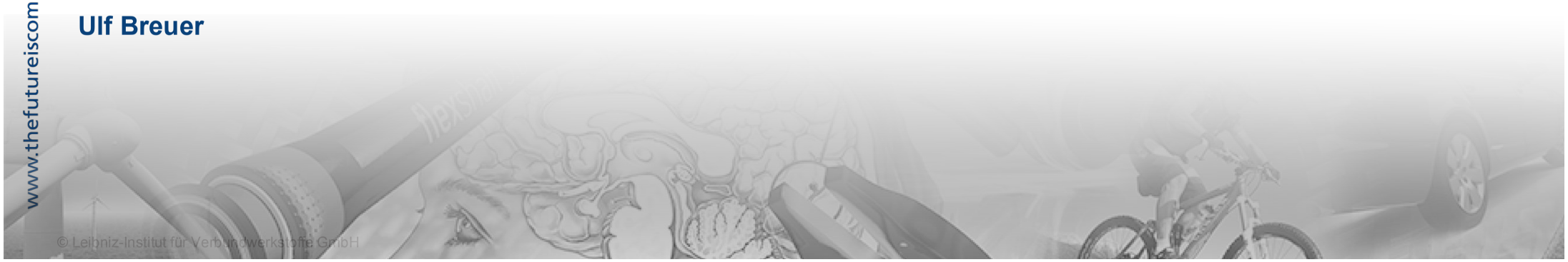
23. Jour Fixe Composites United e.V.

“Neue Leichtbaulösungen in der Luftfahrt”

19 Feb 2024

Ulf Breuer

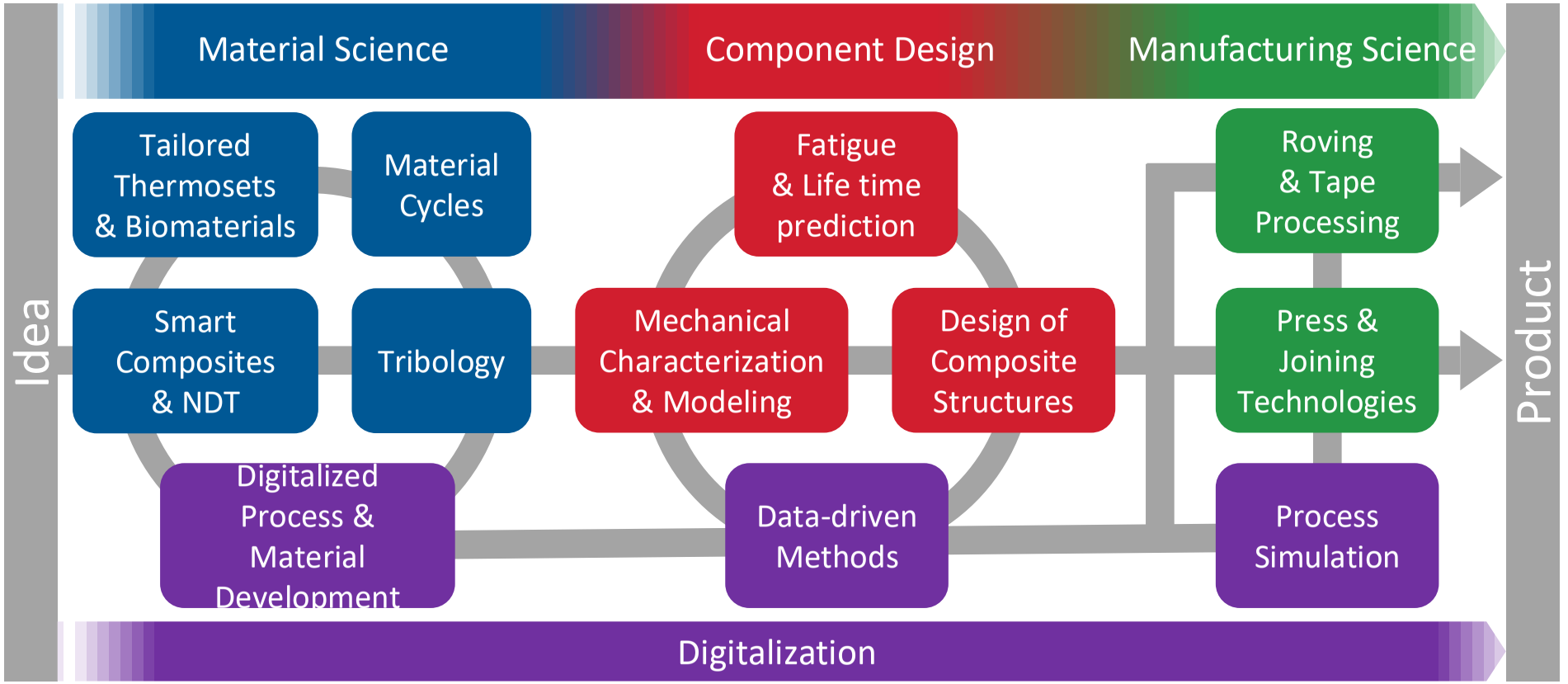
Leibniz-Institut für Verbundwerkstoffe



IVW at a Glance

www.thefutureiscomposite.com

Leibniz-Institut für Verbundwerkstoffe GmbH



www.thefutureiscomposite.com

Modern Aircraft Requirements

Target 2020
- **- 50 % CO_2** *
- - 80 % NO_x *
- - 50 % noise*
- …

[http://www.acare4europe.org/docs/Vision%202020.pdf]

* relative to the capabilities of typical new aircraft in the year 2000

2001

[2011]

Target 2050
- **- 75 % CO_2** *
- - 90 % NO_x *
- - 65 % noise*
- …

2011

Target 2050
- **- 100 % CO_2** *
- …

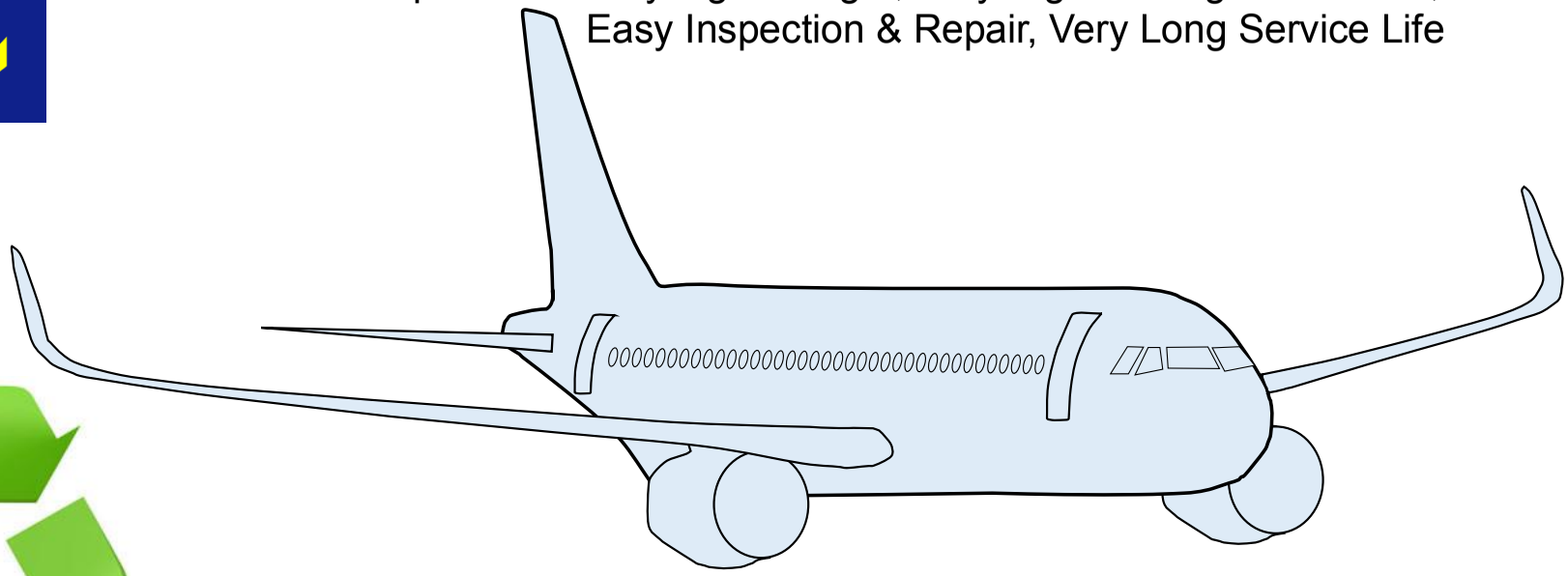
2021

www.thefutureiscomposite.com

Airframe Requirements for Materials & Processes

Manufacturing Cost: Low Material Cost,
Zero Waste Manufacturing, Short Cycle Times

Cost of Ownership: Very Light Weight, Very High Damage Tolerance,
Easy Inspection & Repair, Very Long Service Life

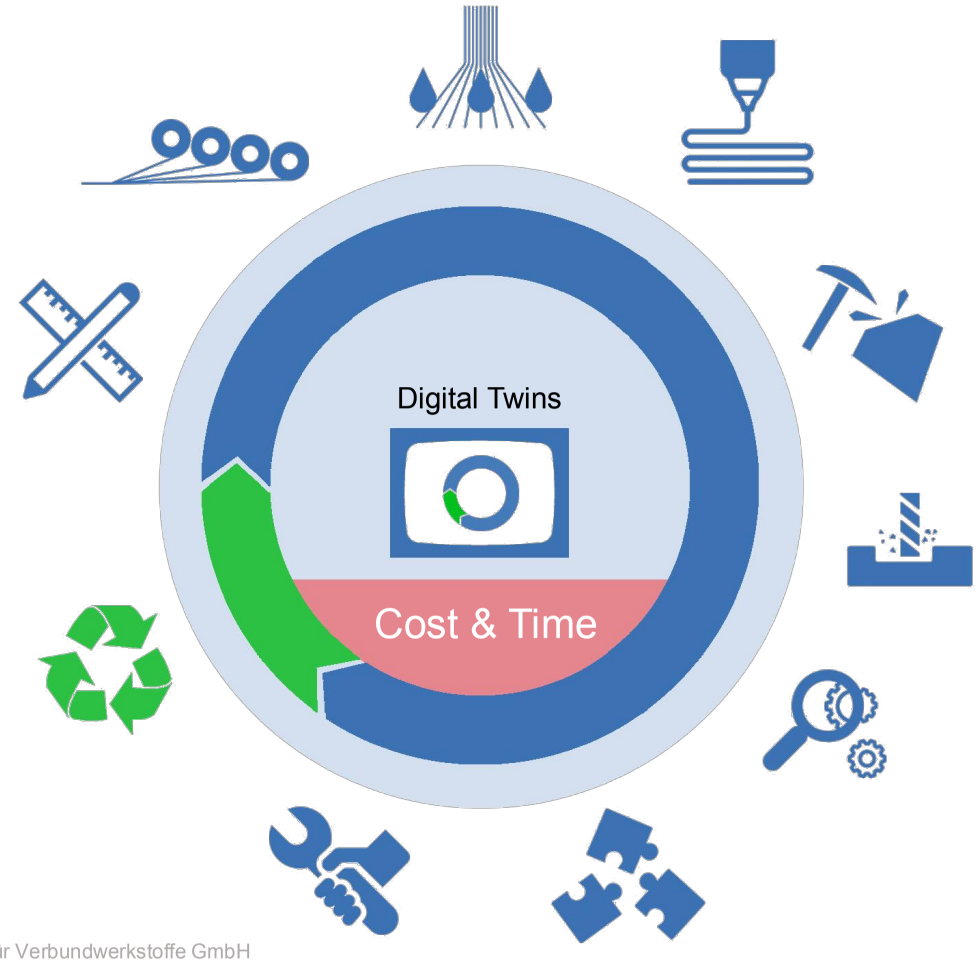


Environment: Zero Production Waste, Zero Production Emissions,
Full Recycling Capability (no downcycling)

www.thefutureiscomposite.com

R&D Principle I: Holistic Approach

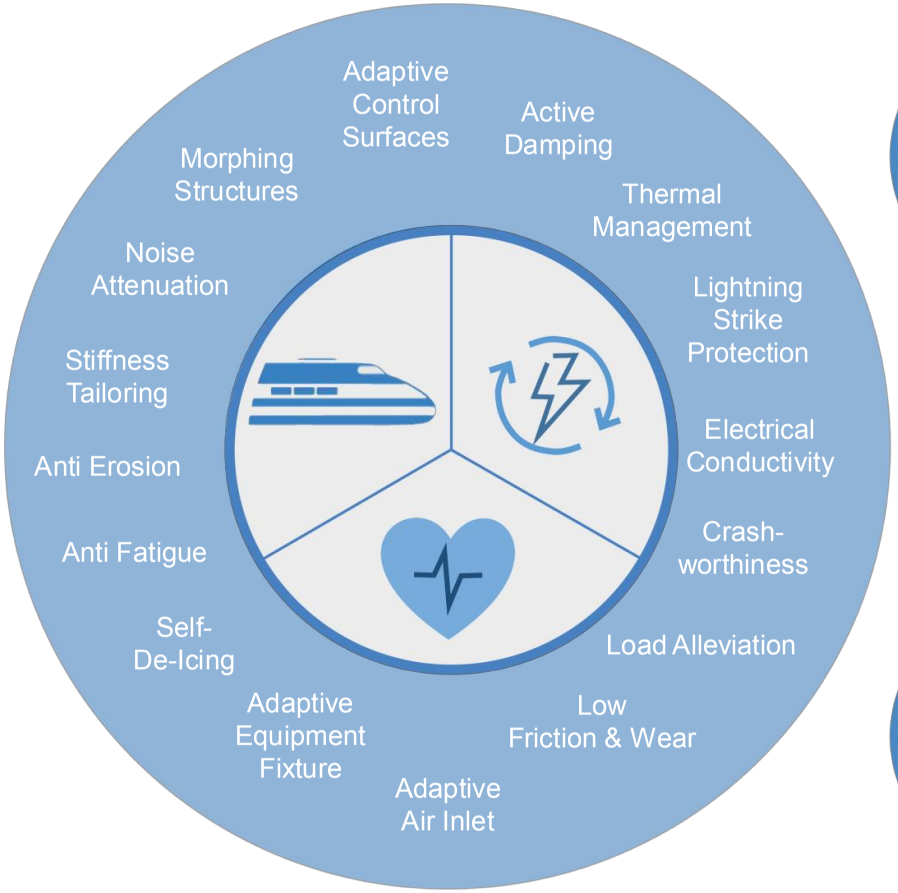
The Composite Process Chain – Tomorrow

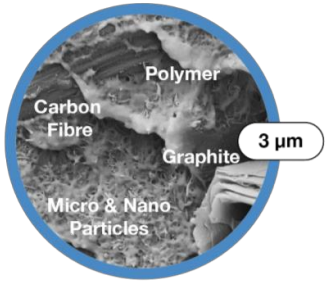


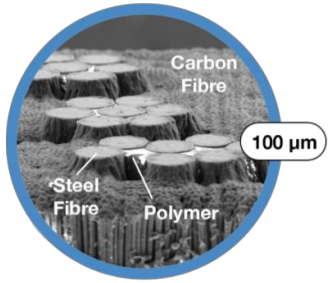
- ✓ Fully integrated and optimized process chain
- ✓ Process hybridization
- ✓ Digital twins
- ✓ Effort and cost minimization

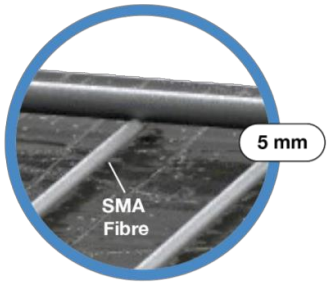
www.thefutureiscomposite.com

Tomorrow – Multifunctional Composites







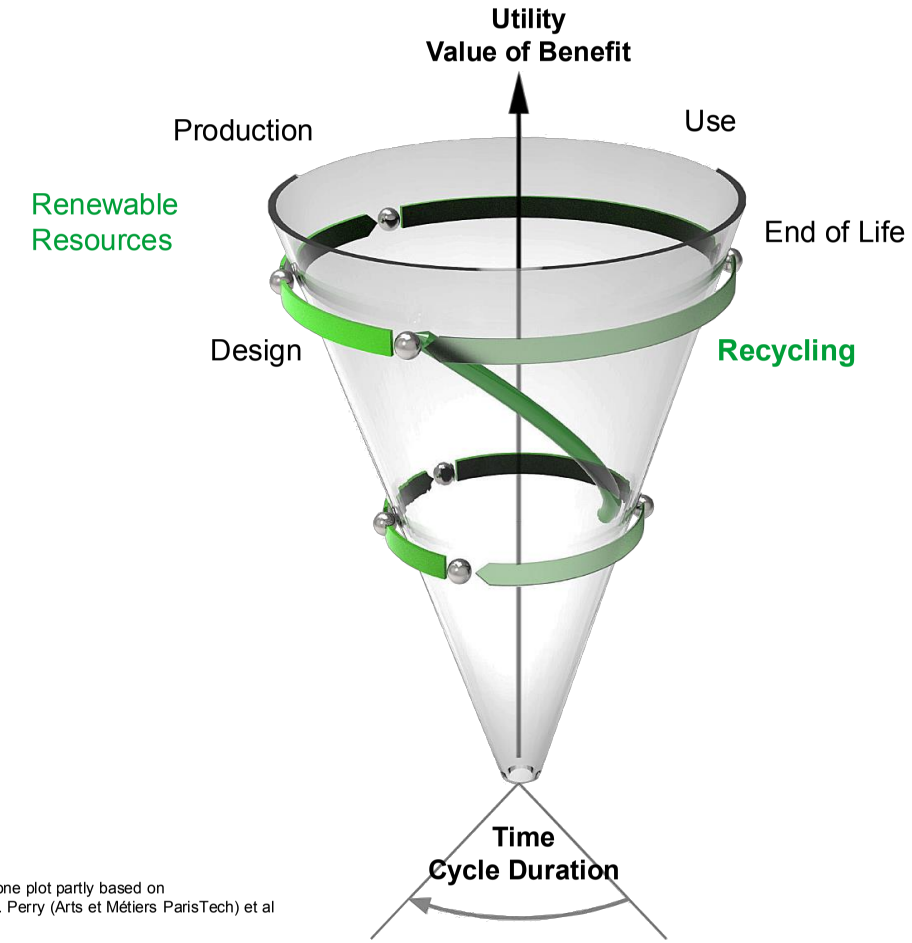


- ✓ Composites enable multifunctionality at (sub) micro- and meso-level
- ✓ Superior product functionality at lower cost

www.thefutureiscomposite.com

R&D Principle III: Sustainability

Tomorrow – Improved Utility and Recycling



cone plot partly based on
N. Perry (Arts et Métiers ParisTech) et al

- ✓ Higher lightweight efficiency increases value of benefit
- ✓ Life extension is possible by better fatigue properties
- ✓ Polymer *and* roving recycling, also for carbon fibers
- ✓ Raw materials from renewable resources

www.thefutureiscomposite.com

The Future…What Will it Look Like?

CityAirbus

Source: Airbus

Silent Air Taxi

Source: e.SAT, https://e-sat.de/de/silent-air-taxi/

Airlander

Source: https://www.hybridairvehicles.com/

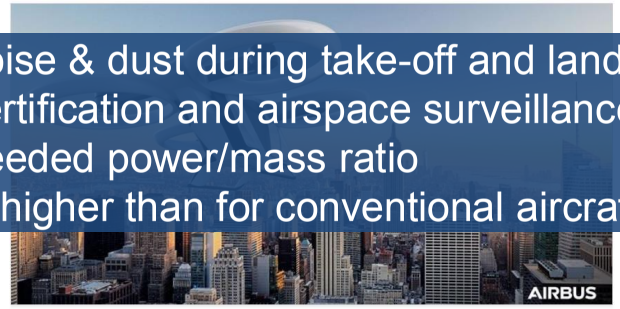
ZEROe

Source: Airbus

www.thefutureiscomposite.com

The Future…What Will it Look Like?

CityAirbus



- noise & dust during take-off and landing
- certification and airspace surveillance
- needed power/mass ratio
  is higher than for conventional aircraft

Source: Airbus

Silent Air Taxi

Source: e.SAT, https://e-sat.de/de/silent-air-taxi/

Airlander

Source: https://www.hybridairvehicles.com/

ZEROe

Source: Airbus

www.thefutureiscomposite.com

The Future…What Will it Look Like?

CityAirbus

Source: Airbus

Silent Air Taxi

Source: e.SAT, https://e-sat.de/de/silent-air-taxi/

Airlander

- 90 passengers, 130 km/h (max)
- range 350km (fully electric)
  750 km (hybrid-electric)
  7400 km (empty)
- lift with helium
- no airports needed
- large volume and lift available for hydrogen storage (and fuel cell)
- EIS planned for 2026
- initially with combustion engines, later substitution with hydrogen

ZEROe

Source: Airbus

www.thefutureiscomposite.com

The Future…What Will it Look Like?

CityAirbus

Source: Airbus

Airlander

Source: https://www.hybridairvehicles.com/

Silent Air Taxi

- 4 passengers
- 300 km/h
- 1,000 km range
- low cost transportation (as 1st class train ticket)
- very short take off and landing distance
- very low noise emmission
- hybrid propulsion (e-boost for take off)
- first flight 2024, EIS 2025
- later hydrogen propulsion possible

Source: Airbus

www.thefutureiscomposite.com

The Future…What Will it Look Like?

CityAirbus

Source: Airbus

Silent Air Taxi

Source: e.SAT, https://e-sat.de/de/silent-air-taxi/

Airlander

Source: https://www.hybridairvehicles.com/

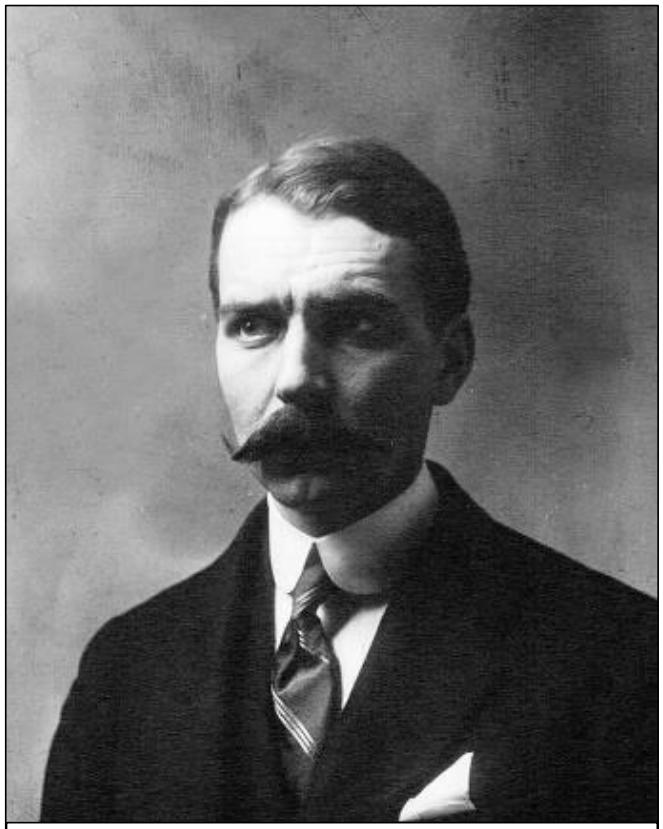
ZEROe

Source: Airbus

- really zero e?
- configuration?
- space requirement for LH2 storage
- system installation weight
- drag

www.thefutureiscomposite.com

The Value of Low Weight



Louis Charles Breguet
1880-1955
[Image Source: Wikipedia]

$$R = \frac{v}{b_F \cdot g} \cdot \frac{c_L}{c_D} \cdot \ln \frac{m_0}{(m_0 - m_t)}$$

R	range [m]
v	velocity (True Air Speed) [m/s]
b_F	specific fuel burn [kg/N·s]
g	acceleration of earth [m/s²]
c_L	coefficient of lift [1]
c_D	coefficient of drag [1]
m_0	initial mass of the aircraft [kg]
m_t	mass of the fuel burnt [kg]

(1) Less aircraft mass can be directly transferred into more range, more payload and less energy consumption for lift generation and for overcoming drag!*

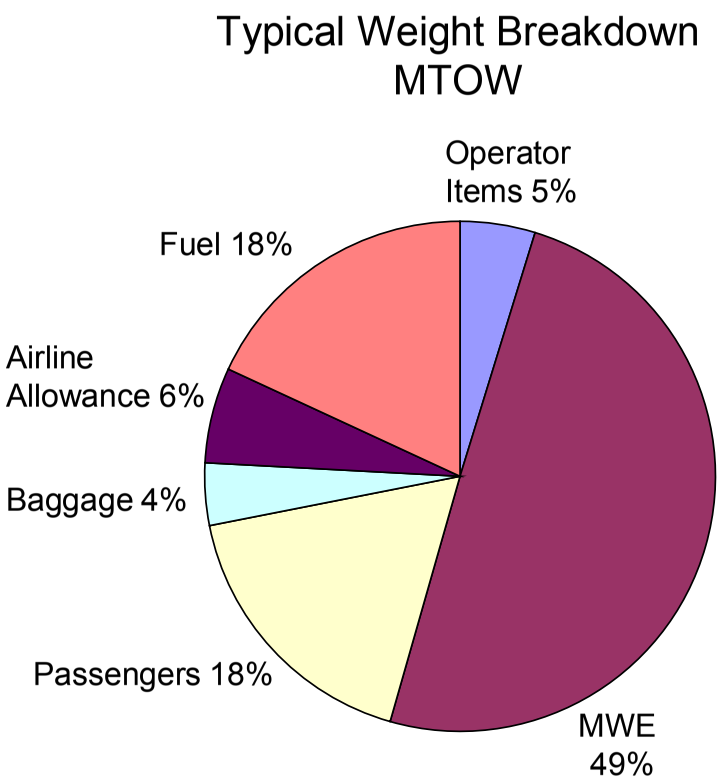
(2) The exchange rate (value of light weight) will increase since SAF (and hydrogen) are more expensive than kerosene!

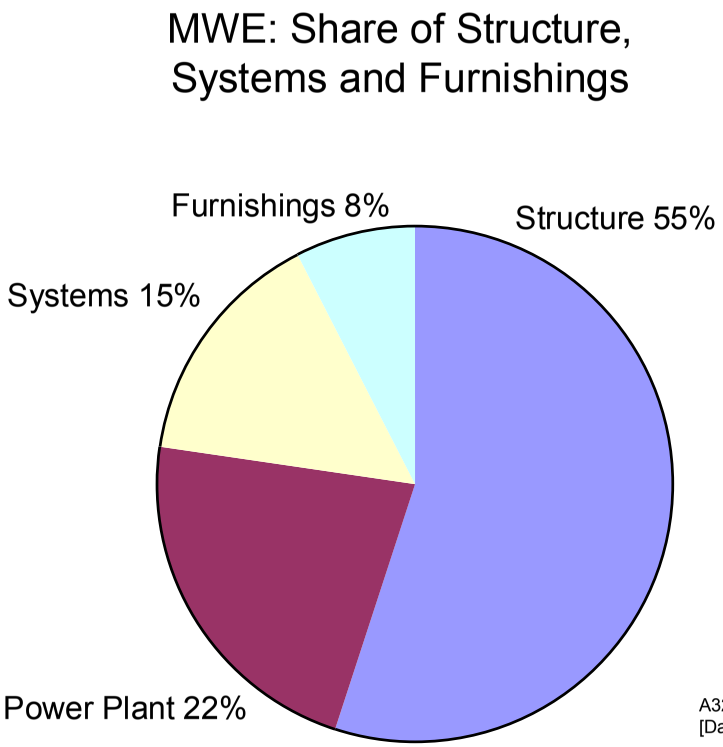
SAF = Sustainable Aviation Fuel

*U.P. Breuer, Commercial Aircraft Composite Technology, Springer International Publishing Switzerland, 2016

www.thefutureiscomposite.com

Aircraft Mass – Where is the Beef?



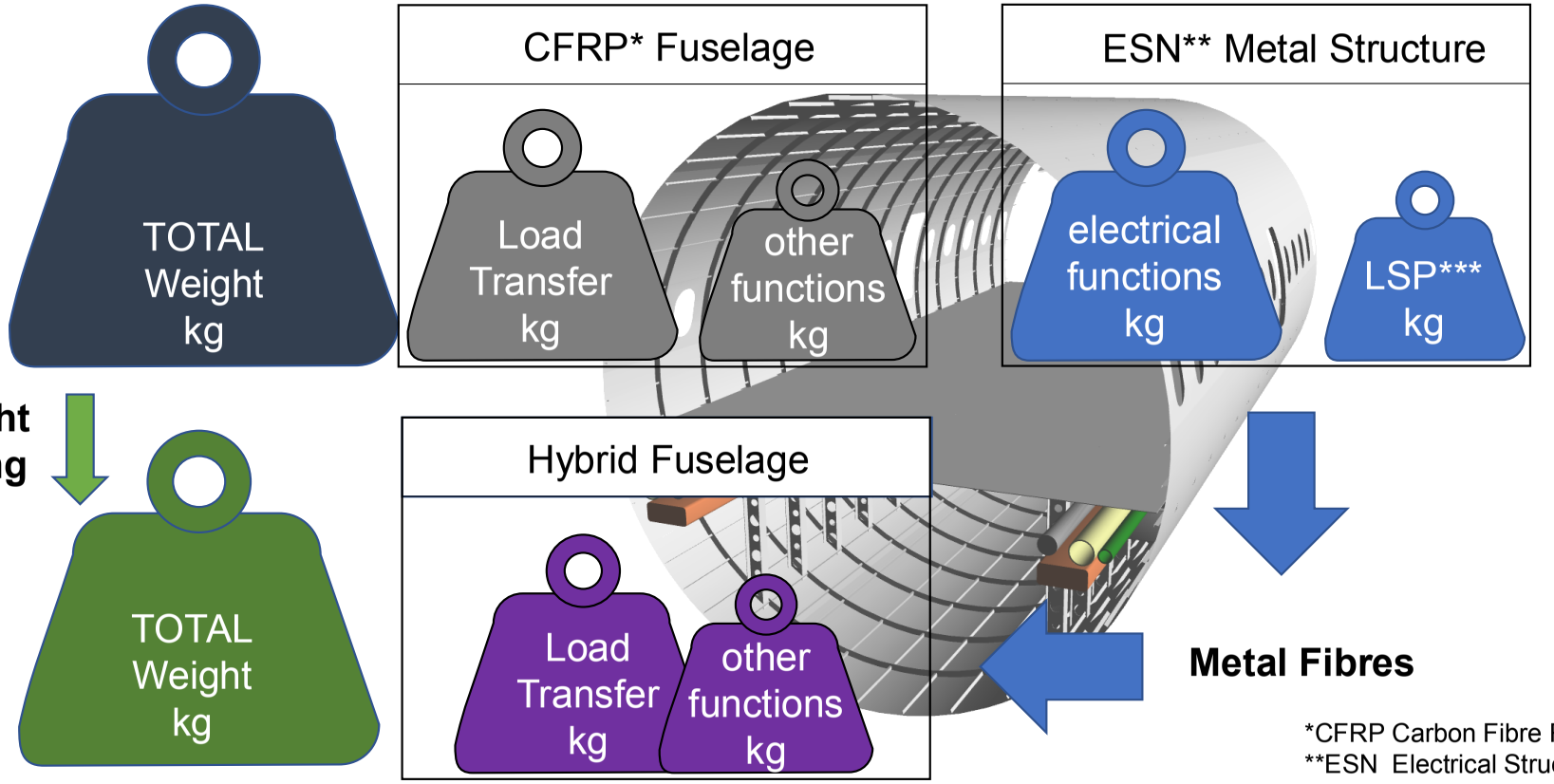


A320-type Aircraft
[Data Source: Jane's All the World's Aircraft]

Structure is the largest contributor to MTOW and MWE, followed by Power Plant & Systems

www.thefutureiscomposite.com

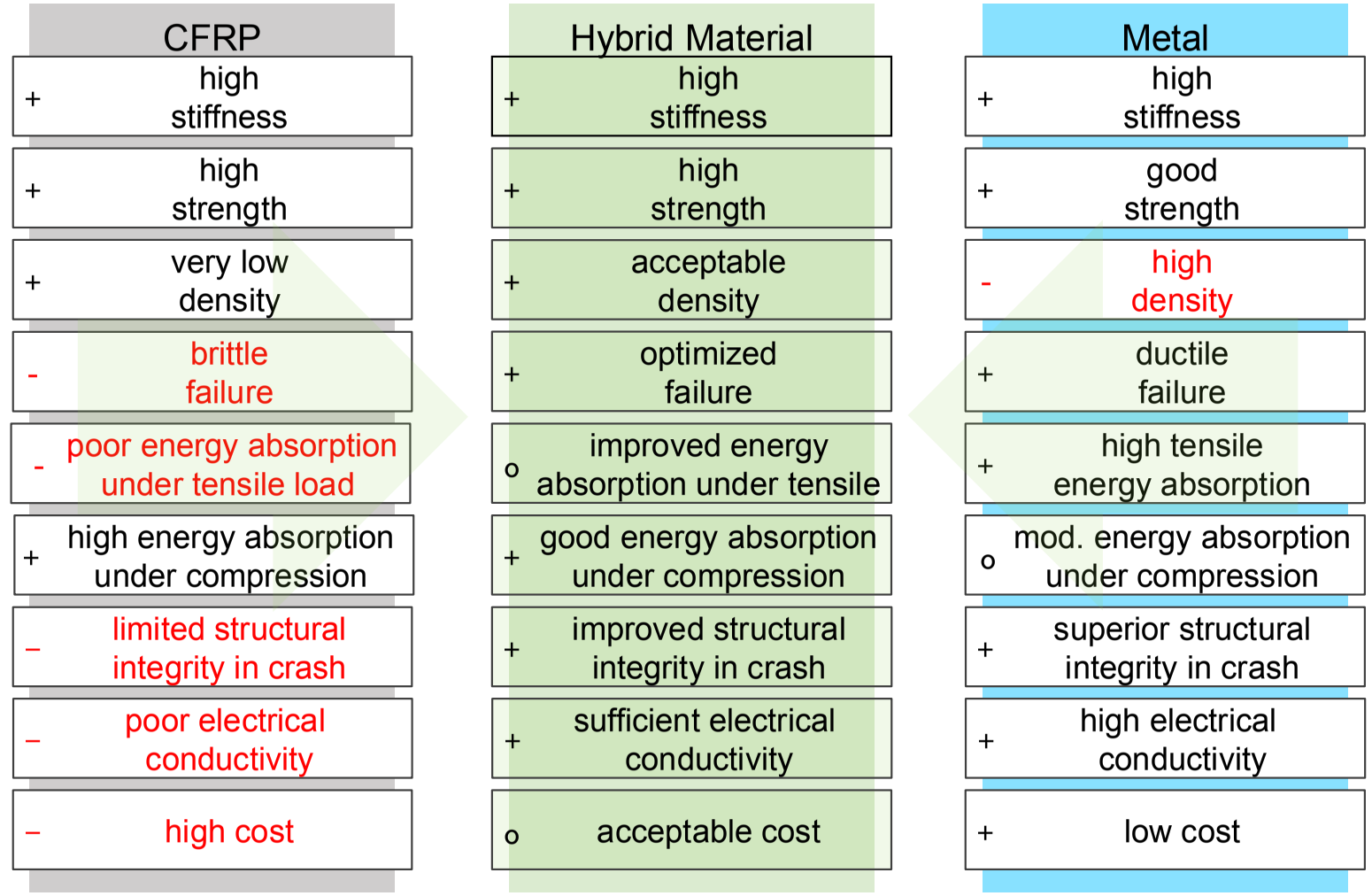
Basic Idea



*CFRP Carbon Fibre Reinforced Plastic
**ESN Electrical Structure Network
***LSP Lightning Strike Protection

www.thefutureiscomposite.com

Combination of Carbon- and Metal fibres



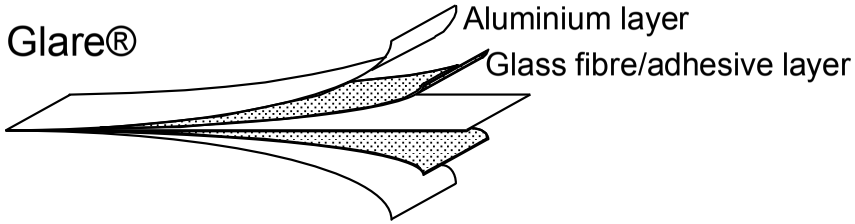
www.thefutureiscomposite.com

Metal *fibres* - but not metal *sheet* layers!

Airbus

Image: By Ward Snoeck - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=79499190

Image: Zoltek

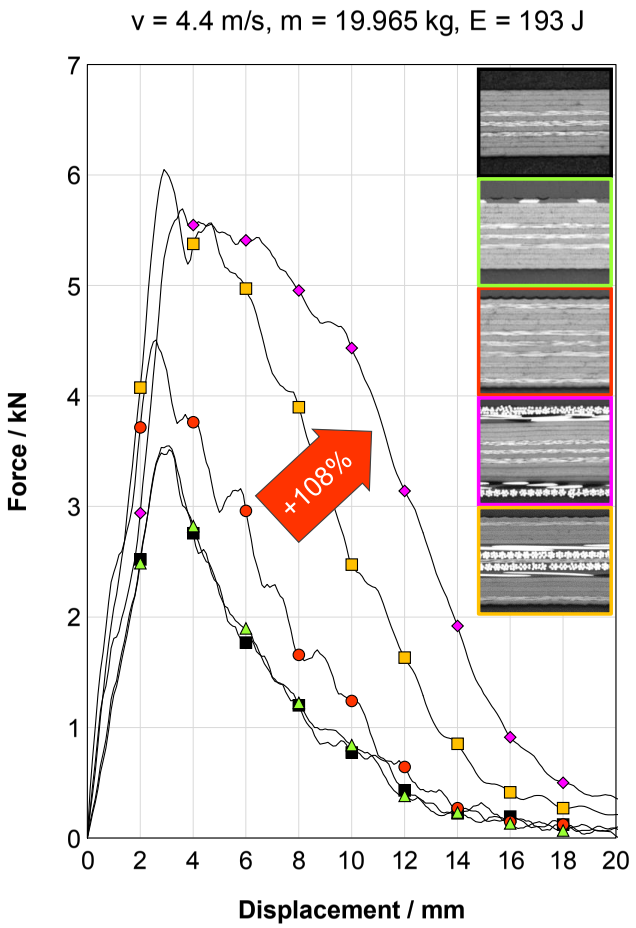


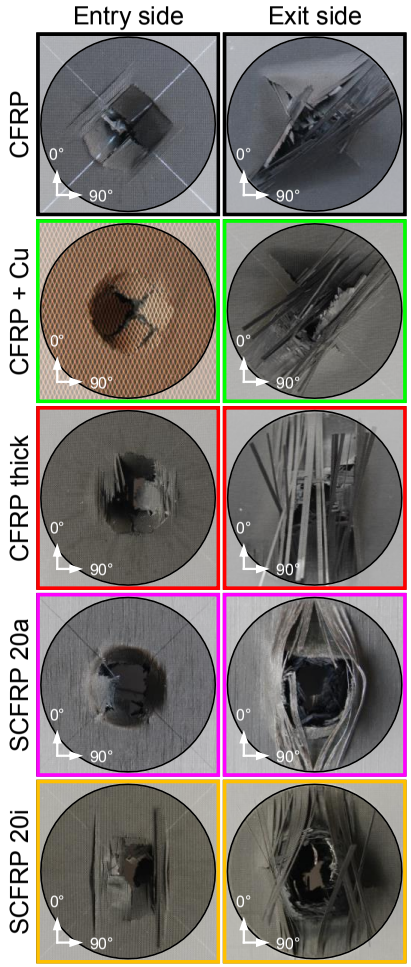
Difficult automated manufacturing!

Fully automated manufacturing and utilization of anisiotropy!

www.thefutureiscomposite.com

Penetration Resistance Tests





Substitution of carbon fibre layers by steel fibre layers leads to significant improvement of penetration properties!

impactor diameter = 20 mm

free diameter of clamped sample = 40 mm

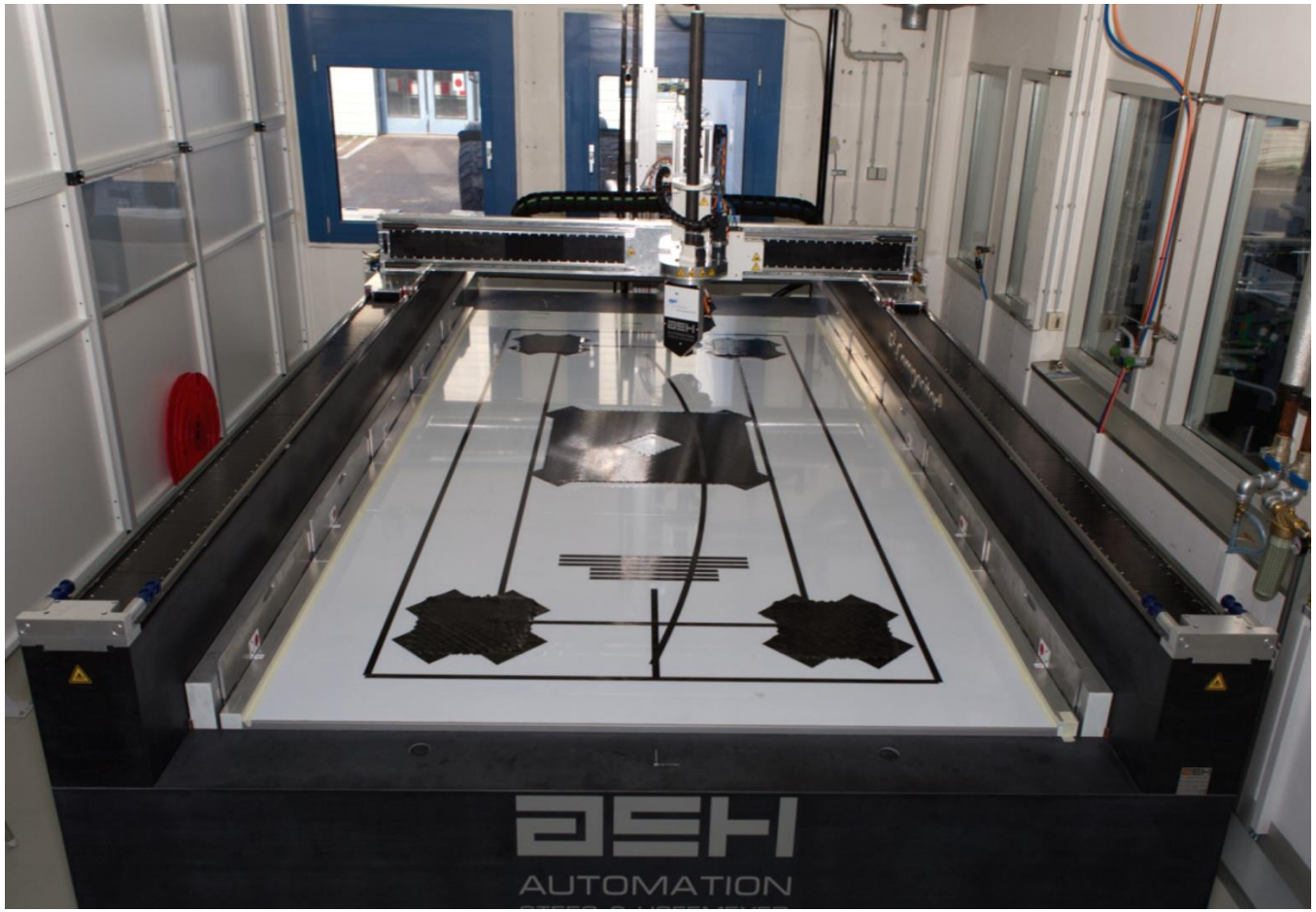
www.thefutureiscomposite.com

Hybrid Ice Protection on Advanced Natural Laminar Slat

- LuFo 6-3
- 8/23-10/26
- Development of hybrid steel- and carbon fibre reinforced **thermoplastic** polymer (PEEK) slat structures
- Advanced energy absorption during bird impact
- Tape laying and stamp forming manufacturing technology
- Induction welding joining technology

www.thefutureiscomposite.com

Rapid Thermoplastic Tape Laying



ASH Automation F2-Compositor®

- Area 3500 mm x 1500 mm
- CF/ PPS, PEEK, PEKK etc.
- Tape Width ¼" to 2"
- Tape Thickness 0,05 to 0,5 mm
- Speed up to 4 m/s (240 m/min)
- Ultra high precision placement & cutting
- Straight and curved placement

www.thefutureiscomposite.com

Stamp- (Press-) Forming & Overmoulding

Langzauner Perfect Press

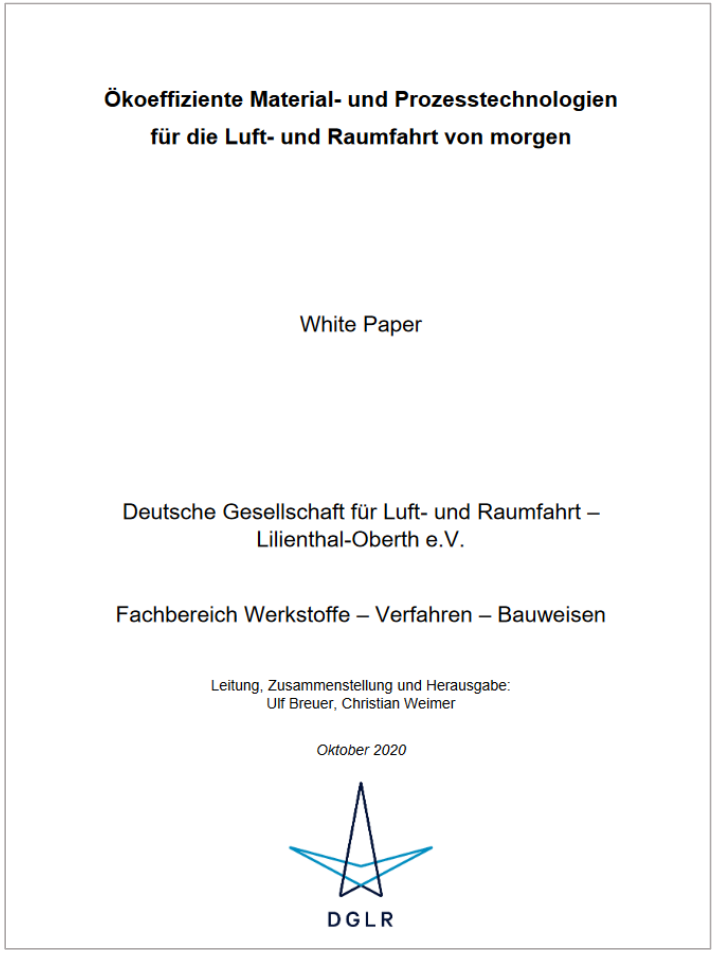
- 25.000 kN Force
- 3 x 2 m^2 Tool size
- 800 mm/s Closing speed
- Pressure in < 1 s
- up to 450 °C Infrared oven
- Combined injection moulding possible

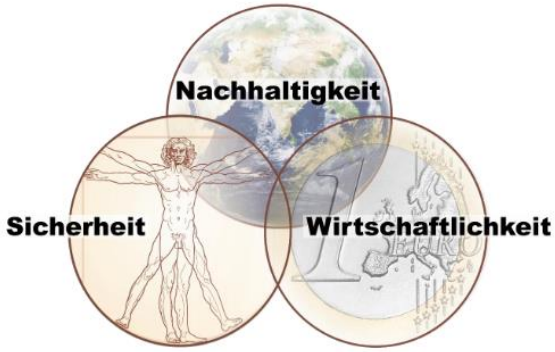
www.thefutureiscomposite.com

Conclusion

- Whatever new aircraft will look like –
  CFRP will enable low mass, max payload and range at low fuel consumption
- The exchange rate (value of light weight design) will increase
  since SAF (and / or hydrogen) are more expensive than kerosene
- The „beef“ of the mass of the aircraft is within the load carrying structure
- New airframe materials & processes must enable a long service life design, superior damage tolerance, easy repair and economic recycling solutions
- Thermoplastic composites enable short cycle time manufacturing and welding
- Function integration can improve weight savings on aircraft level

White Paper





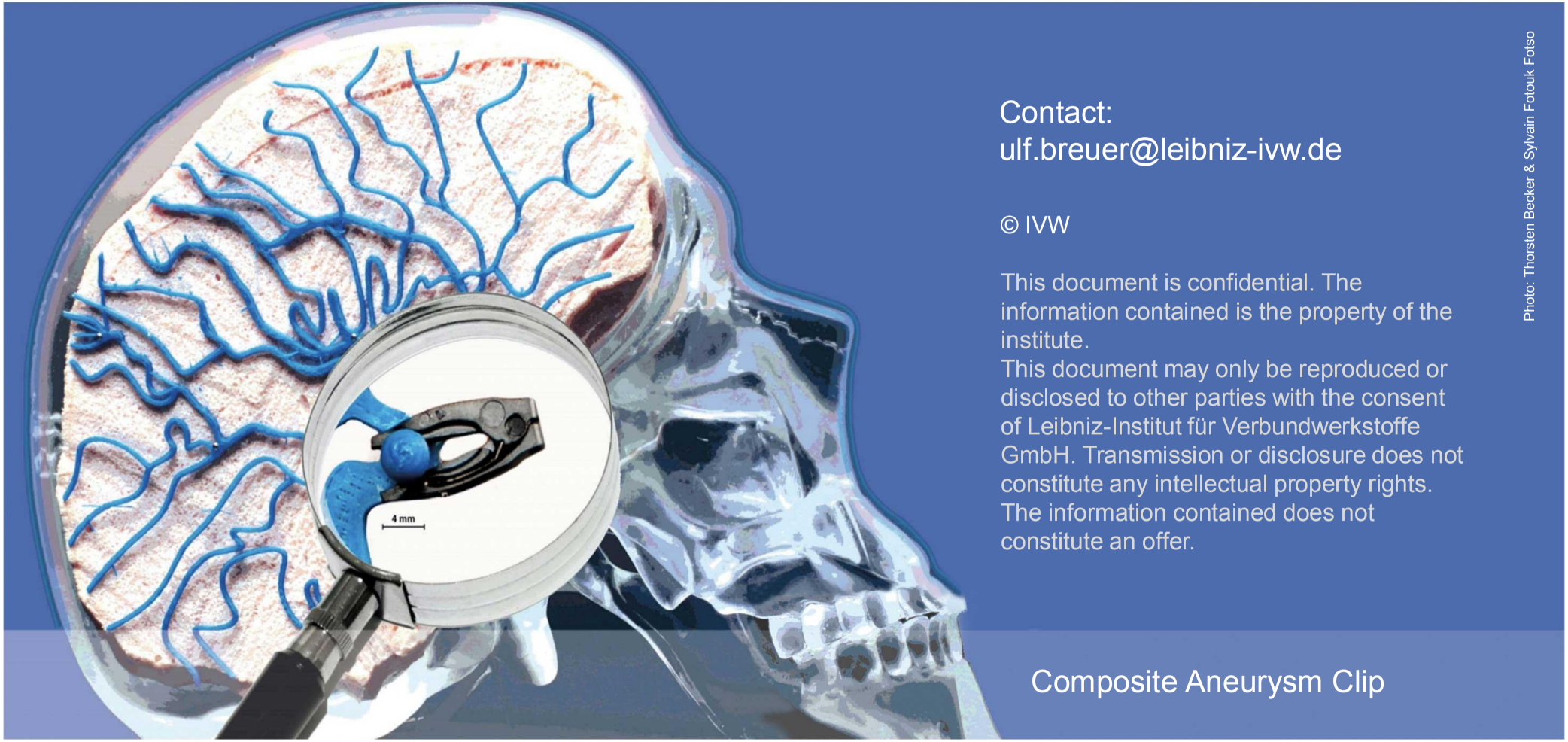
Arbeitsgruppe aus Industriebetrieben
entlang der Wertschöpfungskette
und Forschungseinrichtungen

- Herausforderungen
- Notwendige Befähigungen und Schlüsseltechnologien
- Handlungsempfehlungen

https://www.dglr.de/fileadmin/daten-dglr/vernetzen/fachbereiche/q1/White_Paper_Oekoeffiziente_Material_und_Prozesstechnologien.pdf

www.thefutureiscomposite.com

Thank you for your attention!



Contact:
ulf.breuer@leibniz-ivw.de

Photo: Thorsten Becker & Sylvain Fotouk Fotso

Composite Aneurysm Clip

www.thefutureiscomposite.com