AIRBUS Composite fatigue &damage tolerance Sessions

Louis RATIER– Chantal FUALDES

Sept 2015: FAA/Bombardier Composite Transport DT & Maintenance Workshop

Airbus Composite Fatigue and Damage Tolerance certification experiences.

Composite Fatigue and damage tolerance Experience

✓ **Long History of Composite technologies in Primary Airframe structure**

Fleet experience , on Airbus programs, show more *than 200 millions of Flight Hours* now been cumulated

Design & analysis & validation methodology benefit *of 50 years of experiences*, since A300 to A380,

***Hundreds* of large Sub components to full scale Components Tested**

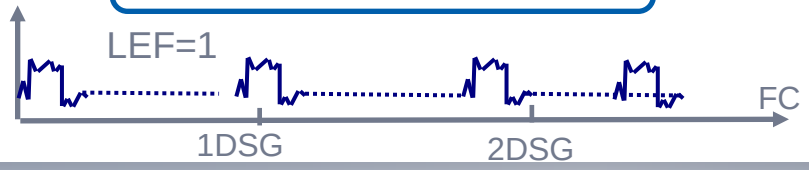
Good reliability & durability established that should benefit to A350 Fatigue and damage tolerance validation.

The challenge: Hybrid Fatigue Full scale Cells ?

Current scenarios: Tests cells duplication ➔schedule& cost impact…

Metal test scenario

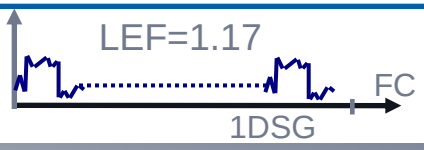
- Fatigue sensitive areas: all stress concentration areas
- Fatigue mainly driven by local tension loading R=0.1
- Scatter covered by Test Life factor : 2 …3



Composite test scenario

- Fatigue sensitive features: Feature with out-of-plane stresses Shear and Tensile inter lamina strength
- Compression: Mainly driven by compression and alternative loading R=-1
- Scatter covered by LEF Load Enhancement Factor: 1.17*

*from Northrop approach



The challenge: Hybrid Fatigue Full scale Cells ?

Adapted scenarios: Consolidate composite Fatigue sensitive feature, Converge on LEF (metal/composite) :

Metal test scenario

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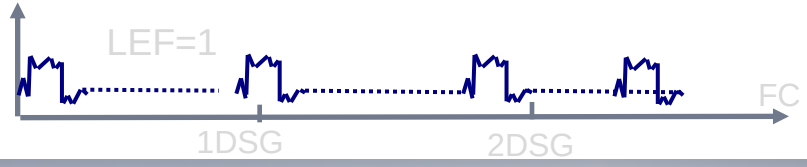

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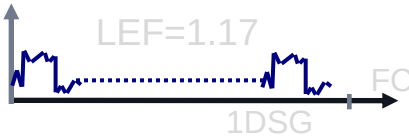

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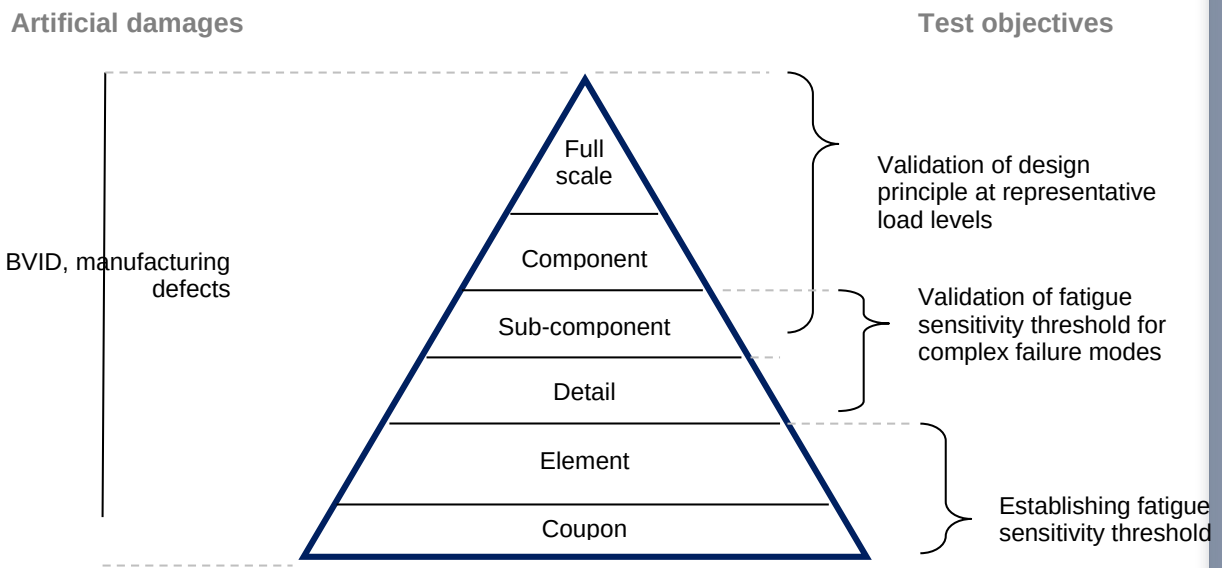
Overall Approach for Fatigue & Damage Tolerance

➔ **The principle : Large testing background capitalized on a building block approach used to consolidate the fatigue insensitive threshold of the material**

- Comprehensive tests program developed for the fatigue scatter characteristic from key design/strength:
- Consolidate the fatigue insensitivity thresholds, through coupon and element testing
- validating the approach at higher levels when required



BVID: Barely Visible Impact Damage

➔ **Dedicated A350 tests developed**

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Coupons to elements specimens

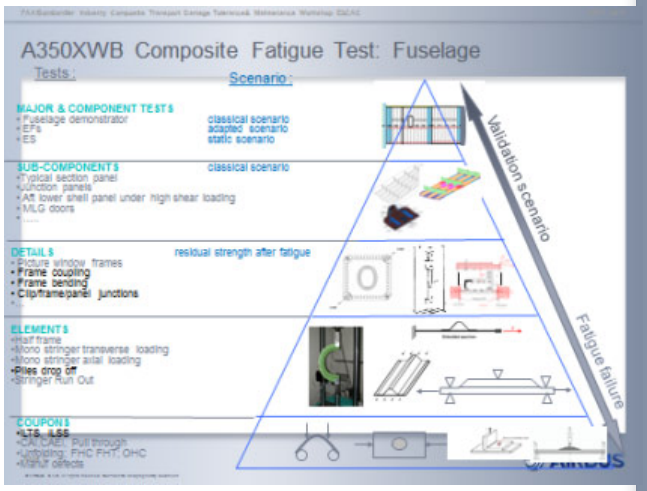
Goal: Establish Suitability and Durability of materials after repeated loading (as per CS25.603 & AC20.107B (8) b)

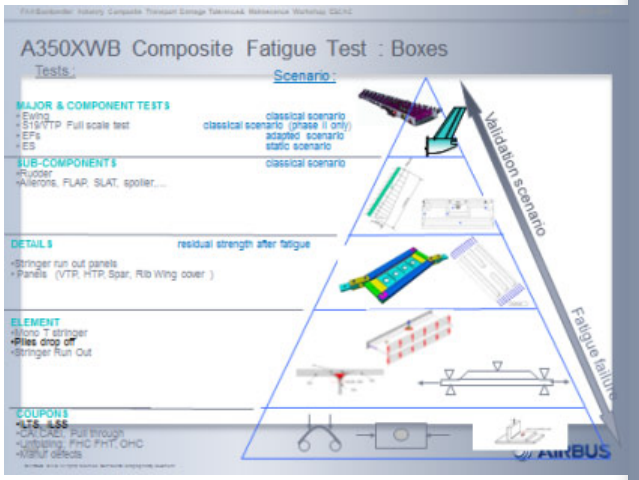
How:

Determine on selected feature failure mode & material :

- Damage onset and residual strength capability
- Variability in fatigue results (scatter characteristics)
- Environment effect (wet exposure)
- Relationship stress – life (SN curve and slope)
- Load sequence: spectrum / constant amplitude loading effect

➔ **No material degradation from repeated loading was demonstrated**.





LEF definition: Northrop's analysis

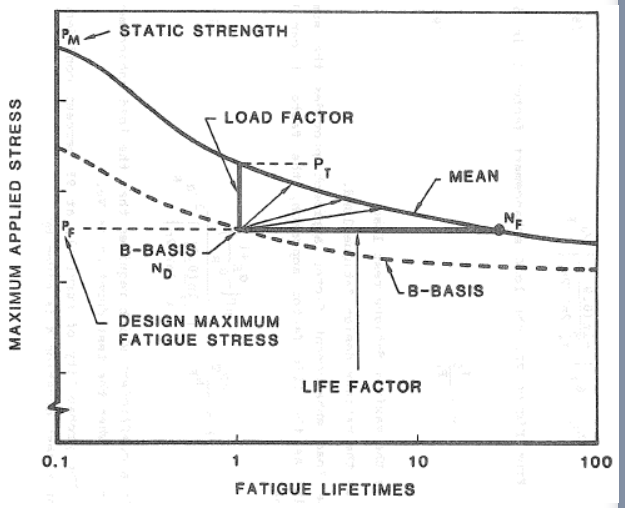
Load Enhancement Factor has been introduced on fatigue composite full scale test as a response to the higher scatter observed on fatigue composite tests

Composite standard approach:

1986-Northrop's report proposed a 2 parameters Weibull law analysis.

Resulting from a large number of coupon tests,

N	1	1.5	3	13.3
LEF	1.177	1.148	1.10	1



$$LEF = \left(\frac{N_F}{N}\right)^{\frac{\alpha_L}{\alpha_R}}$$

$$N_F = \frac{\Gamma\left(\frac{\alpha_L+1}{\alpha_L}\right)}{\left[\frac{-\ln(p)}{\chi^2_\gamma(2n)/2n}\right]^{\frac{1}{\alpha_L}}}$$

N_F is the resulting life factor for LEF=1
α_R Weibull shape parameter for the scatter on residual strength properties
α_L Weibull shape parameter for the scatter on fatigue life properties
p Survival probability (90% for the B-value definition)
g Confidence (95%)
N Coefficient applied on the life (N = Life Factor when LEF = 1)
n Number of test articles (usually one for a full-scale test)

Remarks : Test campaign with all failure mode (not focused on sizing criteria)

LEF definition: Northrop's analysis (con't)

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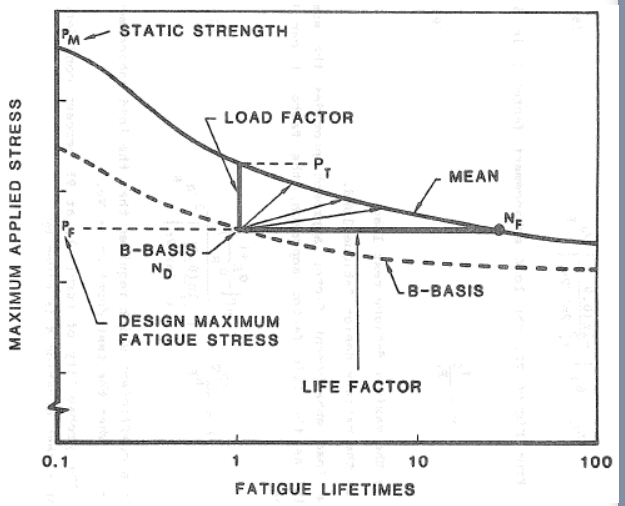

Composite standard approach:

AIRBUS Applied LEF.

Resulting from a large number of coupon tests,

	Imputs			LEF				
LEF \Life Factor	Alpha R	Alpha L	Nf (LEF=1)	0.55 DSG	0,67 DSG	1 DSG	2 DSG	3 DSG
Northrop 1986	20,00	1,25	13,56	1,22	1,21	1,177	1,13	1,10
EADS ATR 1989			5,13			1,100		
EADS CASA 2001	19,86	2,74	3,02		1,23	1,165	1,06	1,00
NIAR 2008 AS4/E7K8	24,23	1,74	6,09		1,17	1,139	1,08	1,05
NIAR 2008 T700	34,58	4,06	2,07		1,14	1,089	1,00	0,96
Airbus 2014	26,008	1,65	6,80	1,17	1,16	1,129	1,08	1,05

$$LEF = \left(\frac{N_F}{N}\right)^{\frac{\alpha_L}{\alpha_R}}$$

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Conclusions

Extensive works performed to understand Composite Fatigue performance

- Current composite material show no fatigue degradation
- Fatigue Design sensitivity adress by Coupons to Element test specimen
- Failure mode with higher LEF may-be accomplished at sub-component test level

Demonstrator principle tests properly support durability , combining impact damage demonstration and no detrimental fatigue propagation

- Potential to reduce testing at full scale level, using ‘conventional ‘ metallic tests specimens