8IARCSFC 2016 – ATLANTIC CITY

D. HACHENBERG / V.LAVIGNE / M.MAHE

Crashworthiness of fuselage hybrid structure

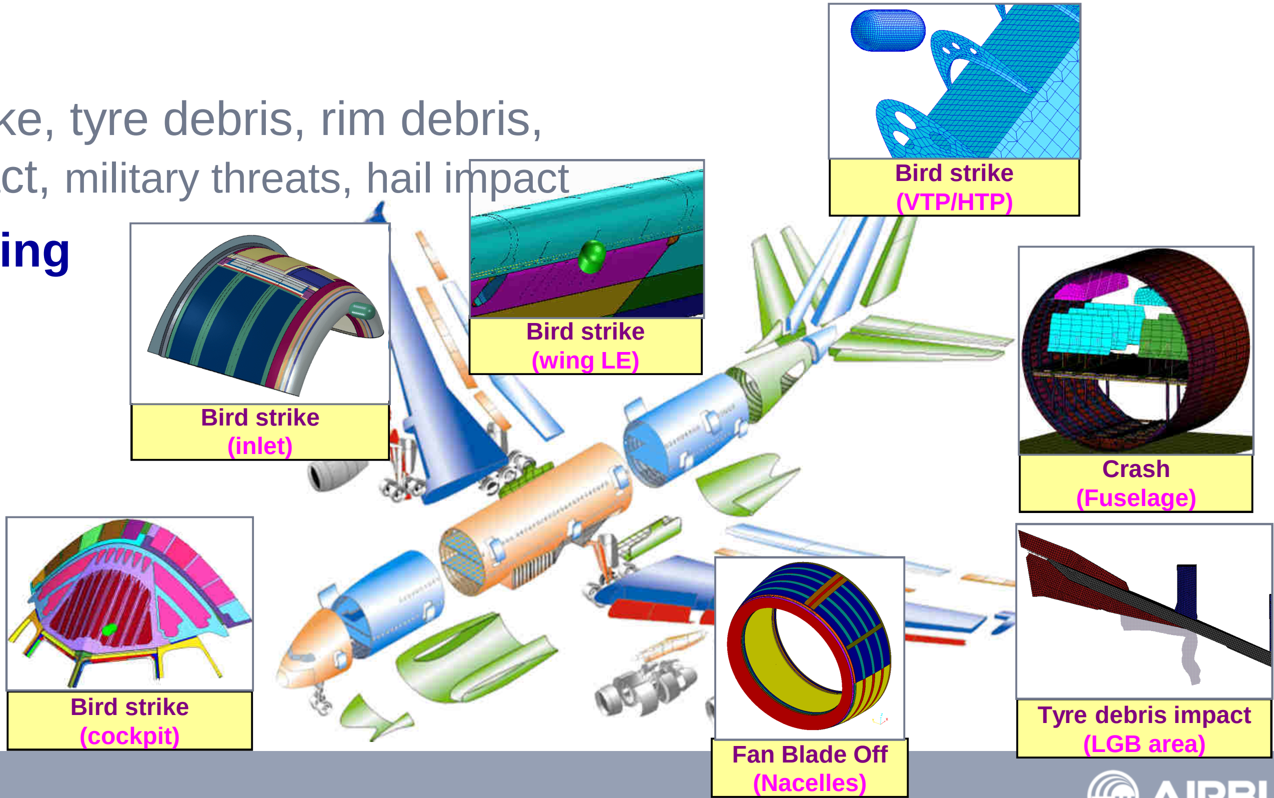
AIRBUS

Contents

Application of dynamic simulation on the aircraft

More than 20 years of experience for both metallic and composite airframe structures

- **Impacts:** bird strike, tyre debris, rim debris, Hard Debris Impact, military threats, hail impact
- **Crash and ditching**



Application of dynamic simulation on the aircraft

Extensive usage of dynamic analysis from early development stage:
Close collaboration between material, design, stress and test up to process and manufacturing

- Design principles: investigate technologies, concept
- Detailed sizing : safe and optimised design
- Experimental tests : define optimal test set-up and de-risk tests
- Compliance demonstration

➔ Bring robustness to the design

AIRBUS

Fuselage crashworthiness requirement

- Regulation: *(CS/FAR 25.561): "The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing"*
- EASA & FAA raised a Special Condition (SC) on crashworthiness to address new fuselage concept (CFRP material):
- For fuselage crashworthiness, the SC requires the demonstration of *Equivalent Level Of Crash Survivability* w.r.t. already certified comparable metallic aircrafts. Comparison is addressed based on 4 survivability criteria :

- Living space
- Retention of heavy items of mass
- Passenger acceleration levels
- Maintenance of egress path

AIRBUS

Hybrid fuselage crashworthiness technical challenges

1. Find the right balance between :

- Ensure the maintenance of the living space.

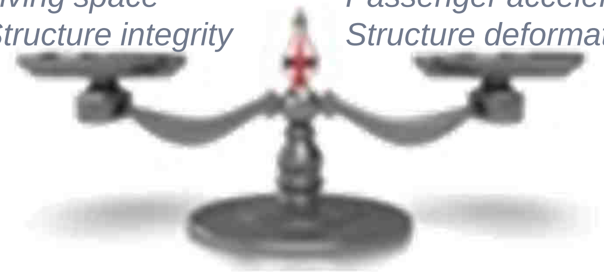
[ENABLER]: limit the deformation of cabin floor & cabin upper structures

- Limit the passenger acceleration levels = limited & regular deceleration during impact.

[ENABLER]: mechanism of energy absorption : intrinsic structure behaviour w/o additional features

Living space
Structure integrity

Passenger acceleration
Structure deformation



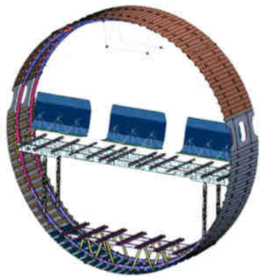
Hybrid fuselage crashworthiness technical challenges

2. Hybrid structure: coexistence of two material behaviours:

- Metallic ductile (plastic deformation)
- Composite primarily elastic behaviour but good design can offer efficient energy absorption

3. Complex analysis

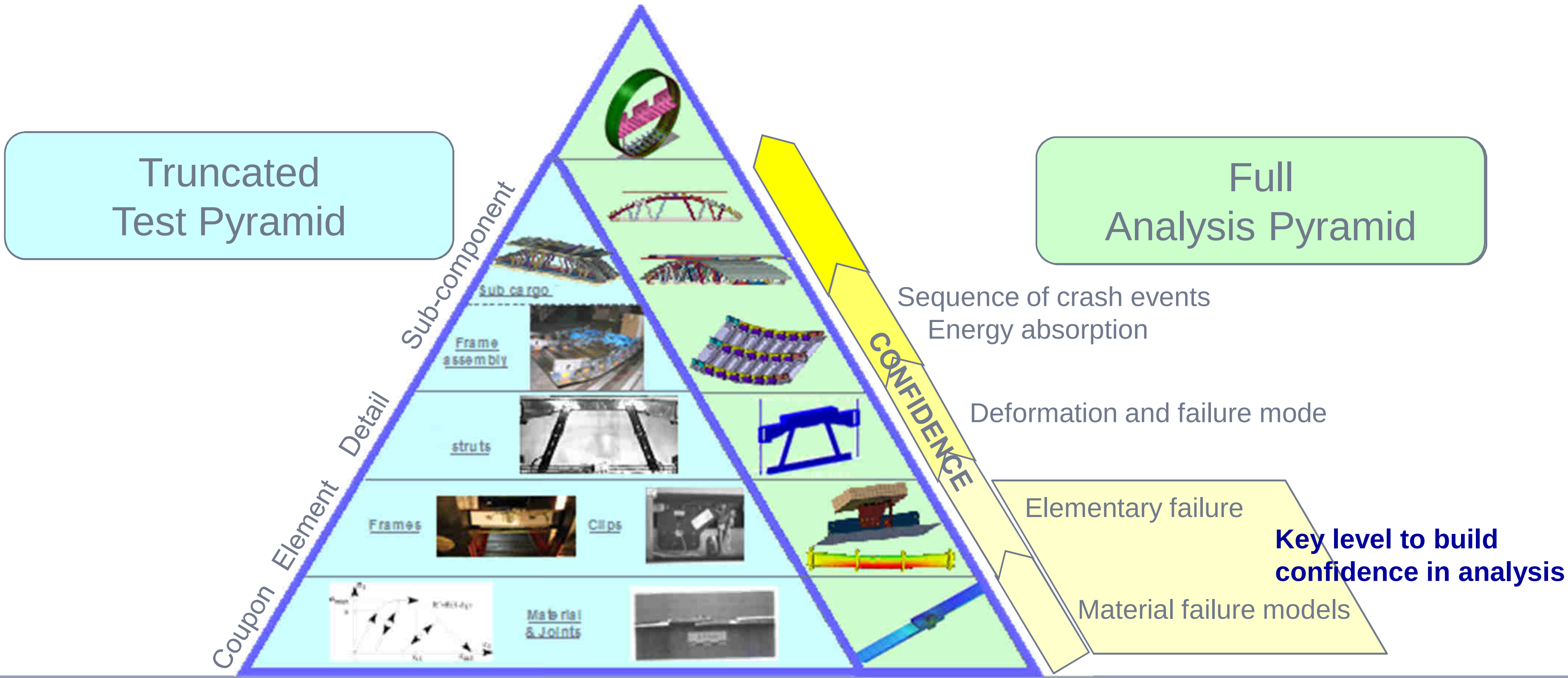
- Large fuselage section DFEM
- Crash duration ~500 ms
- High deformation and multiple failures involved
- Several pax/cargo load configurations



2 frame bay DFEM

➔ Need for predictive, reasonably quick numerical tool to be used all along the aircraft development

Crashworthiness building block approach



AIRBUS

Crashworthiness building block approach

- Added value of pre-test simulation:
  - Define appropriate test set-up and conditions (tolerances …)
  - Define instrumentation means and set-up : HS camera, strain gages, displacement sensors, load cells
  - De-risk test: robustness analyses including test condition tolerances, back-up instrumentation.

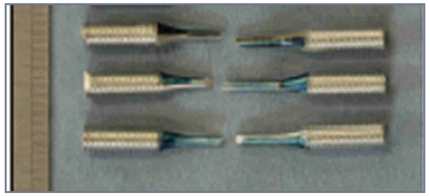
➔ Right the first time

Crashworthiness building block approach

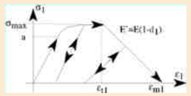
Coupon level

[identification] Material and joints full characterisation up to failure

Metallic material:
Tensile/compressive properties

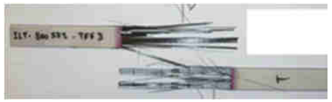


- Elastic properties
- Hardening
- Damage & plastic failure



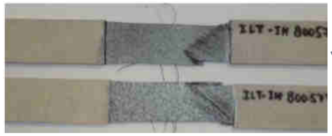
Composite material:
Intra & inter-laminar properties

Fibre failure



Matrix failure

Shear failure



DCB …

- Elastic properties
- Strengths
- Shear damage/plasticity
- Fracture toughness

Joints:
metallic, composite, hybrid

Single (Double) Lap Shear Test

Bolt Pull-Through Test (BPT)

- Elasto-plastic inc. failure for tensile, BPT, shear

➔ Extensive test programs = key to set up accurate failure models allowing to build confidence

AIRBUS

Crashworthiness building block approach

Element / Detail level

[validation] Understanding & prediction of elementary failure of parts or function

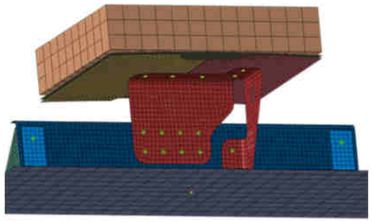
Under static loading
- Metallic frame bending
- Composite frame bending

…

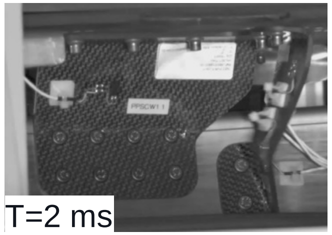
Under dynamic loading
- Clip failure
- Composite strut
- Metallic strut

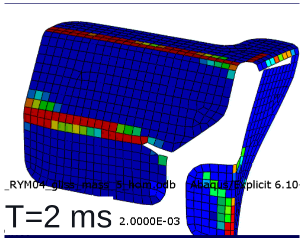
…

CLIP



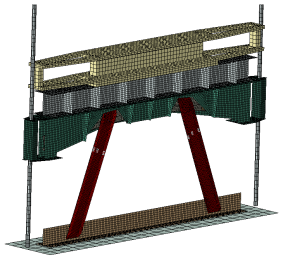
Falling mass on an "upside-down" specimen

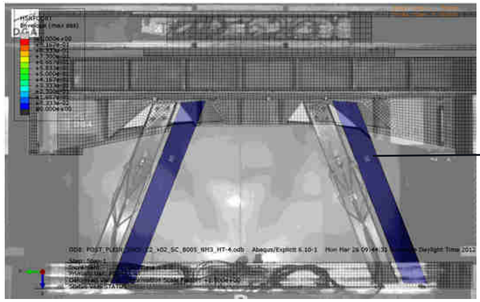


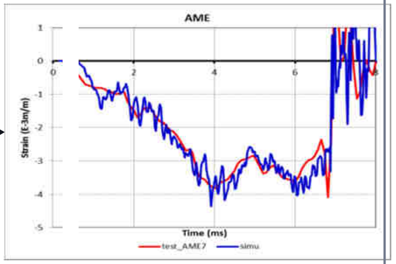


➔ Unfolding/bending failure

STRUT







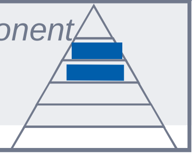
Falling mass on an "upside-down" specimen

➔ compressive/bending failure

➔ Good level of prediction of the deformation and failure modes under crash loading

Crashworthiness building block approach

Sub-component level

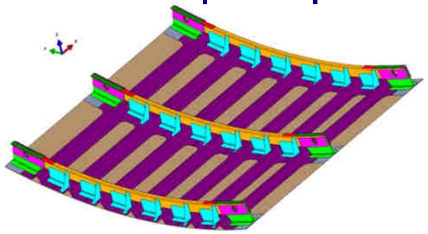


[validation] Prediction of crash mechanisms sequence and structural failure modes

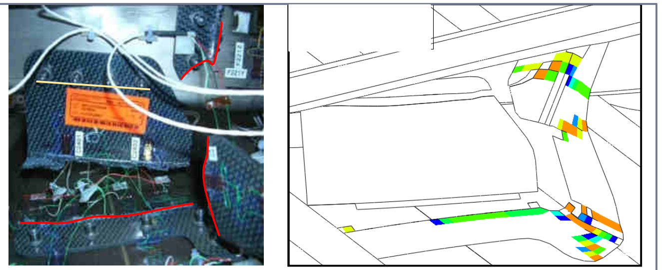
Under crash loading
- Frame assembly

Correlation of :
- clip failure
- frame deformation
- skin bending

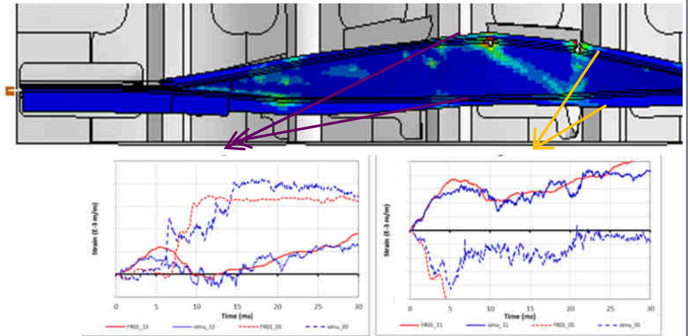
3 frames curved panel specimen



Falling mass on an "upside-down" specimen



➔Elementary failure mode



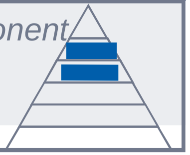
➔ Sequence of events & energy absorption

➔ Good level of prediction of crash mechanisms, sequence of events, energy absorption capability

AIRBUS

Crashworthiness building block approach

Sub-component level



[validation] Prediction of crash mechanisms sequence and structural failure modes

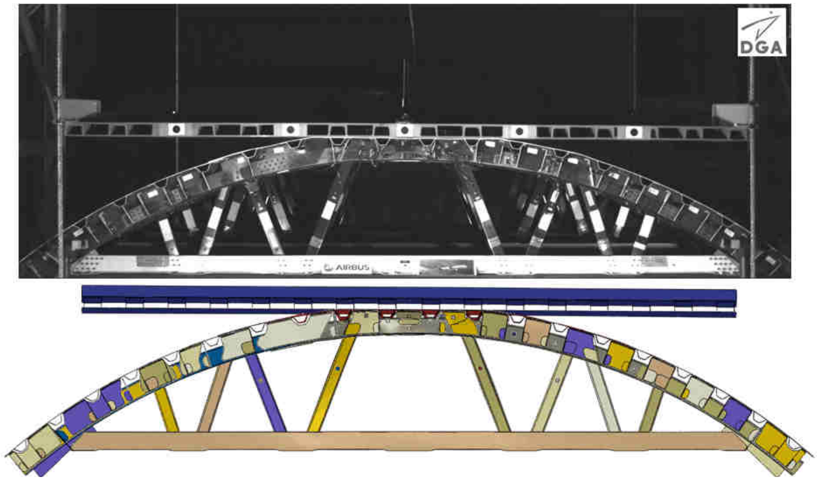
Under dynamic loading

- Fuselage bilge structure

Correlation of :
- clip/strut failure
- frame deformation
- skin bending

Fuselage bilge area (multi frames)

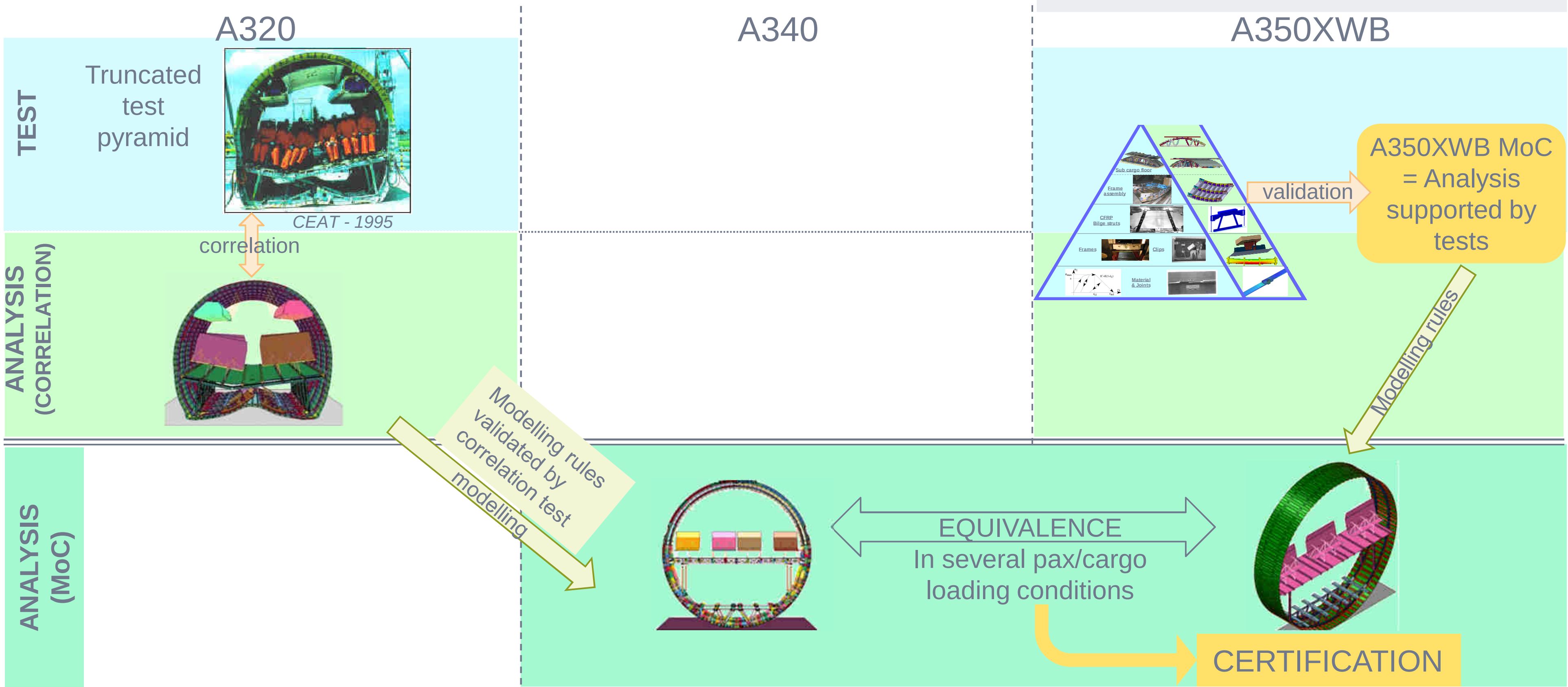
Falling mass on an "upside-down" specimen



➔ Good level of prediction of crash mechanisms, sequence of events, energy absorption capability

AIRBUS

Dynamic numerical analysis as Means of Compliance



AIRBUS

Synthesis

- Maturity of dynamic simulations for both metallic and composite structures
- Future need of intensive usage of validated dynamic simulation to select: material, technologies and design principles
- High level of robustness of the developed hybrid fuselage concept versus crashworthiness requirement
- Further usage of validated dynamic simulations for derivative and future programs
- Build model for dynamic numerical analysis, validation, test program, run simulations, and analysis of results = significant engineering effort

Thank you for your attention

AIRBUS