Airbus
Ch Fualdes: Head of Airframe certification

# Experience and lessons learned of a Composite Aircraft

30th CONGRESS
28 Sept 2016-Daejeon KOREA

# A350 XWB – All new efficient design shaping the future

**810**
Orders

**43**
Customers

**30**
Deliveries

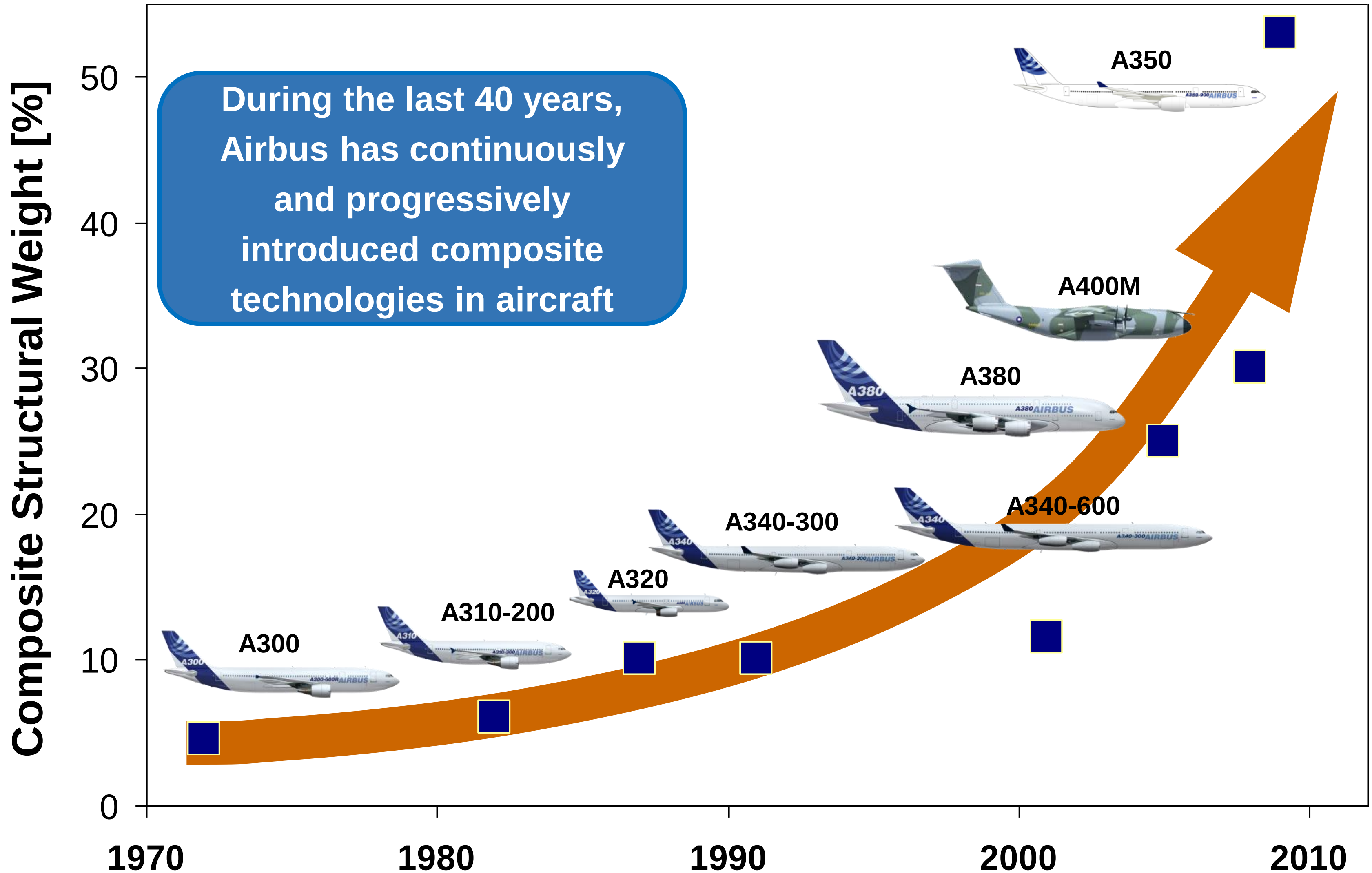
**25%**
Lower operating cost


end July 2016

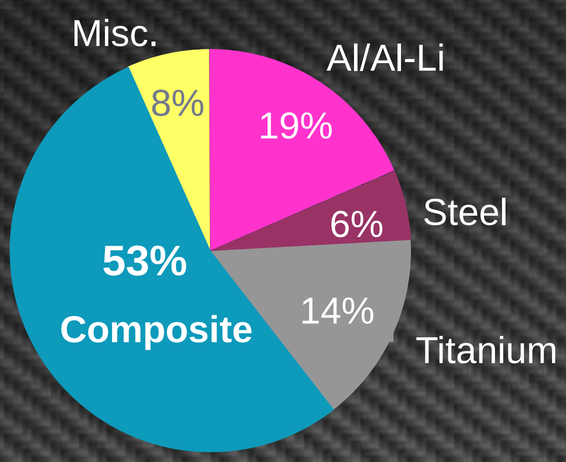
# Content

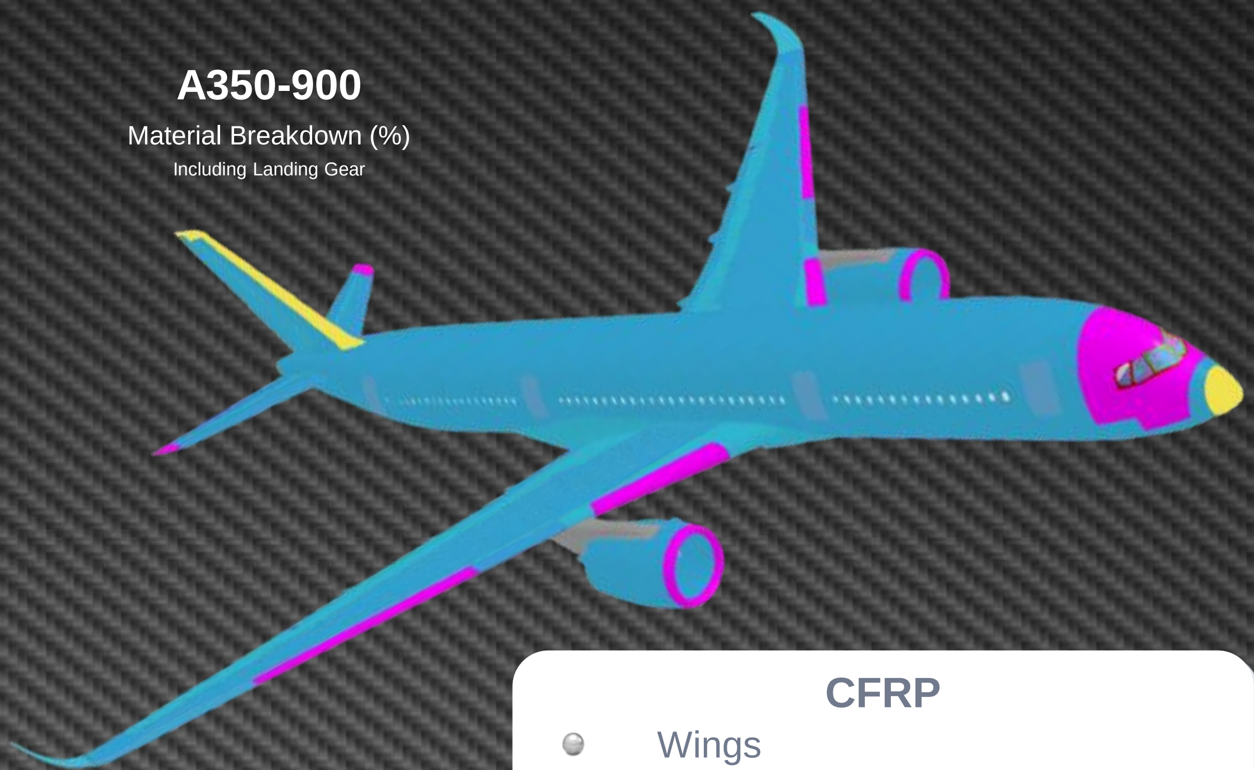
- A350 Composite Technologies & Design
  - Overall design
- Certification & Testing approach
  - Regulatory & advisory material
  - Overall Full Scale Tests
- Key criteria for Maintainability

# Composites use in Airbus aircraft – growing



# A350XWB: The lighter Aircraft 70 % of advanced materials




## Titanium

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

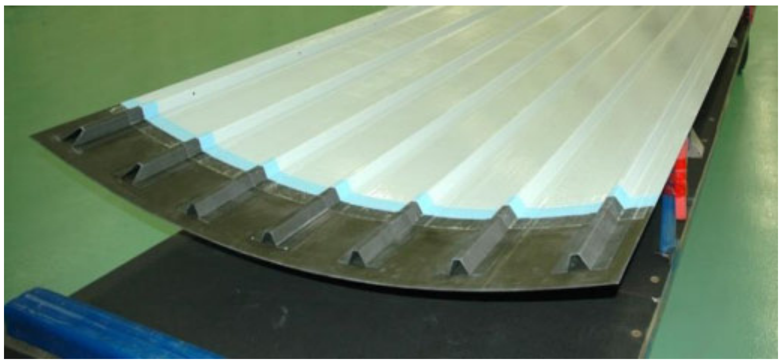
## CFRP

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

# Why Composite?

## Integration of functions

- Bonding replaces riveting
- Reduction of number of parts



## Fiber orientation to fit structural needs

- Better weight optimization
- Better stiffness control (wing shape)

## Reduced maintenance cost

- No need for specific corrosion (re-)protection
- No fatigue behavior

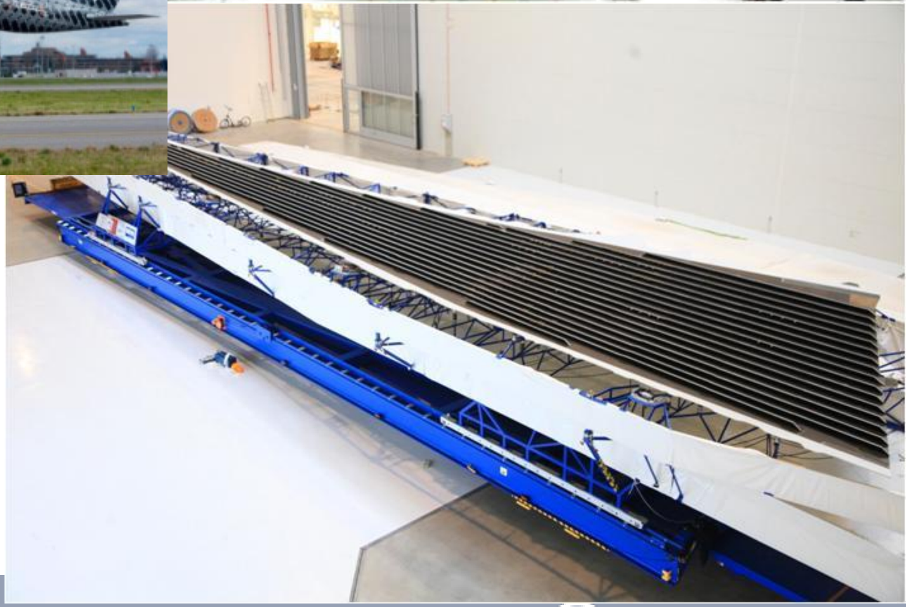
| | 1990 | Today |
|---|---|---|
| Flight cycles | 48.000 | 60.000 |
| Scheduled Maintenance Tasks | 4 years | 12 years |
| Design Service Goal | 20 years | 30 years |

## Higher residual value on 2nd hand market

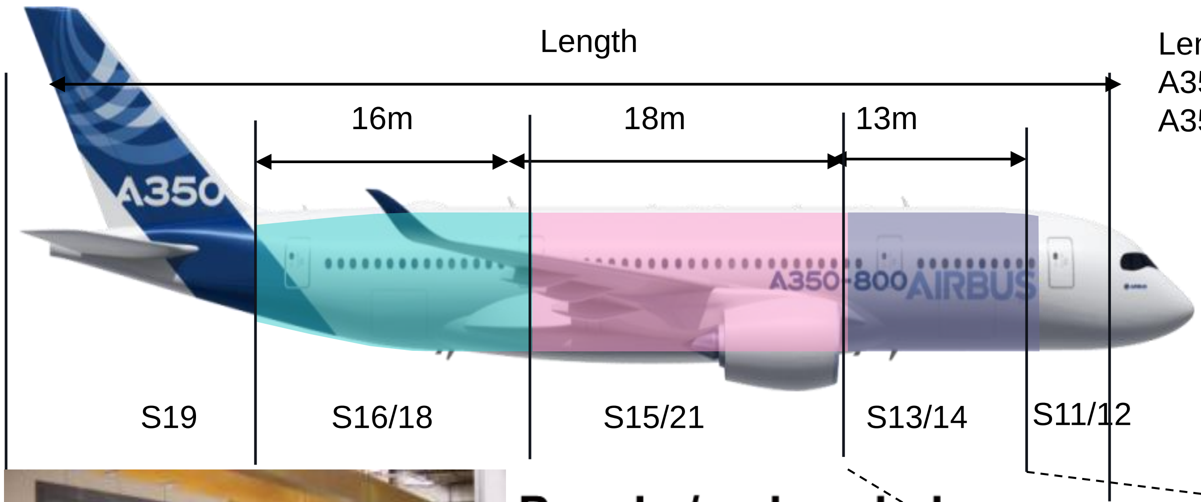
- Major airlines renew fleets every 6-8 years
- Composite repairs / re-build without patches

# A350XWB – Composite Parts

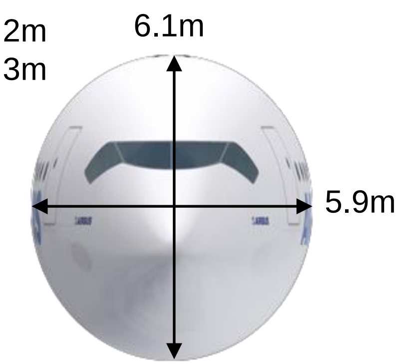




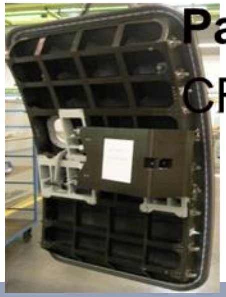
# A350XWB: Composite Technologies & design
## Fuselage Status



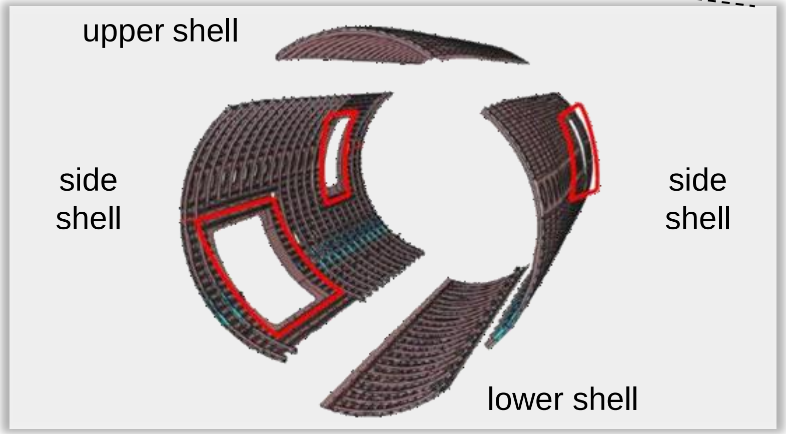

Length
A350-900 65.2m
A350-1000 72.3m




**Panels / cobonded stringers**
CFRP



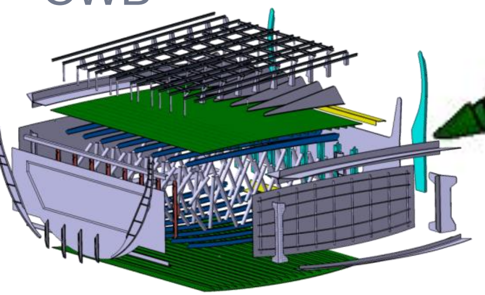
**Pax Doors**
CFRP

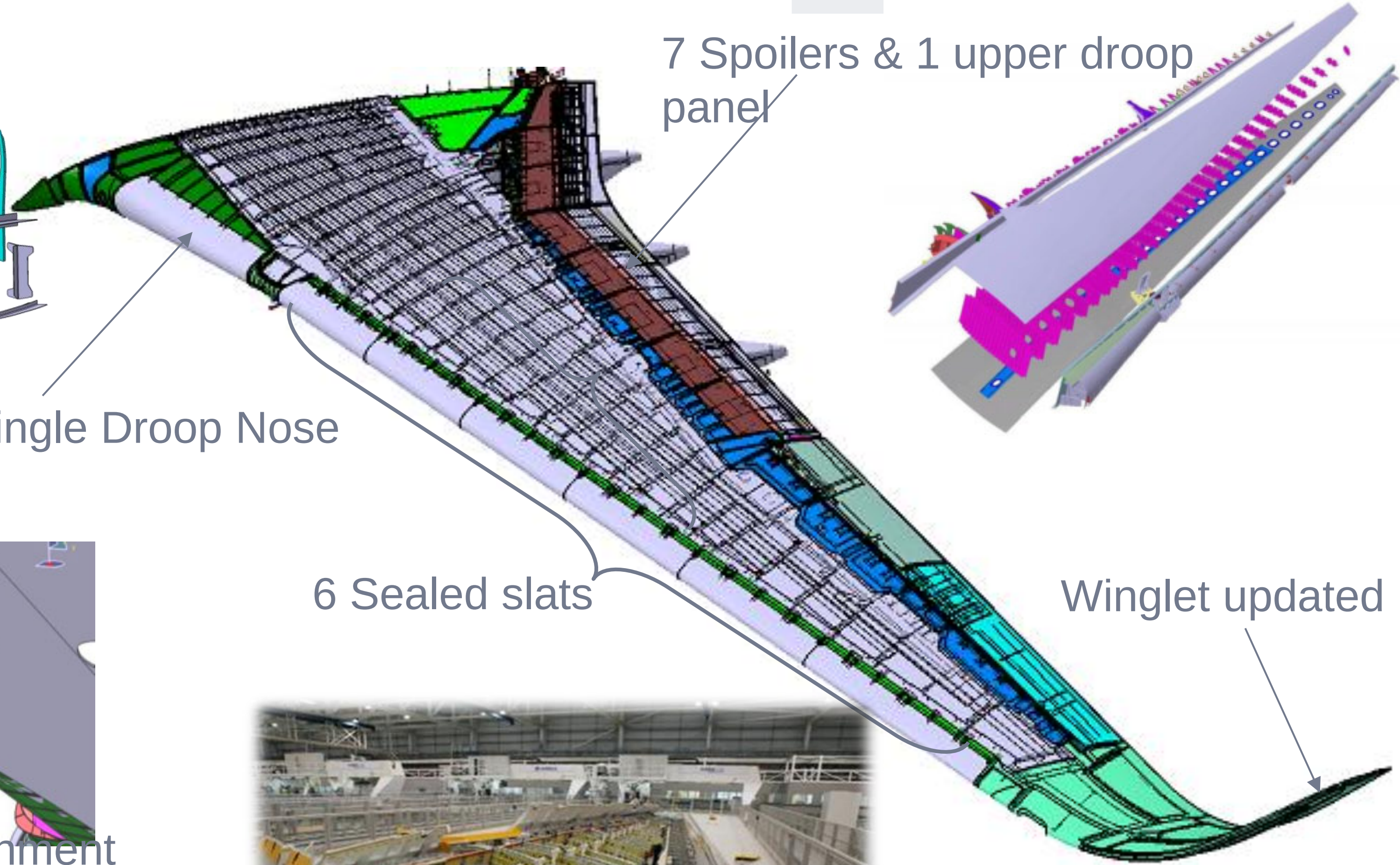


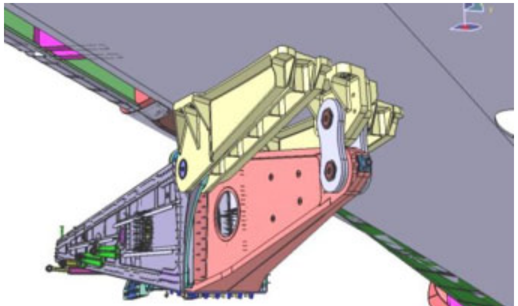

➔Design for efficiency

# A350XWB: Wing Status
## Design for Performance

CWB





Engine pylon Attachment

Metallic Ribs

# A350XWB: Wing Status

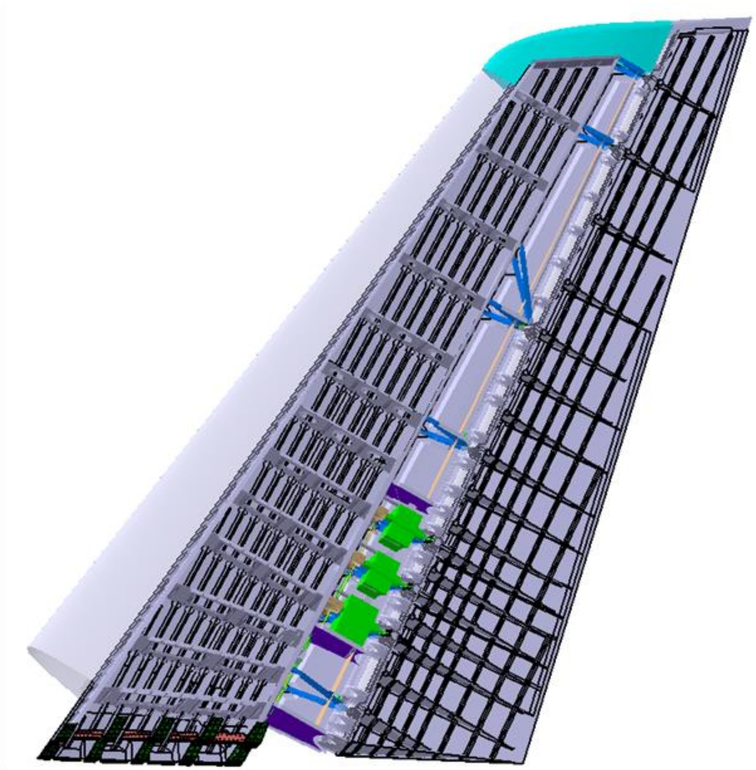

- One piece Cover 32m long,
- Co-bonded process, ATL, pre-cured skin, Tee section stringers ‘wet’
- Copper foil for lightning protection

# A350XWB Empennage Status
## Proven maturity

**HTP &VTP: Improved communality**

Covers: Monolithic construction with “T” shape stringers

- Material : CFRP Tape ( ATL skins )
- Manufacturing process: Hard stringers co bonded to wet skins

*Root Joint : Continuous with tension bolts and Shear angles*

# A350XWB Structure &Technologies

## 3 keys challenges:

- Assess our Airbus “route of the art” with Composite technologies.
  - Certification rules ‘adapted’
  - Need new baseline and re-evaluation (Tail strike, ESN, crash..)

- Reduce Maintenance cost: 12 years maintenance target threshold
  - Fatigue & Corrosion free
  - Design robustness equivalent or better that A330 one

- Design for weight maintaining aggressive industrial ramp up.
  - New technologies with proven maturity (TRL&MRL,...)
  - Engineering & Manufacturing consolidation up to Extended Enterprise

**Standardization was a must to ensure program objectives**

# Content

- *A350 Composite Technologies & Design*
  - *Overall design*

- **Certification & Testing approach**
  - **Regulatory & advisory material**
  - **Overall Full Scale Tests**

- *Key criteria for Maintainability*

# A350XWB CERTIFICATION &TESTING APPROACH

## Regulatory & Means of Compliance Basis updated for Composite Airframe Structure…

- Crash Survivability for Composite structure:
- Static, F& DT for Composite structure
- Post-crash fire resistance of CFRP materials:
- Lightning protection CFRP fuel tanks
- Rotor burst small fragment impact on CFRP fuel tank:
- Tyre debris for fuel tank Structural
- Substantiation of CFRP, Materials & manufacturing processes variability…

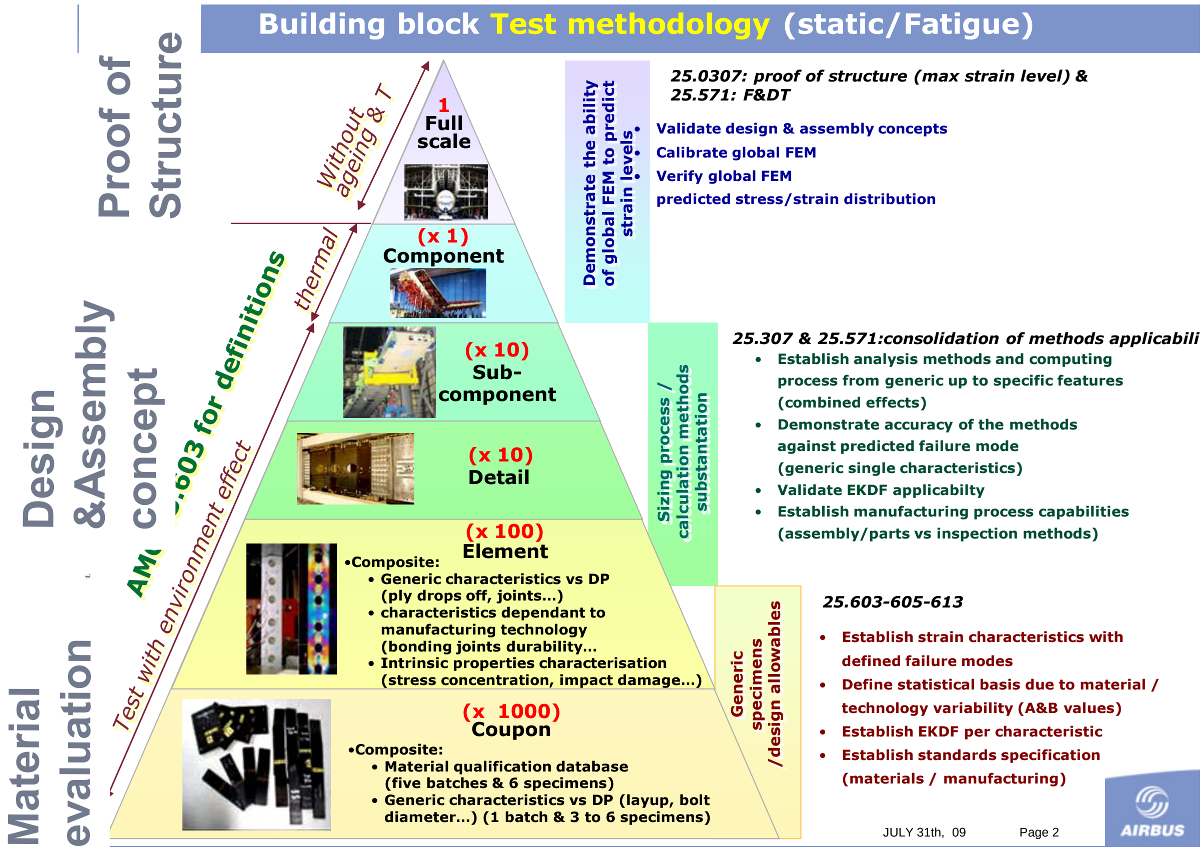
➔Extensive use of established Standard to develop equivalent safety level:
- Building block approach for Tests
- Advanced numerical computing methods

# CERTIFICATION & TESTING APPROACH
## Overall Approach

**CERTIFY [*"Lat : CERTUM FACERE"* – MADE CERTAIN ]**

## ➔ Tests methodology developed on a building block approach

- Block approach used to establish Composite sizing criteria & analysis process
- Comprehensive tests program developed for Wing & Fuselage design validation :




**➔ Large testing program developed**

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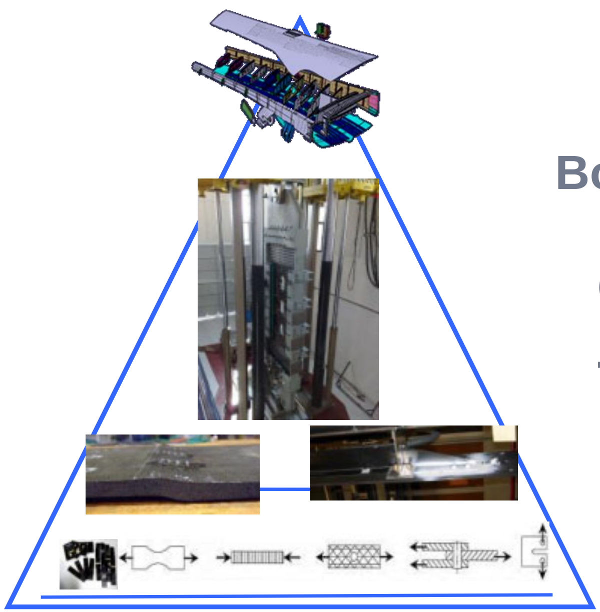
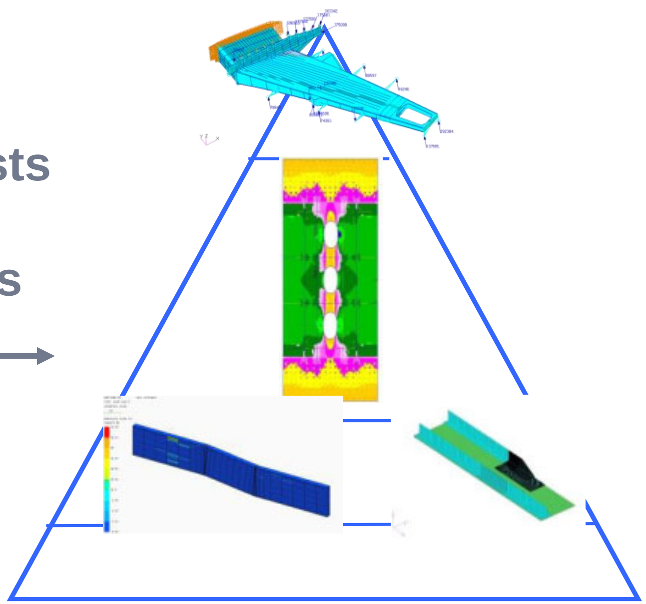
# CERTIFICATION & TESTING APPROACH
## Large demonstrators methodology

- From Physical tests to Computer models
  - 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 is to have calibrated methods & computer models to run predictions' Virtual testing' in anticipation to full scale test: partial wing (EW), fuselage section (Barrels) and full aircraft (ES and EF)



**Boxes Physical Tests**
**to**
**Computed Models**



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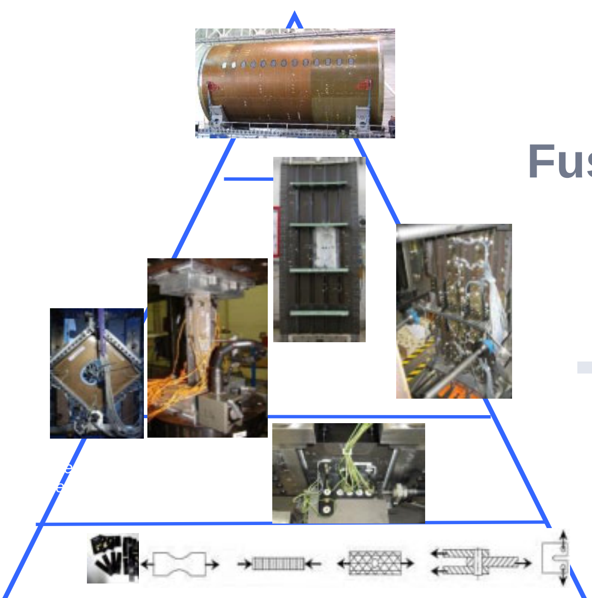
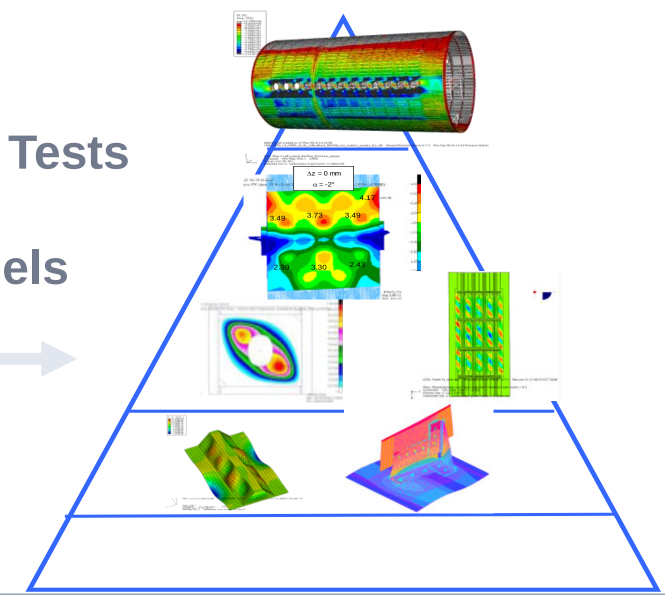


**Fuselage Physical Tests**
**to**
**Computed Models**



# CERTIFICATION & TESTING APPROACH
## Large demonstrators methodology

**Demonstrators developed when design concept doesn't encompass previous experience**

- For Fuselage: 3 Barrels
  - 2 fuselage Demonstrators
  - 1 Pre-development test



- For Wing: 2 Outer Wing Box
  - 1 Wing Demonstrator test

    on top of A400M Wing & Partial wing Box tests

    & CWB test from A380
  - 1 Pre-development Wing Box (E-wing)

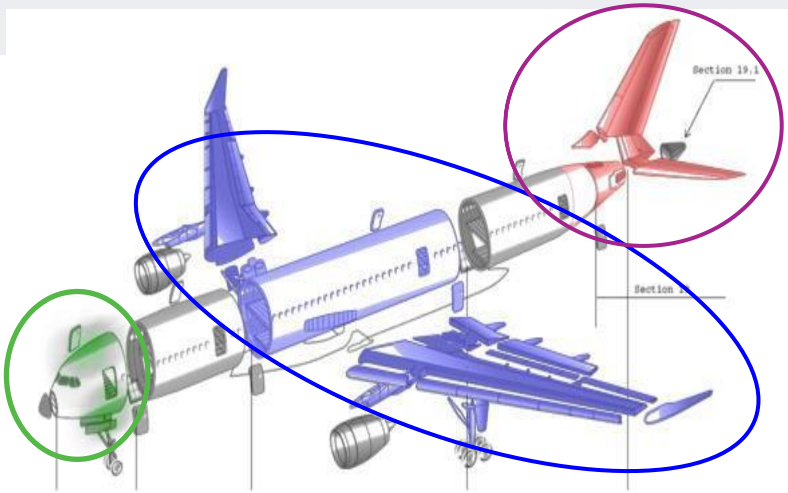


- For Empennage: 1 Root Joint Demonstrator

for Vertical Fin joint attachment towards Tail cone

→ Consolidate Design , Modelling principles & Manufacturing processes

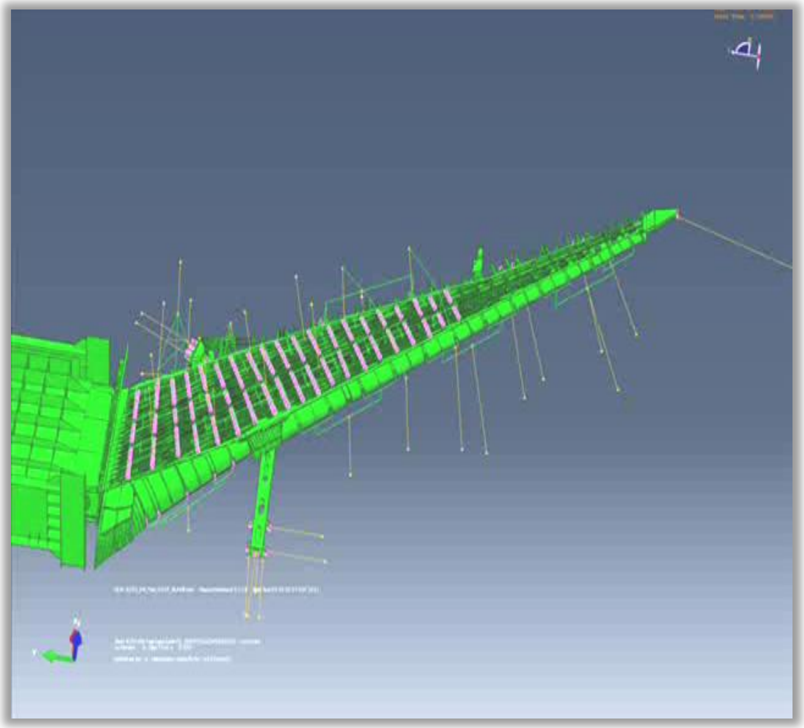
# CERTIFICATION & TESTING APPROACH
## Numerical Simulation

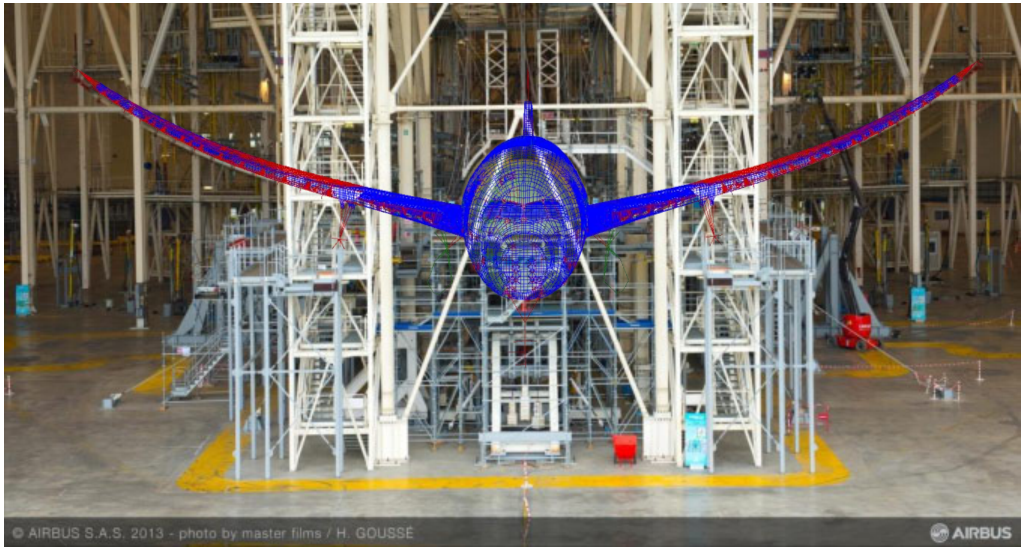



### Finite Element Modelling

Example: Virtual Full-Scale Test

- 68 million degrees of freedom
- Risk mitigation, secure static test campaign





# CERTIFICATION & TESTING APPROACH
## Full-Scale Fatigue Tests

### Nose Fuselage

**Toulouse, France**

Fatigue Campaign started 22/10/13

>10.000 simulated flights achieved in May 2014

Test ended in Q4 2015

### Center Fuselage

**Erding, Germany**

Fatigue Campaign started 24/04/14

<1.000 simulated flights achieved in May 2014

Test ended in Q2 2016

### Rear Fuselage

**Hamburg, Germany**

Fatigue Campaign started 12/03/14

>5.000 simulated flights achieved in May 2014

Test ended in Q3 2015

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# A KEY CRITERIA FOR MAINTAINABILITY DESIGN&ROBUSTNESS EQUIVALENT TO A330

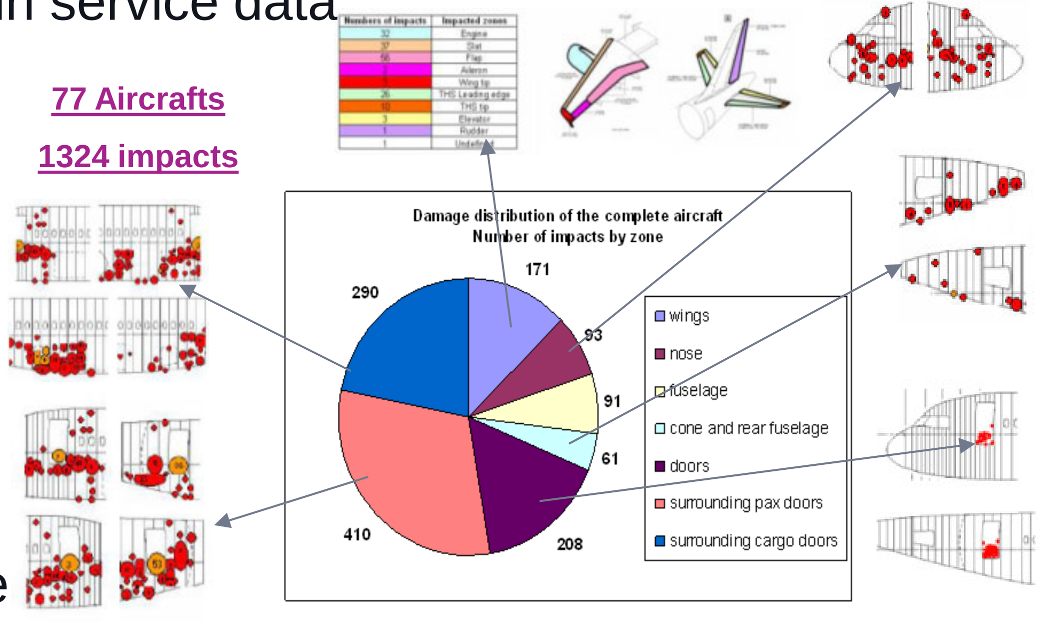

Improved performance and reduced maintenance with a big step as most of the <u>external structure</u> is in CFRP

# A KEY CRITERIA FOR MAINTAINABILITY
## Robustness

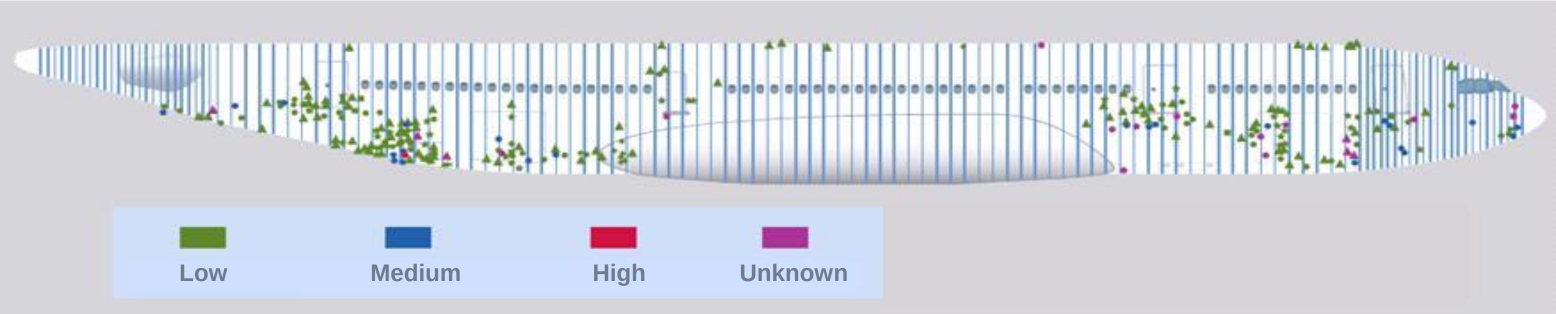
- Accidental dent assessment from in service data
  - Statistical analysis for equivalent robustness between LR program

**77 Aircrafts**

**1324 impacts**




- Aircraft zoning for impact resistance
  - Translation of LR metal dents into A350XWB CFRP dent



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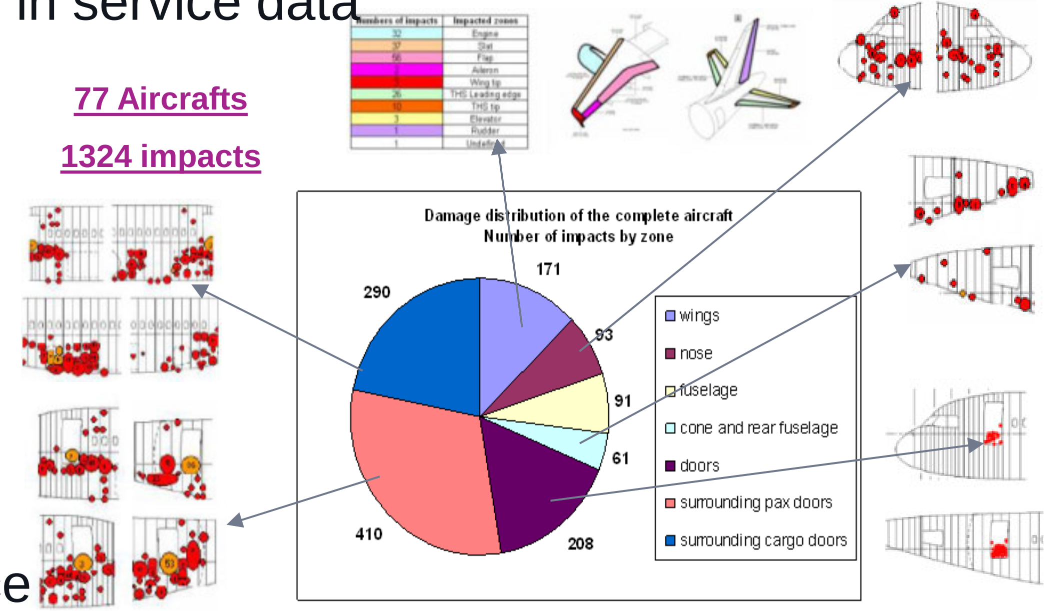


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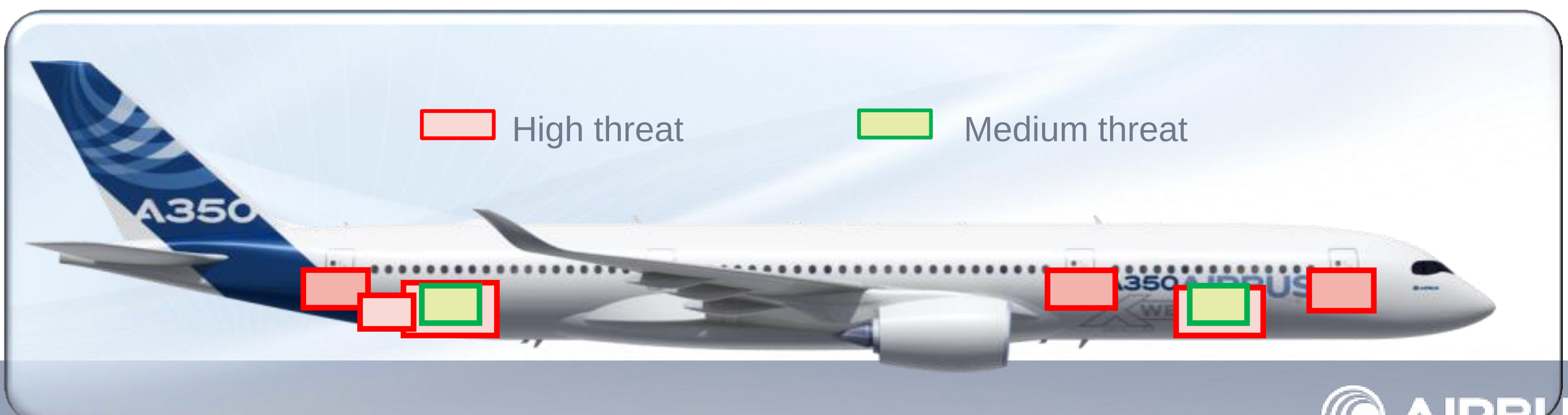


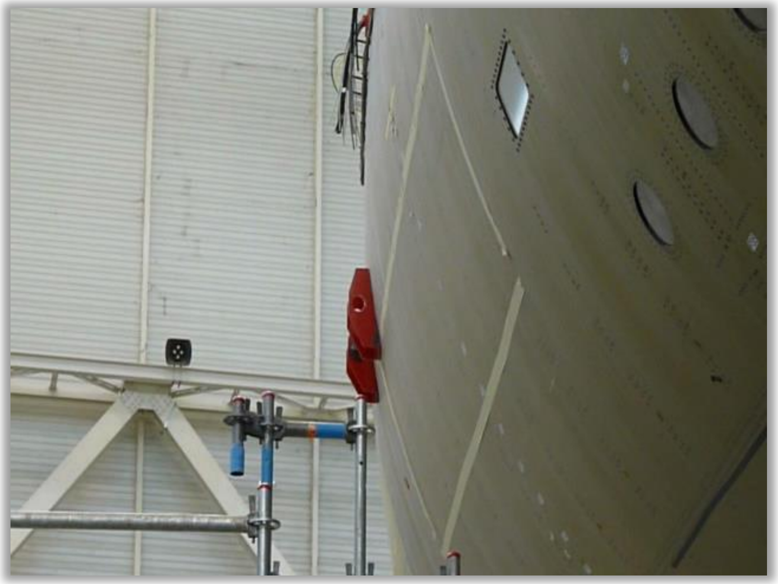
# A KEY CRITERIA FOR MAINTAINABILITY Robustness

## Ground Operation Risks

- Short turnaround times
- Simultaneous operations, multiple vehicles

## A350XWB Maintenance

- **-52%** structure tasks compared with A330
- Structure task interval significantly increased compared with A330
- **-45%** scheduled maintenance hours over heavy maintenance cycle (12 years) than on A330



# A KEY CRITERIA FOR MAINTAINABILITY
## Primary Structure Composite Repairs

Extensive experience to repair regardless whether it's metal or composite

- Majority of events involved secondary structure like belly fairing panels, nacelles...
- Primary structure
  - Empennages (since A300), ATR72 Wing, A380 Rear Fuslelage
  - Example on Recent event of tail cone damage
    - Tail cone cut by winglet of passing aircraft
    - Repaired in situ

Repair definition, production and embodiment in same time as for metallic structure

# A KEY CRITERIA FOR MAINTAINABILITY
## Primary Structural Bonded Repairs

### Concept

- **Flush Bonded repair** (permanent, no inspection) bonded repair on **Principal Structural Elements.**

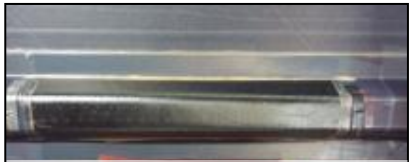
- Current focus on most likely damage scenarios & locations:
  - **Fuselage skin** delamination and perforation.
  - **Fuselage stringer** delamination & disbond.

- **Selected repair material set**
  - Material selection & Qualification in the framework of the CACRC (Civil Aircraft Composite Repair Committee).

Fuselage shell. Lightning strike

Rear fuselage. Double curvature

Skin perforation and two stringers disbonded

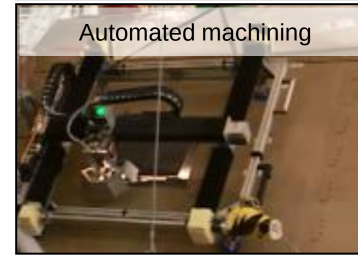


Repair of impact damage on stringer head

# A KEY CRITERIA FOR MAINTAINABILITY
## Primary Structural Bonded Repairs

### Embodiement process

- **Environment conditions**. A/C in hangar. Preparation of prepreg plies in a humidity & temperature controlled environment.
- **Stepping** *either* by hand *or* with portable automated machining GSE
- **Curing.** Conventional hot bonder & heating blanket and single vacuum bag cover most damage scenarios & locations.
- **Checks & inspection**:
    - Water break test.
    - Conventional ultrasonic method.


Automated machining


Repair patch curing set-up


Water break test

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# Conclusions

- Airbus has accumulated a unique experience in Composite technologies. Especially the numerical simulation of composite structures has evolved significantly.
- The progressive introduction approach used by Airbus for new technologies and especially composites, in very close cooperation with the airlines, has proven to be very efficient.
- The in-service experience has validated the designs as well as the certification approach and the maintenance concept of these structure technologies.
- Many opportunities remain, composite not yet at “saturation level”.