Sandwich Implementation - Test Activity

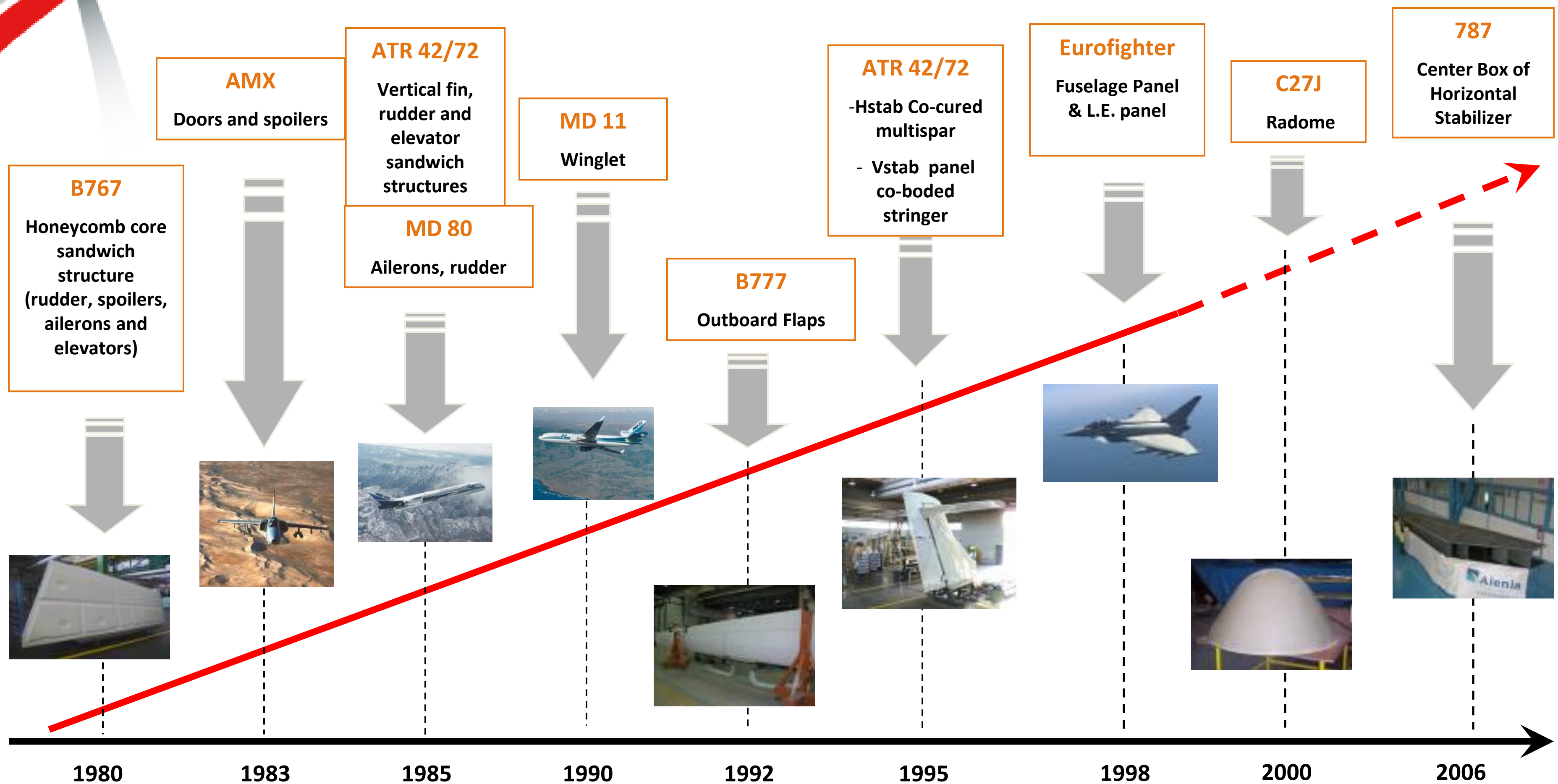
Presented by **Alfredo Lista**

Airframe - Structure Technology

Koln, 13-14 June 2013

Cfrp road map

AAEM "H/C PARTS" HISTORICAL BUSINESS



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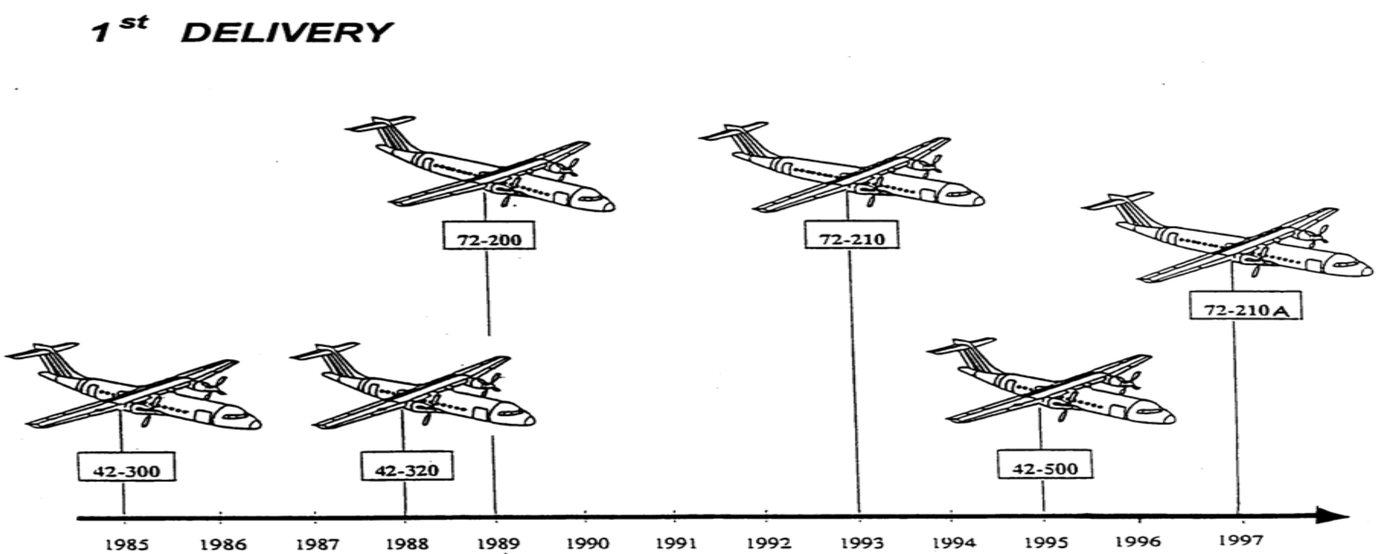
ATR HISTORY

- ✓ ATR 42 was developed and certified on 1985 with primary structure made in full metal configuration with exception of the Rudder and Elevator made in non-metallic sandwich
- ✓ ATR 72 was developed and certified on 1989, the basic primary structure was in full metal configuration with exception of the external wing boxes made in C/Epoxy composite material
- ✓ In 1995 (New Airworthiness Requirement) passenger weight increase, Alenia launched a weight saving project to recover the original Aircraft Take-Off weight demonstrated during ATR 42 & 72 Certification.
- ✓ In 1996 a new Structural Configuration for ATR 42 and ATR 72 Co-cured Horizontal and Co-bonded Vertical Tails was certified consisting mainly in the material change from Aluminum Alloy to C/Epoxy configuration.



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ATR SERVICE HISTORY

✓**ATR 42 and 72 Rudder and Elevator in-service**

- **1200 Rudder and Elevator Flying**
- **ATR 42 and ATR 72 totalized about 20 MLN fleet service hours**
- **The current Life of the Fleet Leader Aircraft is about 60.000 Flights (50.000 Flight Hours)**

✓Summary of Rudder and Elevator service report:

• in-service experience of Rudder and Elevator are very good. There are no significant events inside database

• There are few SRAS (Structural Repair Approved Sheet) number concerning the different damage typology (12 about Elevator and 43 about Rudder).

•The main damage source are :

- Lightning Strike
- Counterbalance arm interference
- Corrosion on metallic parts

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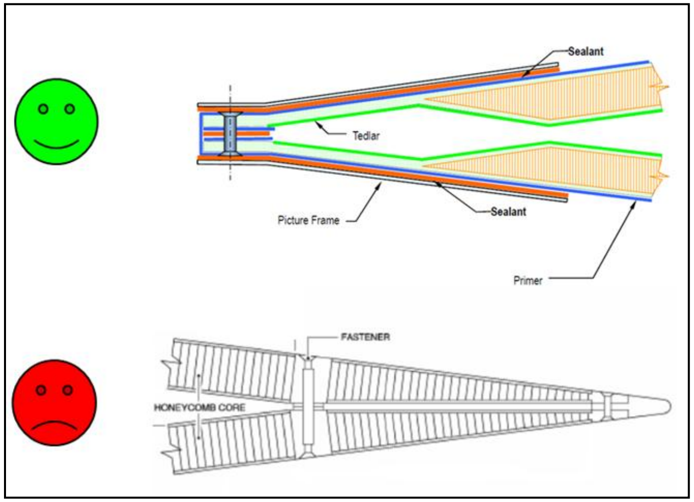
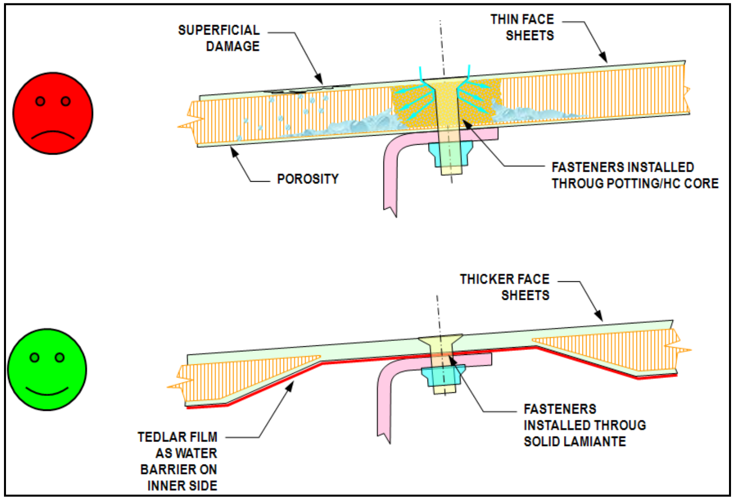
REASONS FOR THE SUCCESS

- Good design
  - No insert and blind rivets usage
  - No bonding strap usage
  - Right choice material (H/C Nomex)
  - Minimum gauge skin thickness to minimize water ingress (3 plies fabric)
  - Internal side with impermeable film (Tedlar)
  - Right design solution





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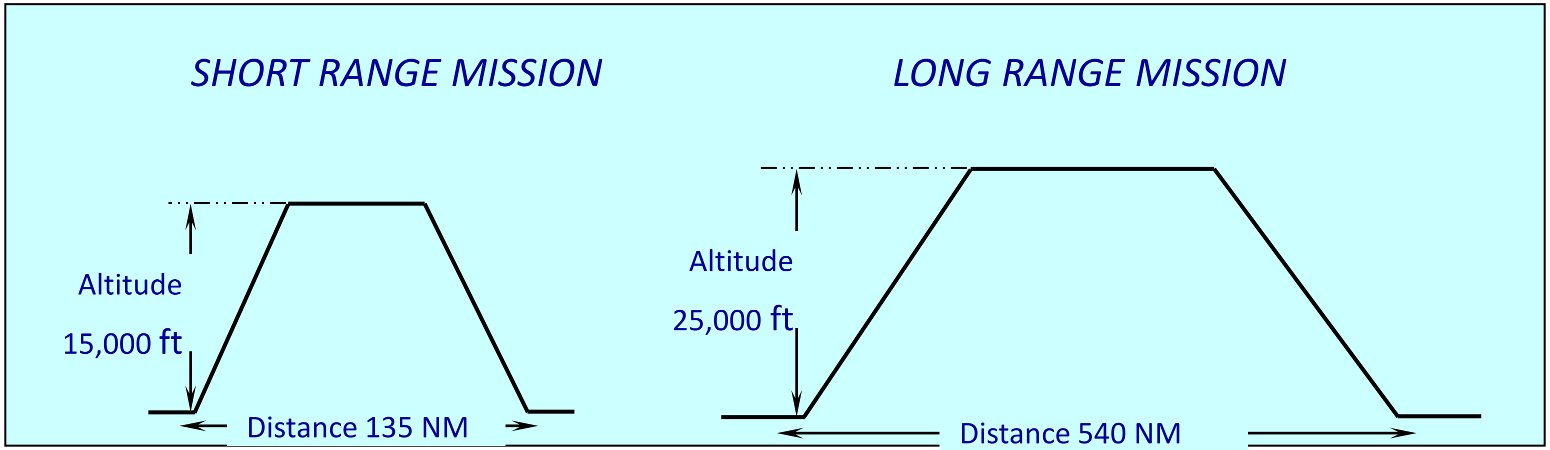
REASONS FOR THE SUCCESS

- Aircraft Architecture
  - high tail configuration leads in less probability of impact following tool drop on elevator

- Mission profile
  - Both short and long range mission fly at cruise altitude, respectively of 15,000 and 25,000 feet, lower than the typical medium/long haul (around 40,000 feet). Sandwich structure benefit of lower ΔP.



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SANDWICH USAGE AND ASSOCIATED RISK CLASSIFICATION

Following a classification based on “DT risk view” for HC primary structures.

➢ HC internal usage, i.e as Vstab ribs and Hstab Center-Box, is a low risk from DT point of view: The internal parts are protected from external threat.

➢ Rudder structure has an associated medium risk from DT point of view:
HC usage and associated risk classification vertical structures are less prone to on ground and tool drops during maintenance operation.

➢ Elevator structure has an associated high risk from DT point of view:

- horizontal low mounted structure are more prone to on ground hail impact, to tool drops and run way debris
- horizontal “high-Tail” configuration (ATR 42 ATR 72) has an associated medium risk from DT point of view: high tail structure are less prone to on ground and tool drops during maintenance operation

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SANDWICH STRUCTURE HISTORICAL TECHNICAL CHALLENGE

- Hail, FOD and Lightning

- Composite face sheet fails as a result of an interaction among matrix cracks, fiber fracture and delamination.

- Sandwich structure may also exhibit core crushing and face sheet debonding. Damage may result from low-velocity impact such as tol drops or high energy events such ballistic penetration

- An initial damage like a face sheet matrix cracking caused by hole, incorrect repair, puncture in the skin, severe hail damage could be lead in water ingress into the H/C and/or cause disbond between face sheet and core

- In-service NDI

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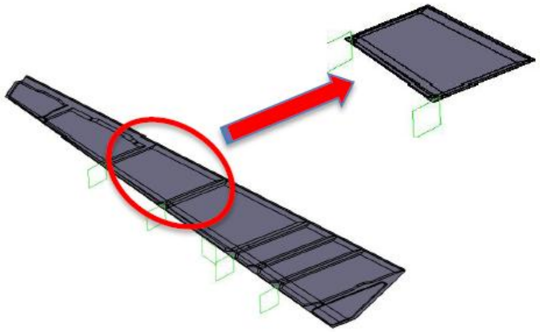
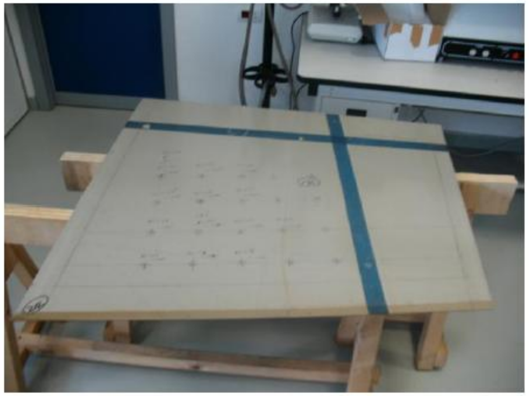
UNDERSTANDING DAMAGE RESISTANCE



Test set up (only for reference)

Impact on external side (3 plies)



Impact on internal side (2 plies)

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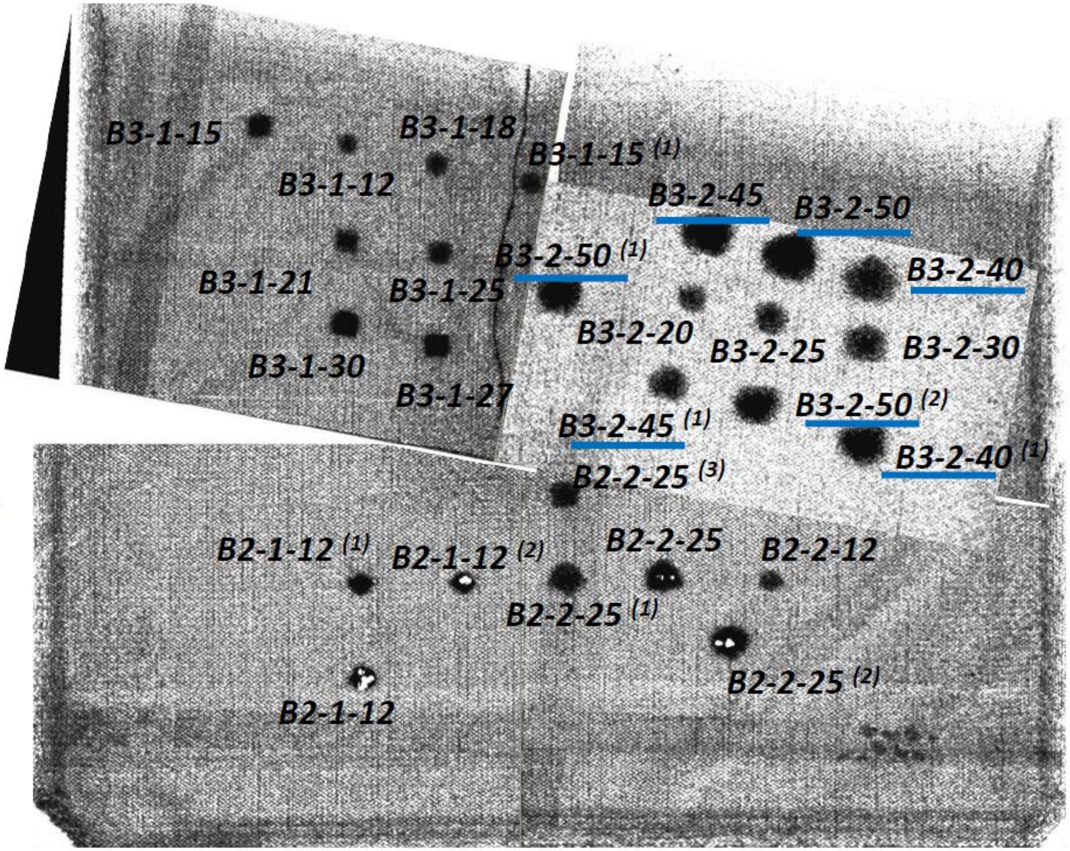
NDI C-SCAN MAP

Figure below shows the C-scan presentation of the results of the Automatic Through-Transmission inspection

<u>Impact coding</u>

XYY – Z – NNN

X = impact location
YY = number of plies
Z = impactor diameter
NNN = impact energy



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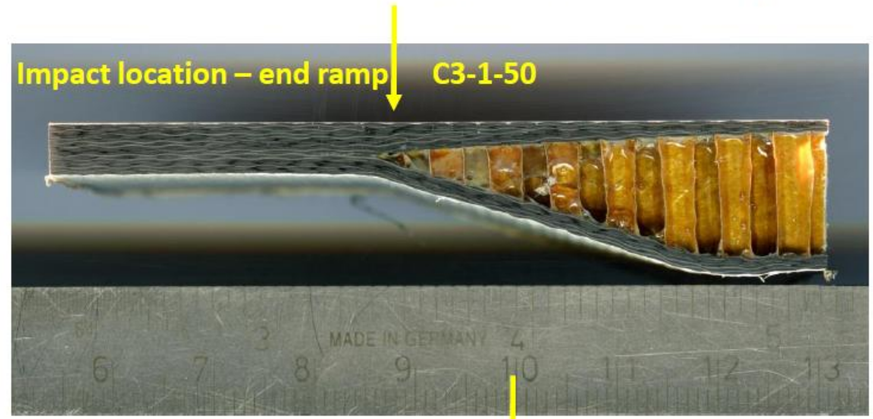
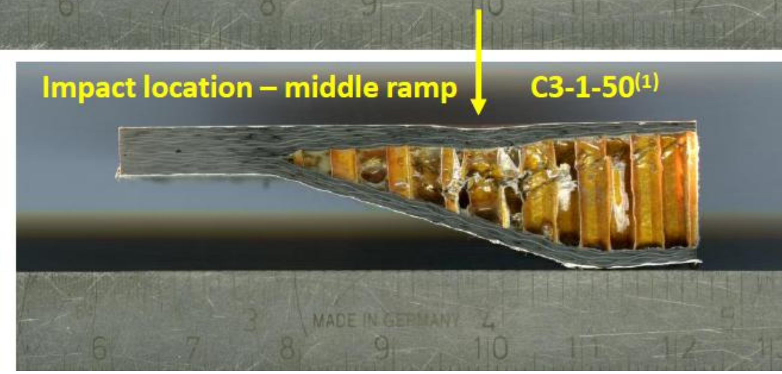
MICROGRAPY INSPECTION RESULTS





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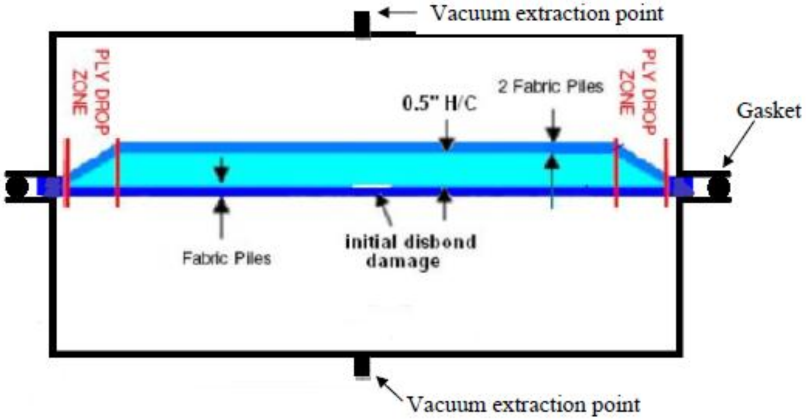
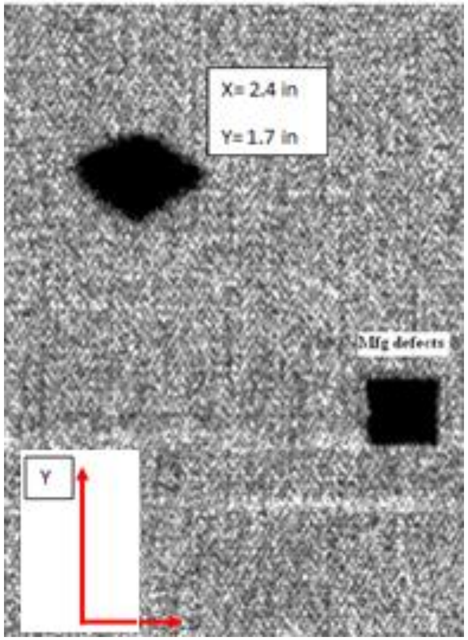
UNDERSTANDING DAMAGE TOLERANCE UNDER ΔP



Vacuum chamber scheme

E= 23 J ; Dia impactor = 2”
(based on Impact Survey)



NDI C-Scan Map

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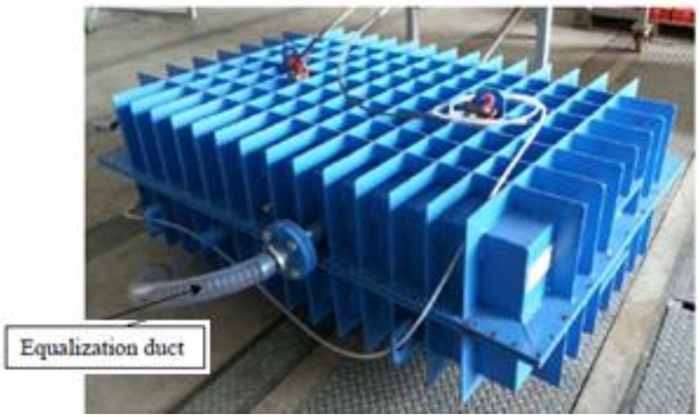
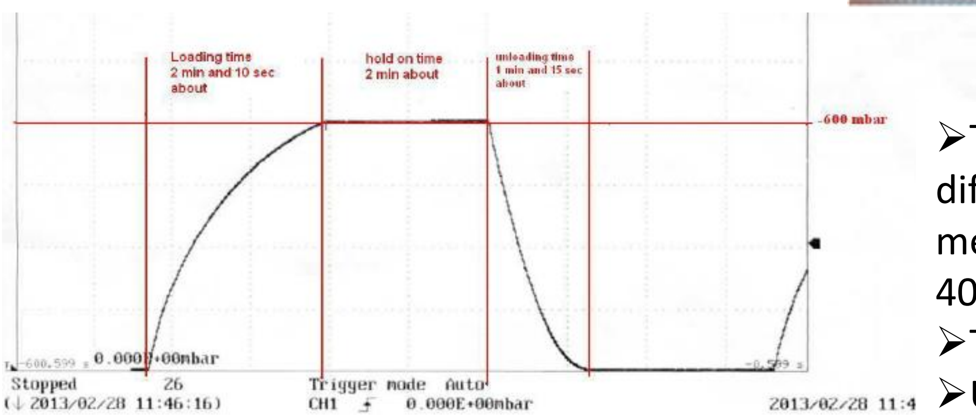
UNDERSTANDING DAMAGE TOLERANCE UNDER ΔP





- The vacuum chamber has been set to apply a differential pressure of 600 mbar (typical of medium/long haul, cruise altitude around 40000 feet).
- Test is currently running
- Up today has been completed 2000 cycles and no growth has been detected

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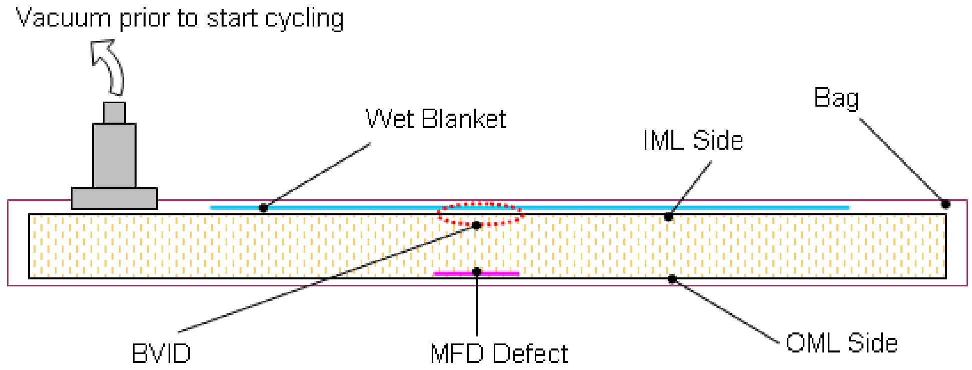
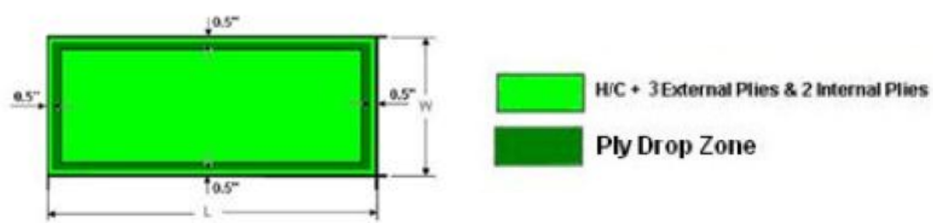
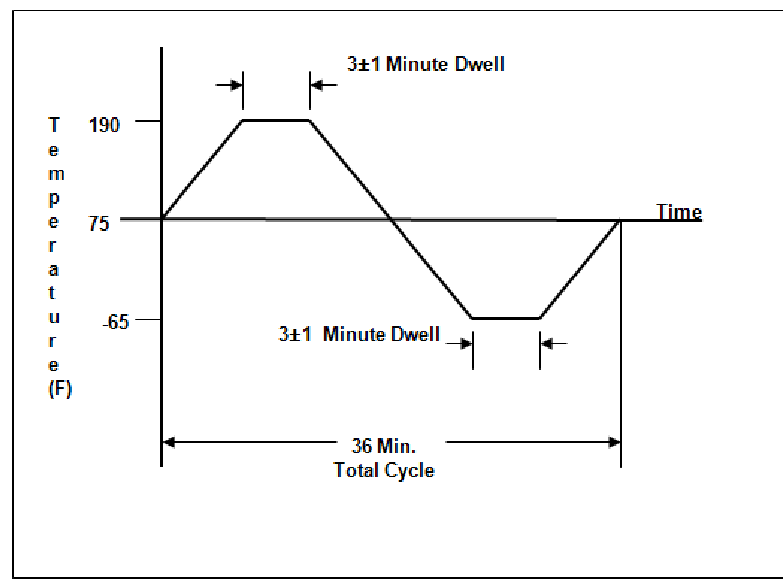
UNDERSTANDING DAMAGE TOLERANCE UNDER THERMAL CYCLES





L (in)	W (in)
20	15



service simulation thermal cycle (specimen temperature)

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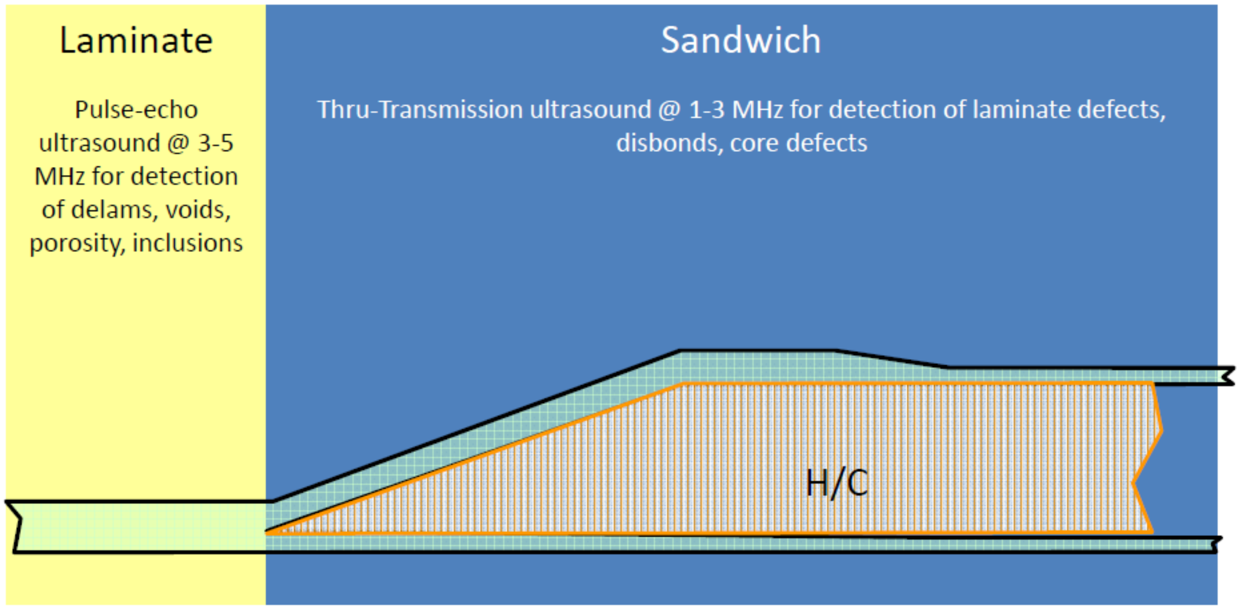
NDI IN QUALITY CONTROL



Typical configuration relevant for NDI

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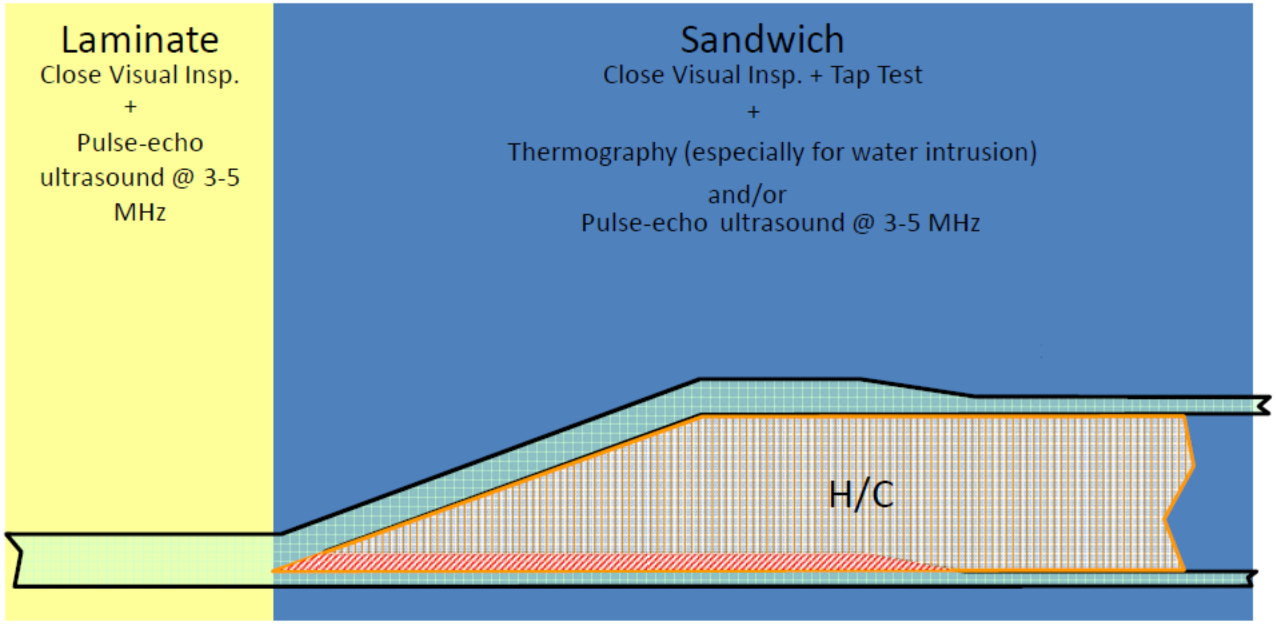
IN-SERVICE NDI

In-service NDI

for possible damages following impact or unexpected events



Typical configuration relevant for NDI

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OVERALL SANDWICH REQUIREMENTS FOR EMPENNAGE

• *Impact Resistance is demonstrate by test for different geometry.*	*Hail Impact, Lightning Strike and Impact survey performed on:* *Elevator* *Rudder* *Center Box* *Vstab Ribs*
•*Ultimate strength is demonstrate based on test data for H/C laminates with BVID and MD (Cat.1).*	*CAI and TAI tests at L1 (allowable).* *Rudder Compression Panel (Fatigue & RS)* *Elevator Compression Panel (Fatigue & RS)* *Center Box Panel (Fatigue & RS)*
•*Residual strength is demonstrated by test for H/C laminates with impact damage associated to the associated threat (Cat.2).*	*Rudder Compression Panel (Fatigue & RS)* *Elevator Compression Panel (Fatigue & RS)* *Center Box Panel (Fatigue & RS)*
• *Structural repair concepts and methodologies are developed and tested.*	*Repair Sandwich static and fatigue*
•*Moisture absorption characteristics are evaluated by test for pristine structure, repaired structure.*	*Moisture Absorption evaluation*

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OVERALL SANDWICH REQUIREMENTS

• *HC methodologies validation and calibration.*	*Ramp Analysis* *Sandwich Panel in Compression* *Sandwich Panel in Shear* *Sandwich Panel (Configuration Rudder) in Compression* *Sandwich Panel (Configuration Elevator) in Compression*
• *Damage propagation under ground-air-ground cycling and flight spectra.*	*Damage Propagation in face-sheet core disbond.*
•*Effect of water freezing an thaw cycling to the skin delamination and damage propagation.*	*Damage Propagation in face-sheet core disbond.*

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THE CONDITIONS NECESSARY FOR THE SUCCESSFUL USE OF HC BASED ON ALENIA EXPERIENCE

➢ Good design

- No insert and blind rivets usage
- No bonding strap usage
- Right choice material (H/C Nomex)
- Minimum gauge skin thickness to minimize water ingress (3 plies fabric)
- Internal side with impermeable film (Tedlar)
- Right design solution

➢ Aircraft Architecture

- high tail configuration leads in less probability of impact following tool drop on elevator

➢ Mission profile

- Both short and long range mission fly at cruise altitude, respectively of 15,000 and 25,000 feet, lower than the typical medium/long haul (around 40,000 feet). Sandwich structure benefit of lower ΔP.

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TEST SUMMARY BY INVESTIGATED DAMAGE

MAIN SCOPE		Description	Investigated Damage/Defect			
			MD	Cat.1	Cat.2	Cat.3
DAMAGE RESISTANCE		Impact Survey on Elevator Sandwich Panel		X	X	
		Impact Survey on Rudder Sandwich Panel		X	X	
		Impact Survey on Center Box Sandwich Panel		X	X	
		Impact Survey on VStab Sandwich Ribs		X	X	
		Sandwich Panel lightning strike test			X	X
DAMAGE TOLERANCE	METHODOLOGIES VALIDATION/ CALIBRATION	Sandwich Panel in Compression (Static)		X		
		Sandwich Panel in Shear (Static)		X		
		Ramp Analysis of sandwich Panel		X		
		Rudder Compression Panel (Fatigue & RS)	X	X	X	
		Elevator Compression Panel (Fatigue & RS)	X	X	X	
		Center Box Sandwich Panel (Fatigue & RS)	X	X	X	
		Damage Propagation on Sandwich structure (Thermal Cycling)	X	X		
		Damage Propagation on Sandwich Structure (GAG ΔP)	X	X		
		Damage Propagation on Sandwich Structure (Flight Load Spectra)	X	X		
REPAIR		Moisture Absorption Evaluation		X	X	
		Sandwich Panels Repairs Validation			X	X

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