

# Extend Your Expectations

NDT for Aviation composites  
Jakov Šekelja

Pilot. Passion. Partnership.



Consider everything.  
Implement the best.  
Only the sky is the limit.

# What sets us apart

**PILOT.**

We find and offer the best solution

**PASSION.**

We are driven by passion

**PARTNERSHIP.**

We are a reliable partner

For over 30 years, FACC has developed and manufactured composite components.  
Today, FACC is a leading system integrator and Tier 1 supplier to the global aviation industry.







# FACC activities are focused

on a defined product portfolio from the product idea to customer tailored solutions



**AEROSTRUCTURES**



**ENGINES & NACELLES**



**INTERIORS**

FACC is a Tier 1 partner with a wide range of services: R&D, Engineering, Manufacturing up to Business Solutions.

# facc on Board

Aerostructures broad market coverage and long-term supply

## Commercial Aircrafts

A318/319/320/321



A330/340



A350XWB



A380



C-Series



Boeing 737



Boeing 747



Boeing 757



Boeing 767



Boeing 777



Boeing 787



SSJ100



MS-21



Comac C919

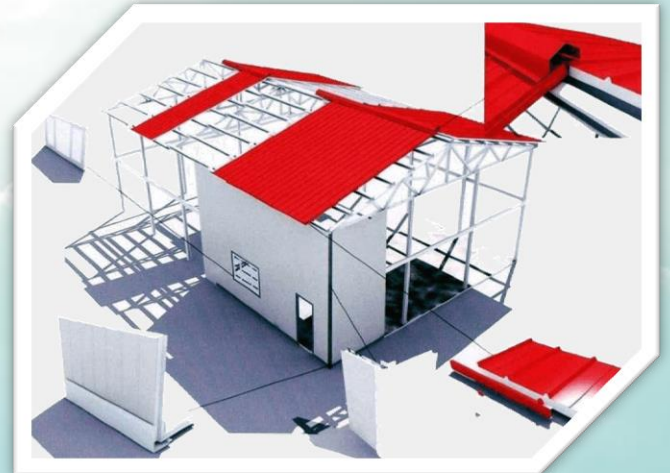
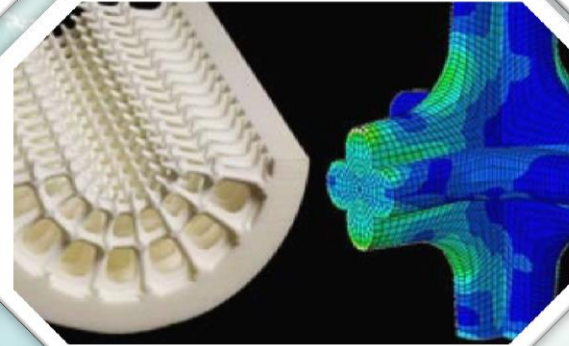


E190/195 E2



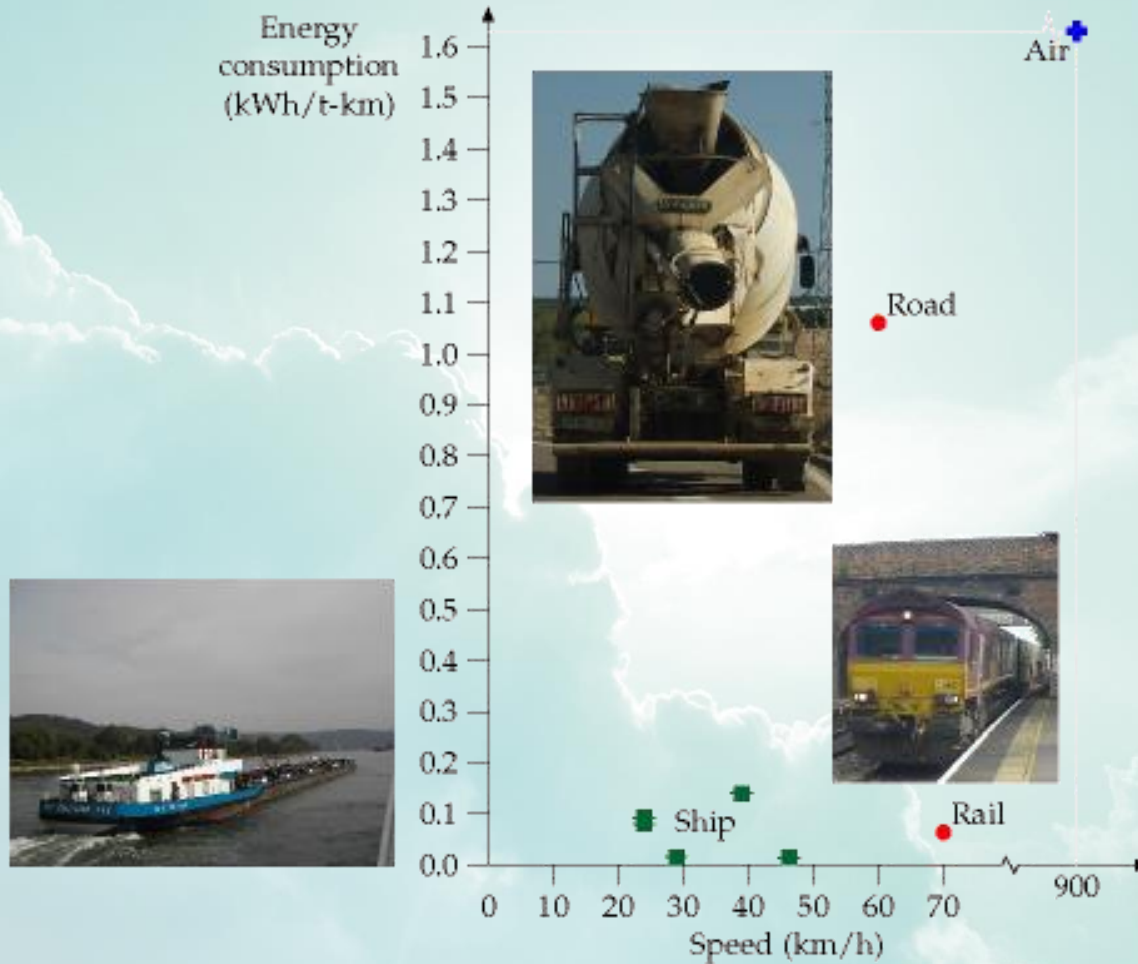
Pilot. Passion. Partnership.

# Lightweight design





# Lightweight design in transport



Source: [http://withouthotair.com/c15/page\\_92.shtml](http://withouthotair.com/c15/page_92.shtml)

Dank an Glatz Florian für den Quellen Hinweis.

# Lightweight design in aviation

Wert	Variable	Quelle
<b>0,0000171</b>	Spezifischer Kraftstoffverbrauch [kg/N/s]	<a href="http://en.wikipedia.org/wiki/Thrust_specific_fuel_consumption#Typical_values_of_SFC_for_thrust_engines">http://en.wikipedia.org/wiki/Thrust_specific_fuel_consumption#Typical_values_of_SFC_for_thrust_engines</a> CF6-80C2B1F turbofan
<b>9,81</b>	Gewichtskraft von 1kg [N]	
<b>17</b>	Lift-drag-ratio	<a href="http://www.sierrafoot.org/mather/fact_checks/lift_to_drag_ratios.html">http://www.sierrafoot.org/mather/fact_checks/lift_to_drag_ratios.html</a> A320
<b>7</b>	Flugzeit pro Tag [h/d]	<a href="http://www.airliners.net/aviation-forums/general_aviation/read.main/492074/">http://www.airliners.net/aviation-forums/general_aviation/read.main/492074/</a> geschätzt
<b>0,804</b>	Dichte JET A-1 [kg/l]	<a href="http://en.wikipedia.org/wiki/Jet_fuel#Typical_physical_properties_for_Jet_A_and_Jet_A-1">http://en.wikipedia.org/wiki/Jet_fuel#Typical_physical_properties_for_Jet_A_and_Jet_A-1</a>
<b>0,5846</b>	Preis JET A-1 [€/l]	<a href="http://www.iata.org/publications/economics/fuel-monitor/Pages/price-development.aspx">http://www.iata.org/publications/economics/fuel-monitor/Pages/price-development.aspx</a>
<b>Formel zur Berechnung: Spezifischer Kraftstoffverbrauch * Gewichtskraft * Lift-drag-ratio * Flugzeit pro Tag * (365 d/a * 3600 s/h) / Dichte JET A1 * Preis JET A-1</b>		
<b>= 66</b>	Kosten pro kg pro Jahr [€/kg/a]	

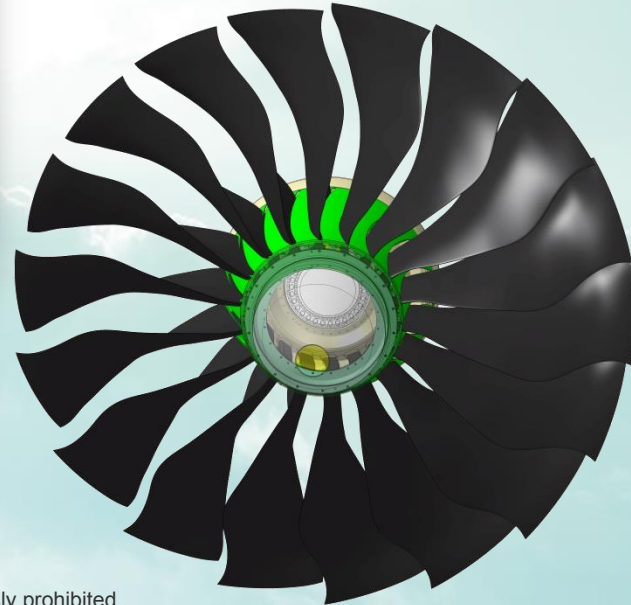
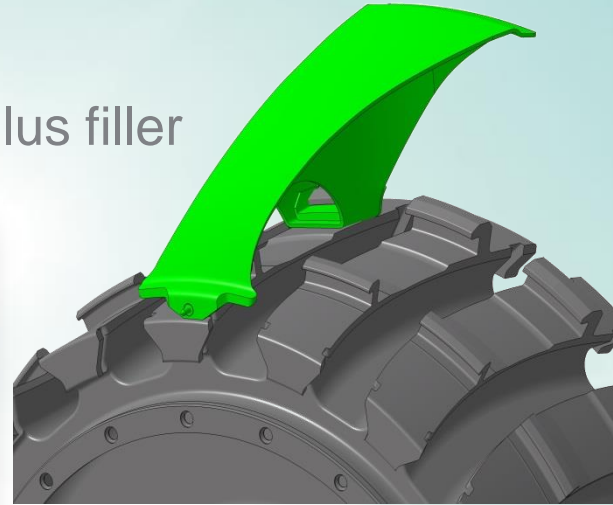
Source: Formel - Technologie des Flugzeuges, Engmann Klaus  
 Dank an Romed Ladstätter für die Beschaffung der Daten



# Substitution of Material

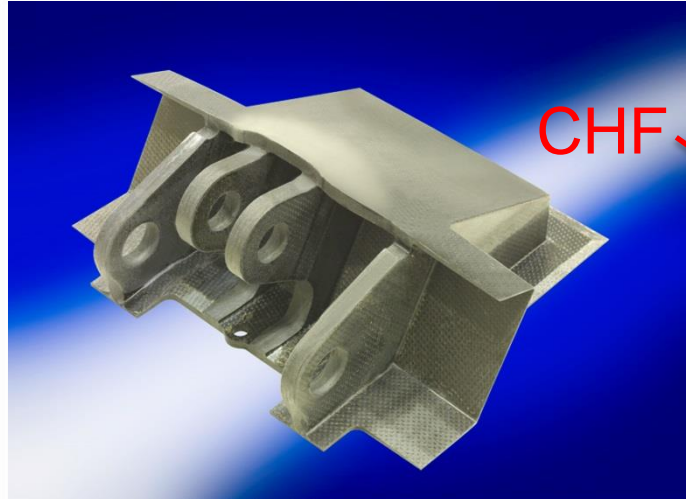
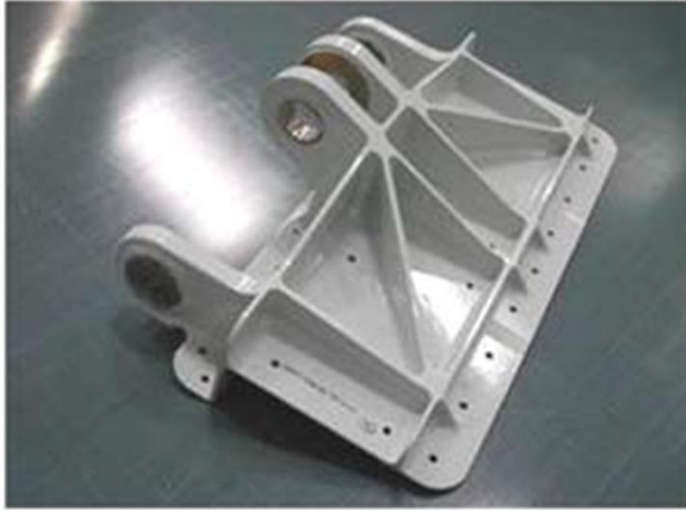
Projekt: ORCA

Optimized large scale engine CFRP annulus filler



Source: FACC Operations GmbH

# A330 – Spoiler Metal to CFRP



Source: HIGH-PERFORMANCE Composites July 2006 (FACC Operations GmbH)

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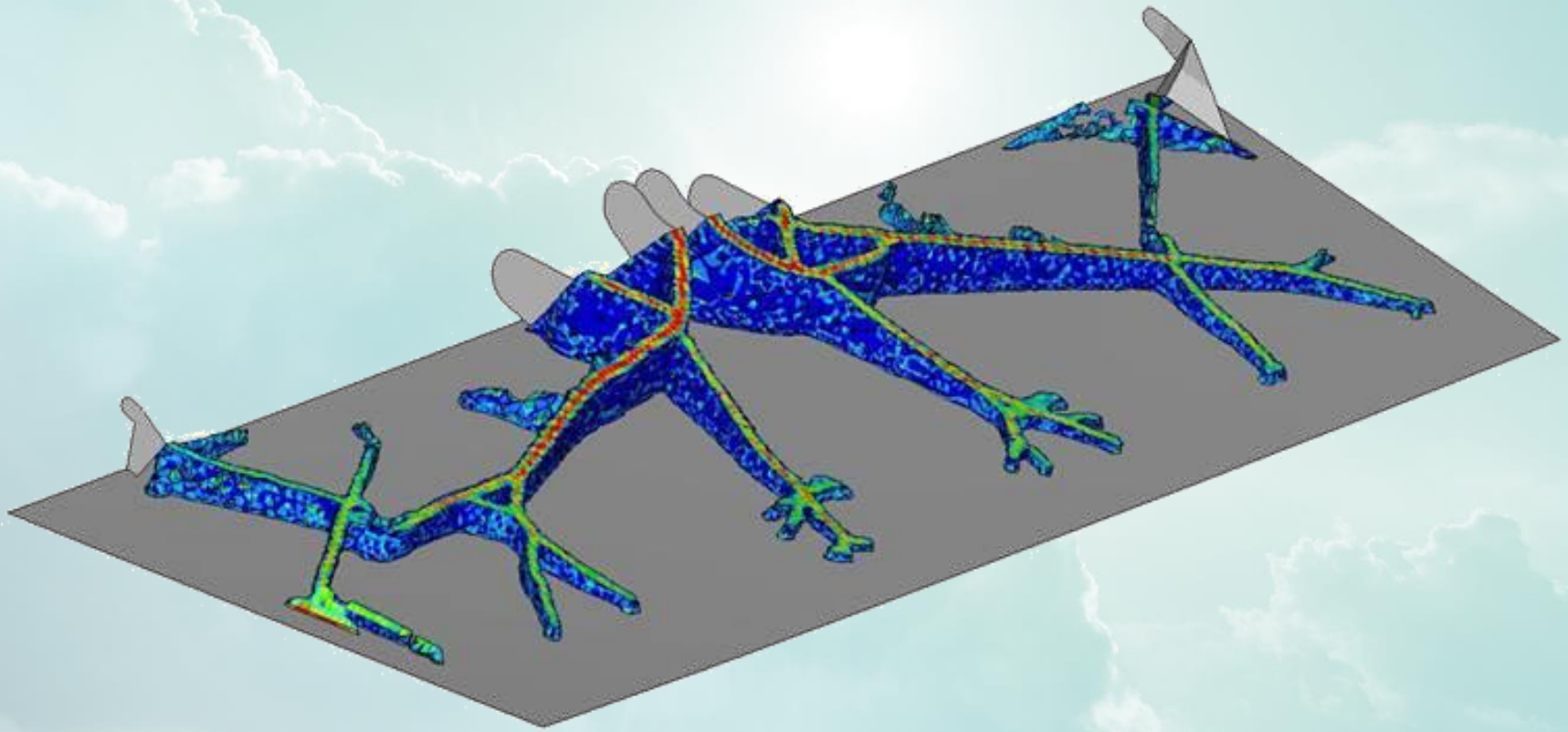
facc

# Coreless Spoiler

IKL Institut für Konstruktiven  
Leichtbau

Project:  DAEDALUS

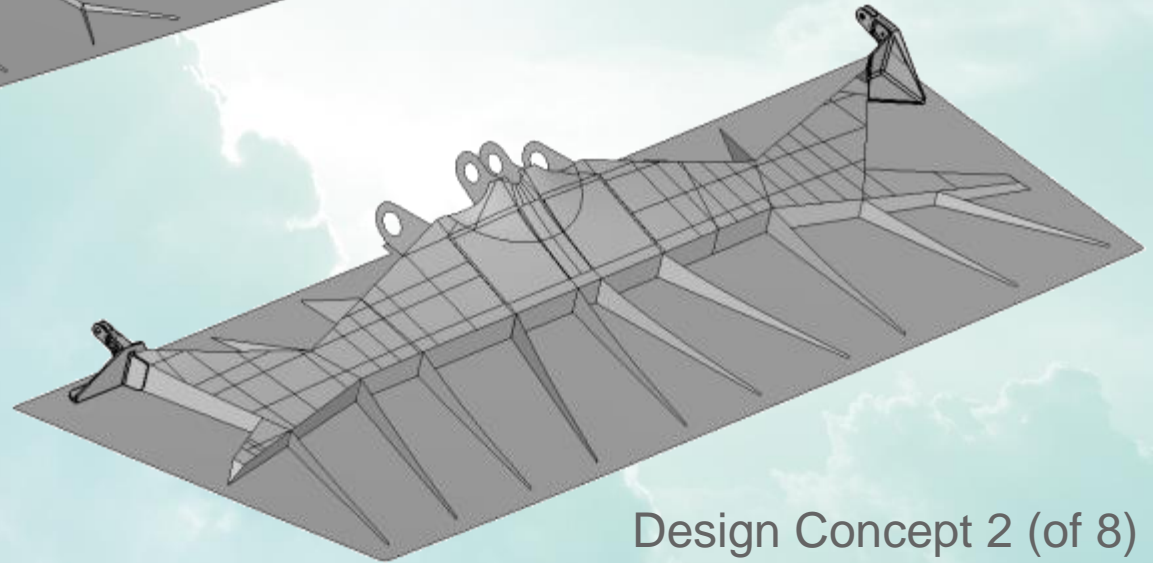
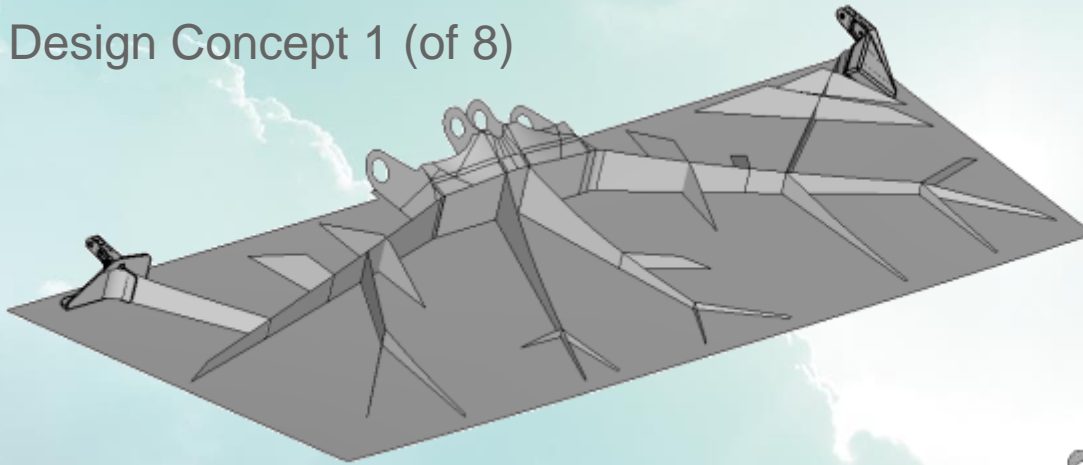
Development of a Composite Aerodynamic Control Surface Structure



Source: FACC Operations GmbH

# Coreless Spoiler

Design Concept 1 (of 8)



Design Concept 2 (of 8)

Source: FACC Operations GmbH

# Lightweight design in aviation

## Use of composites is growing...

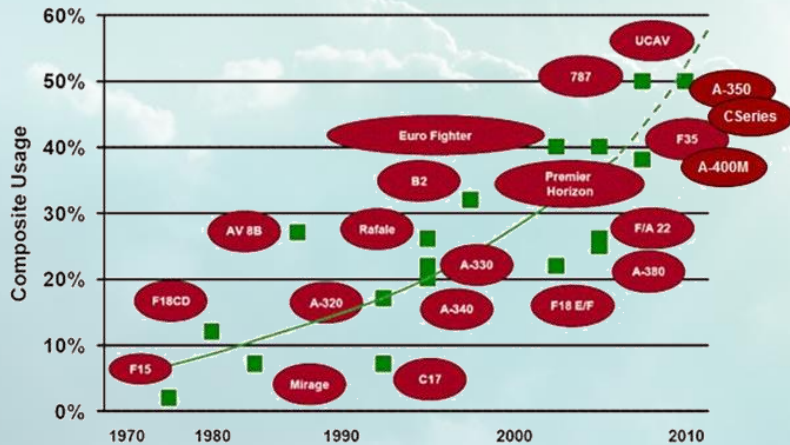
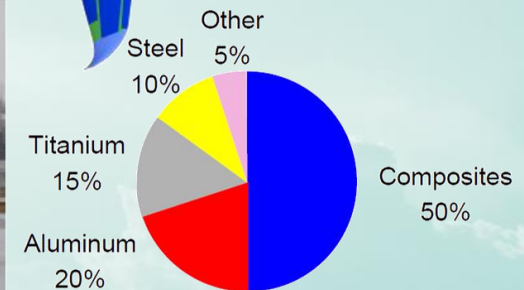
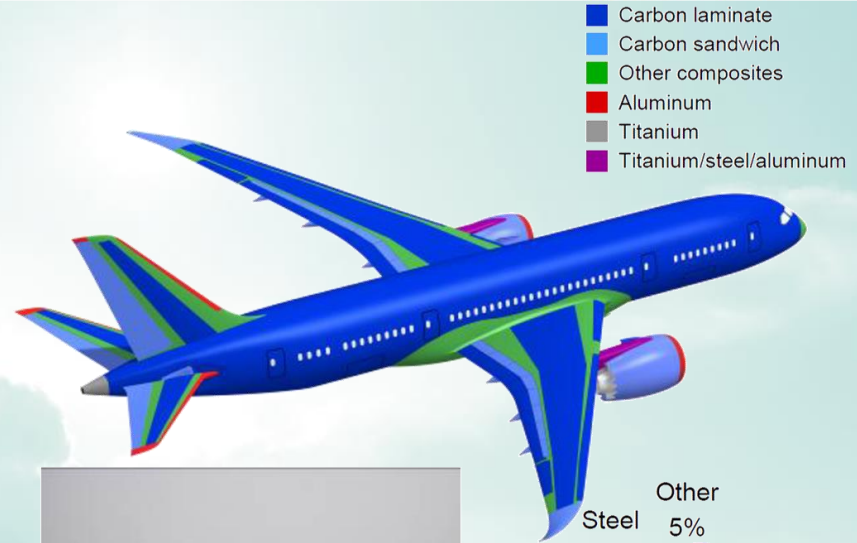


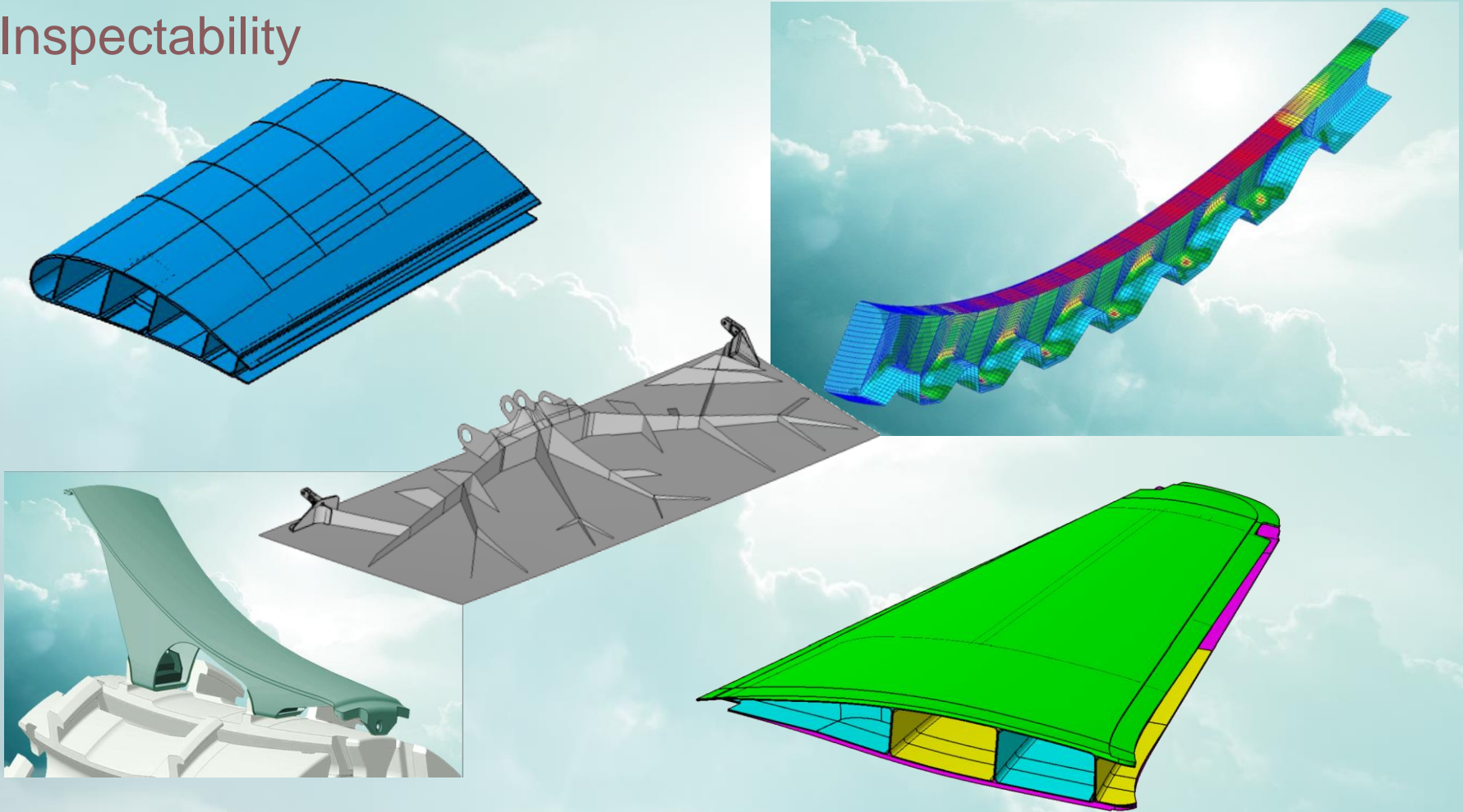
Chart aus einer Präsentation von Hrn. Carmelo Lo Faro, CEM Inc., beim von FACC im Mai 2006 in Salzburg veranstalteten Technischen Colloquium



Source: Boeing

# Challenges

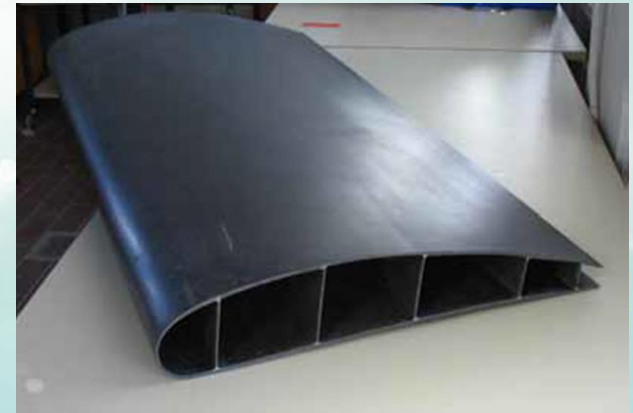
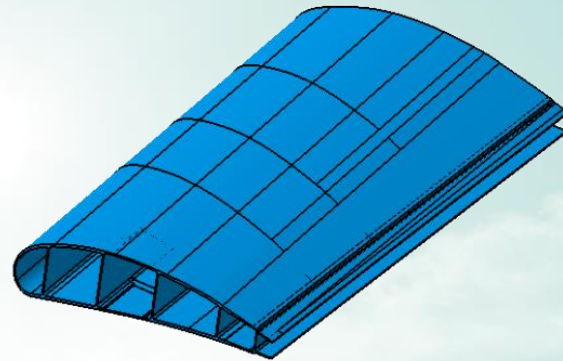
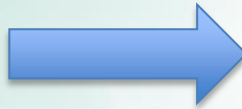
## Inspectability



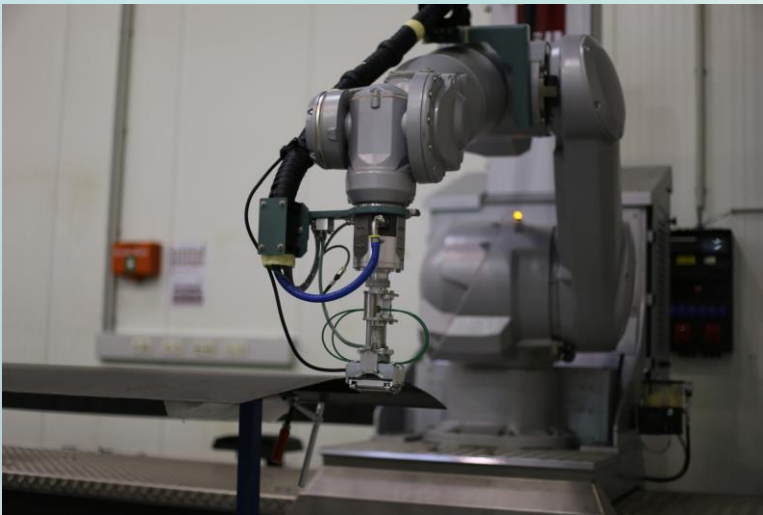


# Challenges

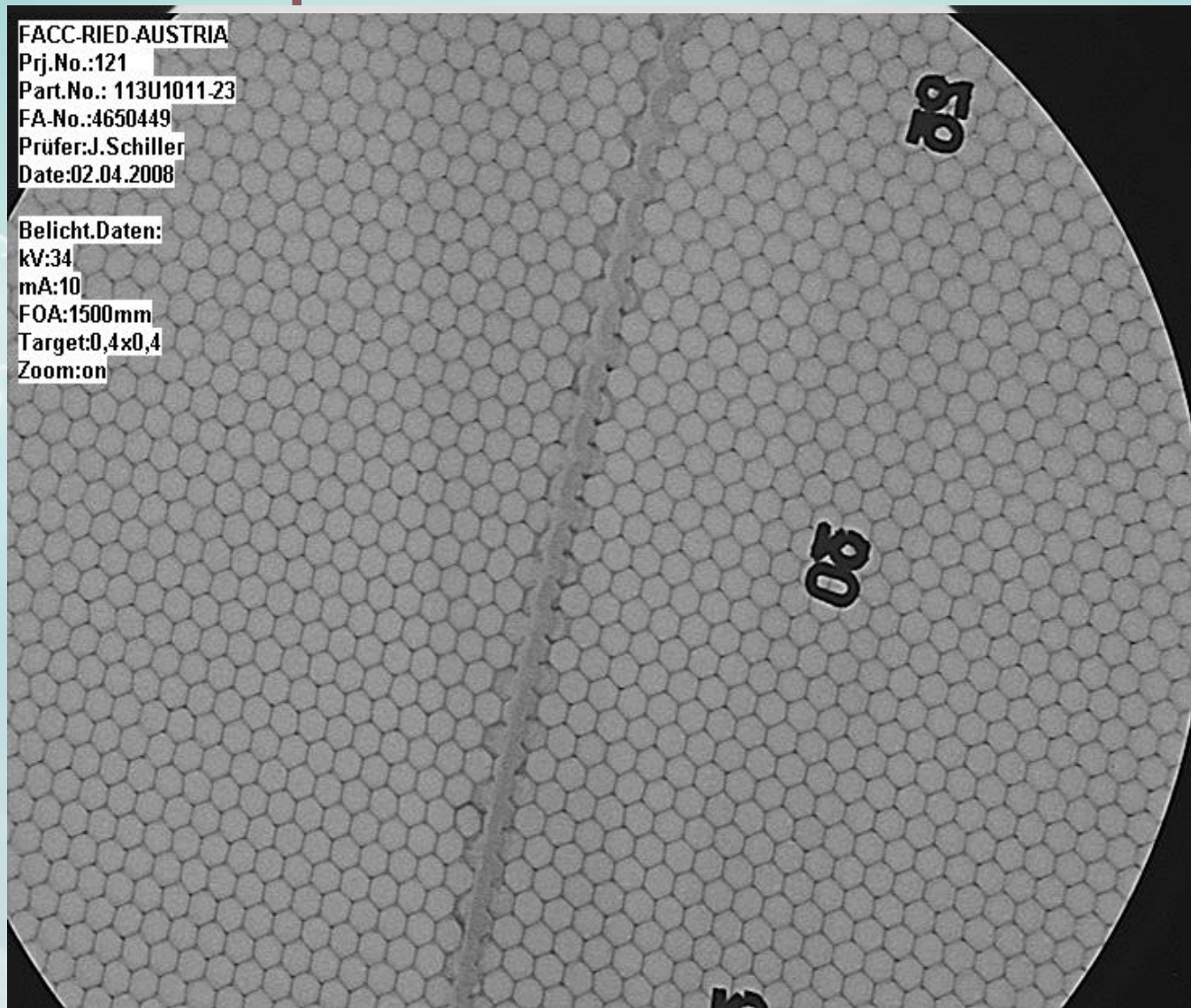
## Inspectability



# Current inspection methods

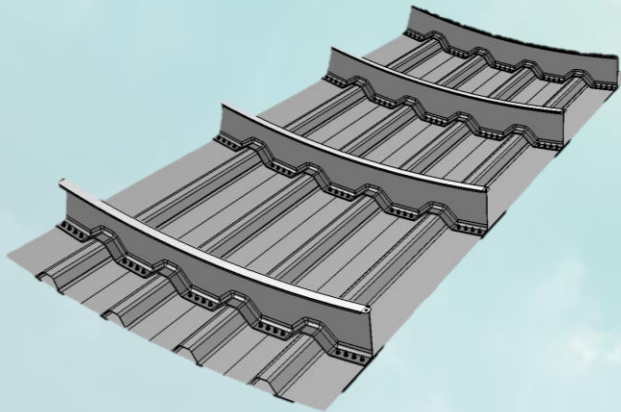


# Current inspection methods



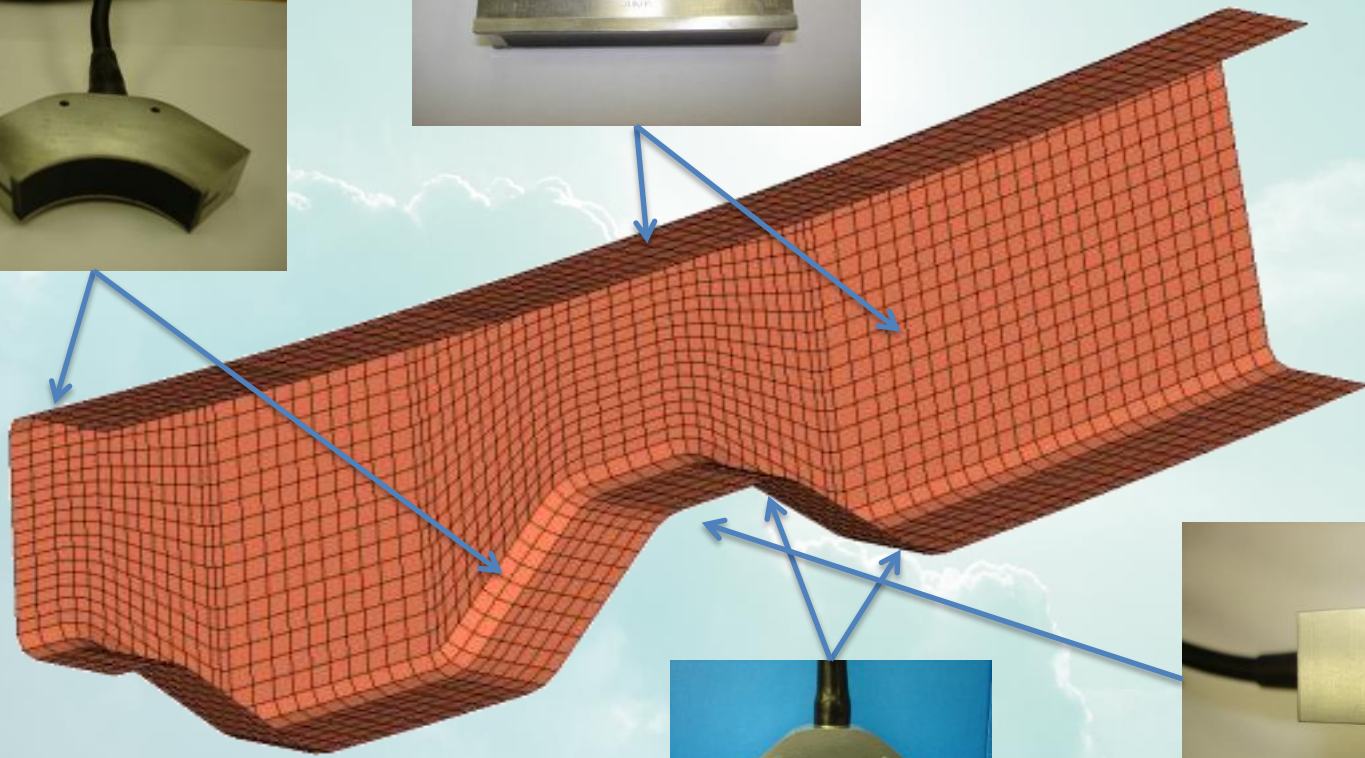
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# Challenges

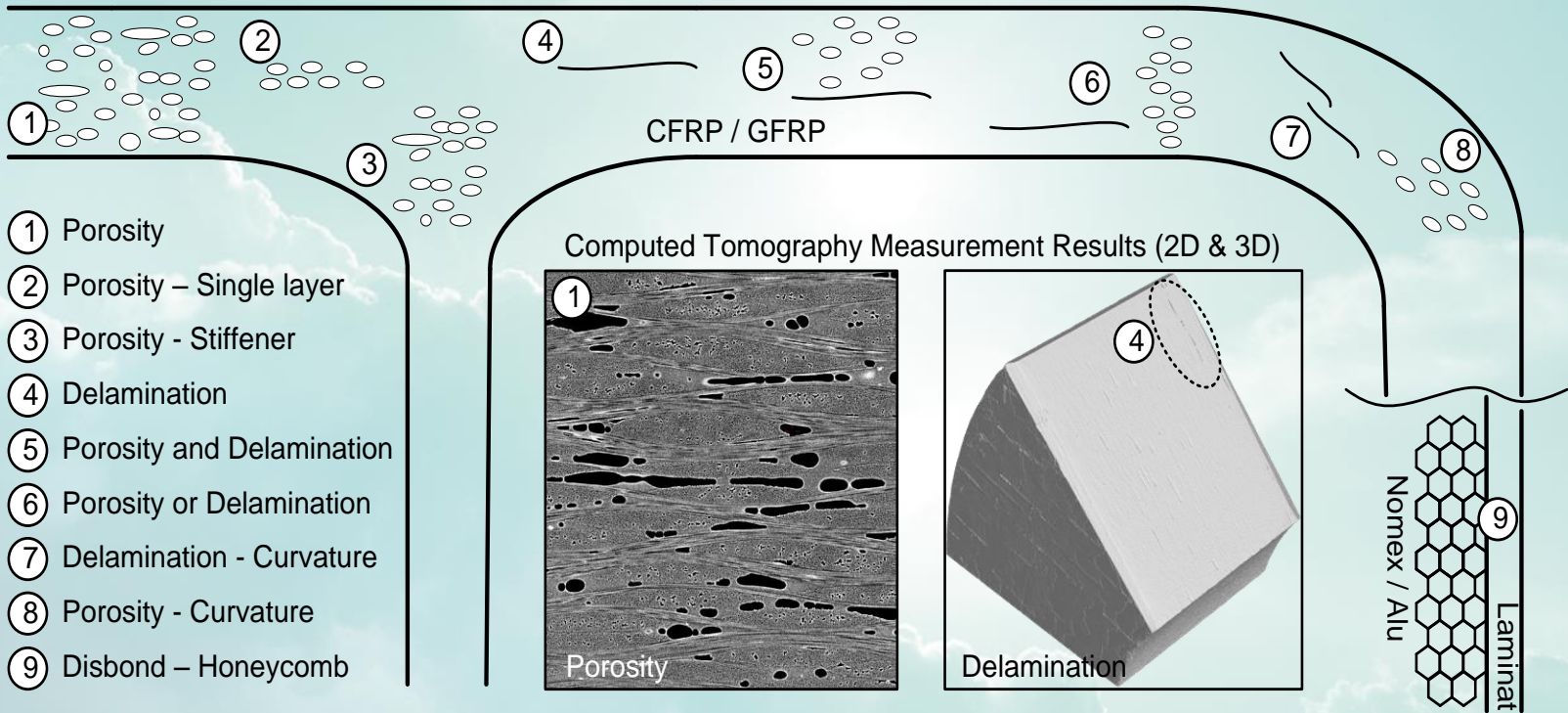


# Challenges

## Inspectability



# Typical defects in CFRP



# Porosity

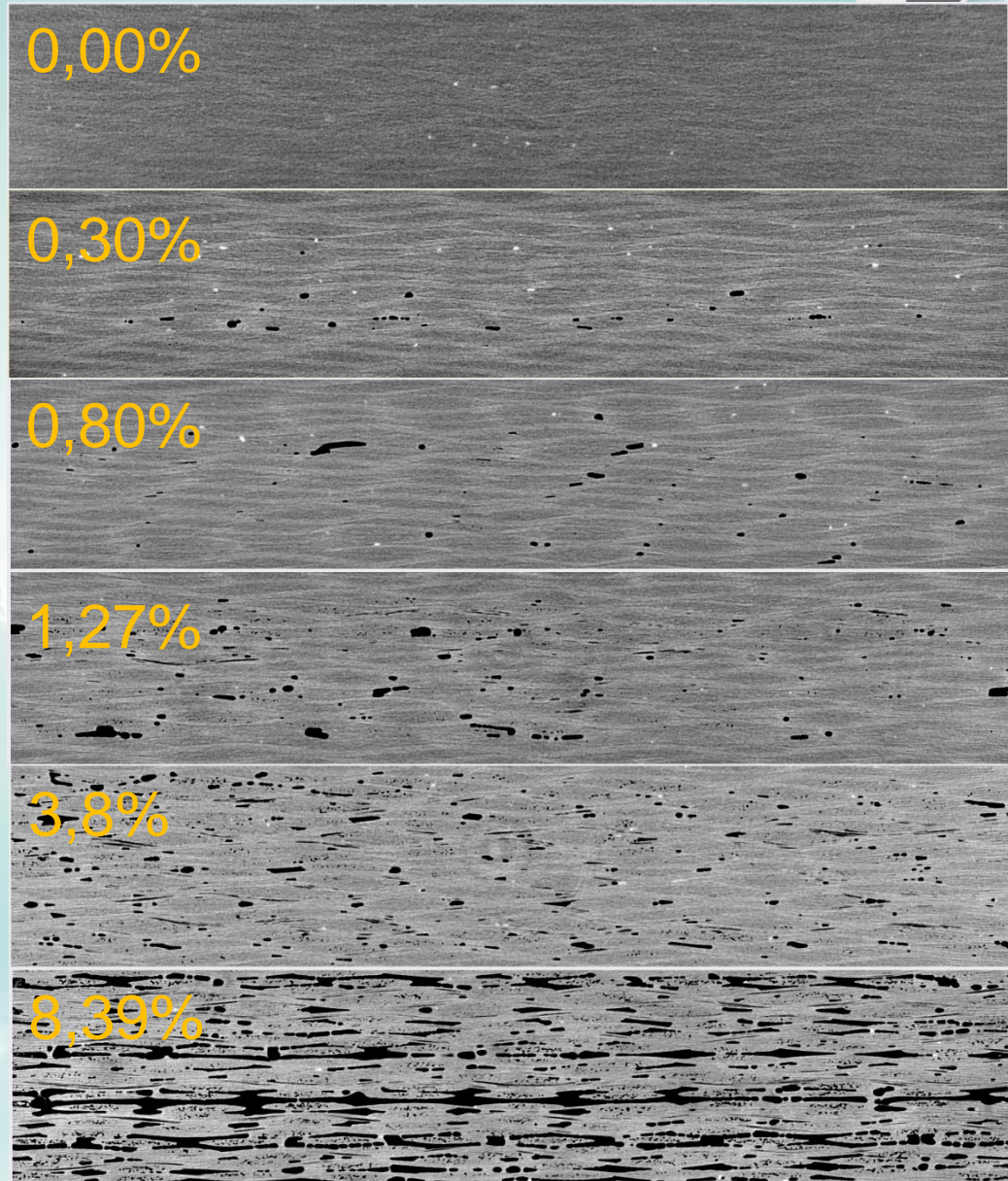
## Airbus AITM6-0011

Volume porosity -  
Accumulation of small voids  
in the material distributed  
throughout part or total  
thickness of the part.

## Boeing BAC5980

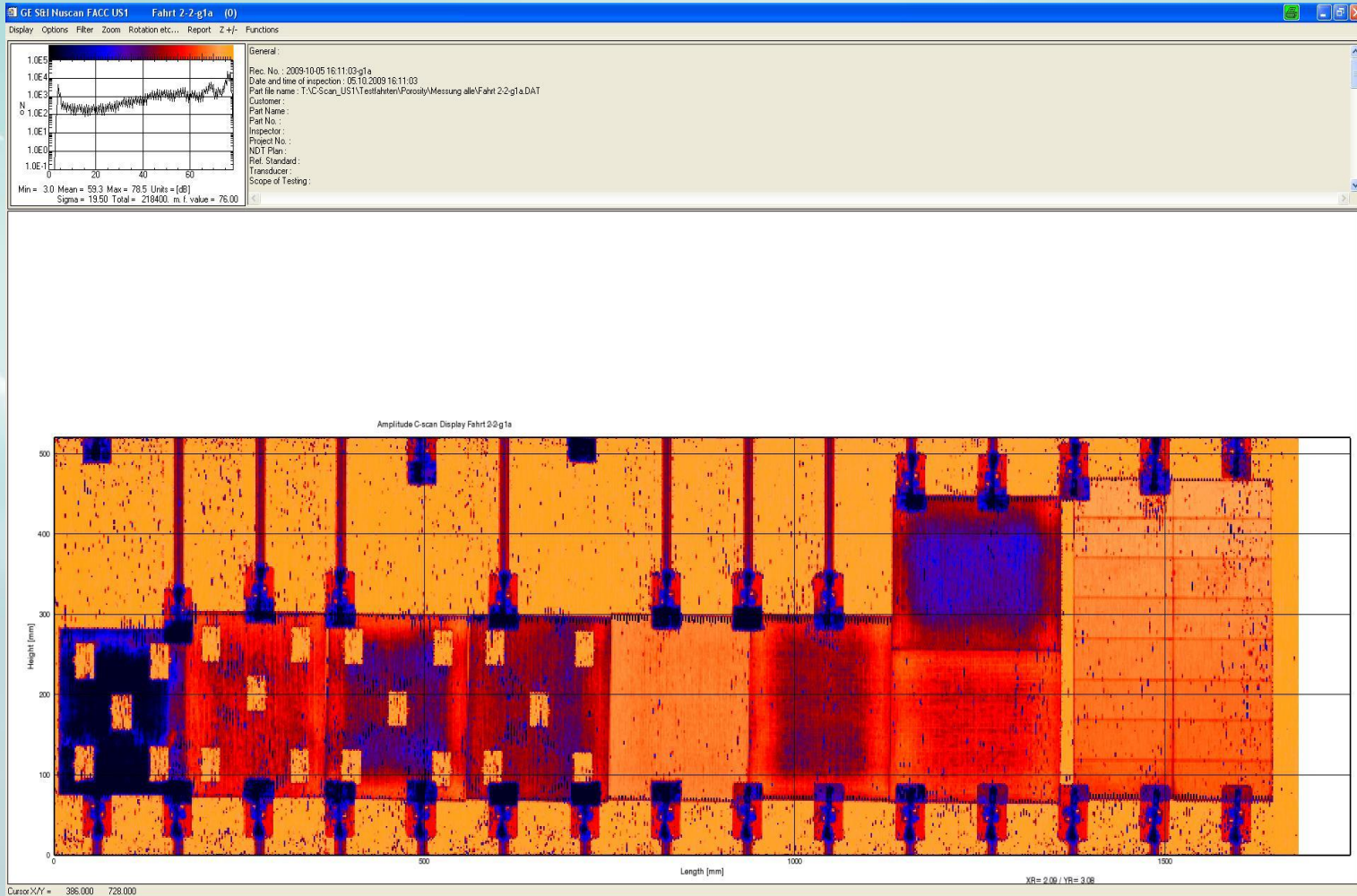
Porosity - An accumulation  
of small voids, often caused  
by volatiles.

**Limits: 2-2,5 Vol.%**



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# Porosity



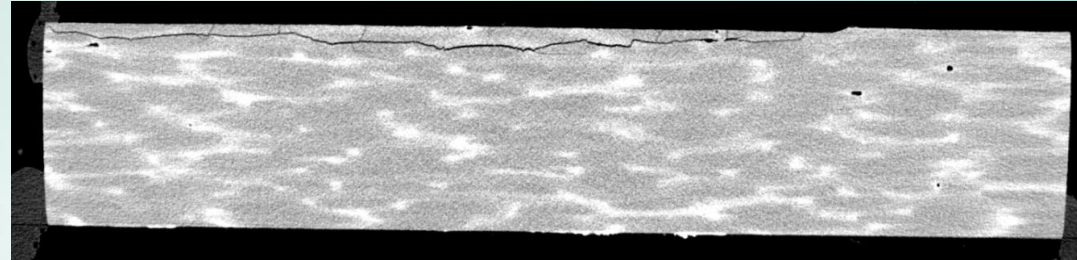
5MHz - TTU C-Scan on samples with porosity between 0-8,39%vol.



# Delamination

## Airbus AITM6-0011

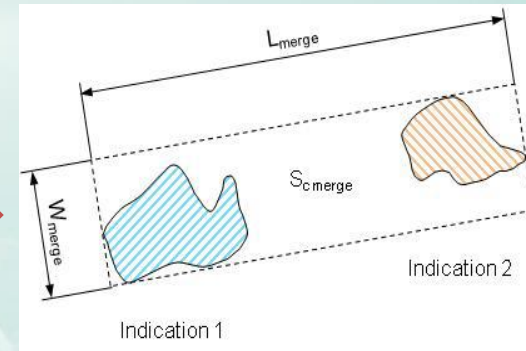
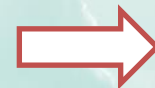
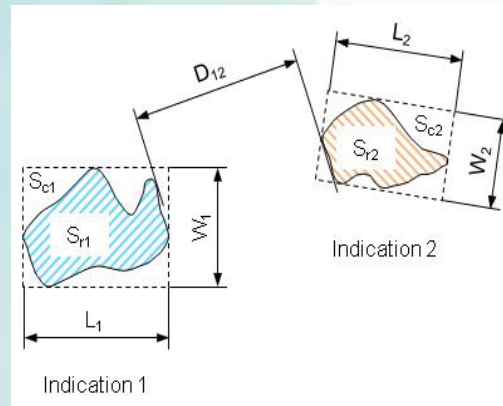
Delamination - Separation between adjacent plies in a multi layer structure.



## Boeing BAC5980

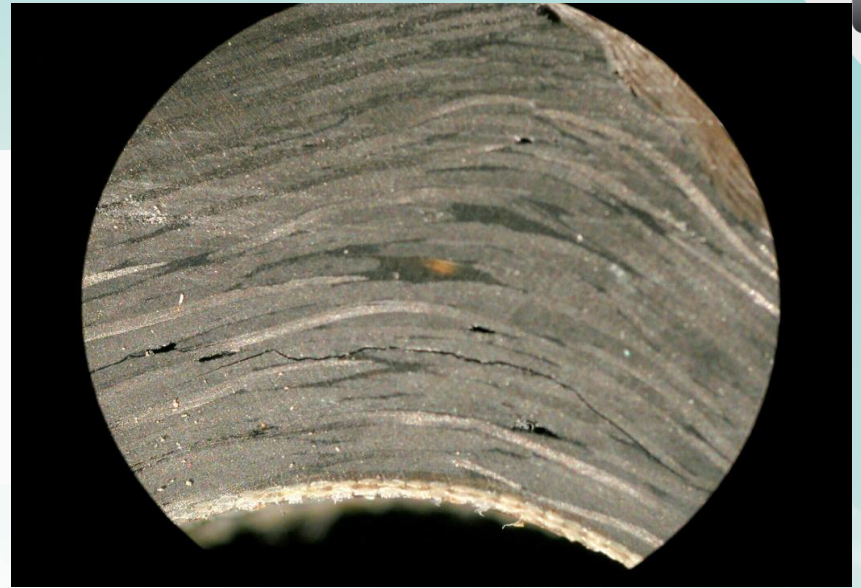
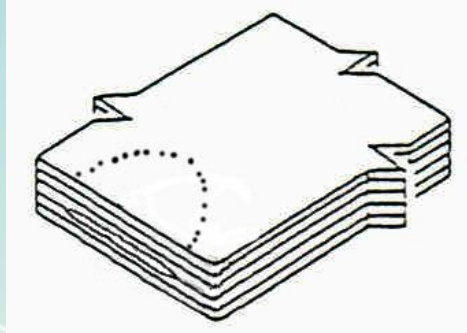
Delamination - Separation of adjacent layers within a multilayer structure.

**Limits:**  
**From 6x6mm to 12,7x12,7mm**

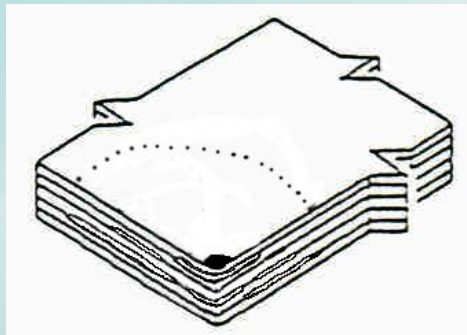


# Delamination

Single Layer Delam



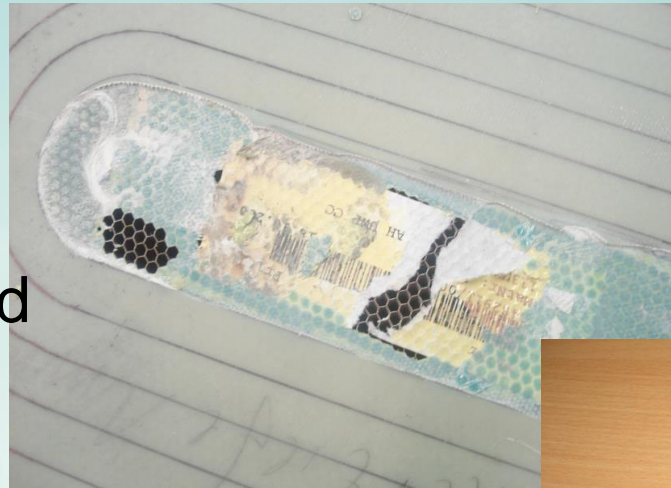
Multi Layer Delam



# Disbond

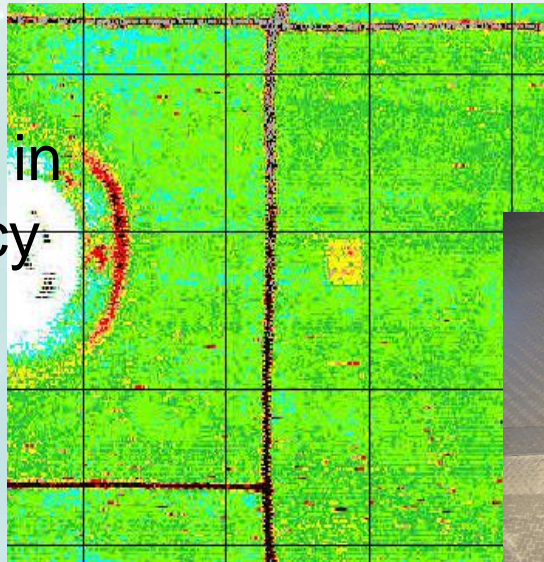
## Airbus AITM6-0011

Debonding - Lack of continuity on unions carried out by means of adhesive.



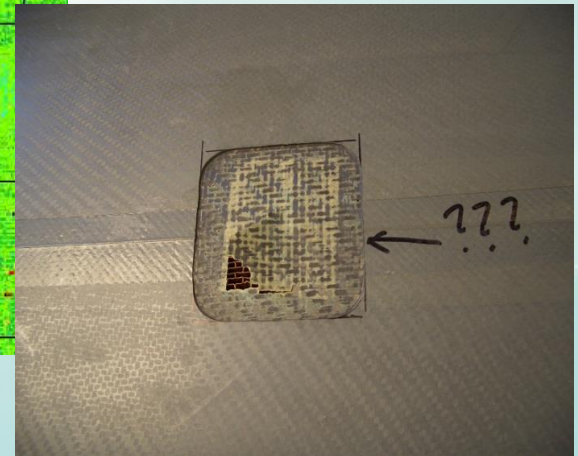
## Boeing BAC5980

Disbond (Unbond) - The separation of adherends in the bondline. Discrepancy within the bondline after cure.

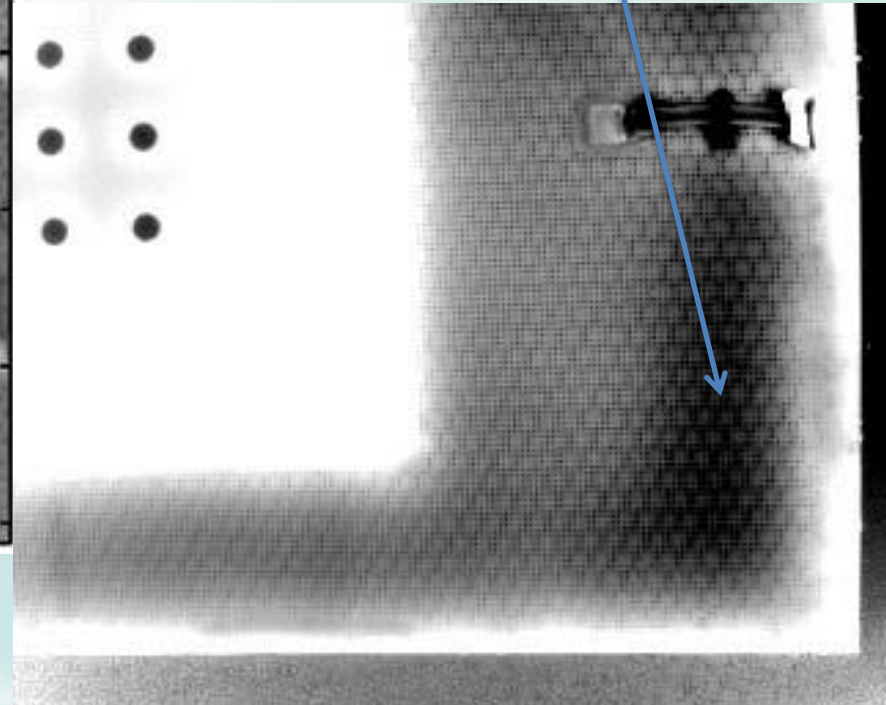
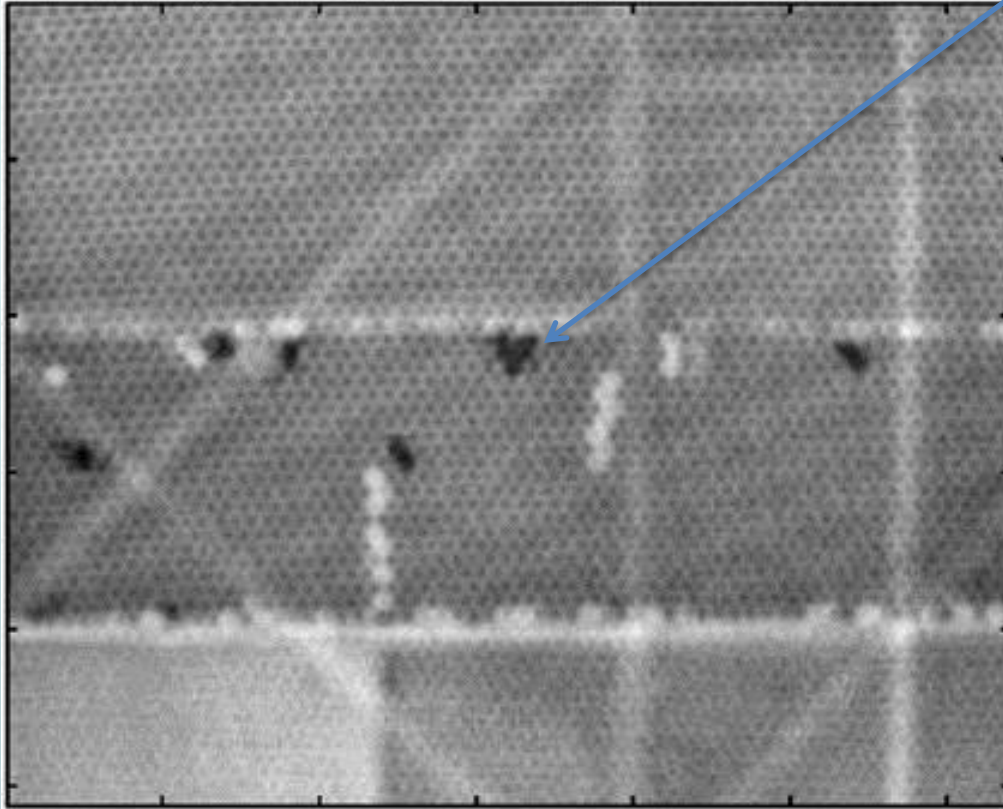
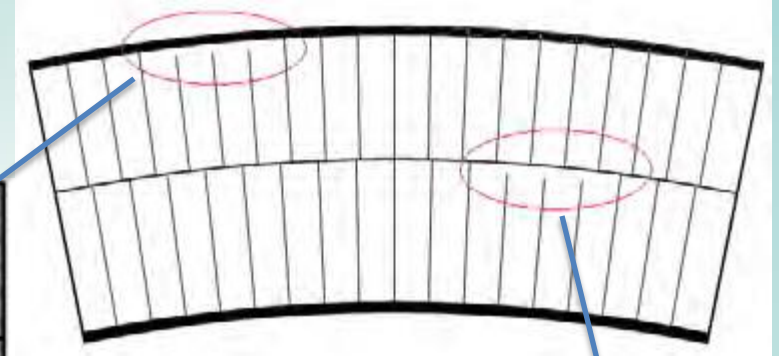


## Limits:

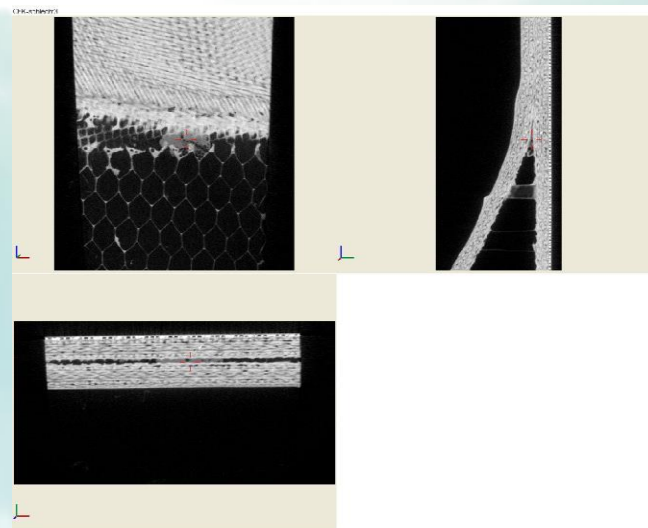
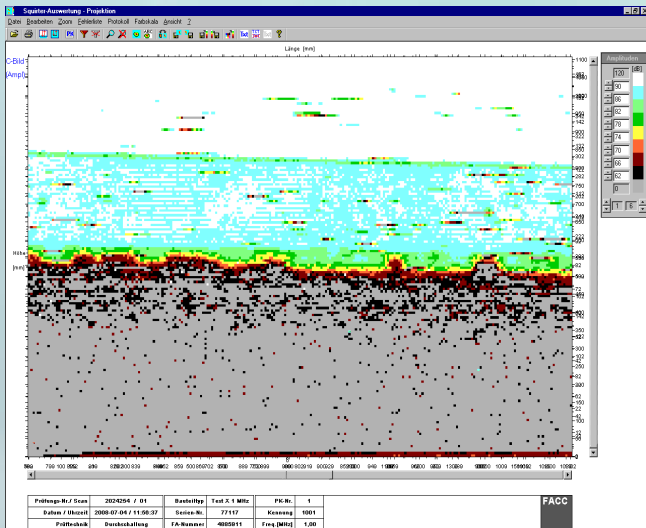
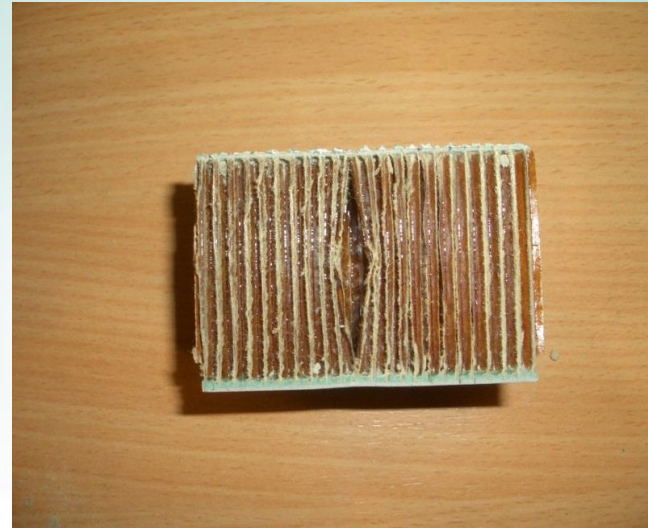
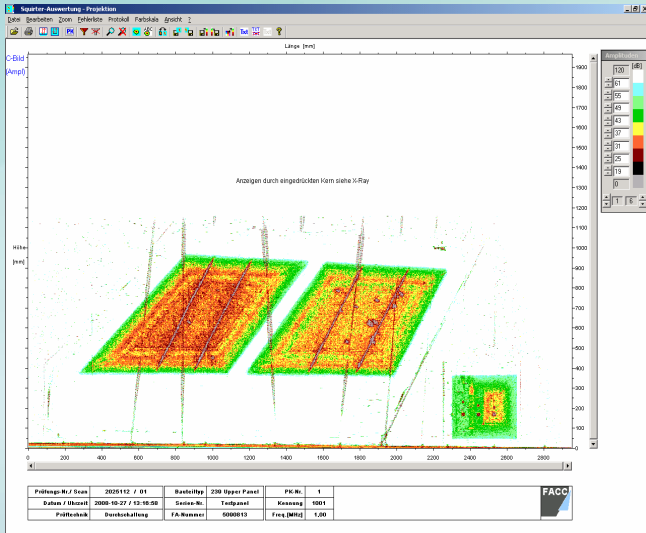
From 6x6mm to 12,7x12,7mm



# Disbond

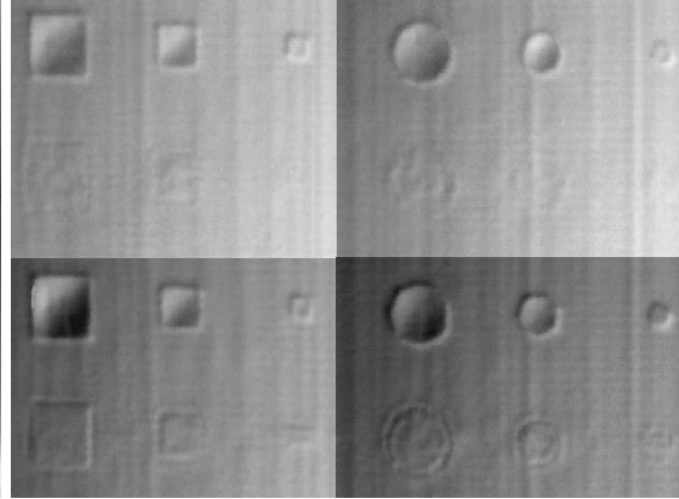
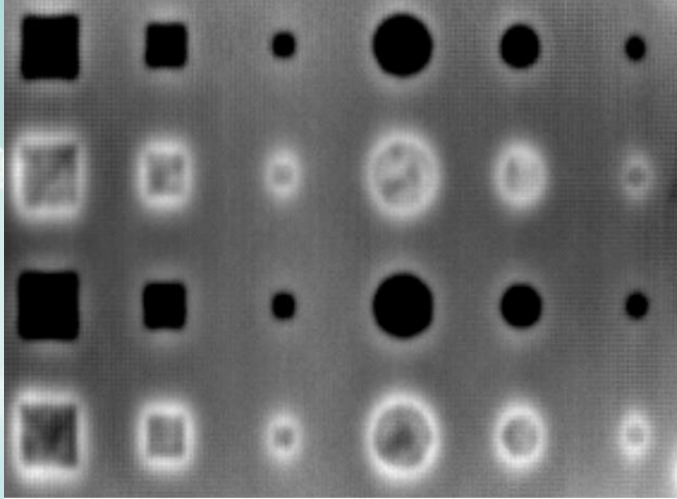


# Few other samples of defects



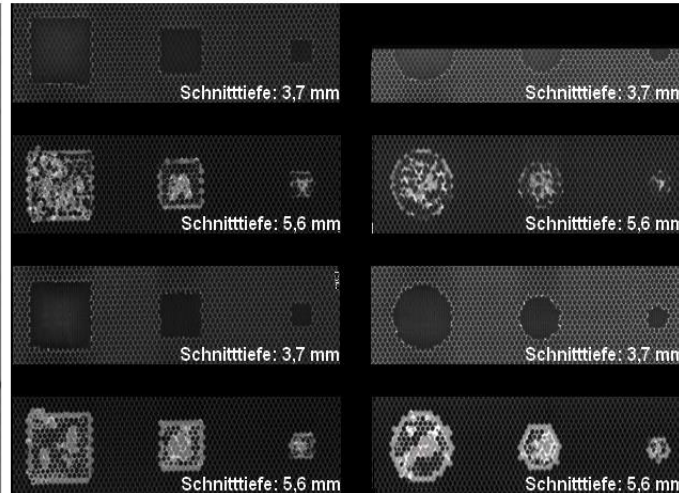
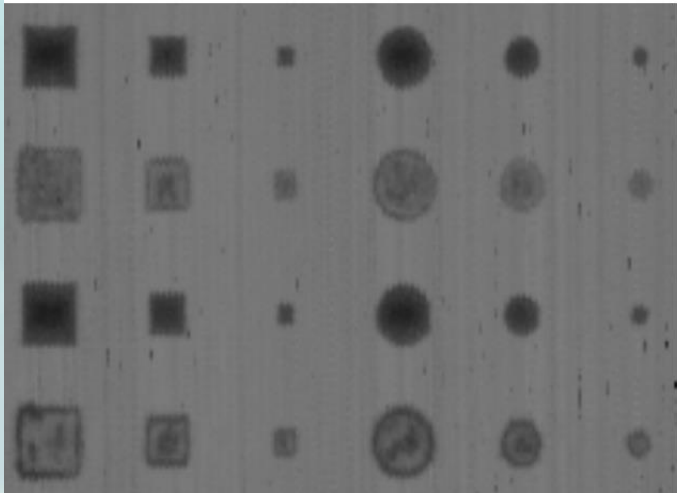
# What is the proper Method?

Active Thermography



Digital Shearography

TT Ultra sound



X-Ray CT

# What is the proper Method?

	Ultrasound UT				Radiography RT		Active Thermography TT		X-Ray Computertomografie XCT	
	Puls Echo UT-PE		Transmission UT-TT		Detect.	Charakt.	Detect.	Charact.	Detect.	Charact.
	Detect.	Charakt.	Detect.	Charakt.						
<b>Porosity</b>	++	+	+	0	0	-	+	+	++	++
<b>Delamination</b>	++	++	+	0	-	-	+	+	+	++
<b>Ondulation</b>	0	-	-	-	-	-	-	-	+	+/0
<b>Fiber Crack</b>	-	-	-	-	-	-	0	0	+	+
<b>Inclusions</b>	+/0	+	+/0	0	+	+	+/0	+	++	+
<b>Disbond</b>	+/0	+	+	0	-	-	++/0	++	+	+
<b>Kissing Bond</b>	-	-	-	-	-	-	-	-	-	-
<b>Septum Disbond</b>	-	-	++	0	-	-	+	+	0	0
<b>Crushed Honey comb</b>	-	-	+	-	++	++	+/0	+/0	++	+

++ very good, + good, 0 limited, - not possible / unknown

# What is the proper Method?

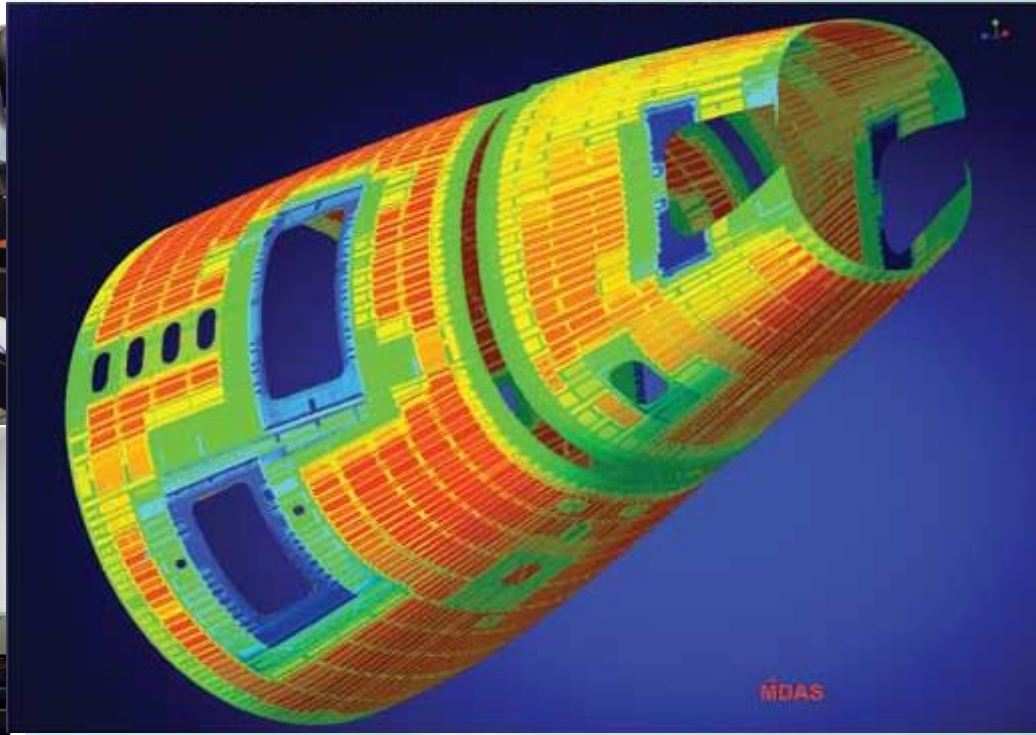
## Fulfilling following criteria:

- **Detection rate of 29/30 (POD)\***
- **Detection of all relevant defect types**
- **Cost effective**
  - **Start investment**
  - **Inspection time**
  - **Evaluation / Documentation time**
- **Not always necessary is the characterization of defect**

\*Signal to Noise ratio of defect high enough to fulfill this. Depending on Method,  $US > 2,5$ ;  $TT > 3-4$ ....



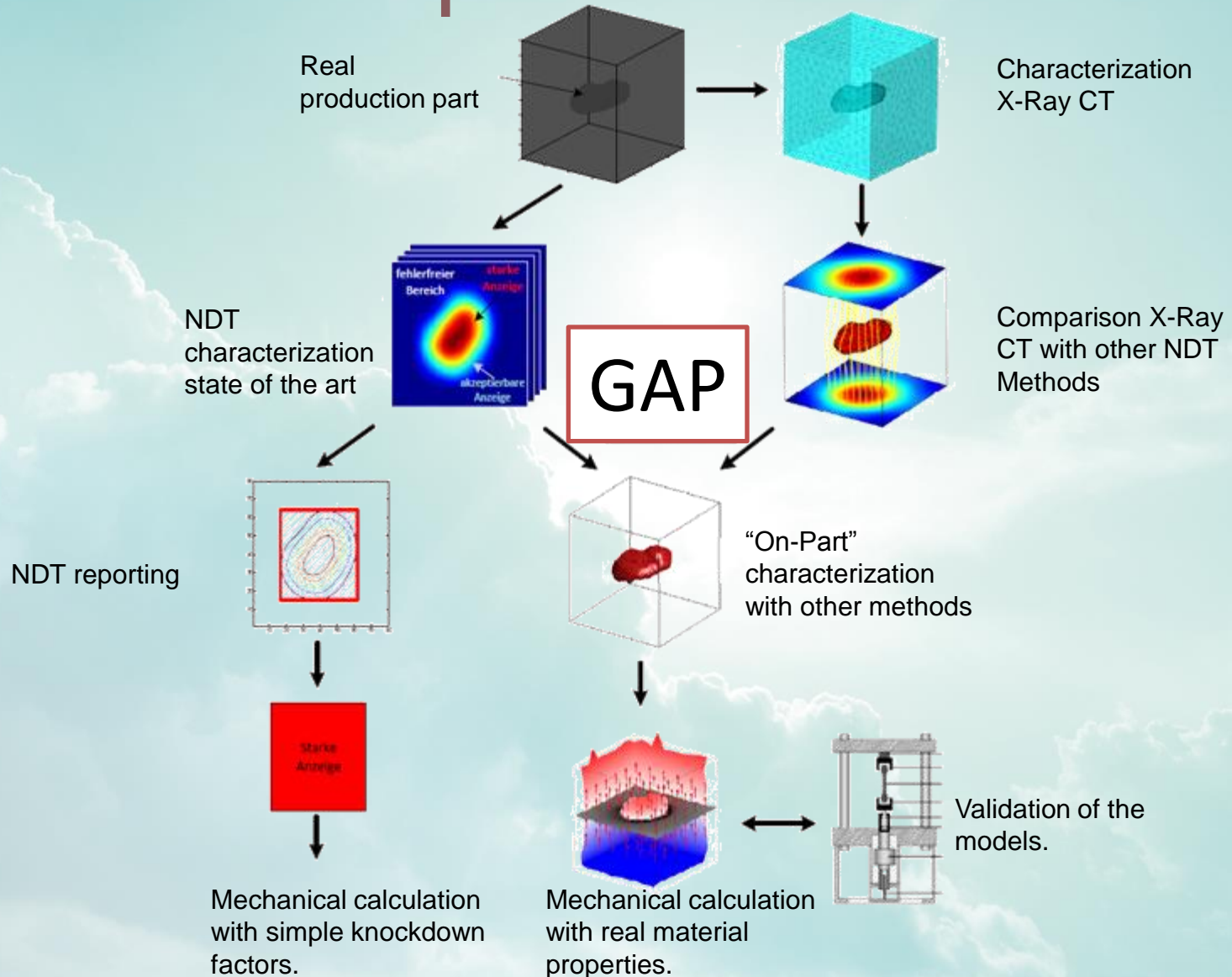
# Sample Laser Ultrasound



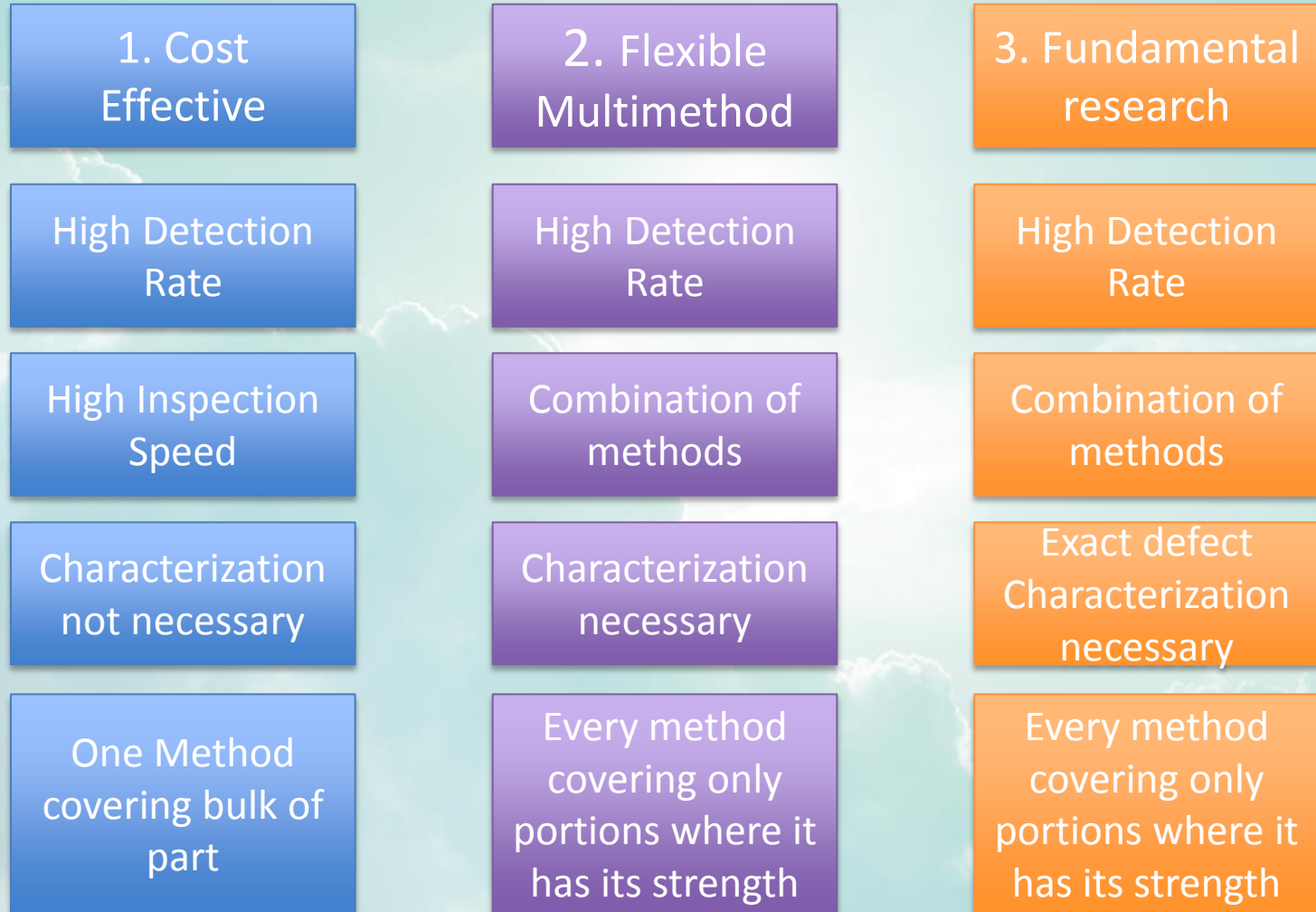
© AIRBUS S.A.S. 2011. Photo by S.BONNODL/Visualies

Source: TecnaTom

# NDT development in the future



# NDT development in the future



Thank you for your attention!