New materials:
An unavoidable evolution
Challenges and opportunities

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The challenge for aviation: sustainable growth

Flightpath 2050

—

-75% CO2

-90% NOx

-65% Noise

Reference year: 2000

History of a continuous fuel burn reduction

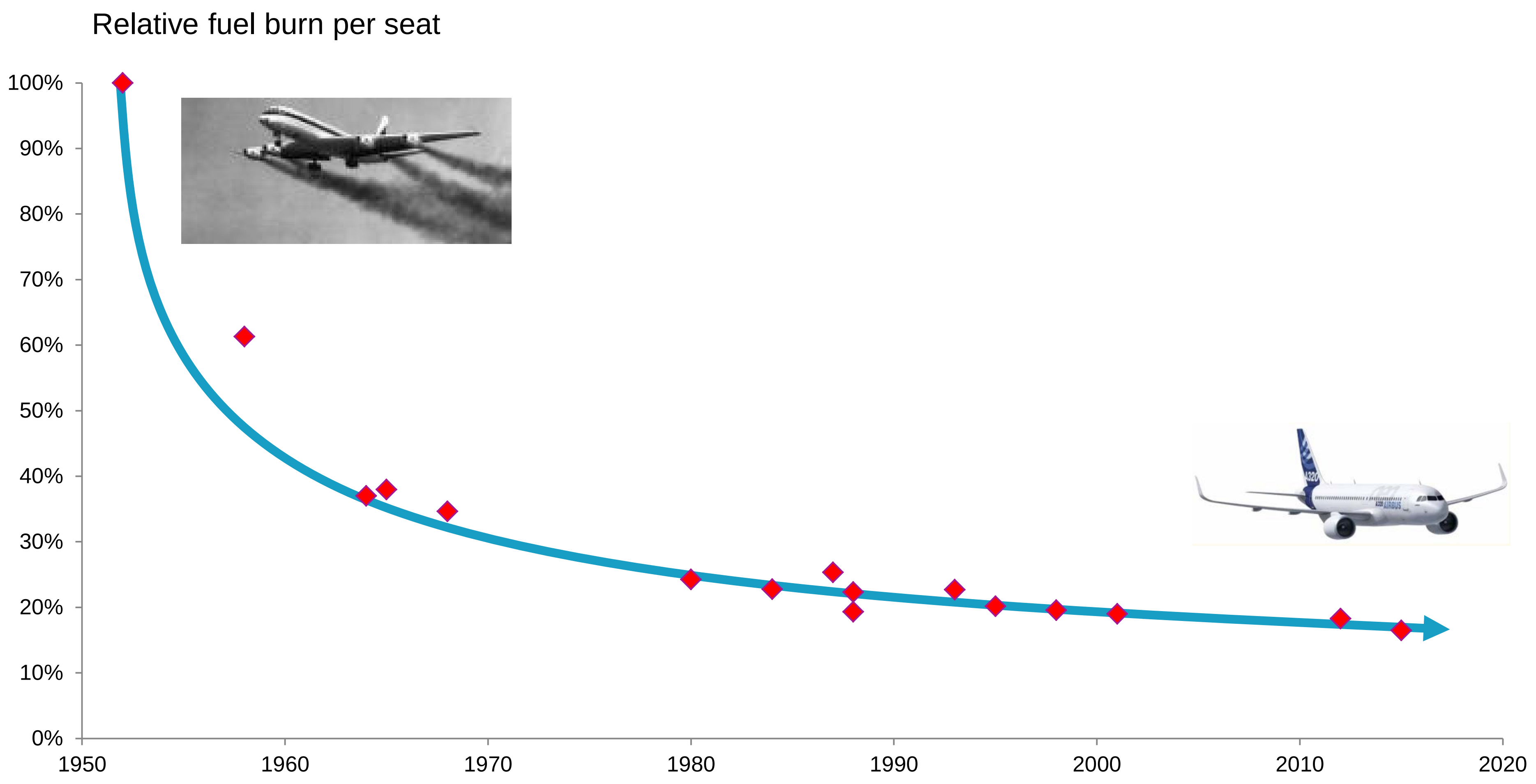
Fuel Burn reduction

—

80% reduction

fuel burn & CO2

per seat since the dawn of the jet age



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Structural Composites in Airbus Aircraft Family

Advanced composites

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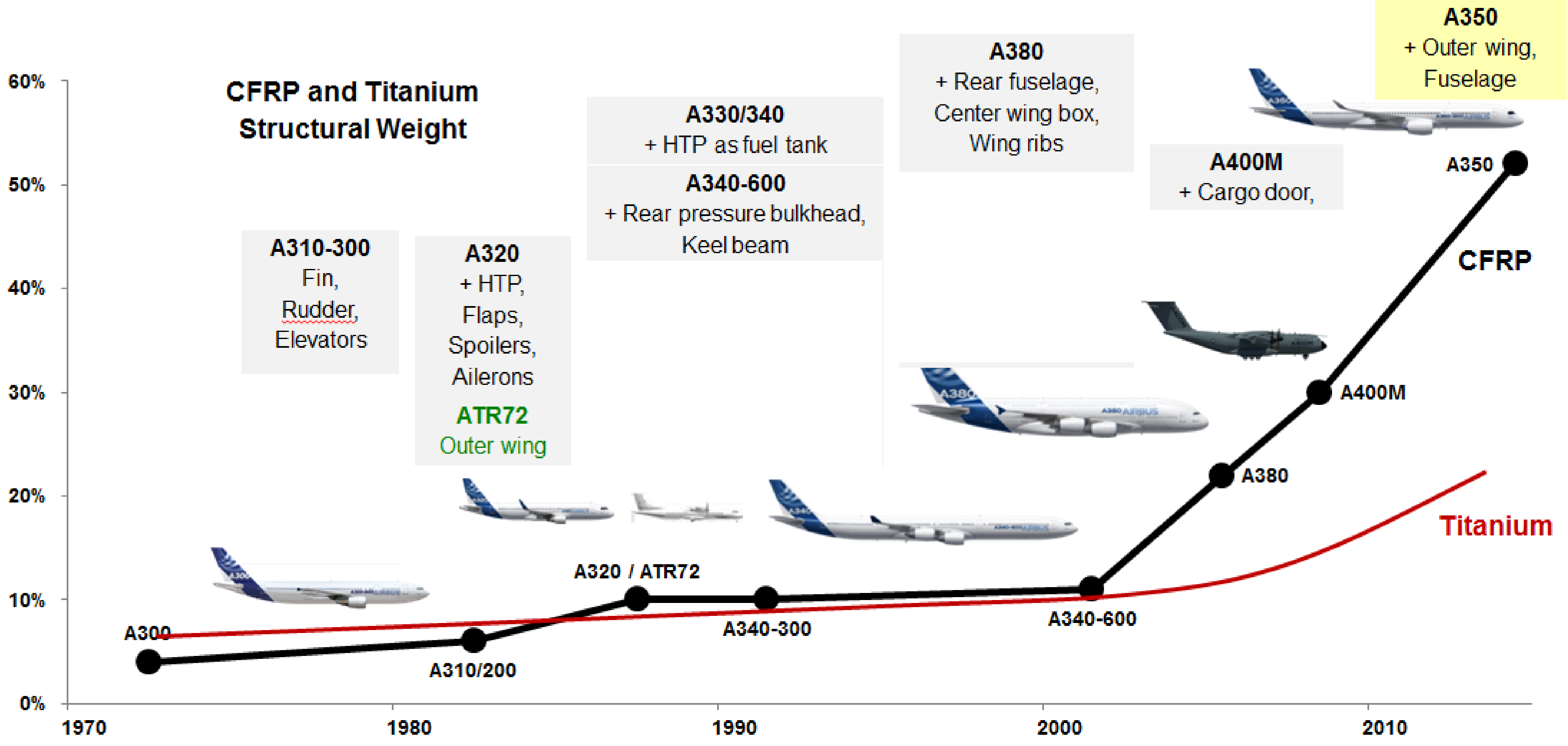
Improve **fuel efficiency**

By achieving
weight saving

While
optimizing design & manufacturing constraints

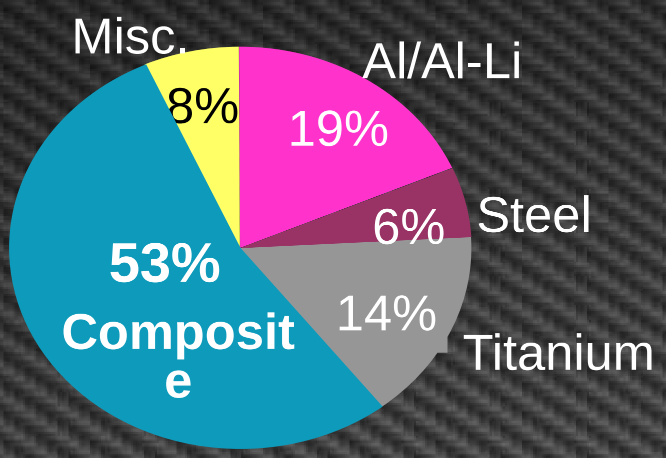


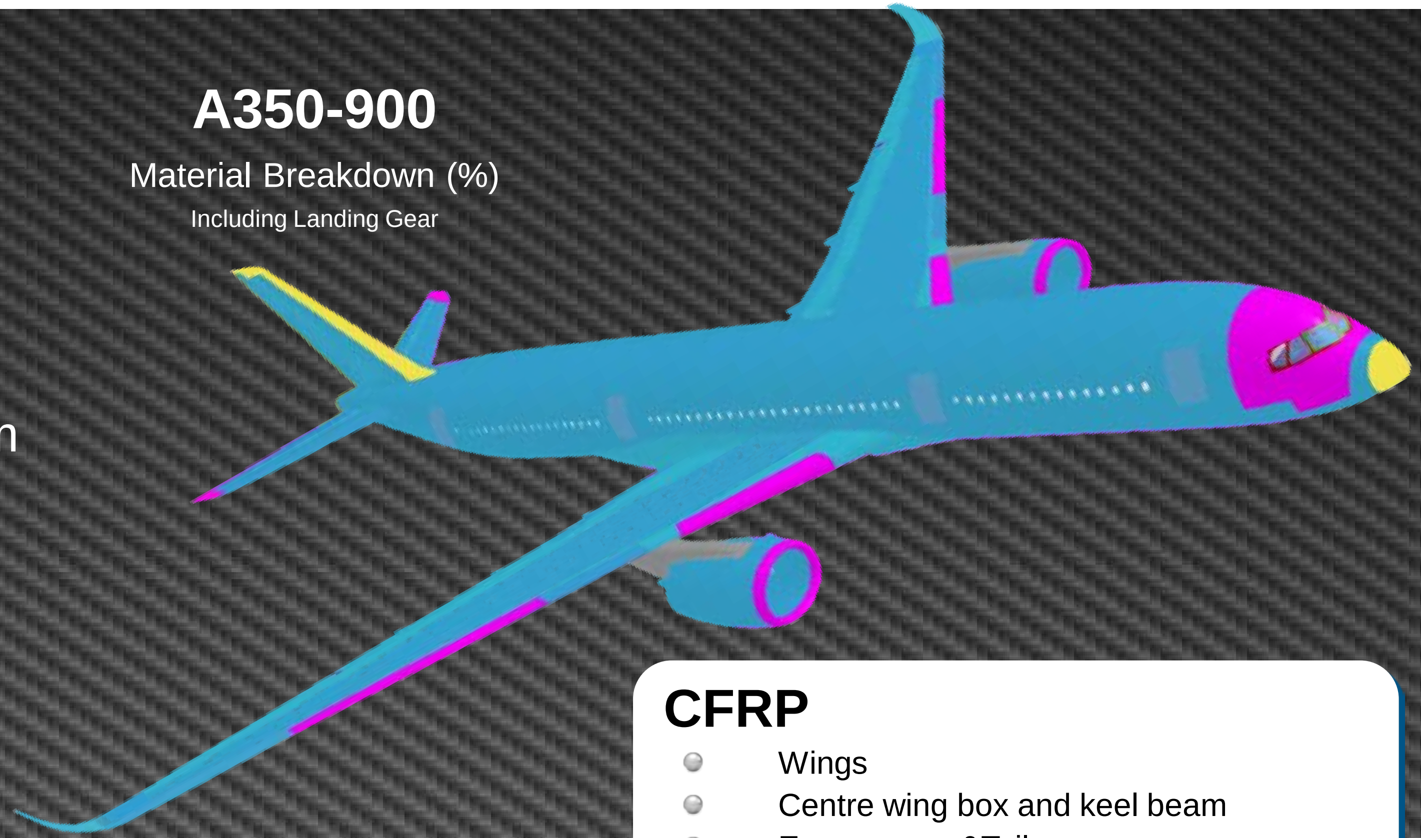
Structural Composites in A350 Aircraft

A350-900

Material Breakdown (%)

Including Landing Gear





Titanium

- High load frames
- Door surroundings
- Landing gear
- Pylons

→ No corrosion tasks

CFRP

- Wings
- Centre wing box and keel beam
- Empennage &Tail cone
- Fuselage Skin panels
- Frames, stringers and doublers
- Doors (Passenger & Cargo)

→ No corrosion & fatigue tasks

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Structural Composites in A350 Aircraft

A350 XWB

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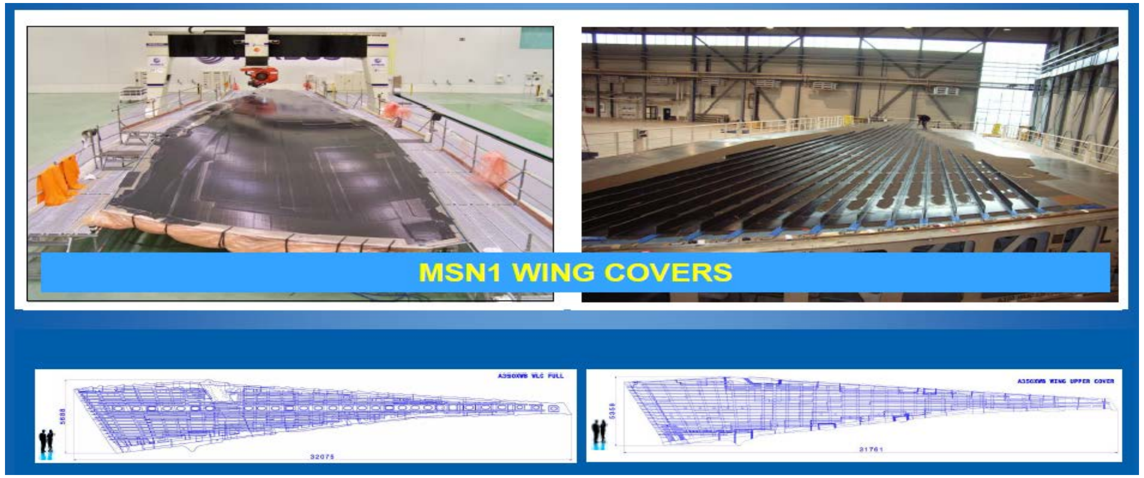
>90% of the wet surface is in **Carbon**

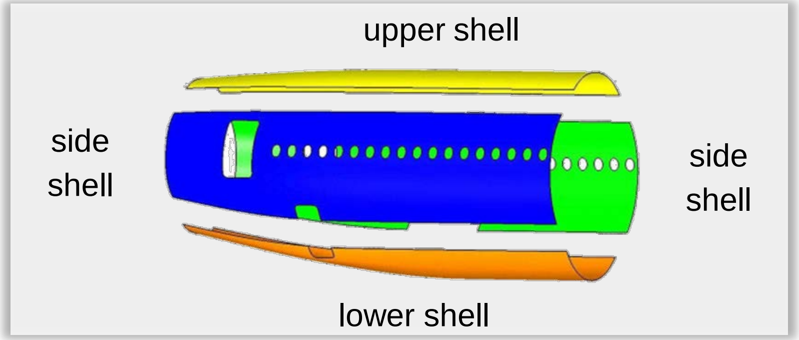
Industry Records:

Wing: 33m length in **1** segment

Fuselage: 1,6mm thick (typical area)



- One-piece wing cover 32m long
- T stringers, pre-cured co-bonded
- Cover thickness range 9.1 – 26.1mm
- Copper foil for lightning protection



- Fuselage section up to 18m long

- A350XWB Keel beam panel ~15m long
- Beam and lower fuselage panel integrated

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Certification standards & Testing approach

- Regulations and certification criteria are performance based requirements

- Specificity of composite properties are taken into account by means of Acceptable Means of Compliance (AMC 20-29 for EASA and AC 20.107B for FAA) and cover following areas:
  - Response or resilience to accidental damage (lightning strikes, bird strikes, in flight hail, fire).
  - Structural substantiation of CFRP materials & manufacturing processes variability
  - Assessment of damage to aircraft structure.
  - Definition of relevant maintenance program and repair methods.
  - Training standards and product awareness…

- Airbus standards are typically exceeding the regulatory requirements

➔Extensive use of established Standard to develop at least equivalent safety level:

- Building block approach for Tests
- Advanced numerical computing methods

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Certification standards & Testing approach - Reliability of analysis is Key

From **Physical** tests to **Simulation** models

—

Optimize design

Establish high reliability

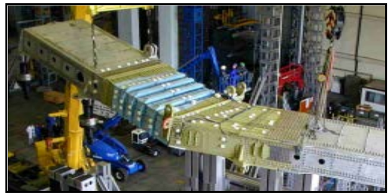
Secure large test scale & Manufacturing ramp-up

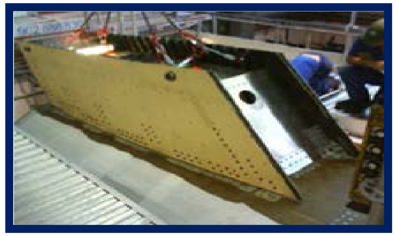
All physical tests (Details, Sub-component to demonstrators) are supported by computed models

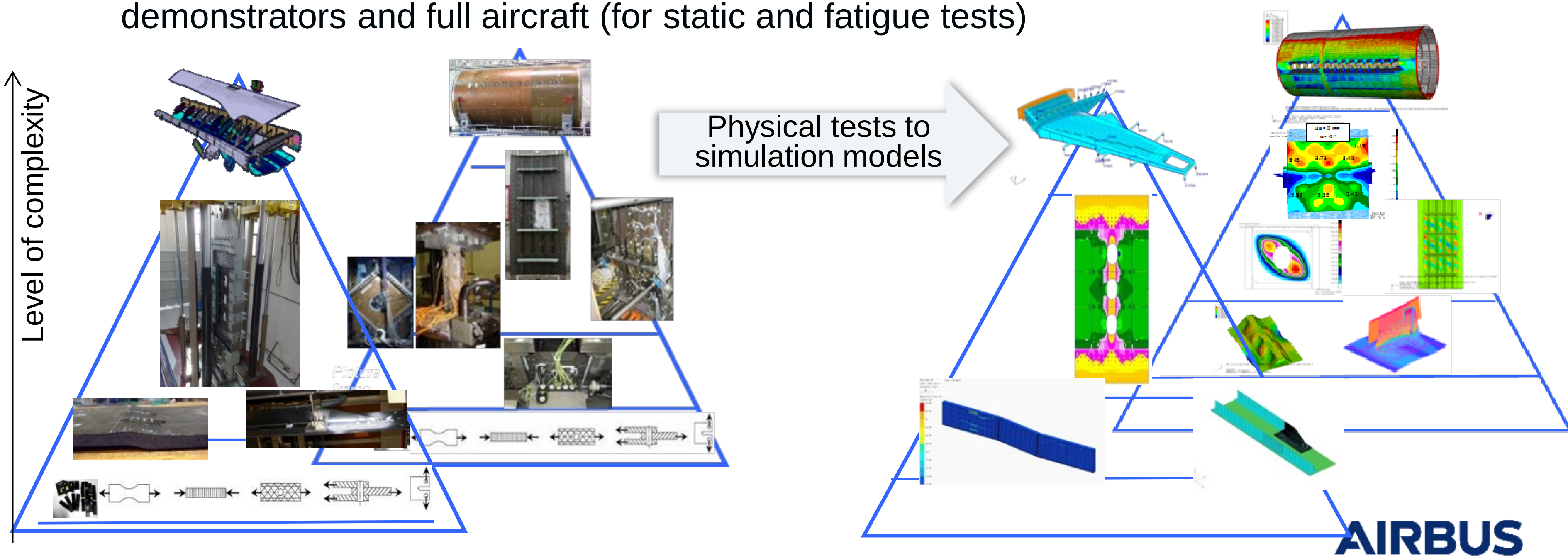
- Extensive measurement on all test levels
- Verified predicted performance and understand combined load

Objective: calibrate methods & computing models

- Run predictions 'Virtual testing' in anticipation to full scale test demonstrators and full aircraft (for static and fatigue tests)

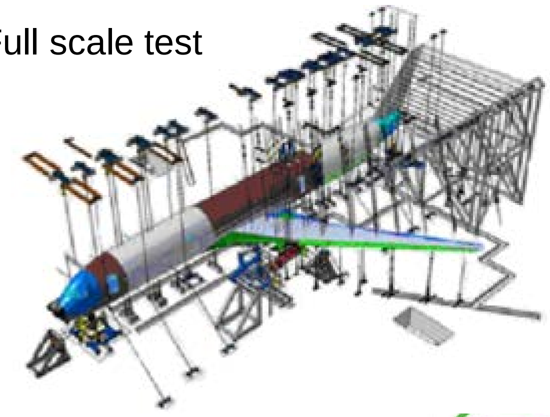






Certification standards & Testing approach - Reliability of analysis is Key

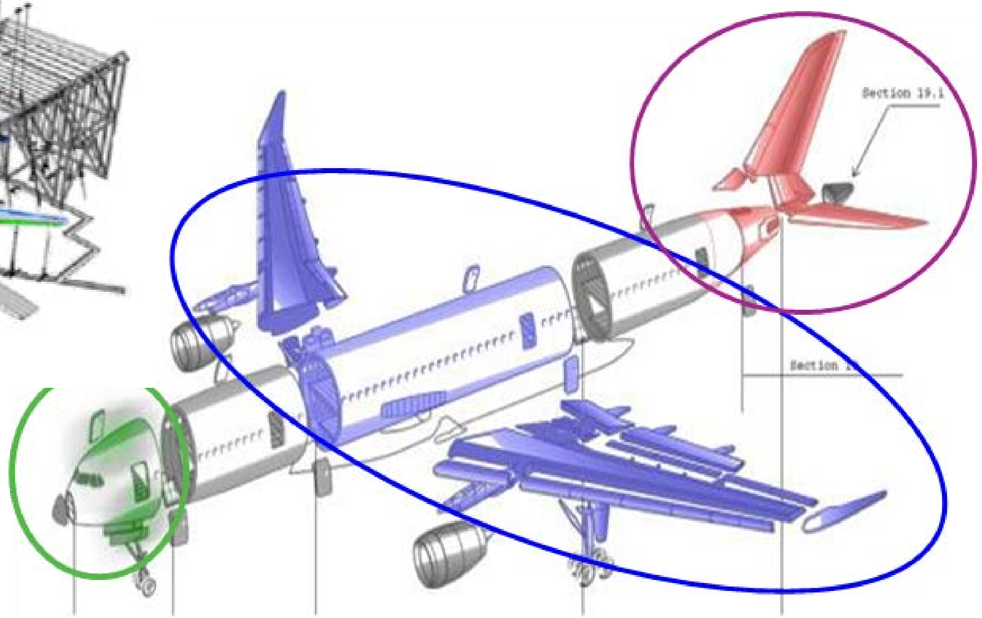
ES Full scale test

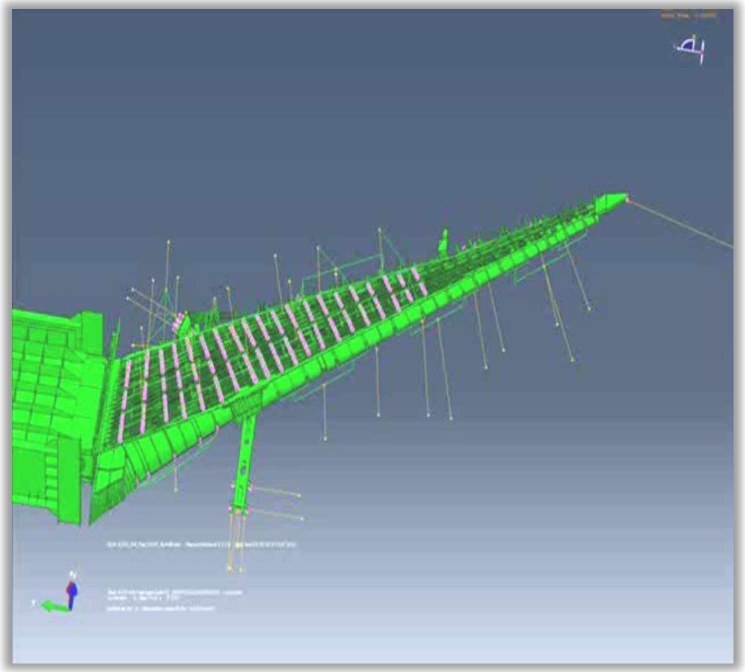


3 different area with refined modelling:

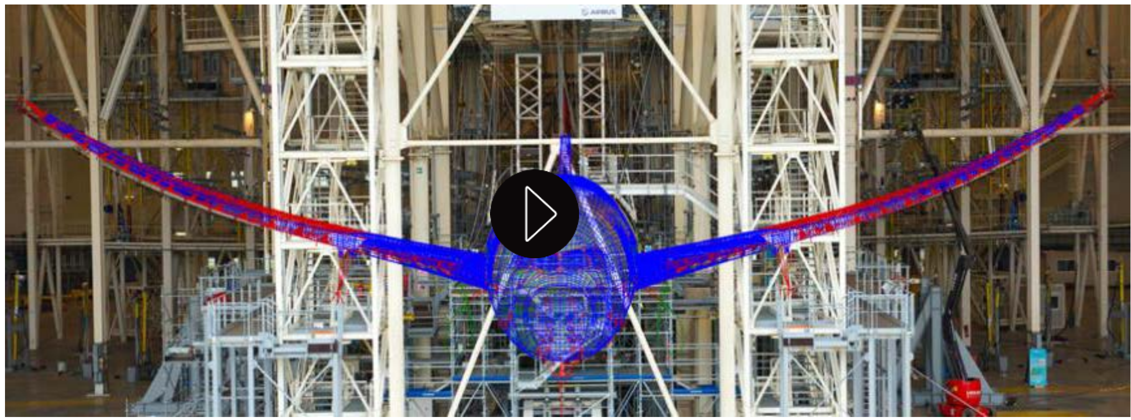
- models running separately
- Linear and Non Linear prediction

✓ Risk mitigation, secure static test campaign





Example:
Virtual Full-Scale Static Test
68 million degrees of freedom
24 Load cases



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Certification standards & Testing approach – Full scale fatigue test

Nose Fuselage

Toulouse, France

Fatigue Campaign
Q4/2013 to Q4/2015

Center Fuselage

Erding, Germany

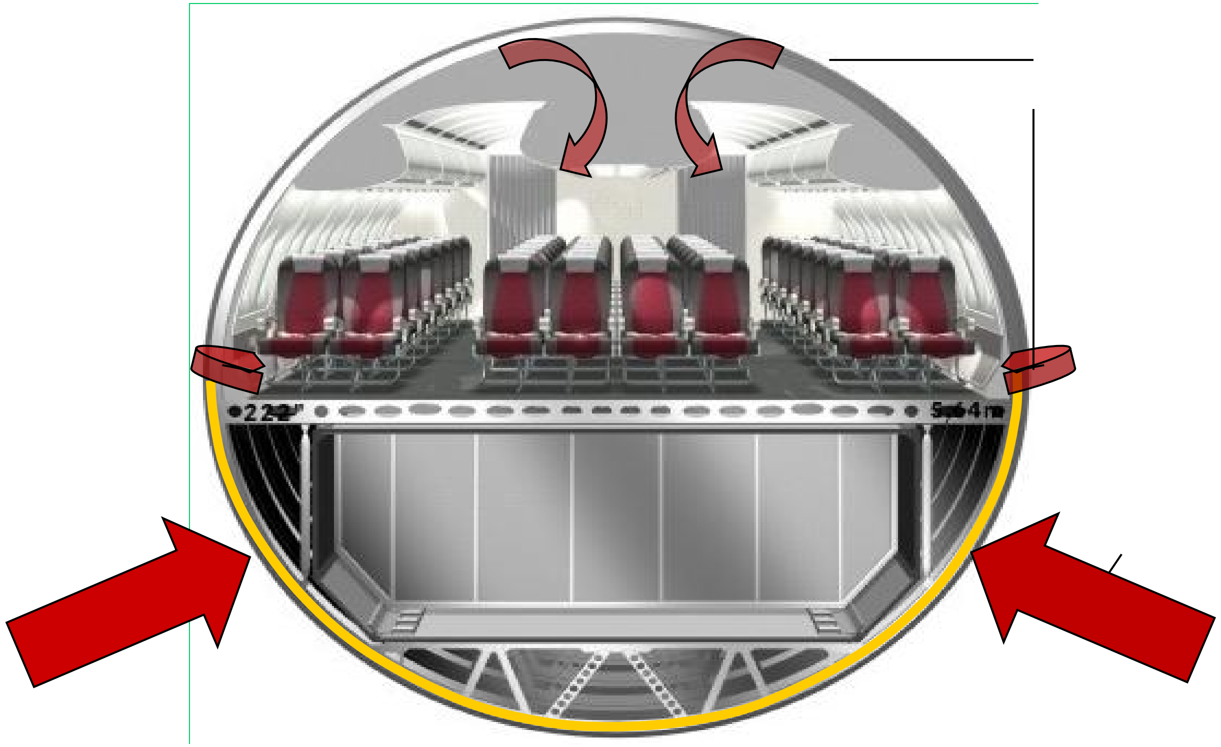
Fatigue Campaign
Q2/2014 to Q2/2016

Rear Fuselage

Hamburg, Germany

Fatigue Campaign
Q1/2014 to Q3/2015

Focus on fire cases – requirements



In-flight fire:

- survivability > 3h

  in consideration of active fire means

  ≤ 60 KW/m², 1,5 min

  Flame propagation

Flame propagation fire source

Ground fire:

- survivability > 5 min

  in consideration of intact fuselage

  180 KW/m², 5 min

Fuselage burn through

Ground fire source

→In-flight fire requirements are addressed to all CFRP fuselage structure parts.

Burn through requirement applies to the lower half of the shell only

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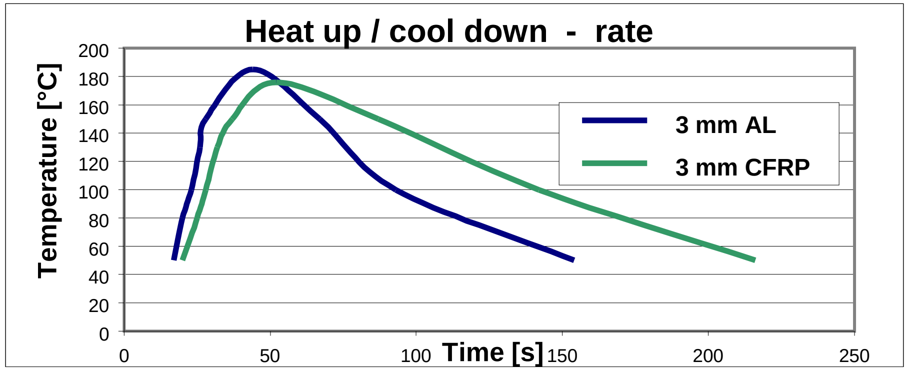
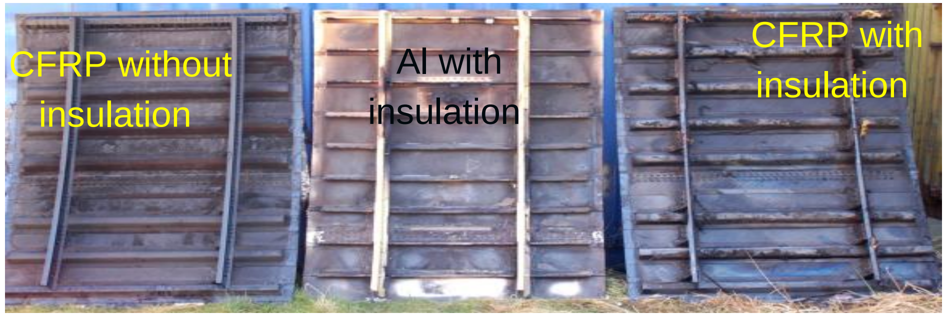
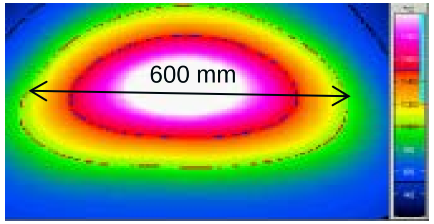
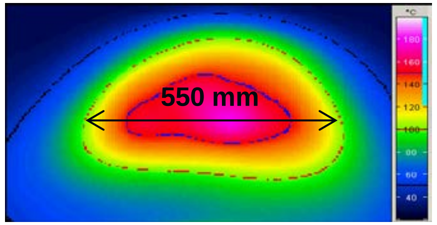
Focus on fire cases – results







3 mm Al Surface temp.
186 °C, after 44 s



3 mm CFRP Surface temp.
176 °C, after 52 s

- **Composite fuselage structure do not sustain combustion and do not favor the spread of fire**
- **Composite fuselage structure exhibit longer burn-through times than aluminium structure**
- **Composite fuselage structure does not transfer heat to the same degree as aluminium structure**
- **No fire propagation have been detected**

Design for robustness & Maintainability

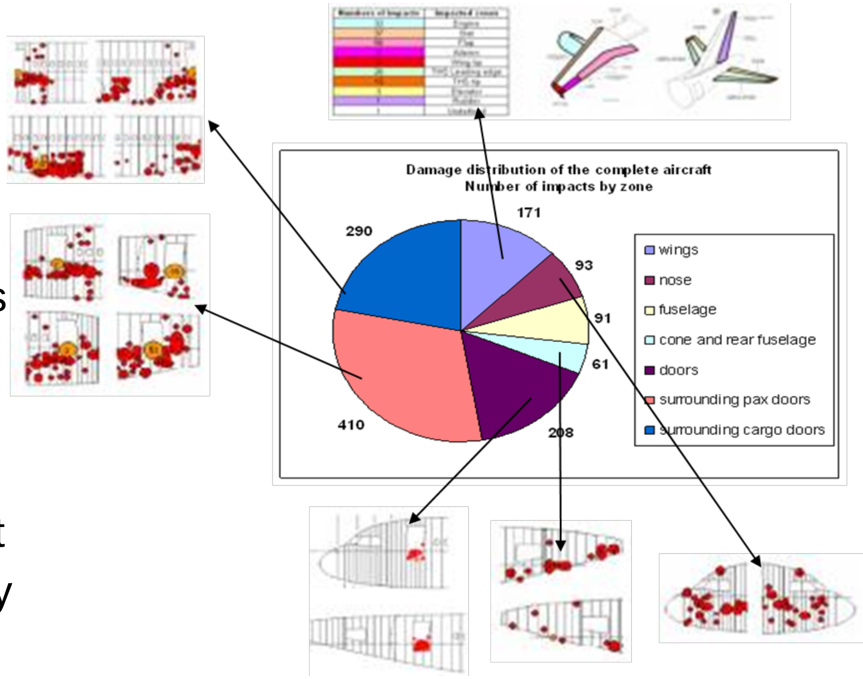
ACCIDENTAL DAMAGE METHODOLOGY: (refer to AC 20-107B)

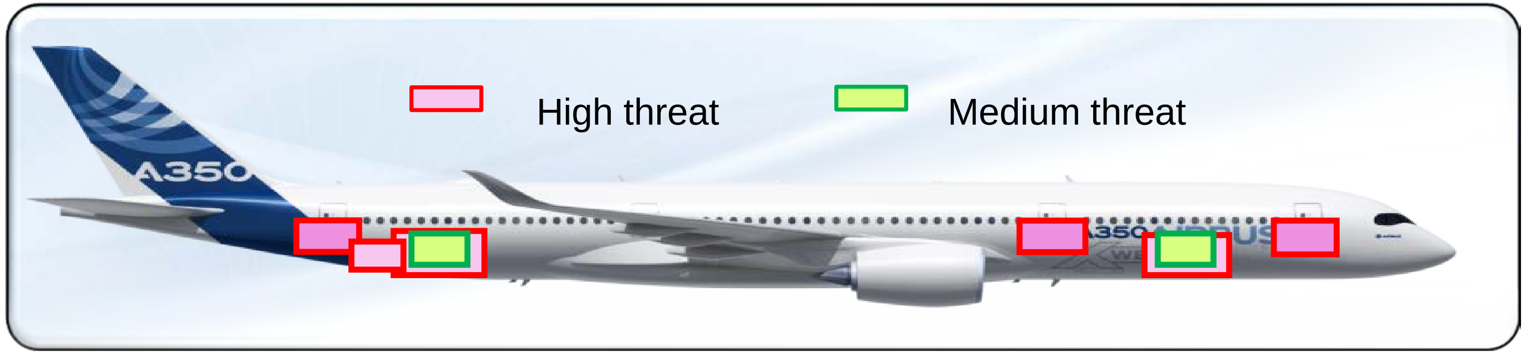
Anticipate impact damage occurrence

Develop design criteria

Consolidate design to ensure maintenability equivalent to A330

- Develop survey from in service damage report (cumulated experience from > 2500 reports)
- Address all kind of threat/damage, hail, stone, lightning, ground equipment…. calibrated for tests by low speed impactors, impact with and without bumpers..
- Aircraft zoning to support A350XWD development with regards to impact resistance & maintainability





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Structure Robustness to routine damage

- Allowable Damage coverage focuses on Routine damage on Prone to Damage Areas

Lightning strike

Mechanical impact & scratch

Allowable Damage Limits (ADL) defined in these areas **to enable A/C dispatch**

The structure can sustain certification loads with such damage without need for repair

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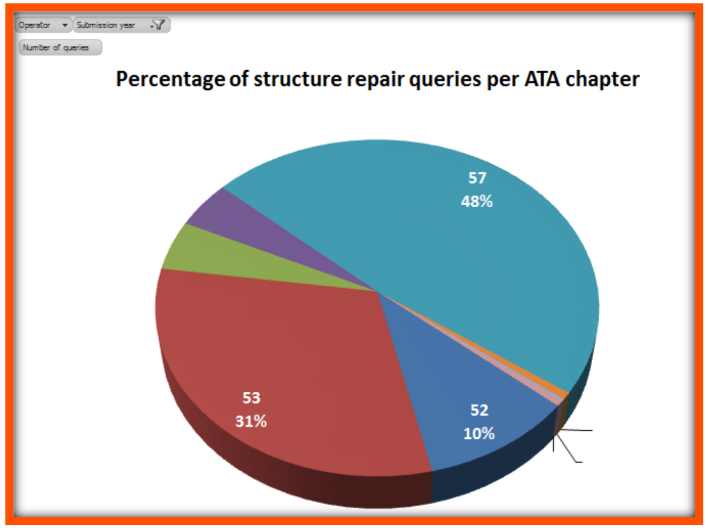
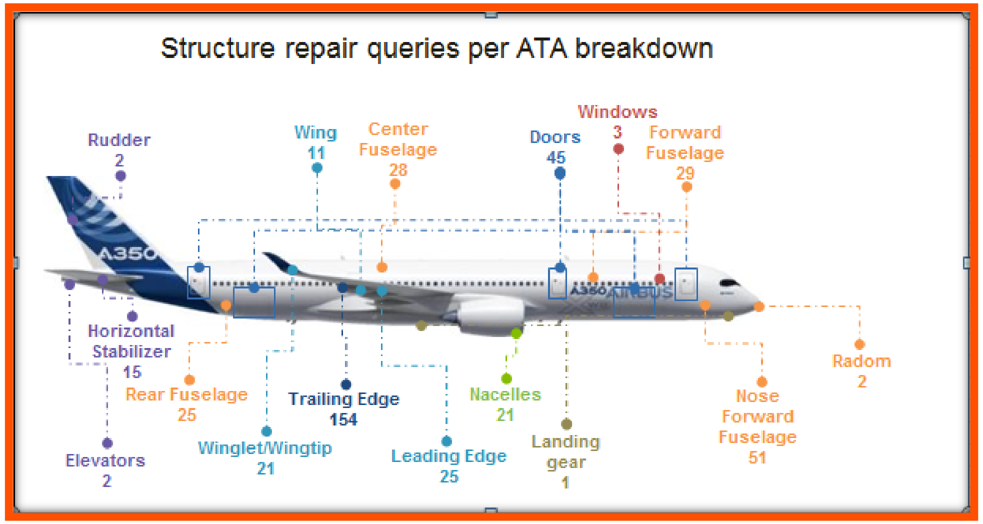
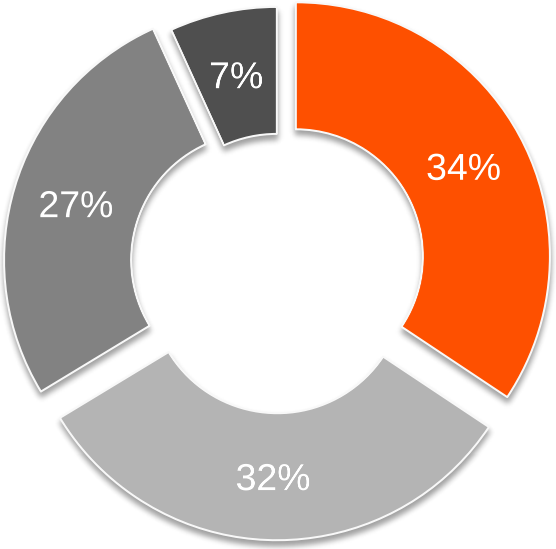
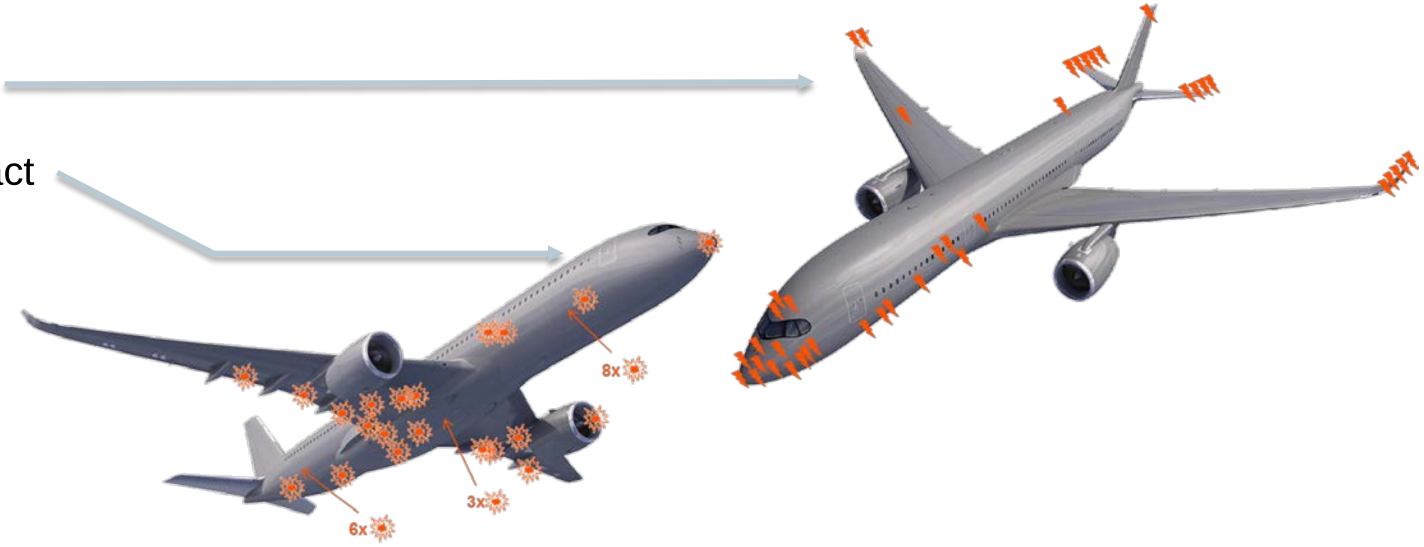
In-service damage since EIS (Entry into Service)







- Lightning strike
- Mechanical impact
- Other
- Bird strike



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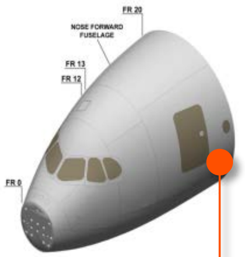
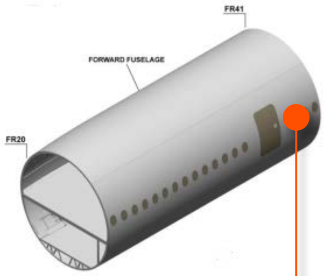
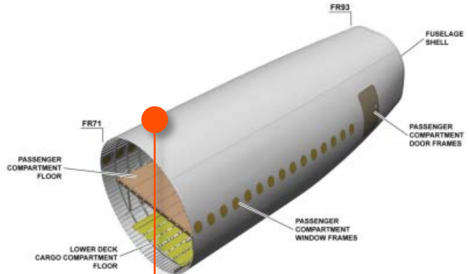
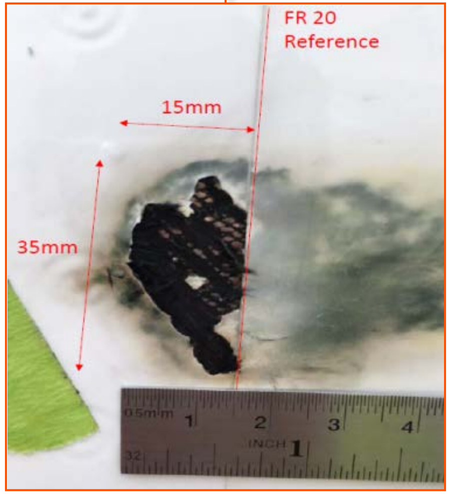
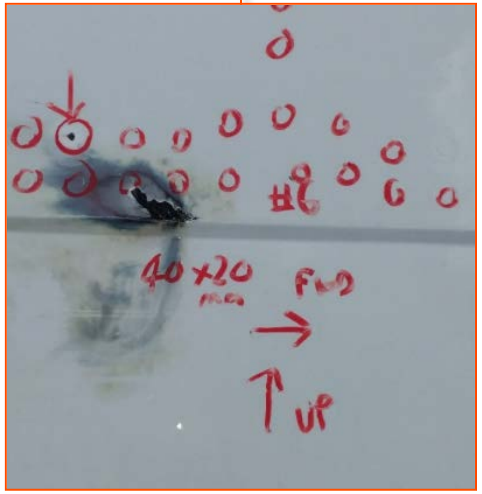
Examples of Lightning strike damage











In service experience = All damage within ADL limits

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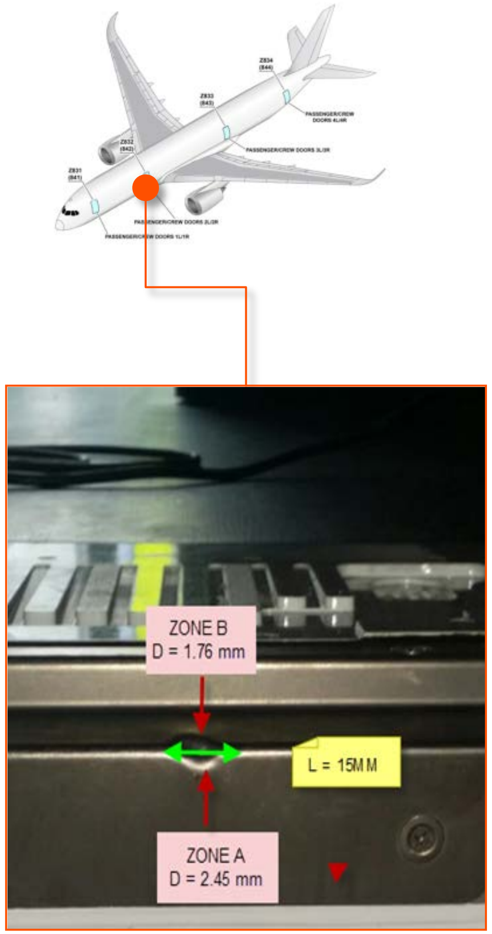
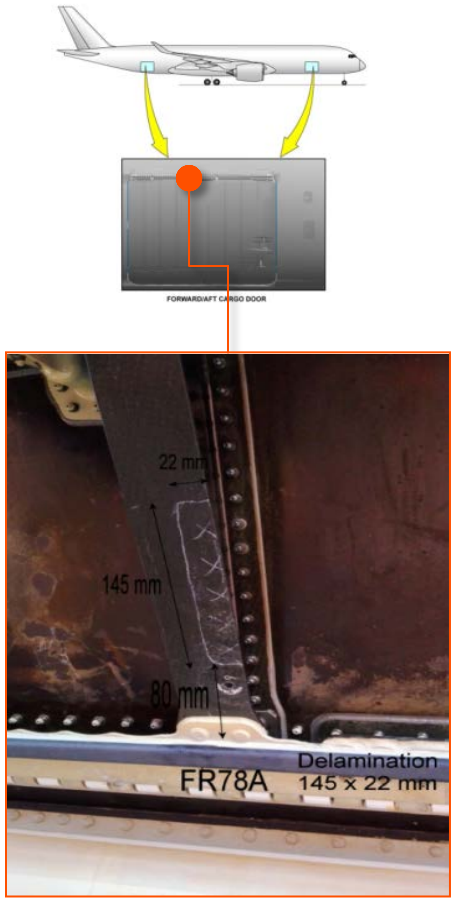
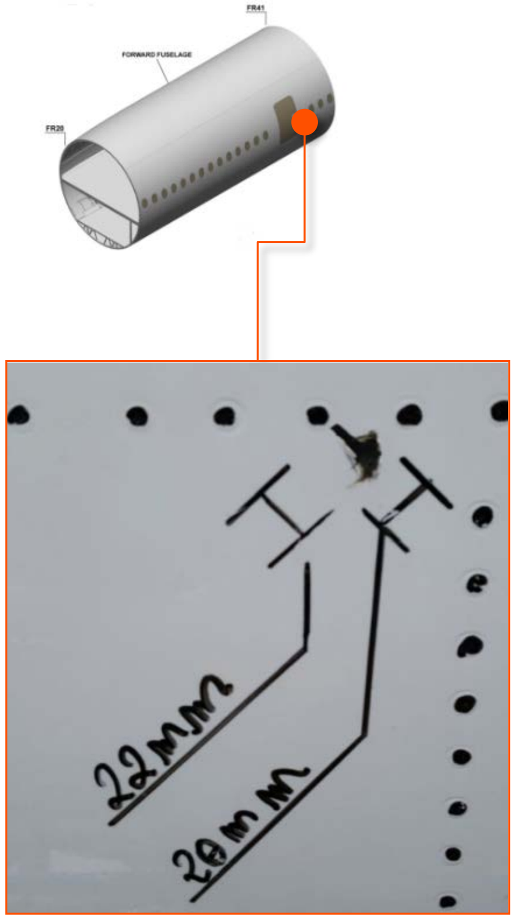
Example of Mechanical impacts



(1) Impact scuff plate



(2) Impact cargo door



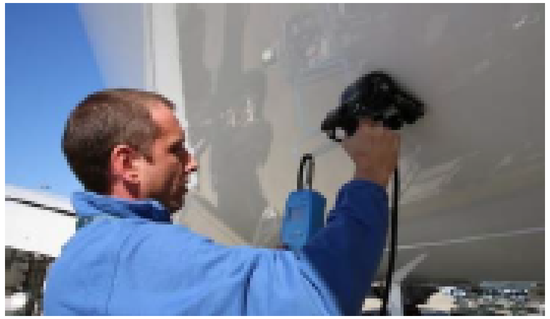
(3) Scratch on fuselage

In service experience = All damage within ADL limits

NDT inspection by non-specialist

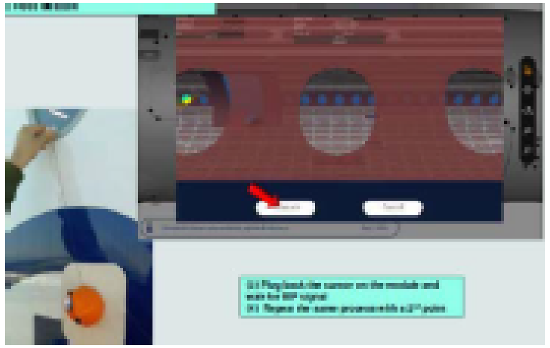
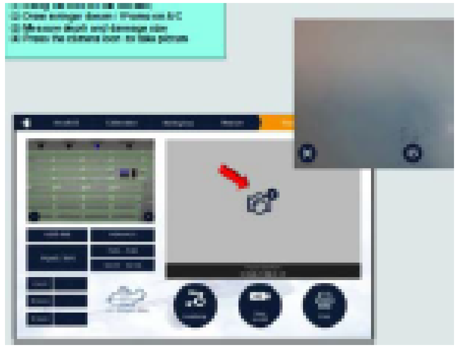
LineTOOL: go/no go composite delamination assessment tool

- Prevent flight delay and cancellation due to lack of Non Destructive Testing expert personnel availability
- Provide quick and reliable statement
- Already available and used by several Operators



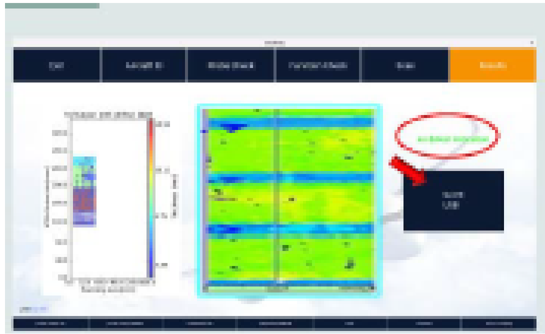

LineMAP: Damage Localisation

- Accurate location of damage on A/C fuselage, automatic integration in A/C DMU (Digital Mock-Up)
- Damage location tracking and report generation
- Already available and used by several operators

LineSIZING: Damage sizing and reporting

- Easy to use device, enable B1 or equivalent mechanics to perform damage sizing on A350 monolithic CFRP.
- Ultrasonic C-scan , automatic damage size measurement.
- Enhanced damage tracking and automatic report creation.

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Quick Cosmetic Repair

- Goal : restoration of Expanded Copper Foil (ECF), filling of small damages, flush result
- Wet lay-up process, 1h cure at 100°C
- “Repair Box” pre-defined with all materials in the same packaging

Available in ASR

Ordering in small quantity

now possible

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Structural Bolted Repairs

- Structural repair are bolted doublers
- Critical step is composite drilling → dedicated equipment required
- Pre-cured standard Repair parts defined to avoid on-demand manufacturing (on lead time)

Figure ICN-A350-A-531161-A-FAPE3-01BGF-A-001-01 SHEET 1/2 - Temporary External Skin Repair

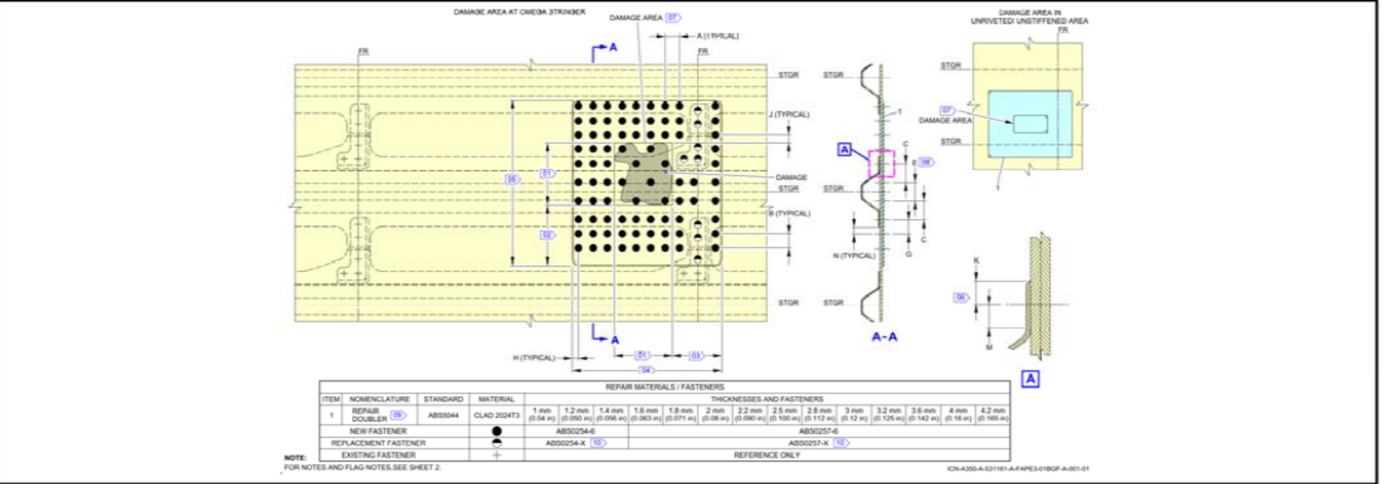
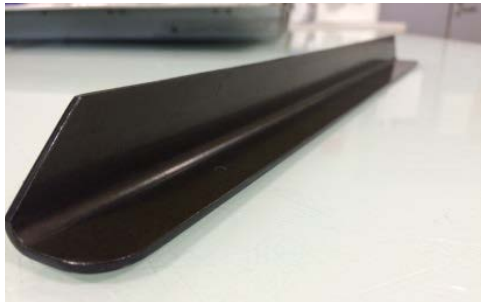
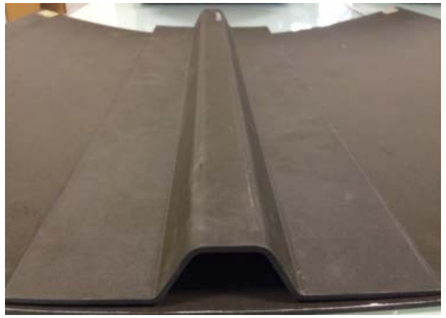


Figure ICN-A350-A-531161-A-FAPE3-01BGF-A-001-01 SHEET 1/2 - Temporary External Skin Repair ON A/C 0006-0020





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Structural Bonded repair

- **Environment conditions**.

›Controlled humidity & temperature

- **Stepping**

›*either* by hand *or* with portable automated machining GSE

- **Curing.**

›Conventional hot bonder & heating blanket and vacuum bag

- **Checks & inspection**:

›Conventional ultrasonic method.

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VIDEO #2

BONDED REPAIR

What's next ?

Flying Economically & Efficiently

Flying Green

Flying "Simple"

Overall airframe architecture and components

Design enabling the integration of systems and other functionalities (Laminar technologies)

Design with highly efficient associated production processes

Capabilities

Design and analysis for value

Rapid prototyping

Virtual testing

In-service support

Self-monitored structures

Predictive maintenance solutions

Technology enablers

Additive manufacturing

Affordable CFRP technologies

Recycling

Recycling and reuse of CFRP structures

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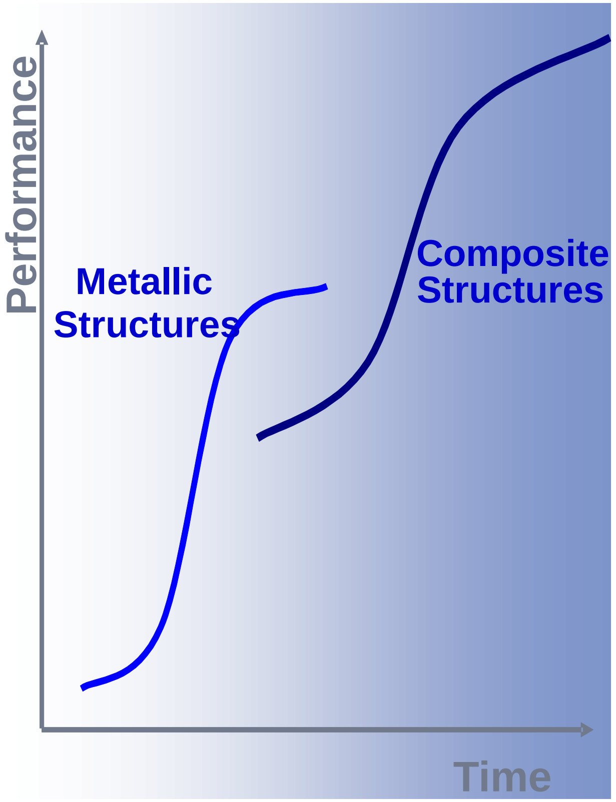
Conclusion



- Airbus accumulates a unique experience in Composite technologies and use of advanced numerical analysis
- Close collaboration with airlines is a strong asset
- Airbus targets higher state-of-the-art standards to ensure that composite components have at least equivalent safety level than metallic product.
- The in-service experience has validated the designs as well as the certification & maintenance concept
- Composite offers unprecedented benefits in terms of efficiency, durability and maintainability and is not yet at technological saturation level
- Composites are part of the solution to the environmental challenges ahead!

Thank You

Q&A