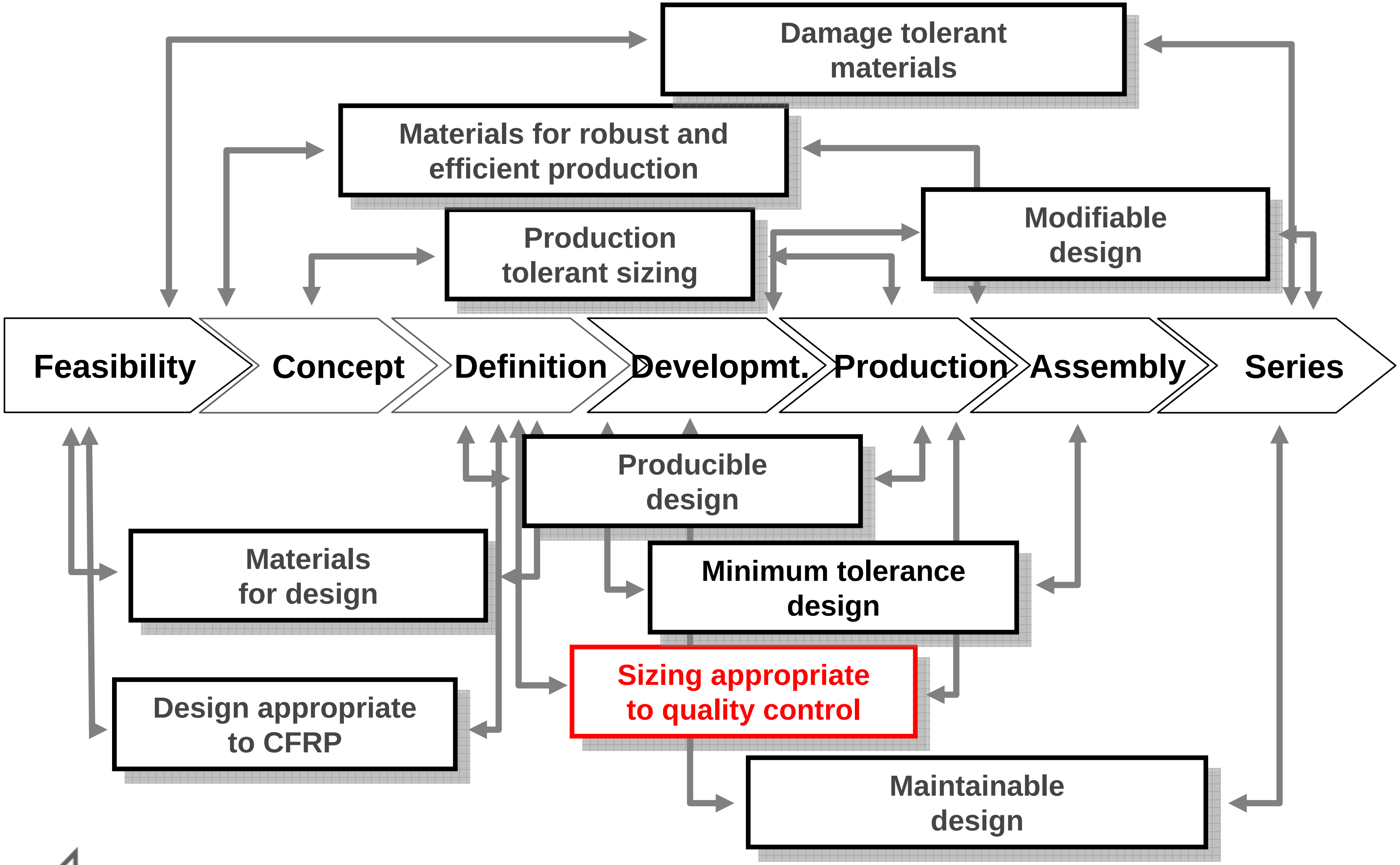
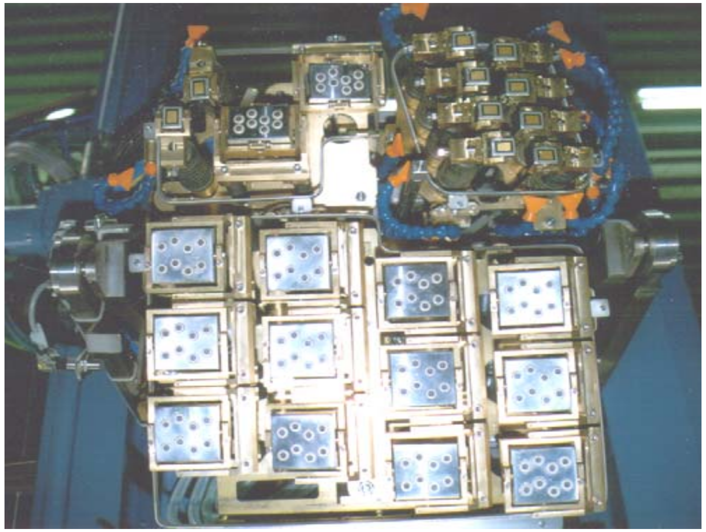


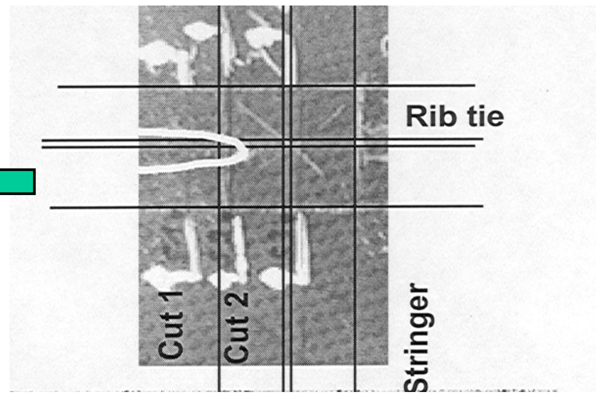
Sizing appropriate to Quality Control Techniques

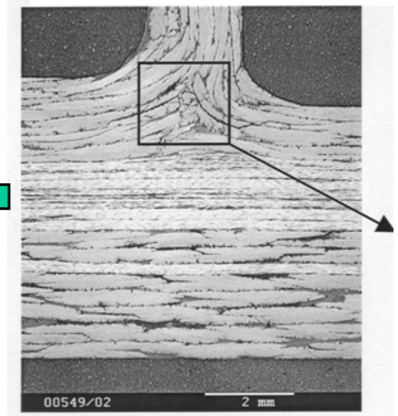
e.g. consideration of undetectable imperfections in sizing

Old Squirter-Tool 4 Channels

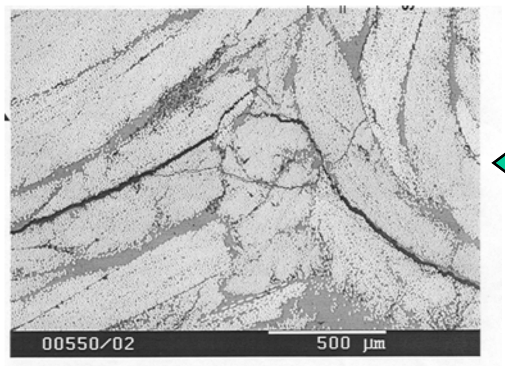
Better Impuls-Echo Tool with 192 Channels





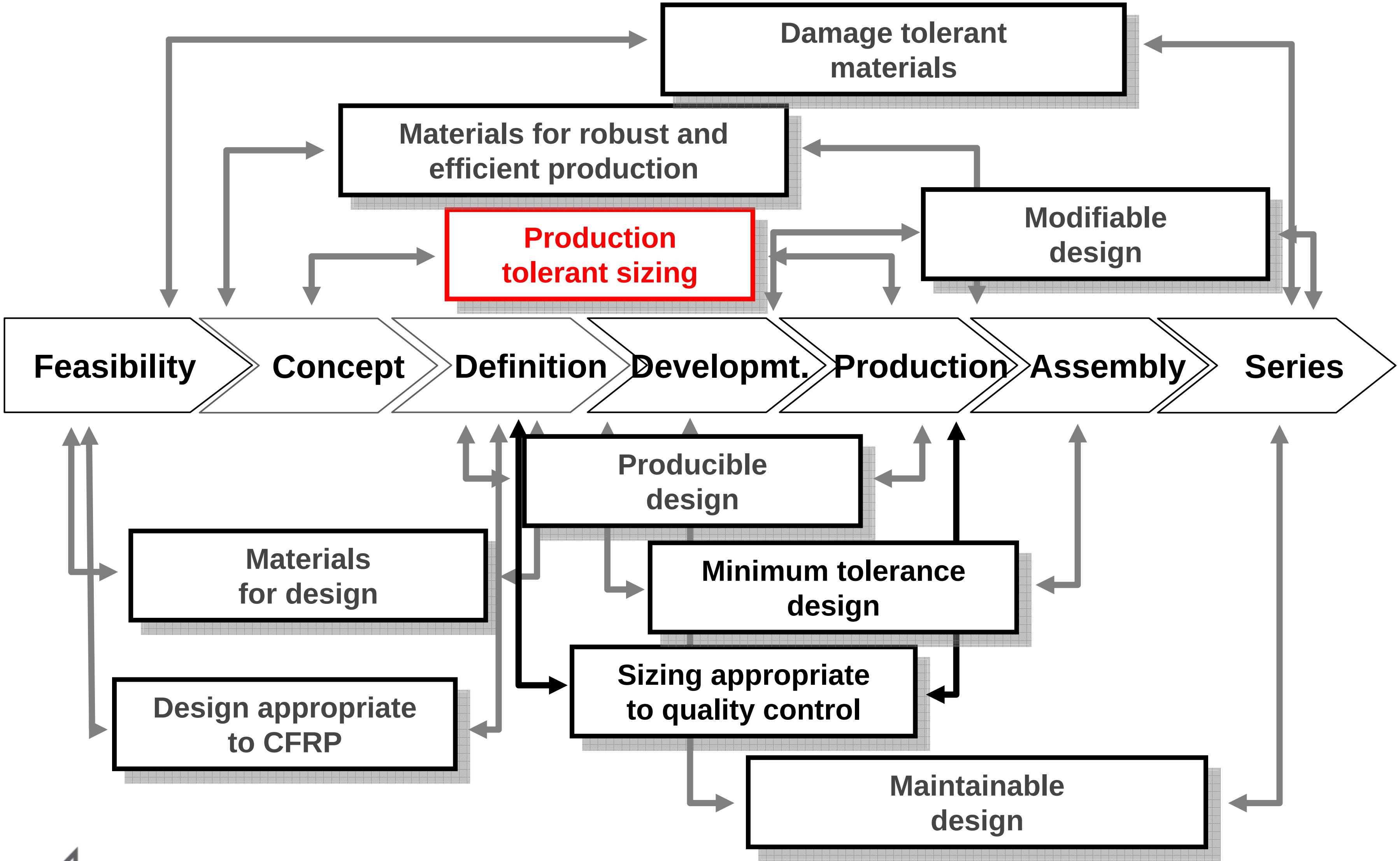


Cut 2 from Cut-Out-Example



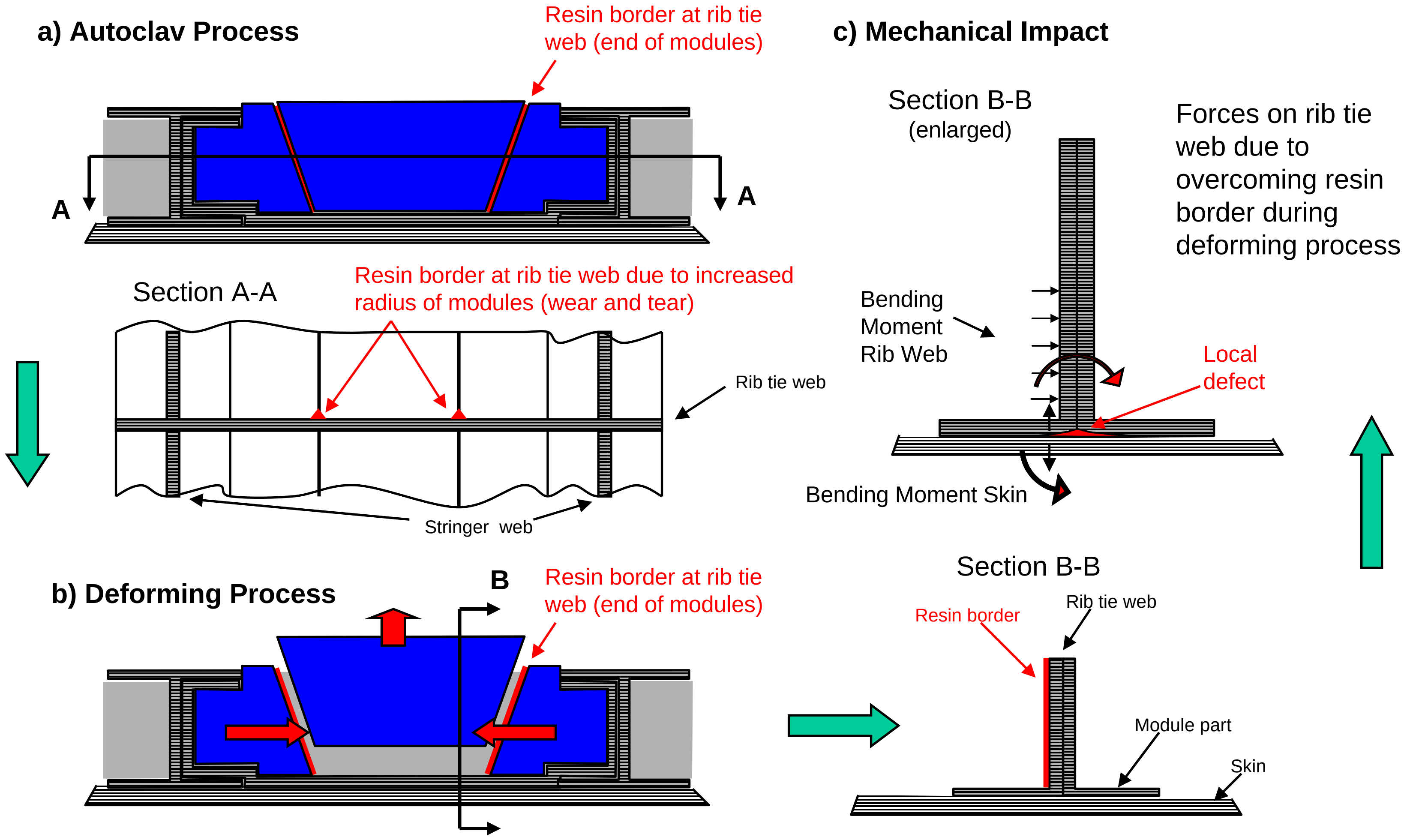
Detail from Cut 2

Examples of Dependencies in CFRP Structure Development

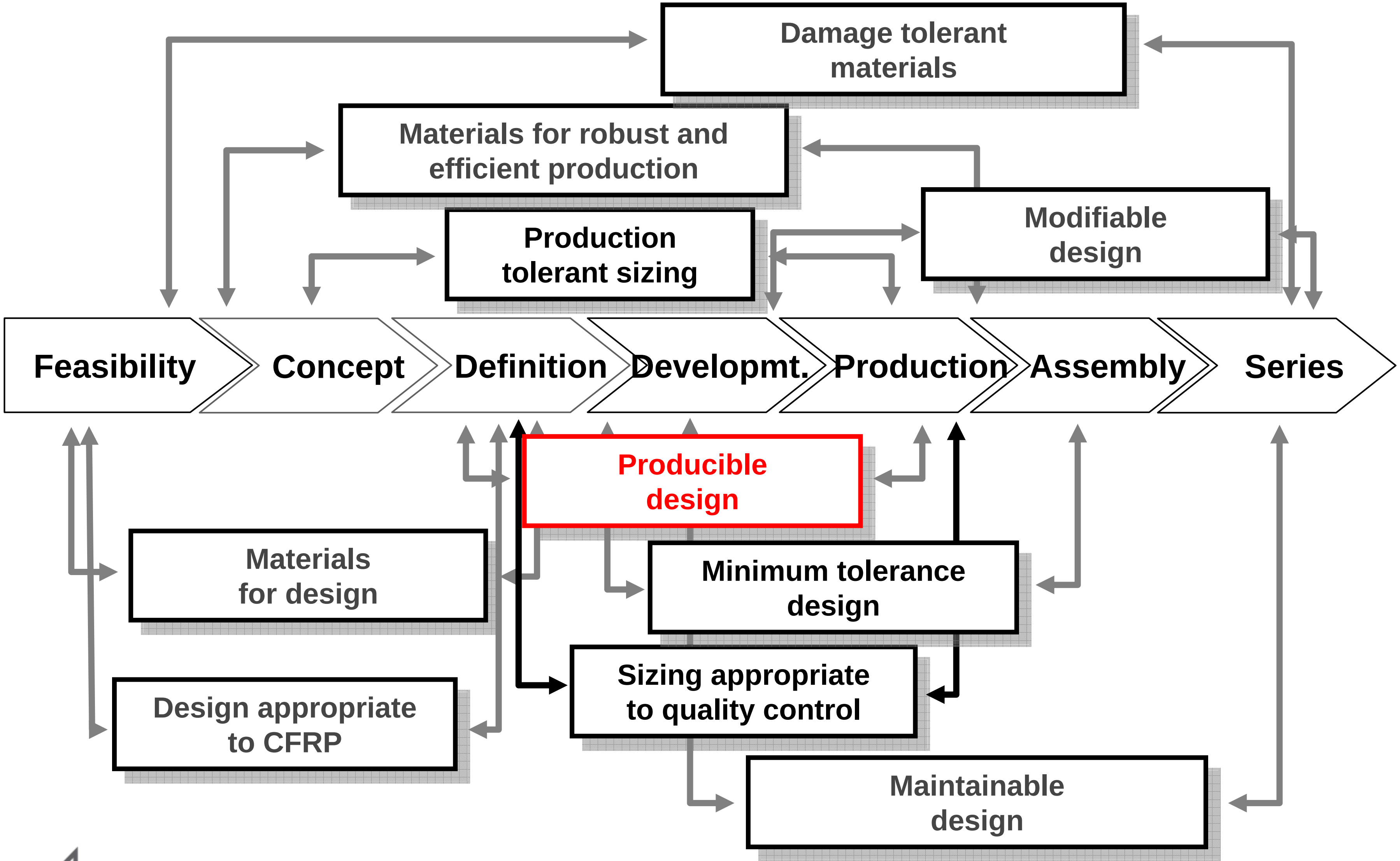


Sizing appropriate for Production Tooling

e.g. mechanism to produce manufacturing driven imperfections



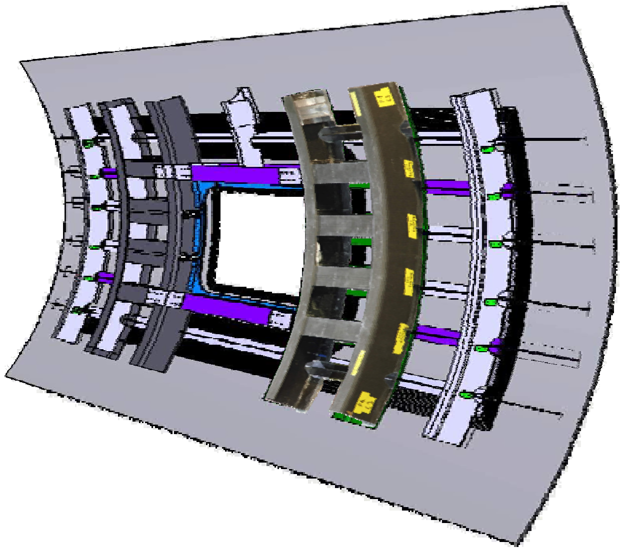
Examples of Dependencies in CFRP Structure Development



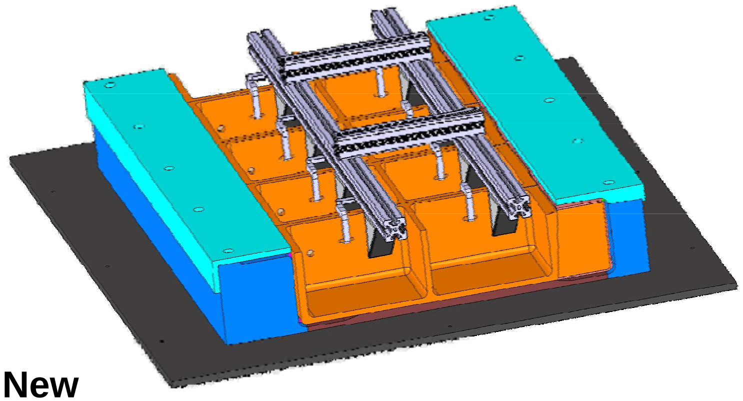
Producible Design

e.g. surround structure for fuselage cutout

1) Selected Design Concept:
   Cutout Frame as Ladder Structure



2) Manufacturing Concept
   Target: Lower manuf. cost



New tooling concept developed

Simplified demonstrator to validate the concept

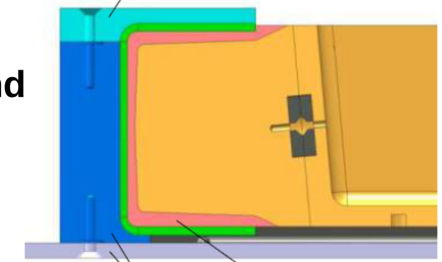
+ Lighter
  Easier to assemble
  Better for repair

- High manufacturing cost

Producible Design

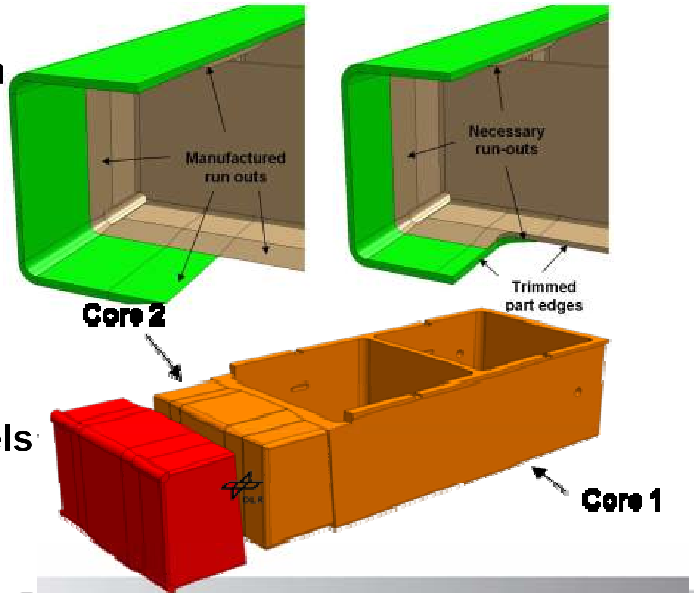
Examples for Improvement

New forming and aircast concept



Better groupin and runout of plies

Flexible kernels

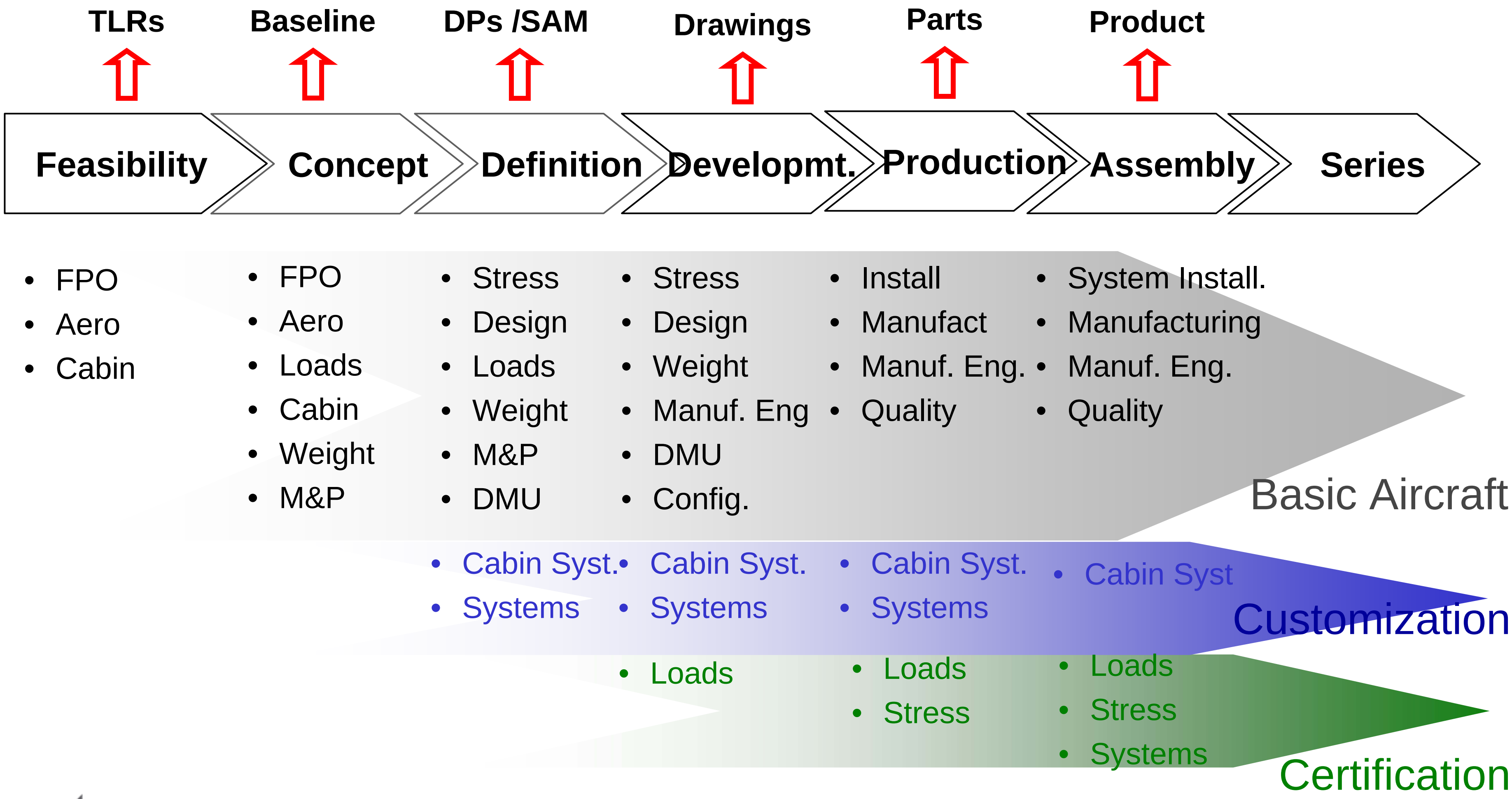


Results

- **Reduction in preforming >50%**
- **Reliable filling concept integrated in the tooling**
- **Cheaper Tools**
  - *Plug and Play* kernels
  - Number of kernels reduced
  - Demoulding simplified
  - Reusable kernels
  - Rework minimized
- **Reduction in Assembly**
  - Shimless concept (shape to adjacent parts given by the female tooling)
  - Spring-in pre-calculated and anticipated in tooling
  - Number of single parts and attachments significantly reduced

Develop New Aircraft (DNA) Process

and contributing disciplines…



Concepts of concurrent development process today

Feasibility → Concept → Definition → Developmt. → Production → Assembly → Series

Too many people working concurrent on one major subcomponent not efficient

Sub-structuring required

Substructuring by Parts?
Small team with all relevant disciplines responsible for one part.
Preferred Manufacturing Solution

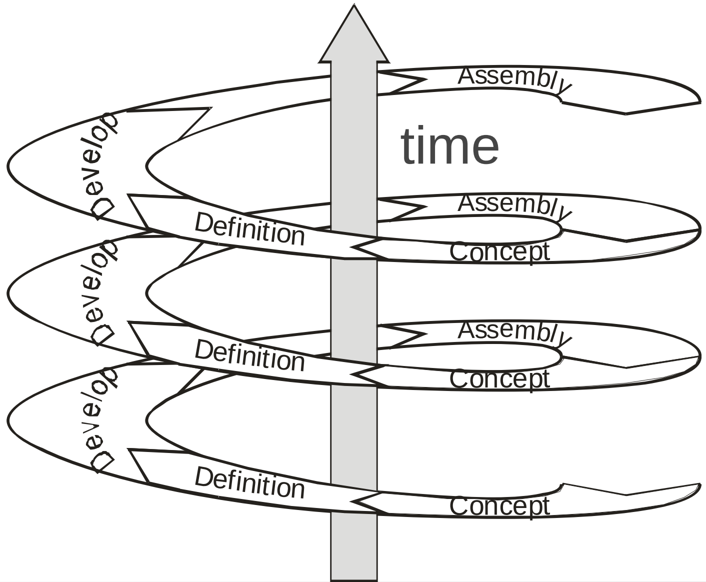
Substructuring by Disciplines?
Earlier involvement of relevant disciplines and regular DPMs.
Preferred Engineering Solution

Substructuring by Components?
Component build teams for fully equipped sections for assembly.
Preferred FAL and Programs Solution

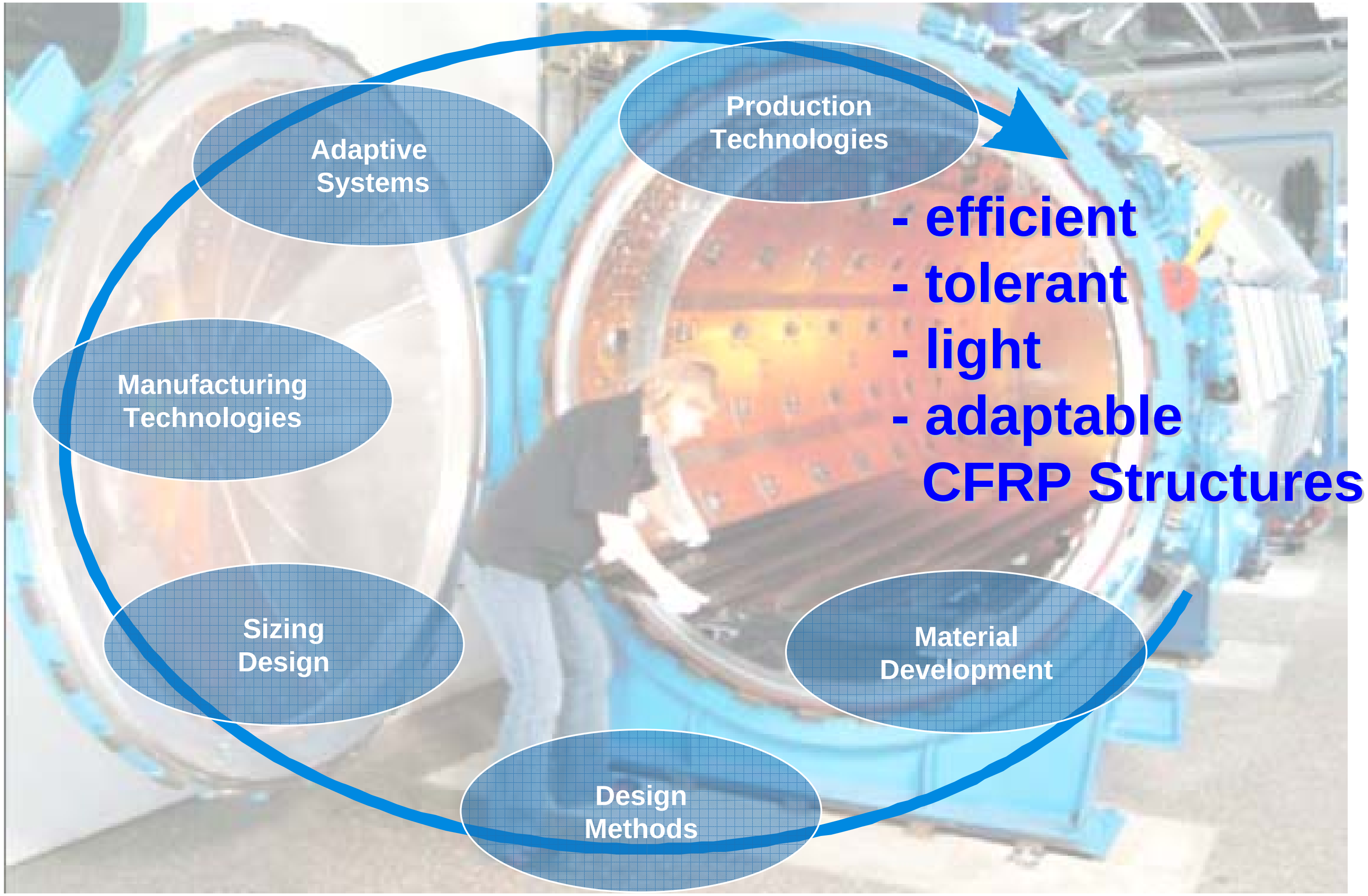
Proposed CFPR Development Process: Iterative

Feasibility → **Concept** → **Definition** → **Developmt.** → **Production** → **Assembly** → **Series**

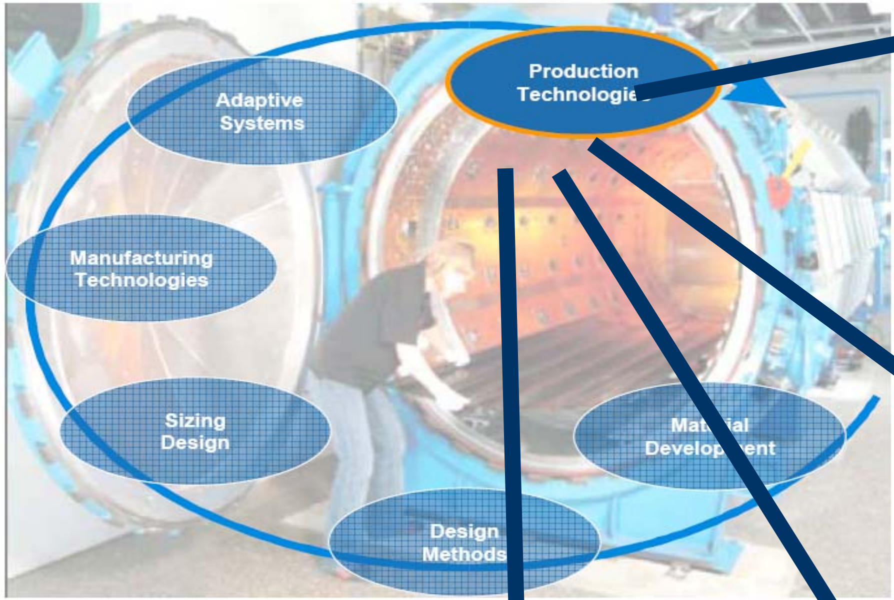
One CFK Core Team with design responsibility and budget
(Materials&Process, Stress, Design, Cabin, System Installation, Manufact. Engineering, Quality, Design to Cost, Automation,…)



We take care for full process chain in CFRP structures

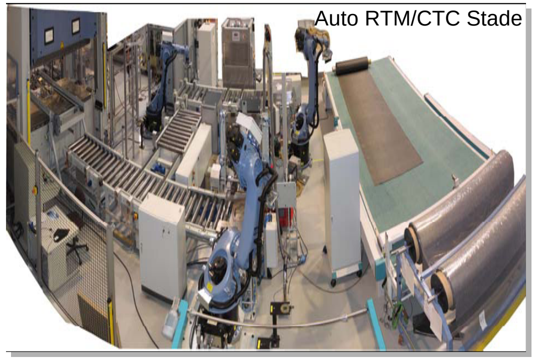


Production Technologies for High Performance Structures

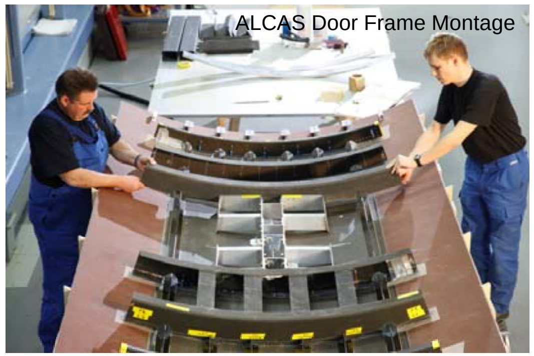


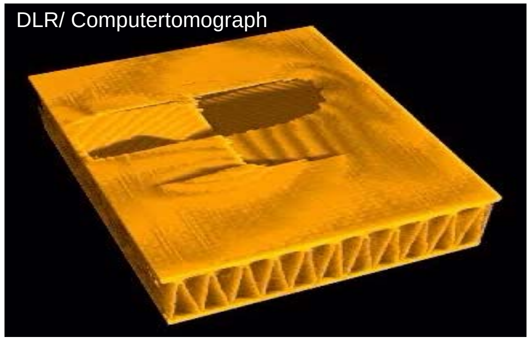
Large Components

High Volume Parts



Assembly





NDT

DLR Center for Lightweight Production Technologies

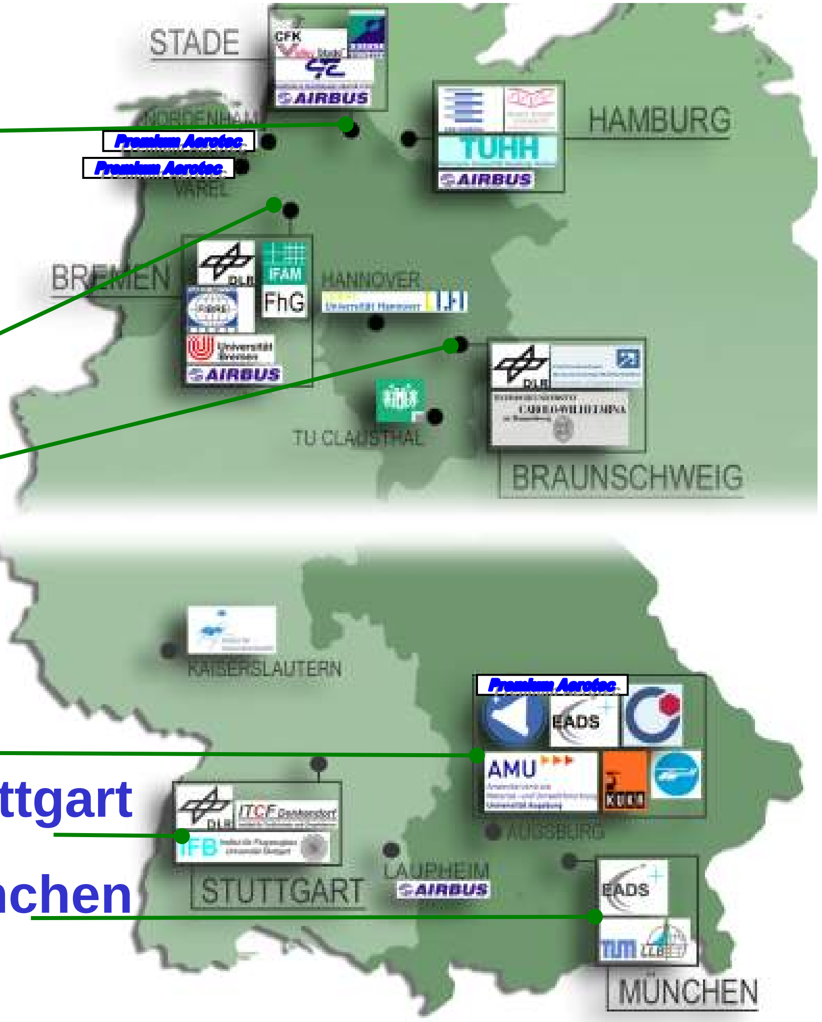
Sites, Partners and Customer

Stade

The North Platform

Bremen

Braunschweig



Augsburg

Stuttgart

München

The South Platform

“In light of the fact that humanity is not able to learn from past mistakes …..we can not afford to make mistakes in the future.”

Ernst Ferstl

Thank you for listening

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