DLR Deutsches Zentrum für Luft- und Raumfahrt

ACstyria Leichtbautag 18.10.2017

Perspektive „Composites“ in der Luft- und Raumfahrt

Dr. Markus Kleineberg

DLR - Deutsches Zentrum für Luft- und Raumfahrt

Aufgaben

- Forschungseinrichtung
- Raumfahrt-Agentur
- Projektträger

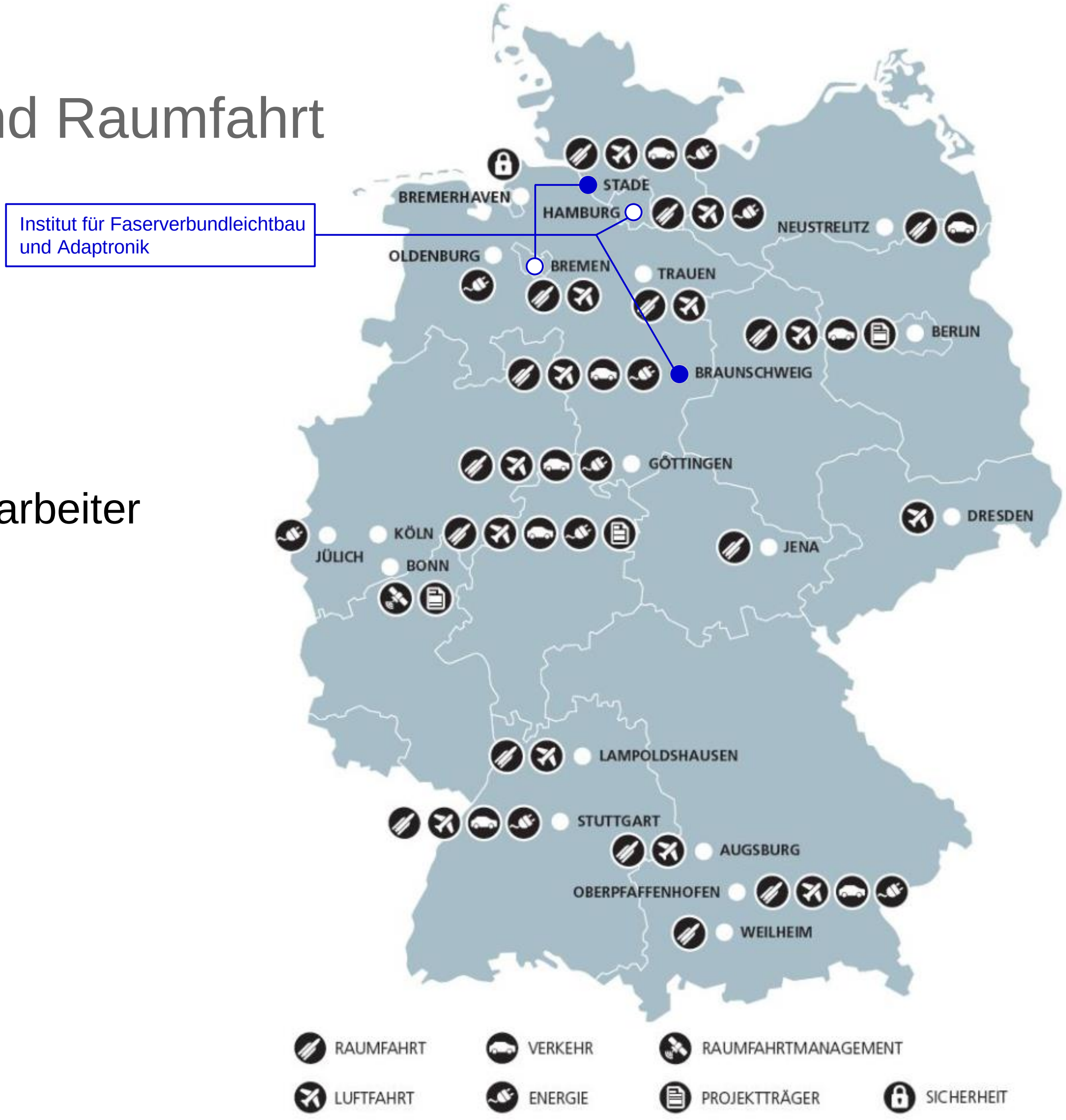
Forschungsschwerpunkte und Querschnittsbereiche

- Luftfahrt
- Raumfahrtforschung und -technologie
- Energie
- Verkehr
- Sicherheit
- Digitalisierung (u.a. „Factory of the Future“, „Condition Monitoring“)

DLR - Deutsches Zentrum für Luft- und Raumfahrt

Standorte und Personal

- Ca. 8.000 Mitarbeiterinnen und Mitarbeiter
- 42 Instituten und Einrichtungen
- 20 Standorten
- Büros in Brüssel, Paris, Tokio und Washington.



DLR

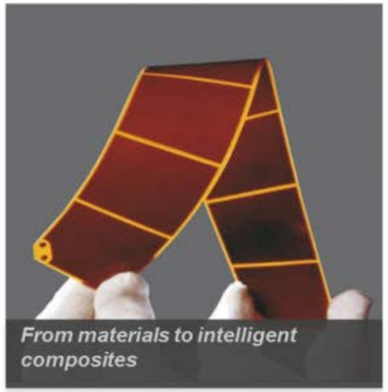
The Institute of Composite Structures and Adaptive Systems (DLR-FA)

Direktor: Prof. Dr.-Ing. Martin Wiedemann
Stellv. Direktor: Prof. Dr.-Ing. Peter Wierach

Multifunctional Materials

Prof. P. Wirach

We increase the ability of the materials!



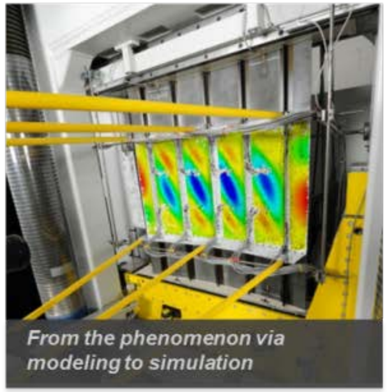
From materials to intelligent composites

- Fiber- and nanocomposites
- Smart materials
- Structural health monitoring
- Material characterization

Structural Mechanics

Dr. T. Wille

With high fidelity to virtual reality for the entire life cycle!



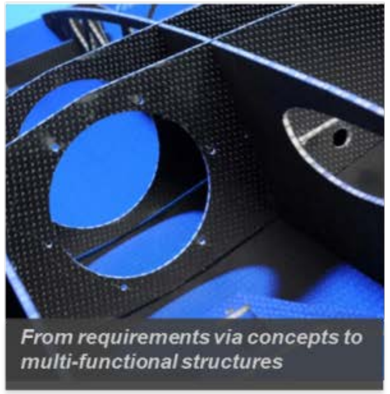
From the phenomenon via modeling to simulation

- Global design methods
- Stability and damage tolerance
- Structural dynamics
- Thermal analysis
- Multi-scale analysis
- Process simulation

Composite Design

Prof. C. Hühne

Our design for your structures!



From requirements via concepts to multi-functional structures

- Design and Sizing
- Structure concepts and assessment
- Multi-functional structures
- Shape-variable structures
- Hybrid structures

Composite Technology

Dr. M. Kleineberg

Tailored manufacturing concepts

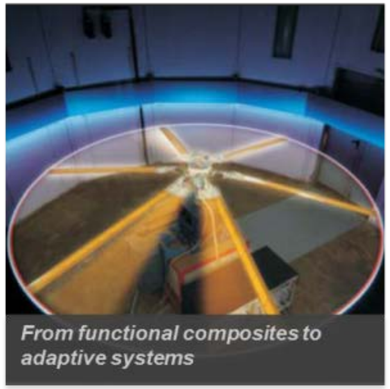
From the idea via processes to prototypes

- Tolerance Management
- Process Simulation
- Functional Demonstrators
- Digital Production Network
- Online Process Assessment
- Design to Cost Modelling

Adaptronics

Prof. H. P. Monner

The adaptronics pioneers in Europe



From functional composites to adaptive systems

- Simulation and demonstration of adaptive systems
- Active vibration control
- Active noise control
- Active shape control
- Autarkic systems

Composite Process Technology

Dr. J. Stüve

Research with industrial dimension

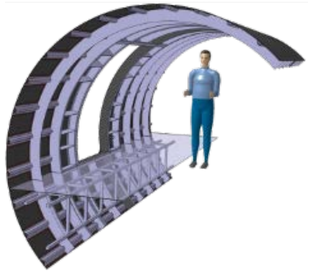
For sustainable processes

- Automated FP und TL
- Online QA within autoclaves
- Automated manufacturing for mass-production
- Simulation methods for maximum process reliability and process assessment

The Institute of Composite Structures and Adaptive Systems (DLR-FA)

Schwerpunkt
Rumpftechnologien

Dr. J. Kreikemeier



- Rumpfbauweisen
- Große Rumpfausschnitte
- Fertigungstechnologien

Schwerpunkt
Steuerflächen und Leitwerke

Dr. M. Kintscher

- Flexible Flügelvorderkanten
- Morphing an Hochauftriebs-systemen
- Strukturintegration aktiver Strömungskontrolle

Schwerpunkt
Spezialstrukturen

M. Hanke

- Sicherheitsrelevante Luftfahrtstrukturen und UAVs
- Multifunktionale Verbundstrukturen
- Bauweisen- und Technologie-demonstration

Schwerpunkt
Weltraum

O. Mierheim

- Landerstrukturen
- Entfaltbare Raumfahrtstrukturen
- Oberstufe

Schwerpunkt
Verkehr

I. Roese-Koerner

- Next Generation Train
- Neue Fahrzeugstrukturen

Schwerpunkt
Windenergie

B. Wieland

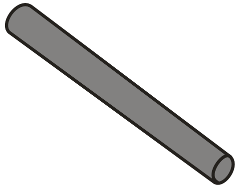
- Multidisziplinäre Auslegungskette
- Qualitätsgesicherte, toleranzgerechte Fertigung
- Passive und aktive Smart Blades
- (Teil-)Automatisierte Produktion
- SHM und Load Monitoring
- Radarabsorption

"Composite" Material Options

CERTIFICATION?

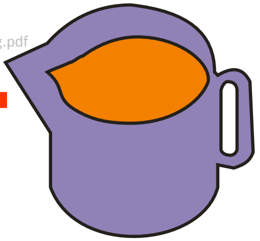
Carbon
Aramid
Glass
Basalt
Hemp
Polyester
Others

Fiber Reinforcement



Laminate

https://download.r-g.de/fvw-einfuehrung.pdf



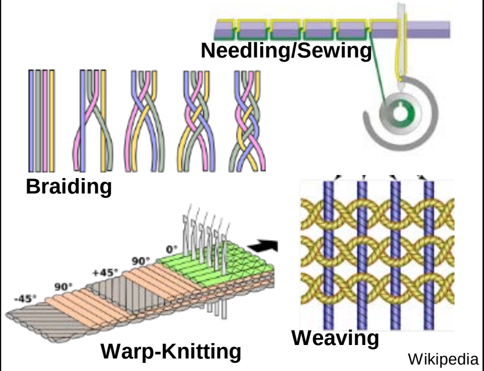
Matrix

Epoxy
Cyanate Ester
PEEK
Polyurethane
Polyester
PA
Others

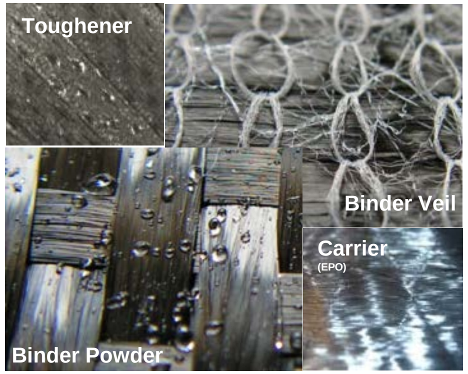
Tooling (Mould)

Additional Options

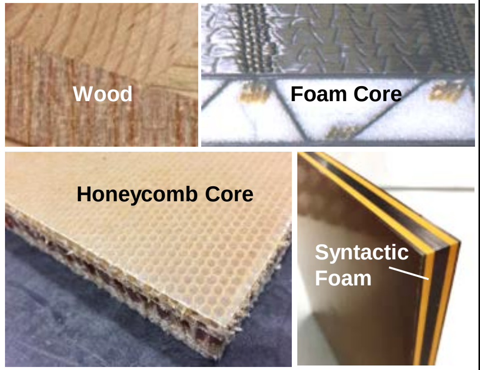
Textile Manipulation



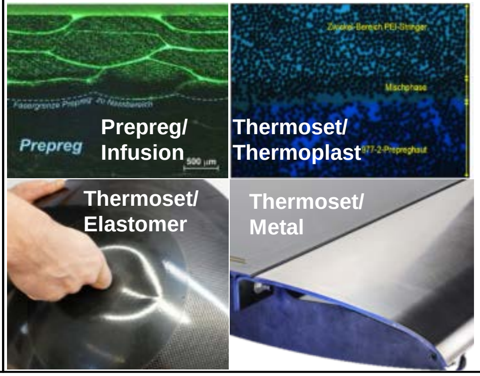
Binder, Toughener, etc.



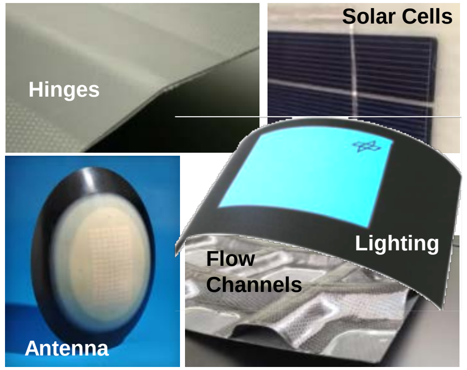
Integration of Cores



Hybridisation



Integration of Functions

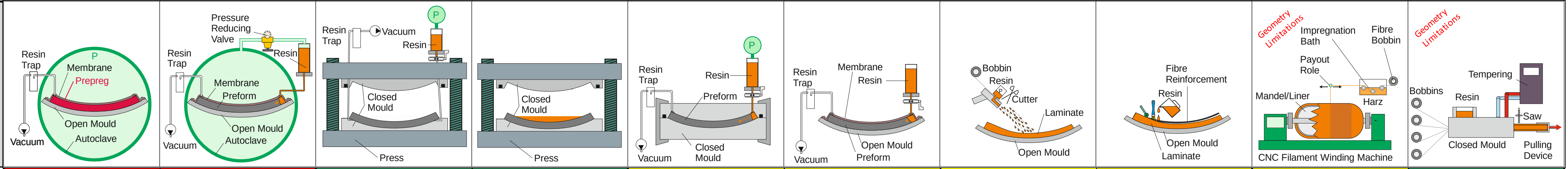


"Composite" Manufacturing Options

rarely used
occasionally used
typical

RETURN OF INVEST?

AC STYRIA



Technology	Autoclave Prepreg	Autoclave Injection	Press RTM	Press Moulding	RTM	Resin Infusion	Fibre Spraying	Hand Laminating	Filament Winding	Pultrusion
Industrial Application										
Automotive (mass prod.)	rarely used	rarely used	typical	typical	occasionally used	occasionally used	occasionally used	occasionally used	occasionally used	typical
Aerospace	typical	occasionally used	typical	rarely used	typical	occasionally used	rarely used	occasionally used	typical	occasionally used
Wind Energie	rarely used	rarely used	rarely used	rarely used	rarely used	typical	occasionally used	occasionally used	typical	occasionally used
Engineering	typical	rarely used	typical	occasionally used	occasionally used	rarely used	occasionally used	occasionally used	typical	occasionally used
Sport and Leasure	occasionally used	rarely used	typical	typical	occasionally used	occasionally used	typical	typical	typical	typical
Criteria										
Laminate Quality	++	+	+	0	+	0	-	-	+	+
Reproducibility	+	+	+	0	+	0	-	-	+	+
Cycle Time	0	0	++	++	0	0	+	0	0	+
Scrap Rate	0	0	0	-	0	0	++	-	++	++
Working Conditions	+	+	+	-	+	+	--	--	-	+
Invest	-	-	-	-	0	+	+	++	-	-
Investment										
Open Mould	x	x				x	x	x	x	
Closed Mould			x	x	x					x
Autoclave	x	x								
Press			x	x						
Oven						x		(x)		
Tempering Device			x	x	x				x	x
Special Machines							x		x	x
Vacuum	x	x	x		x	x				
Pressure	x	x	x		x					
CNC Cutter	x	x	x	x	x	x		(x)		
Hotforming Device	x									
Preforming Device		x	x	(x)	x	x				
Resin Mixer		x	x	x	x	x	x	(x)	x	x
Resin Injection Equippment		x	x		x					
Refrigerator	x									

DLR

Selection of “Composites” Applications

Aeronautics

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https://commons.wikimedia.org/w/index.php?curid=27378309

DLR-FA (Airframe)

Space Structures

Anisogrid composite lattice structures – Development and aerospace applications; V.V. Vasiliev ⇑, V.A. Barynin, A.F. Razin

Von Jeff Foust - Flickr: Zooming in on three noses, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=14222485

DLR-FA (Philae Structure)

Transportation

By Jesper Olsson (Own work) [Public domain], via Wikimedia Commons

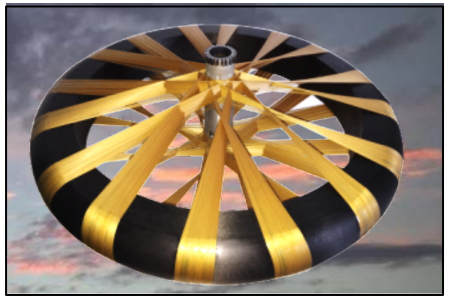
DLR-FA (CFRP Demonstrator)

M. Kleineberg

Energy Systems

DLR-FA (20m Rotor Blade)

DLR-FA (Cryo Tank)



DLR (Fly Wheel)

Sports

http://cloudfront.bernews.com/wp-content/uploads/2017/06/TeamBDA-Bermuda-June-8-2017.jpg

Von FlightReal - 4, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=13440925

Von 100yen - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4935279

Major Structural Components of an Airliner

Pressurized Fuselage
- Functionality driven
- Large Skin, small frame segments

Stabilizers and Rudders
- Cost / Aero driven

Pressurized Front Fuselage
- Functionality driven
- Complex

Engines and Cowlings
- Aero / Performance driven
- Mid size panels
- small complex engine elements

<u>Wings</u> and High Lift Devices
- Aero / Performance driven
- Large skins, small ribs

Non-Pressurized Rear Fuselage
- Cost driven
- Complex

Wing Structure Development

Material Options

Low Cost Metal (e.g. welded stiffeners)

Fibre Metal Laminate (e.g. GLARE)

Composite Thermoset (Epoxy/Carbon)

Composite Thermoplast (PEEK/Carbon)

Multi-Material Approach (Metallic Ribs, CFRP Skins)

Design Decisions

Structural Integration Concept and Interfaces

Panel Strategy (Semi-Monocoque, Sandwich, ...)

Spars (I,L,C), Ribs (I,L,C), Stiffeners (I,Omega, …)

Assembly approach (Bolting, Welding, Bonding,…)

Design to Cost Balancing (short or long range, …)

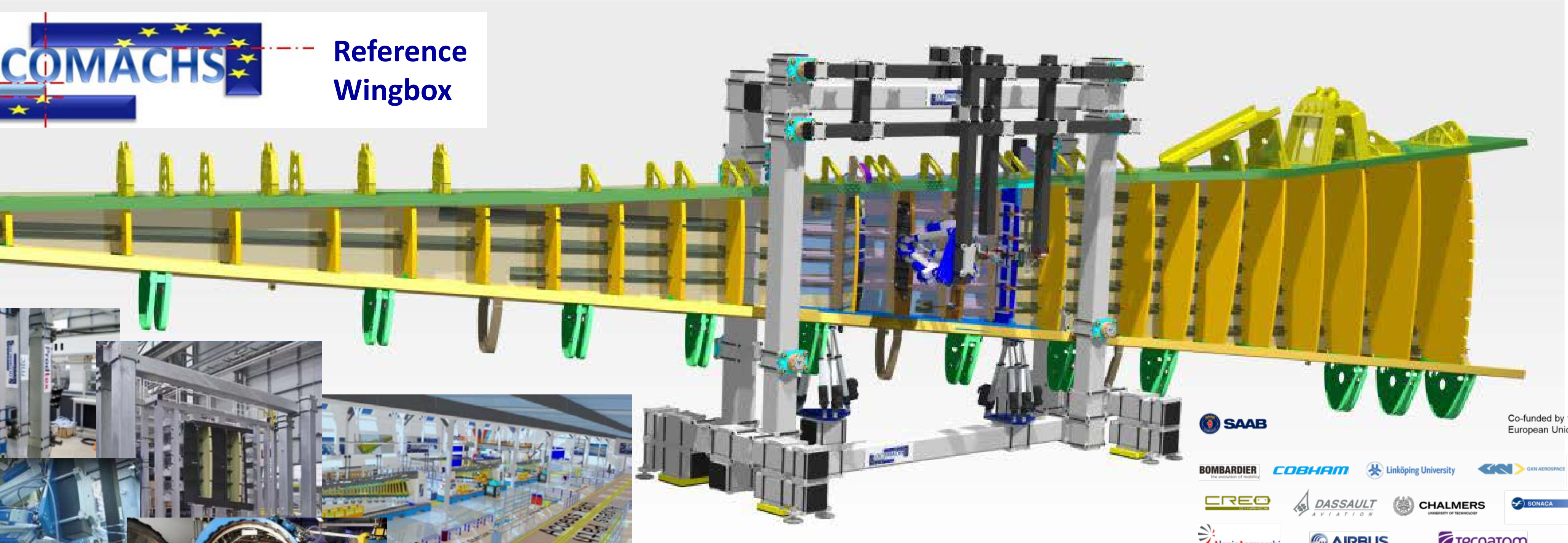
Within last 10 Years → Decision to develop Composite Wings

Wing Box Example

(120 Seater)

Major Components

- Large stringer stiffened lower and upper skin
- Long front and rear spar (locally stiffened)
- 25 box ribs of different size (partly stiffened)
- Several highly individual leading edge and trailing edge ribs



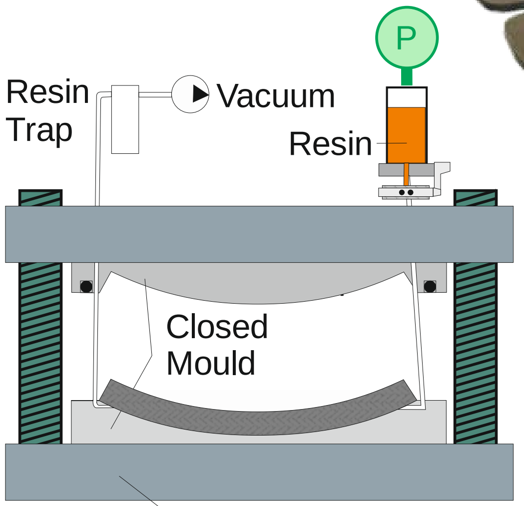
Co-funded by the European Union

High Rate Composite Production

Target: Single Aisle (e.g. A320), Production Rate >70 Aircraft per Month

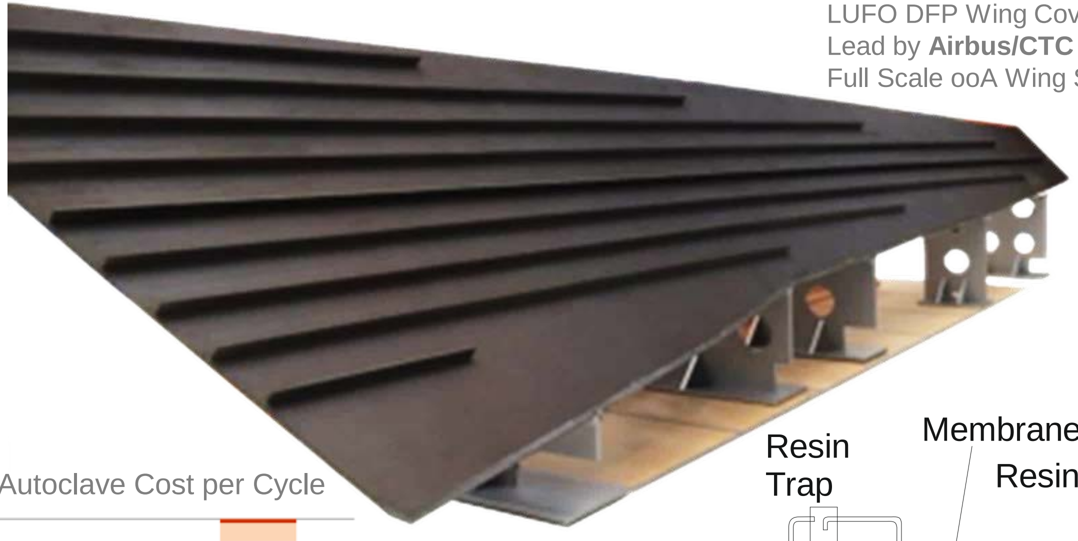
Wing Box Ribs → **NCF Preforming + Press RTM**
(0,75-2,5m length, app. >50.000 parts per year)

EU FP7 LOCOMACHS
Lead by **SAAB**
SLI Wing Rib



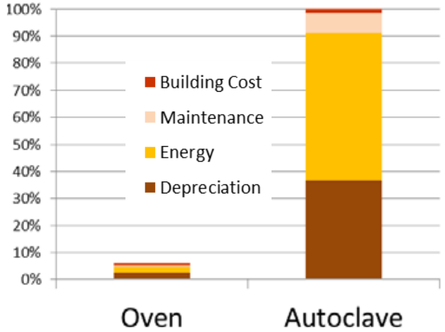
"Short Cycle Time" Scenario

Wing Skin → **Automated DFP + Resin Infusion**
(>15m length, app. 750 parts per year)

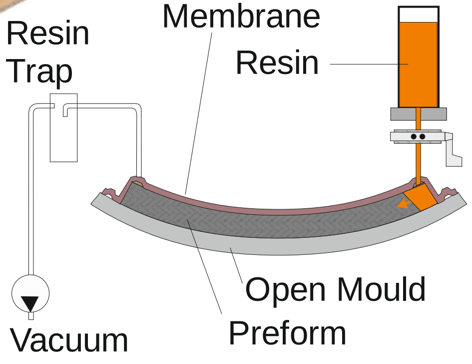


LUFO DFP Wing Cover
Lead by **Airbus/CTC**
Full Scale ooA Wing Skin

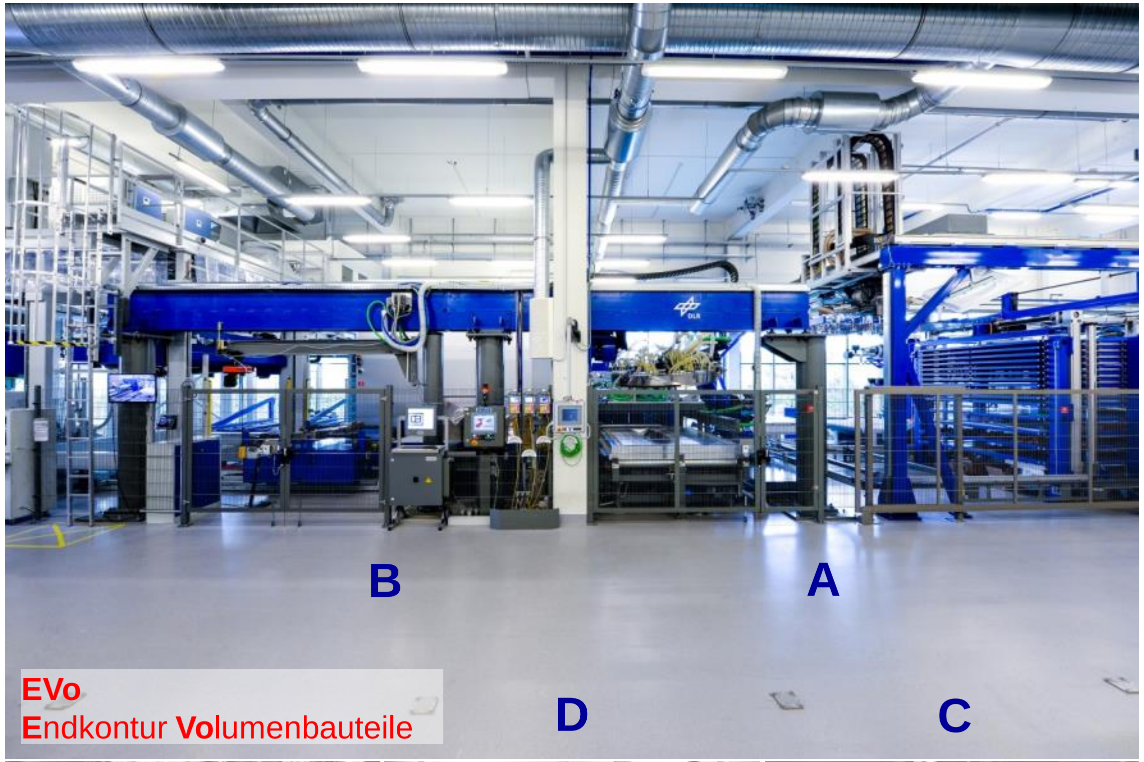
Oven/Autoclave Cost per Cycle

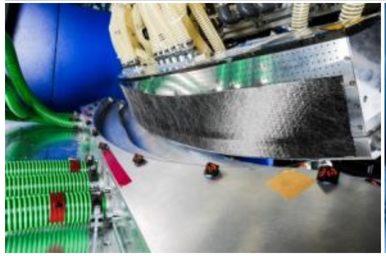


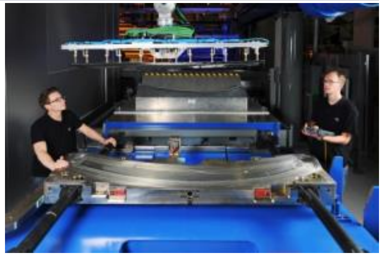
"Large Part" Scenario



NCF Preforming + Press RTM



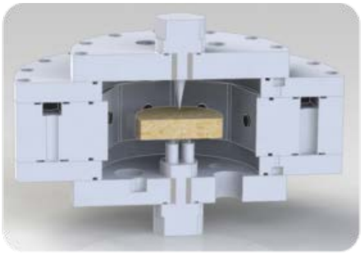




Research Perspective:
Production Setup "Short Cycle Time"

- Automatic material selection, flat pattern cutting, flat pattern buffering (A)
- Automatic flat pattern selection, 3D Preforming, Positioning of preformed layer, binder activation (B)
- Manual selection of dedicated base mould and component specific mould inlays (C)
- Automatic net shape cutting of complete preform, positioning of preform in the mould (D)
- Automatic isothermal injection and cure up to glassy state and final free standing post cure in an oven
- Post cure process to establish final degree of cure

NCF Preforming + Press RTM



Research Perspective:
Process Control "Short Cycle Time"

Flow front detection
Injection line / vacuum port management

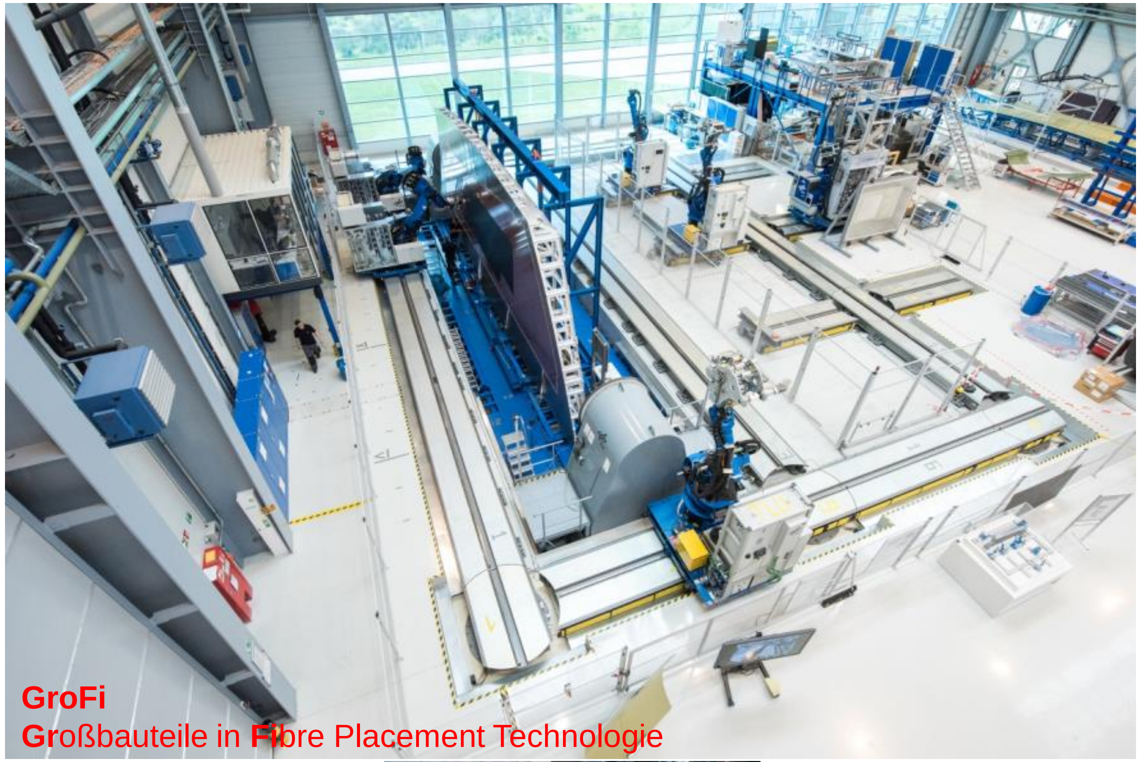
Fibre content / laminate thickness detection
Pressure adjustment

Crosslinking analyses (gelation, glass transition)
Temperature zone control / resin mixture adaption

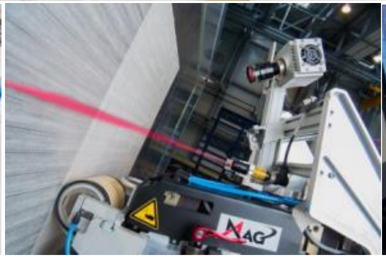
Foam core deformation monitoring
Pressure / Temperature adaption

Moisture analyses
Drying cycle initiation

Automated DFP + Resin Infusion



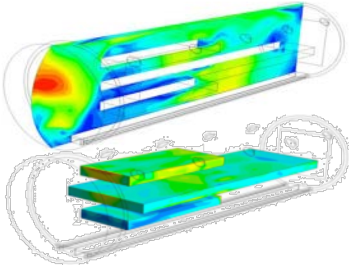
GroFi
Großbauteile in **Fi**bre Placement Technologie

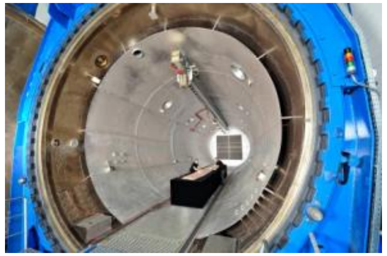


Research Perspective:
Production Setup “Large Part”

- Coordinated rail bound standard robot units
- Multi-head lay-up
- Combination of various lay-up endeffectors
- Real-time lay-up quality monitoring
- Integrated robot maintenance and set-up area
- Integration of mould / mandrel rotation axis
- Offline programming and process tuning
- Reconfigurable robot platforms

Automated DFP + Resin Infusion





Research Perspective:
Process Control "Large Part"

Autoclave/Oven integrated optical sensors
Flow front manipulation

Autoclave/Oven integrated infrared sensors
Temperature management, leakage detection

Process monitoring (flow, thickness, cure)
Active tooling with switchable temperature zones

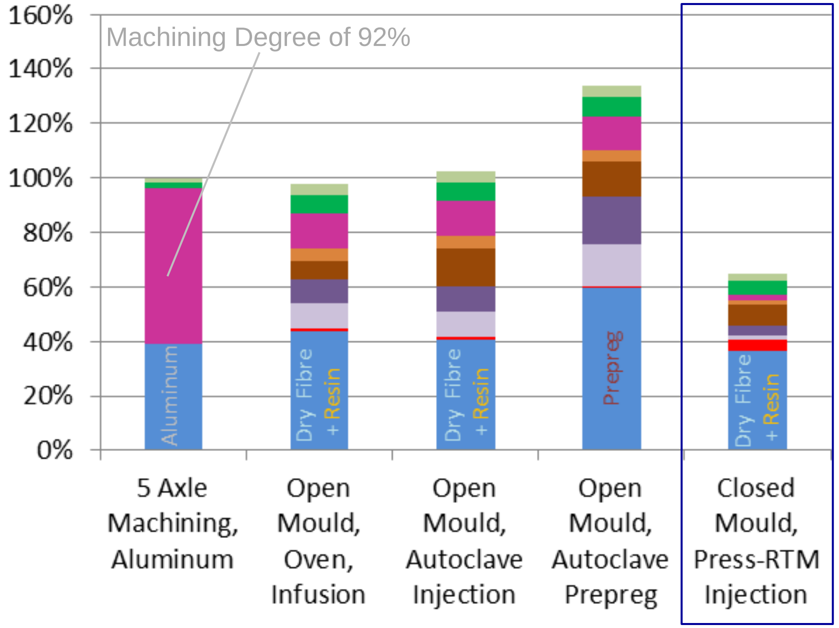
Predictive process analyses
Simulation based adaption of process parameters

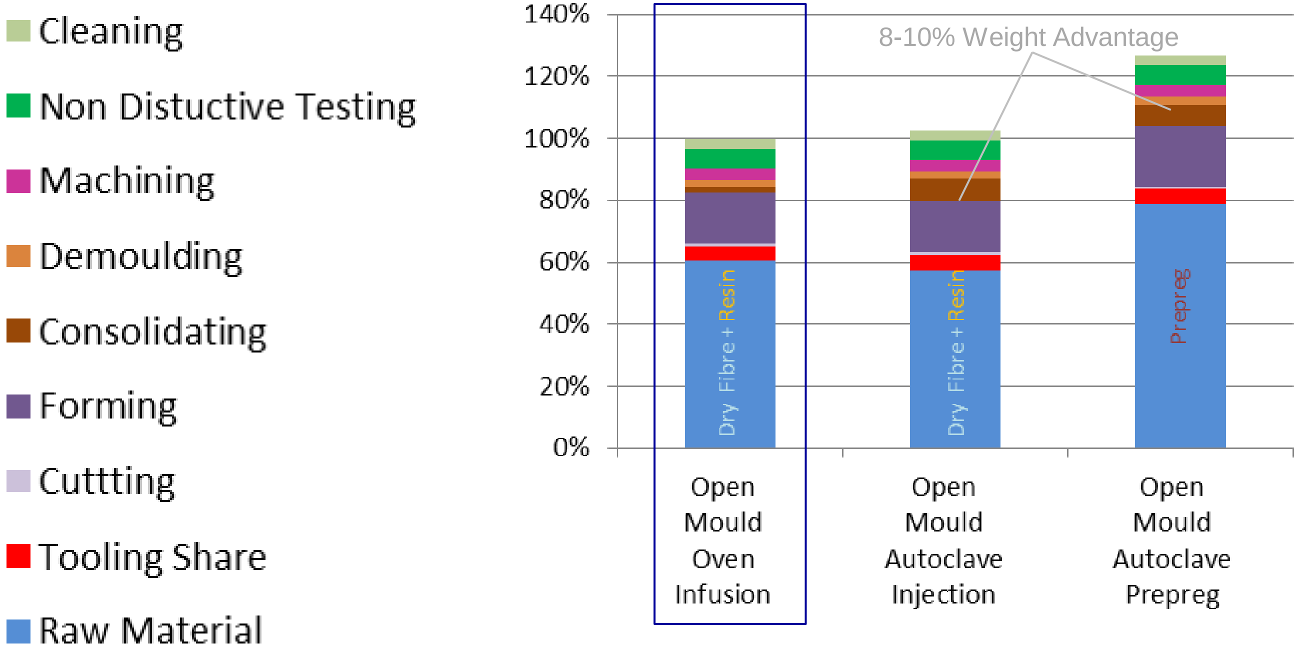
Correlation of monitoring results
Definition of optimised sensor arrangement

Assessment of Wing Box Rib and Wing Skin Production Approach

NCF Preforming + Press RTM

Automated DFP + Resin Infusion

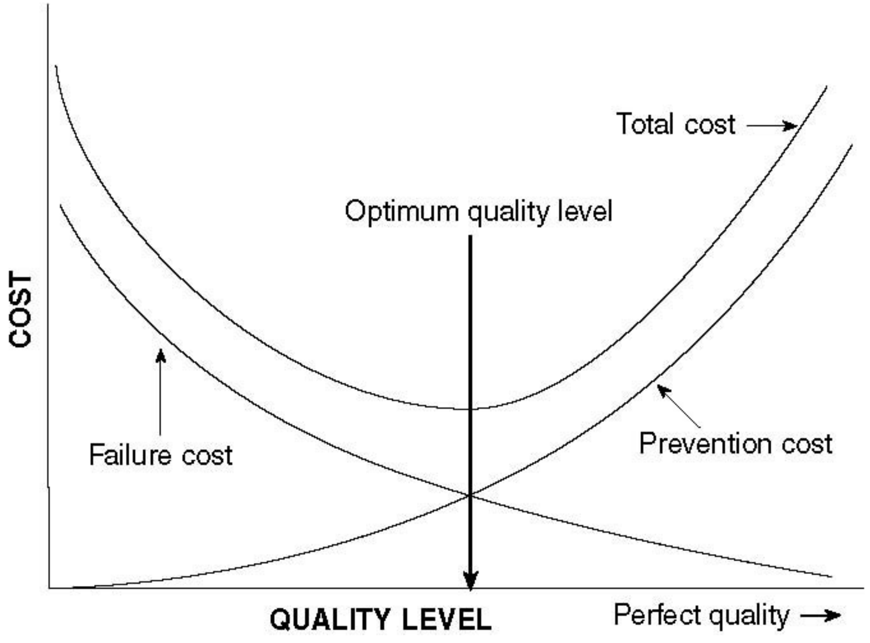




Conclusion

- **To introduce material based innovations current research is focusing on direct monitoring and control of all crucial process parameter in order to provide a solid bases for the CERTIFICATION approach.**

- **To maximise processing results for large structural components and high production rates flexible industrialisation strategies will be investigated in order to ensure maximum "Added Value" and RETURN OF INVEST.**



Classical model of optimum quality costs. From *Jurans Quality Control Handbook, 4th edition*. J.M. Juran, editor. Copyright © 1988, McGraw-Hill.

Outlook: Joined Production and Assembly

Research Perspective:
"Universal, Multi Scale Production Units"

- Demand actuated reconfiguration of available equipment (robot units) and workspace
- Fully autarkic standard robot platforms
- Combined coordinated and cooperative robot activities
- Integrated production and assembly activities
- Fully automated 24/7 production environment
- Safe "Mixed Reality" human-robot-interaction
- Non-specific factory work floor

Synergy Potential

DLR Project
Next Generation Car
(NGC)

DLR-FA Research
- High Rate Tooling Concept
- Fast Injection and Curing
- Sandwich Structure
- Structural Bonding
- System Integration
- Stringent Scrap Avoidance

Target: High-Volume Cars
- Golf, Astra, Focus…
…

Business Case
- Production Rate Driven
- 300.000 p/a
- Small, Complex
- Mainly Identical
- Short Lead Time
- Process Maturity

Target: New Short Range
- Single Aisle Aircraft
…

Business Case
- Performance Driven
- 750 p/a (e.g. Wing Skins)
  Large, Filigree, Vulnerable
- 50.000 p/a (e.g. Frames)
  Small, Complex, Variable
- Certification Aspects

DLR Projects
- High Lift
- CFK-Rumpf
- Fortschrittliche Flugzeug Strukturen (FFS)
- Produktionstechnik (ProTec NSR)
- Mephisto
…

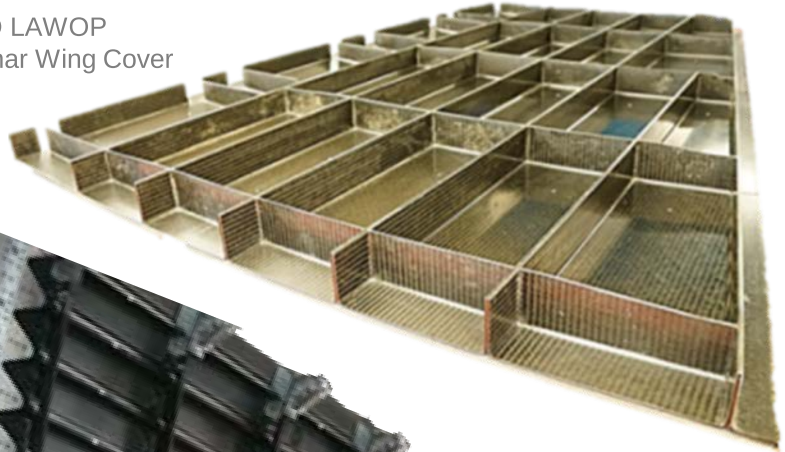
DLR-FA Research
- Variable Automation
- Flexible Tooling Strategies
- System Integration
- Flexible Process Control
- Reconfigurable Workspace
- “As Build” Certification

DLR Project
Next Generation Train
(NGT)

DLR-FA Research
- Low Cost Fibre Products
- Simple, Active Tooling
- Automated Handling and Referencing Strategies
- Modularity
- Bonding/Welding

Target: High Speed Train
- ICE
…

Business Case
- Invest Driven
- 150 p/a
- Large, Firm, Heavy
- Limited Complexity
- Robustness
- Fire/Smoke/Toxicity

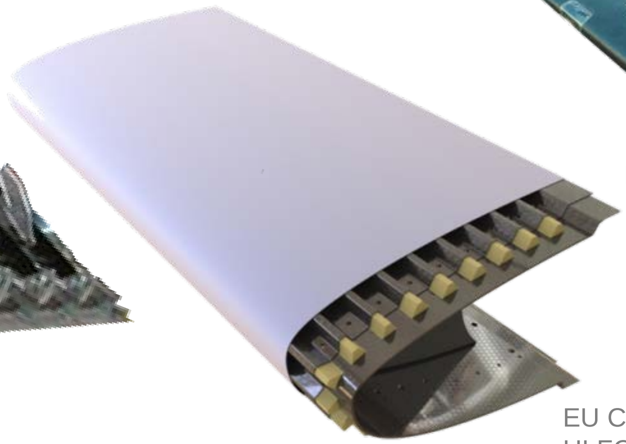

LUFO LAWOP
Laminar Wing Cover


DLR Solar HALE

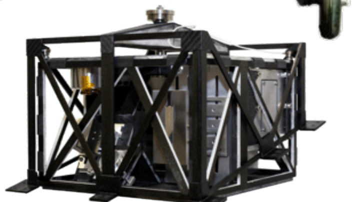

DLR MALE
Laminar Wing

Vielen Dank!


EU FP7 MAAXIMUS
Door Surround Structure


EU CS2 LPA
HLFC HTP LE


Open Innovation Sagitta
UAV Platform


MASCOT Lander


Eu:CROPIS Mission