Validation, Verification and Implementation of SHM at Airbus

IWSHM 2013, Stanford, USA

Presented by

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& SHM Airbus / IW Team

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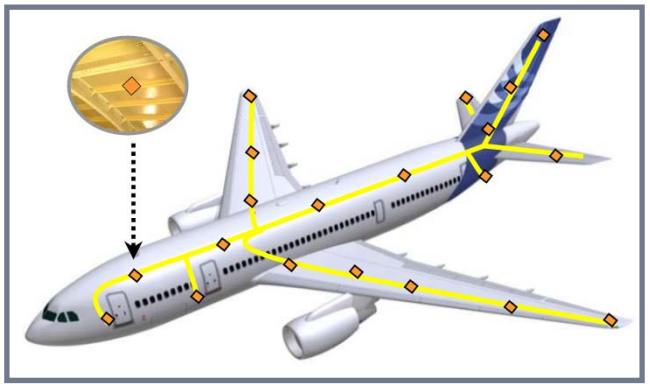
Contents

Structural Health Monitoring (SHM)

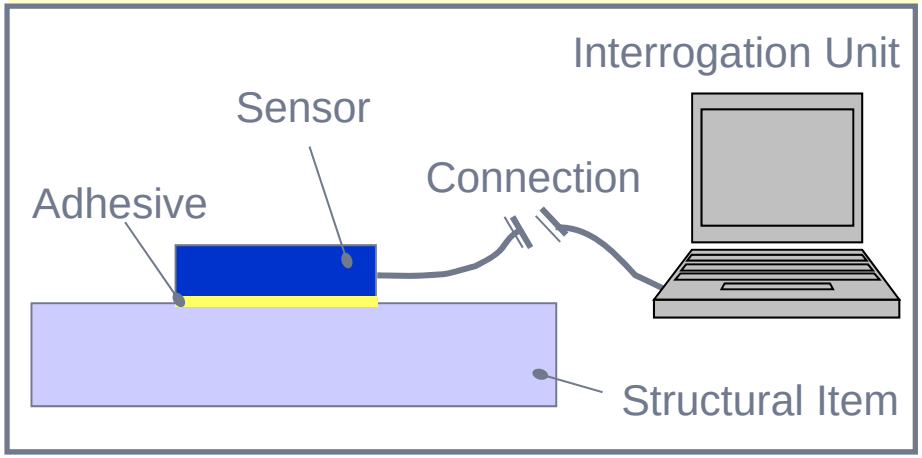
Goals of SHM

- **Reduce Maintenance Costs**
- **Increase Aircraft Availability**
- **Reduce Weight**
- **Quality Control**



Non-Destructive Testing (NDT)

Structural Health Monitoring (SHM)



SHM = Onboard NDT of Defects, Damages, Stress, Conditions, Properties

SHM Development & Application Roadmap

Generation 0
- Structure testing application
- Benefit: Structure analysis, structure testing

Generation 1
- In-service aircraft, off-line sensor
- Benefit: maintenance

Generation 2
- In-service aircraft, on-line sensor
- Benefit: weight saving on component level, maintenance

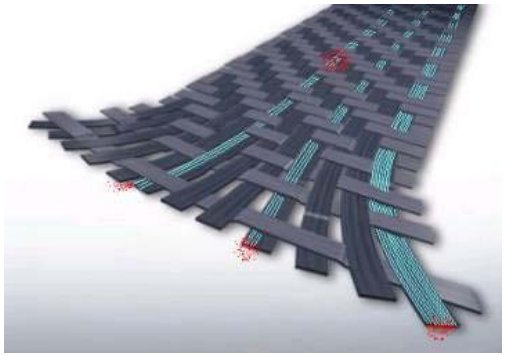
Generation 3
- In-service aircraft, fully integrated sensor
- Benefit: Manufacturing quality control, weight saving on aircraft level, maintenance

Stepwise implementation of capabilities

Gen. 4: Multifunctional Smart Structures / Materials

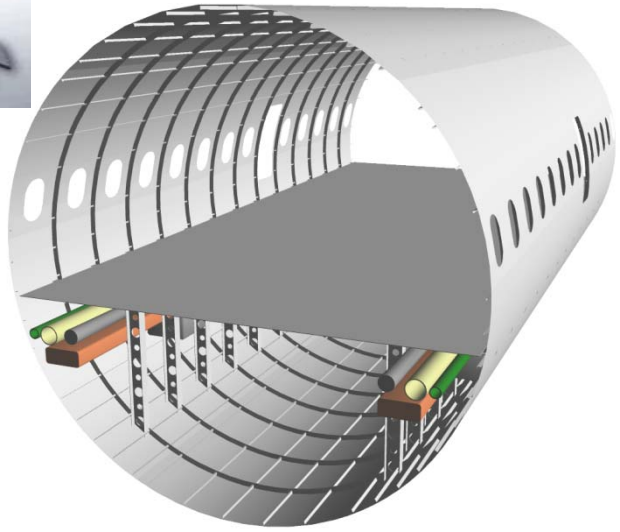
- Load transfer
- Large damage capability
- Robustness
- Crashworthiness
- Morphing & adapting
- **Self-sensing**
- Self-healing
- Thermal insulation
- Noise attenuation
- Lightning strike protection
- Electrical isolation
- Vibration damping
- Electrical energy transport
- Signal transfer
- Cabin furnishing
- etc.

Multifunctional smart structures / materials various intrinsic functions offering new opportunities to reduce weight and costs.



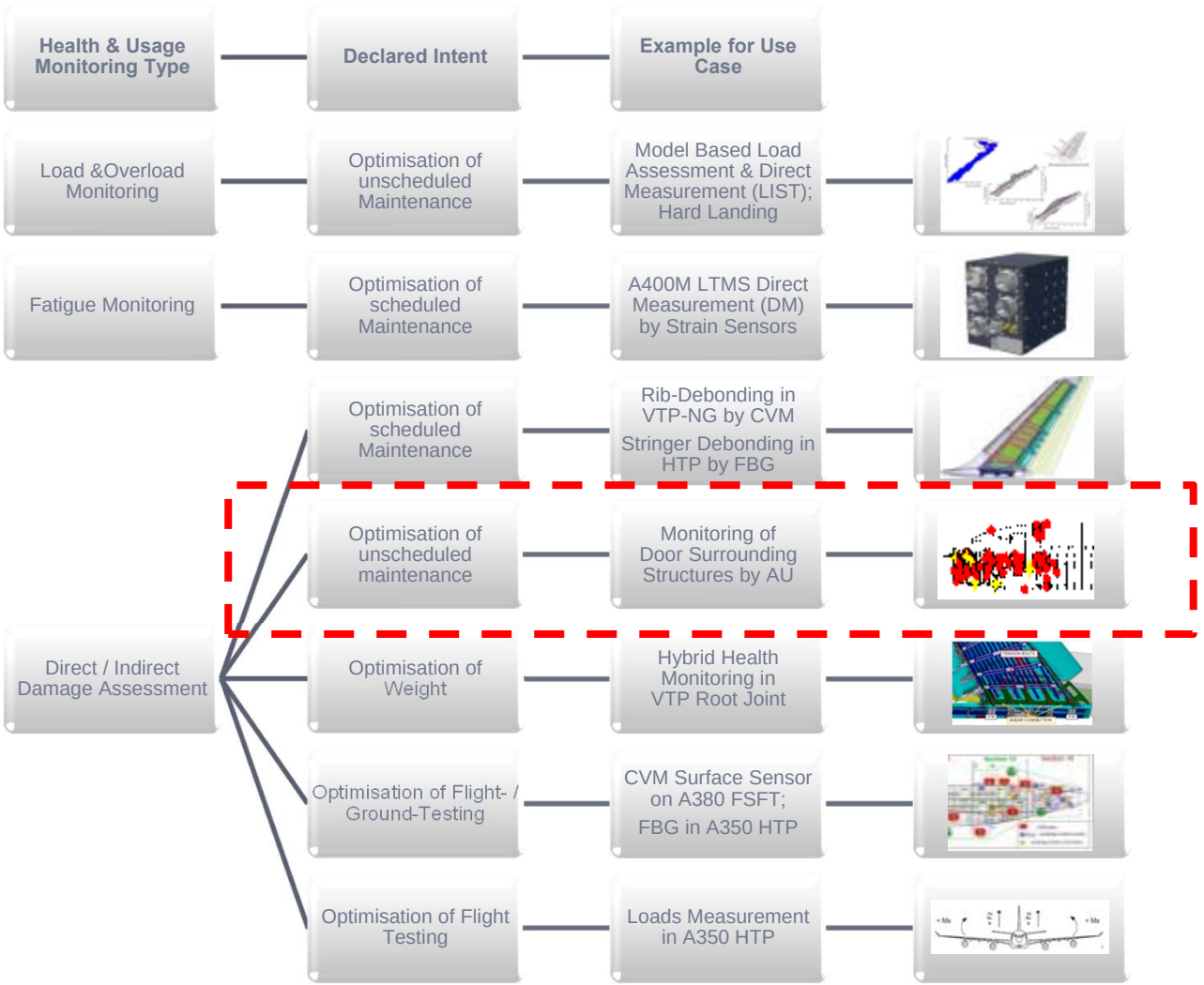
Load and power/signal transferring fibers

Piezoelectric composite



Contents

Overview on selected SHM Use Cases

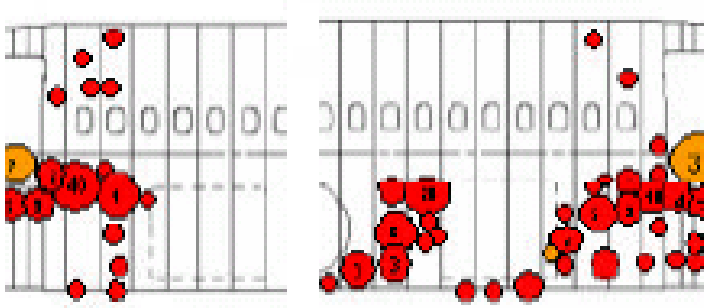


CFRP Impact Damage Detection & Assessment

- Impact risk: runway debris, bird, hail, loader, tool,....
- NDT required after visual indication of CFRP impact
- Goal: Reduce cases where NDT inspection is required by means of SHM

Increase Availability &
Reduce Maintenance Costs

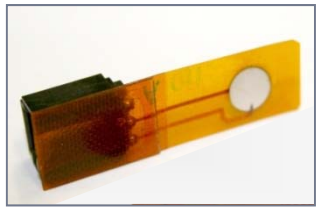
Fuselage In-Service Damage Mapping



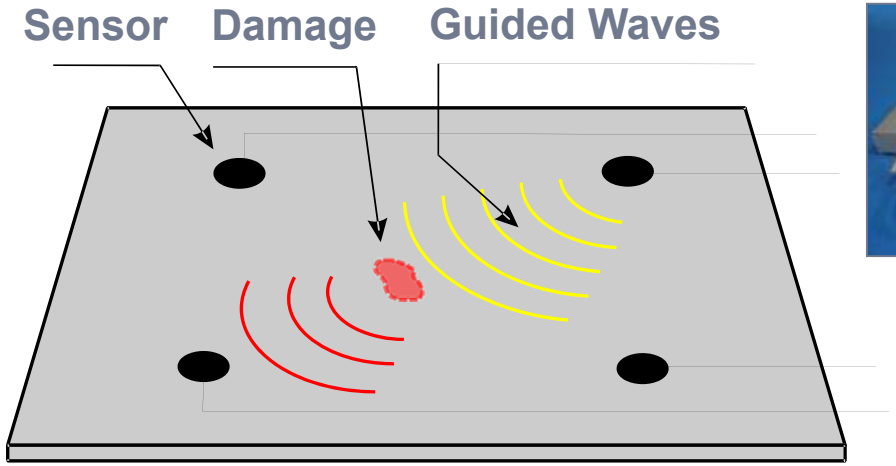
Impact Damage Outboard View

Impact Damage Onboard View

Debonding Detection by Acousto Ultrasonics

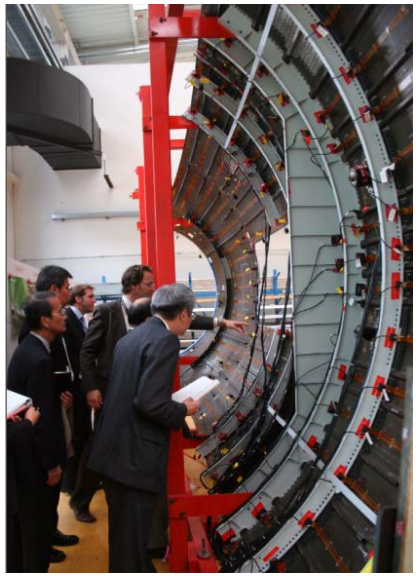


SMART Layer™
Single Sensor



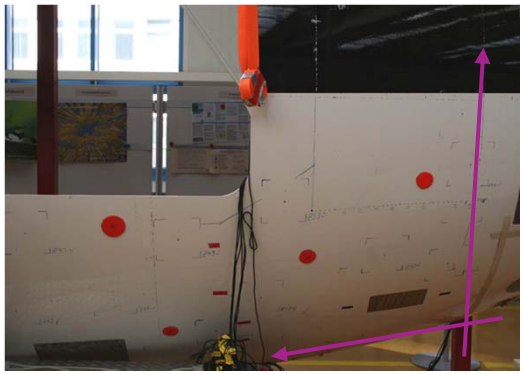
Acousto Ultrasonic Principle

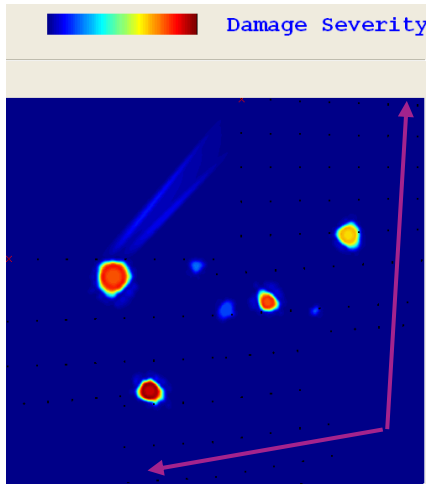
SCANGenie™
Interrogation Unit



Prototype 1: CFRP Fuselage
Shell Ground Validator

Comparison NDT with SHM





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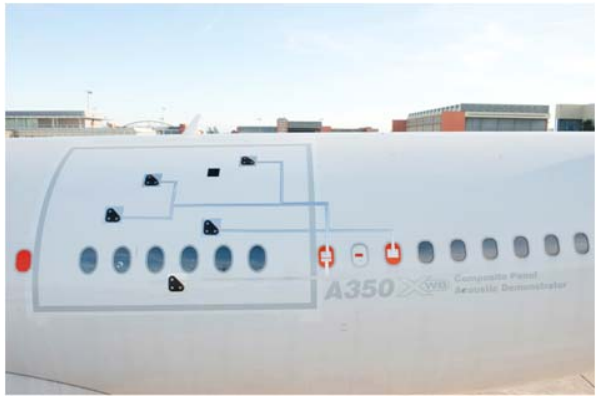
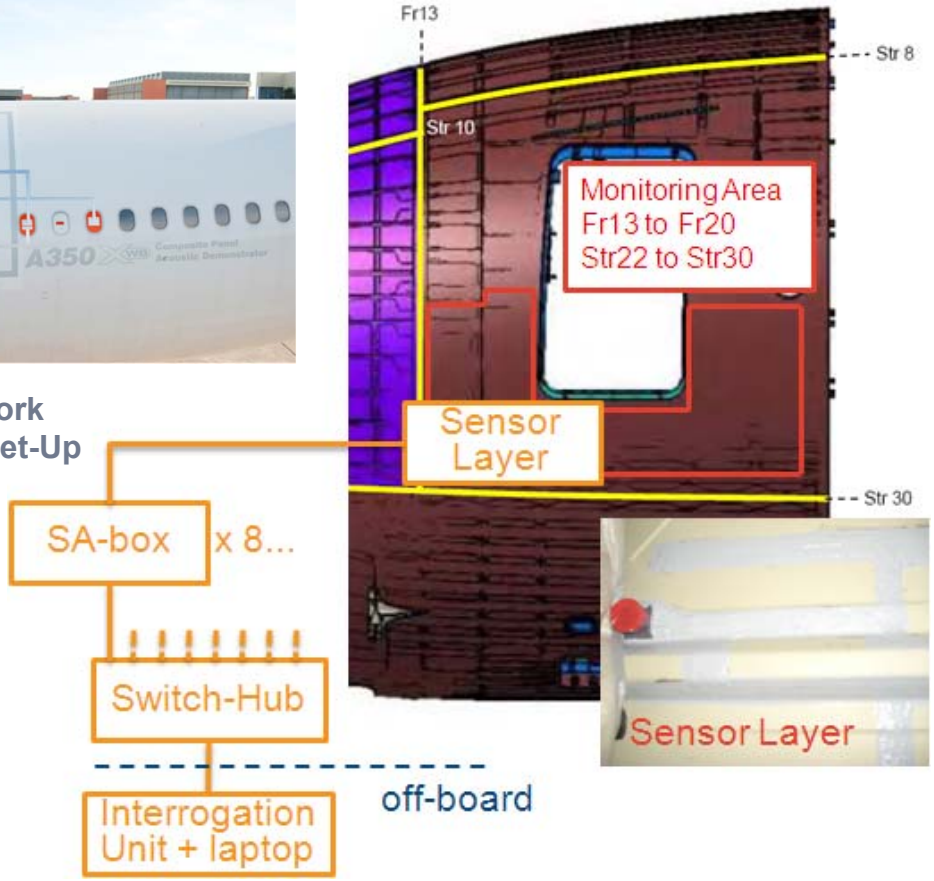
Impact Damage Detection & Assessment System

Prototype 2 & 3: CFRP Fuselage Flight Test Validator on A340 MSN 1 & A350 MSN 1



Sensor Network Installation Set-Up



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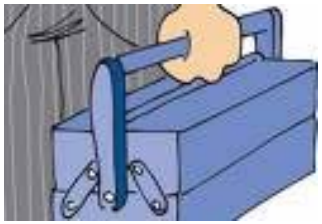
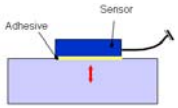
SHM Tool Box

SHM Tool Box

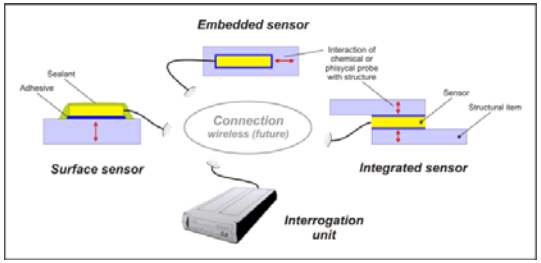
- Mature technical solutions for generic use cases
- Fall-Back Solution: Reduce technological risks for specific use case

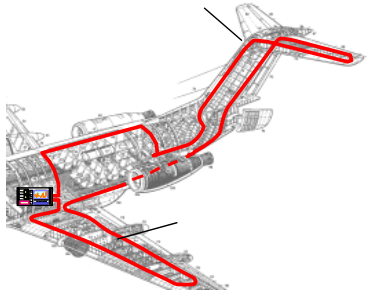


 Generic Use Case versus Technologies 	CVM	ETFS	AE	IU	CW	IDDC	UTFS	AU	FOS	EMI	CVM-TTT	SG	EDMS	OD
'Crack detection and assessment'	X	x		x										
'Rupture detection of structural elements'	x			x	x									
'Detection and assessment of impact events'			X			x	x		X					
'Delamination detection and assessment'			x	x				X	X		x			
'Bond quality assessment'									X	x	X	x		
'Bonded repair monitoring'									X		x	x		
'Structural elements debonding detection and assessment'			x					x	X		X			
'Stress/strain monitoring in structural elements'									X			X		
'Corrosion detection and assessment'													x	x

SHM Way of Working

Programme → Use Case → 'SHM Toolbox' → Technology Solution → Technology Adaptation → Programme





SHM Development Guidance & Maturity Assessment

Stage	TRL	TRL Definition	Requirements & Criteria	Status
Discover	1	System is only an idea on paper	TRL 1.1, TRL 1.2, …	yes/no
	2	In depth formulation on equipment	TRL 2.1, TRL 2.2, …	yes/no
Understand	3	System partly a physical stage	TRL 3.1, TRL 3.2, …	yes/no
Adapt	4	System at a laboratory stage	TRL 4.1, TRL 4.2, …	yes/no
	5	System at a laboratory stage and compliant to aircraft environment		
Validate	6	System at a prototype stage and compliant to aircraft environment		
Refine	7	System at a prototype stage tested in-flight		
	8	System in its final form, qualified through further ground-tests and in-flight trials		
Use	9	System in its final form, further proven through extensive in-service use	TRL9.1, TRL 9.2, …	yes/no

Requirement Sources

- Materials & Processes
- Systems
- Manufacturing
- Customer Service
- Authorities

SHM Development Guideline

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REQUIREMENTS FOR ON-BOARD NDT SENSOR TECHNOLOGIES AND THEIR MATURITY ASSESSMENT TOOL
Technical Report
ORIGIN ESKW
REFERENCE X45RP1040144
ISSUE 1.0
DATE 12 Mar 2011

Requirements for on-Board NDT Sensor Technologies and their Maturity Assessment Tool
Technical Report

REFERENCE	X45RP1040144
A/C APPLICABILITY	All
ATA APPLICABILITY	45
CUSTOMER	
CONFIDENTIALITY	Confidential
DOCUMENT LEVEL	3

SUMMARY:

Purpose (short version)
Based on Lean Engineering, the approaches described in this document aim to reduce the costs and the time for the development of on-board NDT sensor technologies for any given application scenarios as well as to deliver mature technologies to the programmes. This document defines the requirements to guide the development and to assess maturity of on-board NDT sensor technologies for any given application scenarios. Furthermore, a qualification procedure and a corresponding task tracking tool (TDAT – Technology Development Administration Tool) were introduced in order to perform the guided technology development and maturity assessment in a systematic and objective manner.

Scope (short version)
This document is relevant for people in charge of developing on-board NDT sensor technologies for ageing and new aircrafts, for retro-fit or forward-fit installation. The requirements given in this document shall be used as a guideline to identify, develop and adapt all on-board NDT sensor technologies for given application scenarios. Therefore the document providing the baseline requirements to be complemented by programme specific requirements when applicable. However, the requirements proposed in this document are part of the qualification process. The procedure and the corresponding tool for the technology development and maturity assessment introduced by this document is applicable to all on-board NDT sensor technologies and any kind of application scenario.

KEYWORDS	Maturity assessment, durability, reliability, structural health monitoring, SHM, requirements, on-board NDT sensor
RELATED DOCUMENTS	

	NAME	SIGLUM - FUNCTION	DATE & SIGNATURE
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APPROVAL			
AUTHORIZATION			

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- Guided technology development
- Objective TRL assessment

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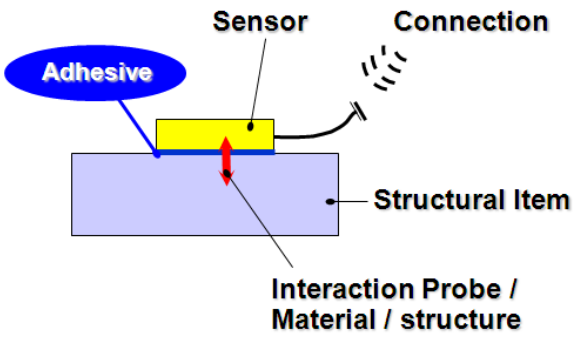
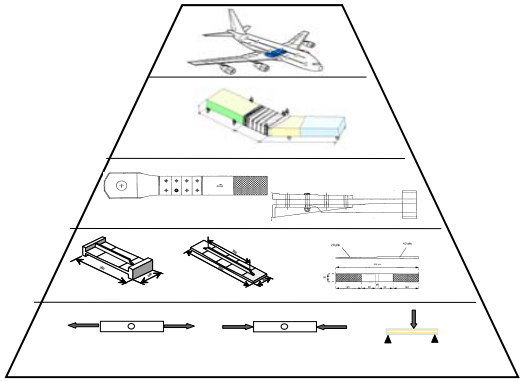
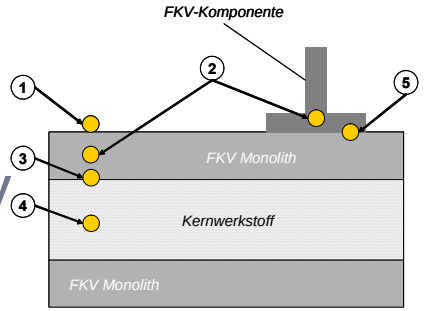
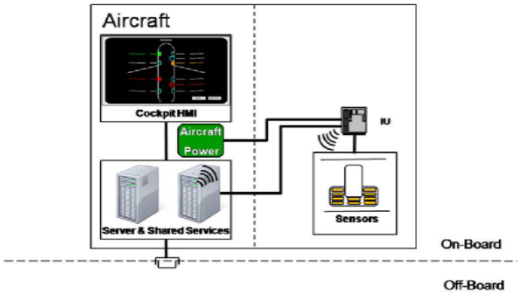
Major Requirement Families

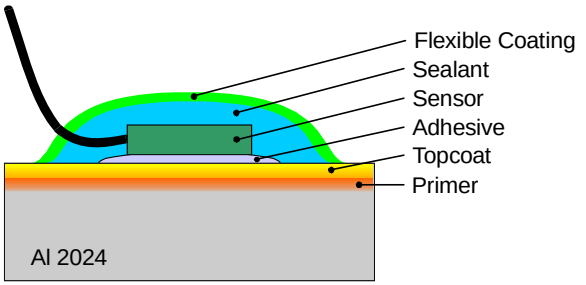
- **Self-Diagnostic**
- **Detection Capability**
- **Durability**
- Manufacturing & Assembly
- Maintainability, Reparability, Interchangeability
- Sensor Bonding Performance
- Sensor Installation
- Systems







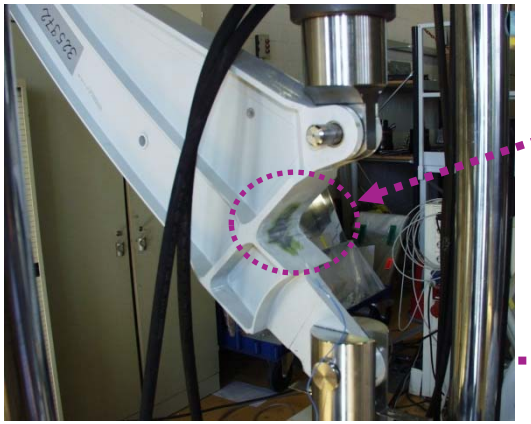




Detection Capability

Requirement Issue

Verify detection capability 90 / 95 considering major influencing effects

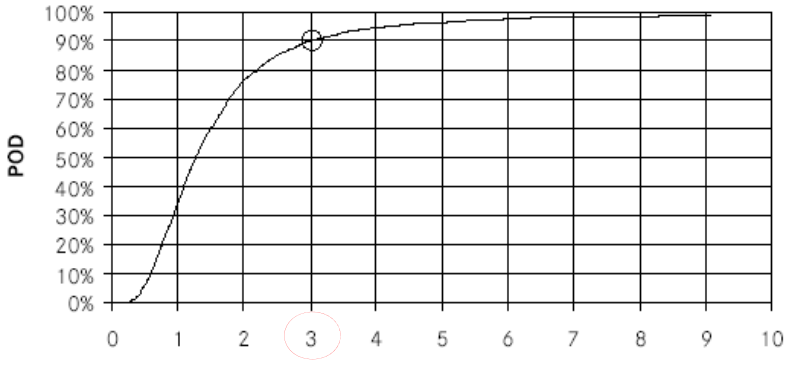


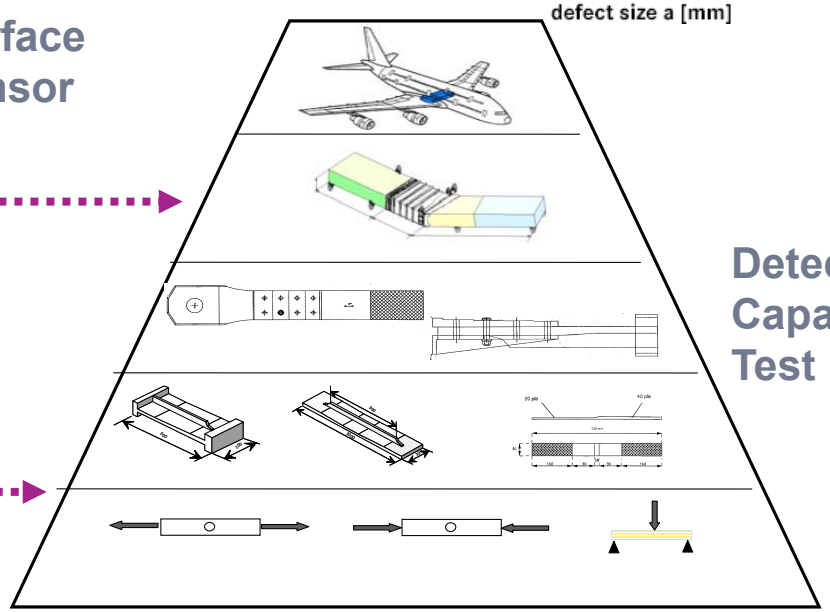
Cargo Door Fitting

Coupon Specimen

Crack Detection by CVM Surface Sensor

Probability of Detection Curve





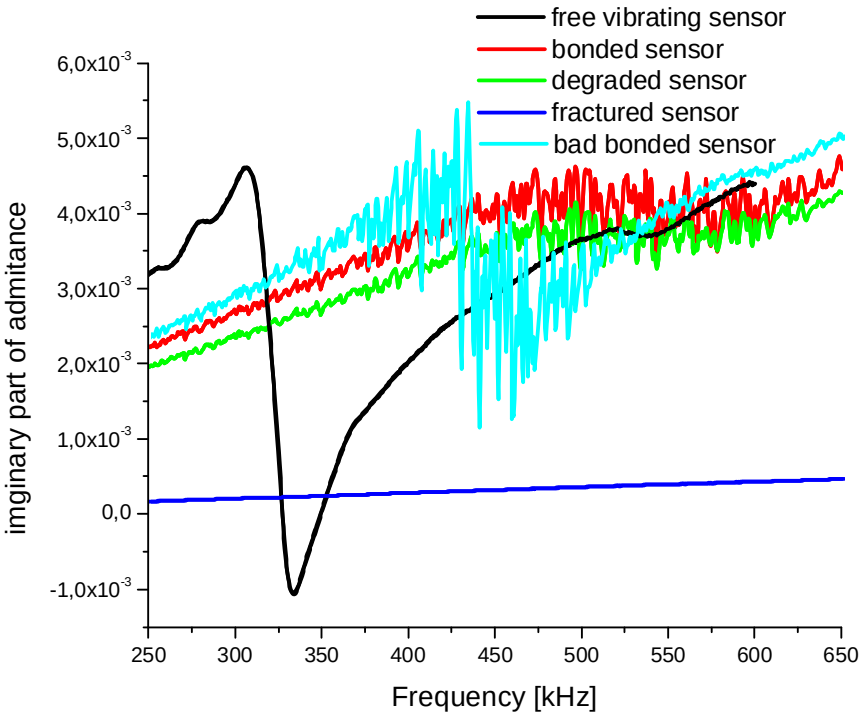
Detection Capability Test Pyramid

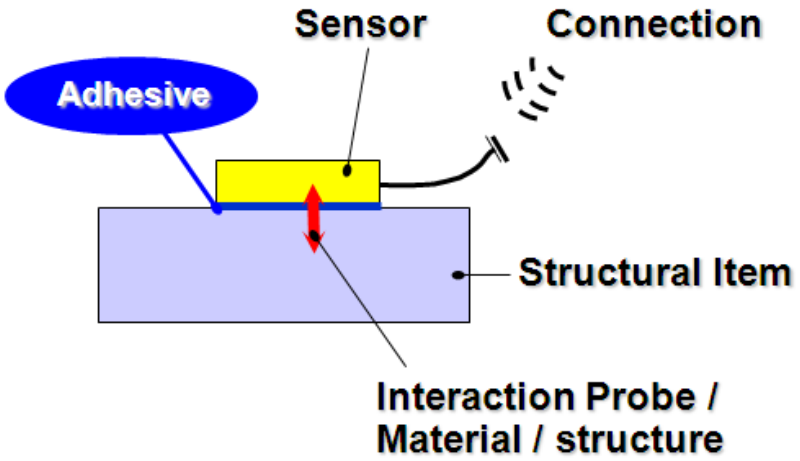
Self-Diagnostic

Requirement Issue

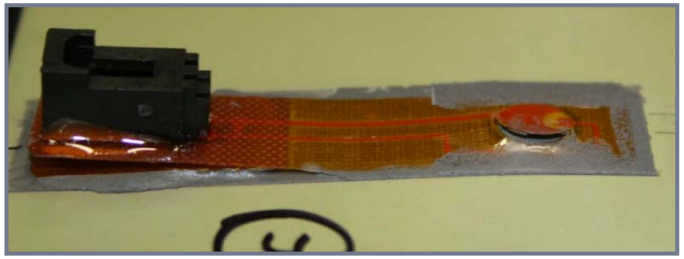
Verify self-diagnostic of system:

- System functioning
- Interaction probe / material





Debonded AU Sensor

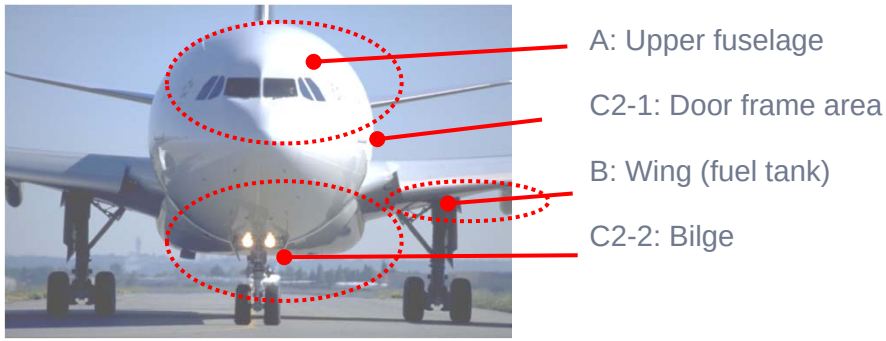


Self-Diagnostic Acousto Ultrasonics: Electro-Mechanical Impedance

Durability

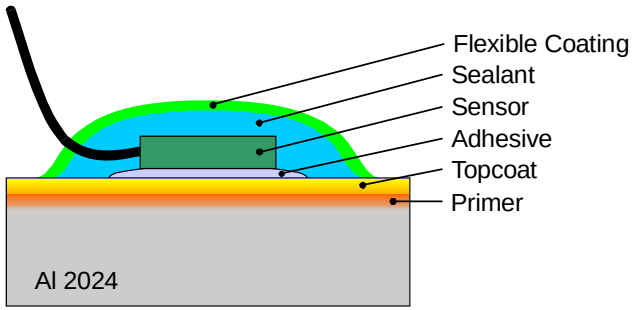
Requirement Issue

Verify resistance to environmental in-service loading for ≥ 30 years

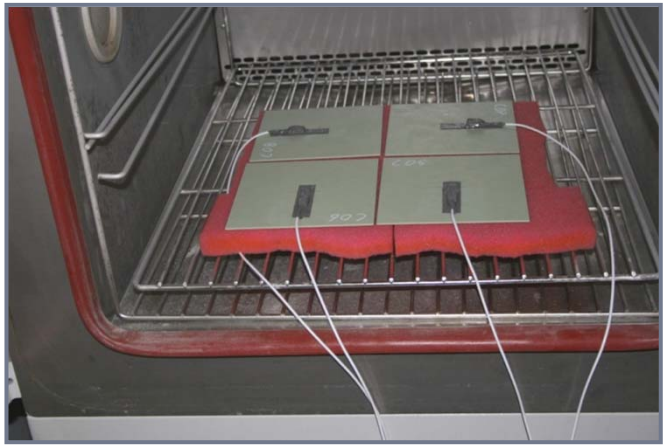


Environmental Aircraft Areas

Environmental Loading Types	
Temperature	Lubrication oil
Humidity	De-icing fluid
Water	Toilet fluid
Kerosene	Salt spray
Hydraulic fluid	Altitude



Sensor Configuration for Area C

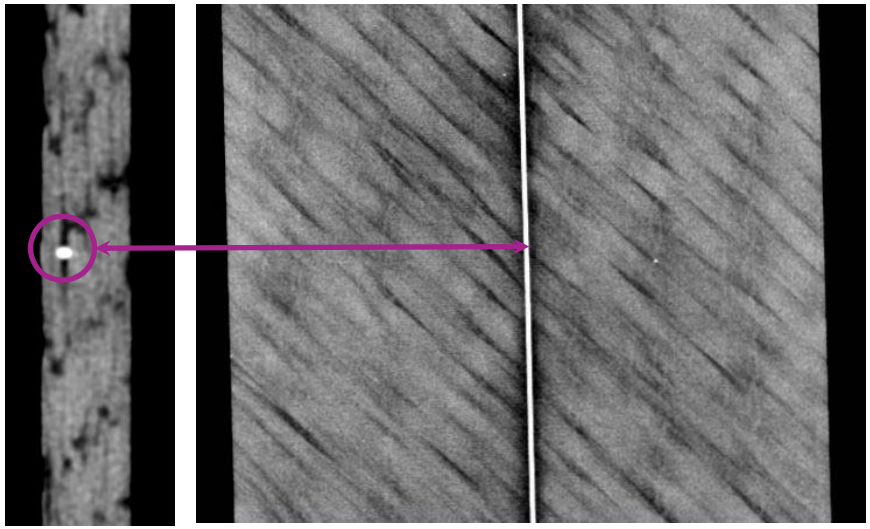


Thermal Loading of Acousto Ultrasonic Sensors

Manufacturing & Assembly

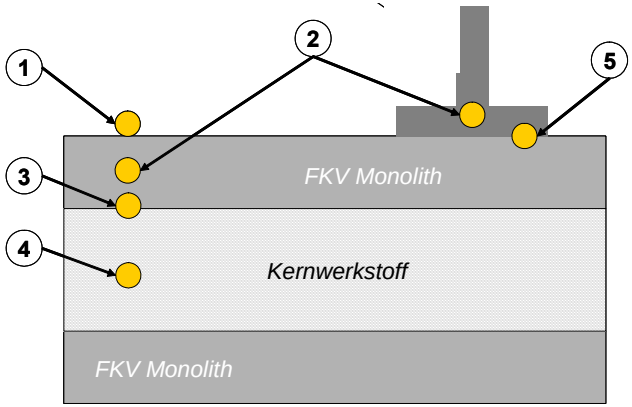
Requirement Issue

Verify sensor implementable during/after manufacturing.
Verify material / structural performance unchanged or even better.

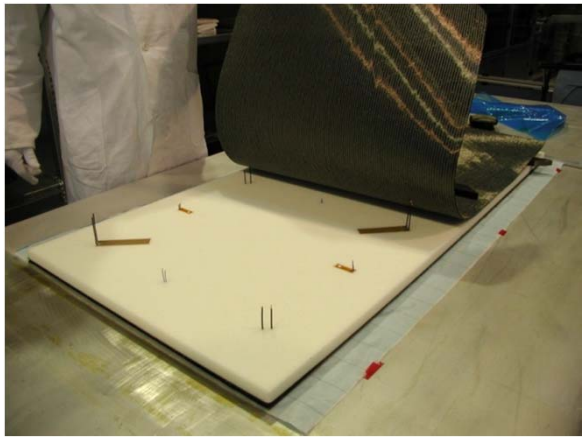


CFRP with Embedded 50 µm Optical Fibres

Sensor Configurations CFRP Structure



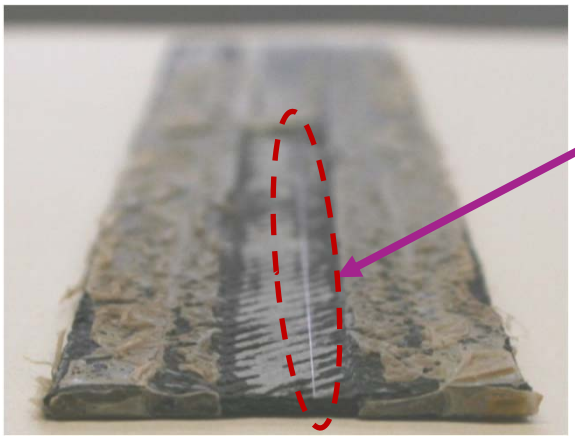
Lay-Up: CFRP Foam Core with Piezo Sensors



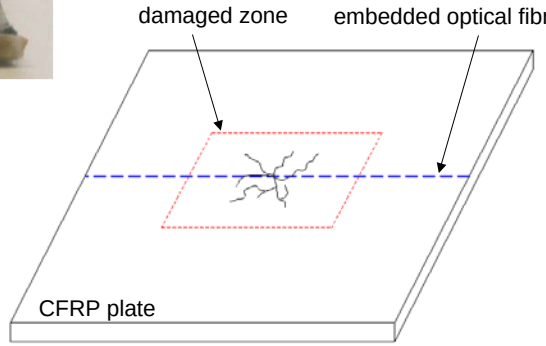
Maintainability, Reparability, Interchangeability

Requirement Issue

Verify maintainability, reparability and interchangeability of system

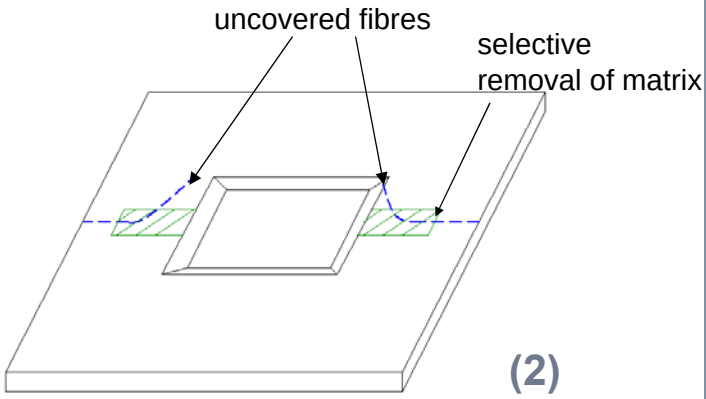


Optical Fibre laid bare by Plasma or Laser Ablation



(1)

Principle of Scarf Joint Repair of CFRP with Optical Fibre



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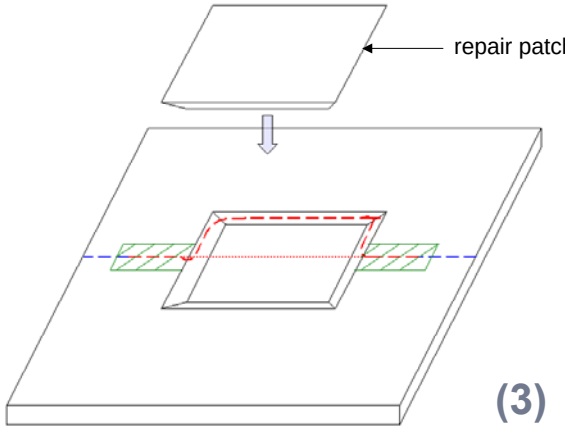


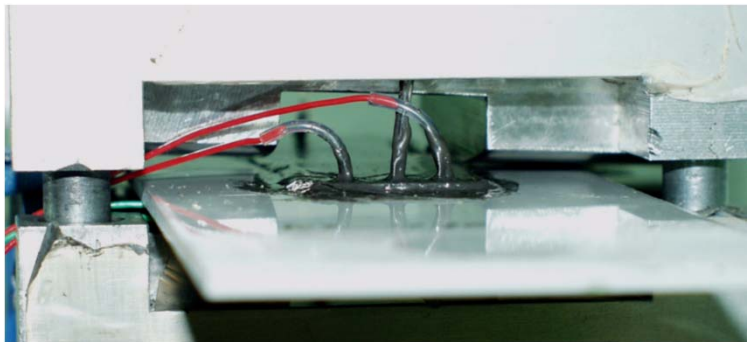
(3)

Sensor Bonding Performance

Requirement Issue

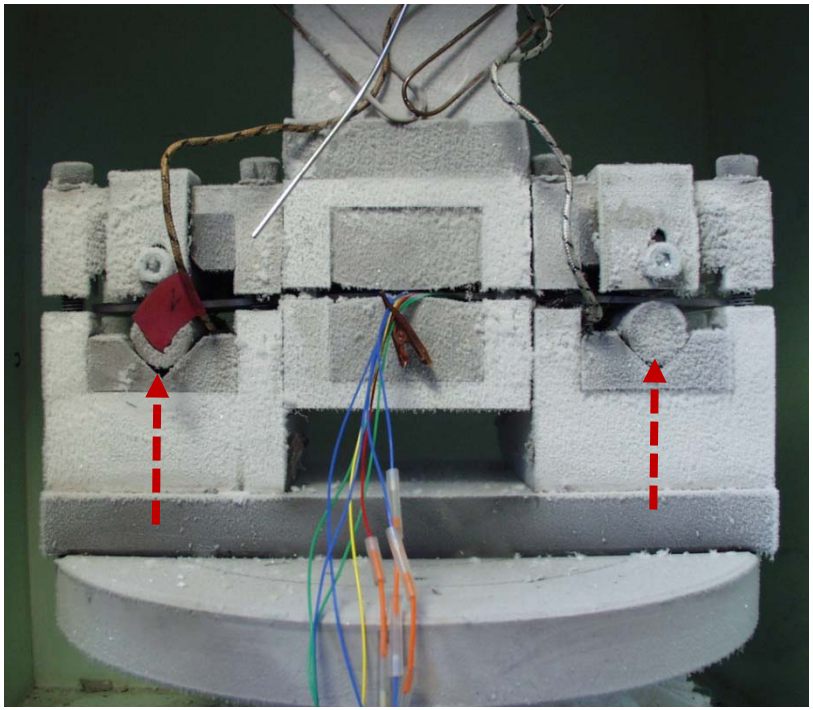
Verify minimum bonding performance of sensor application for ≥ 30 years in-service

CVM Sensor on metallic specimen



Specimen with sensor in Bending Device

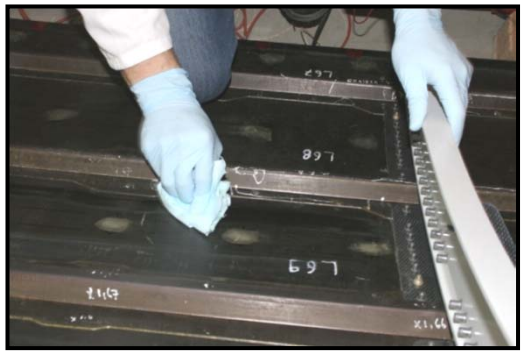
Cyclic mechanical loading



Climatic 4-Point Bending Test

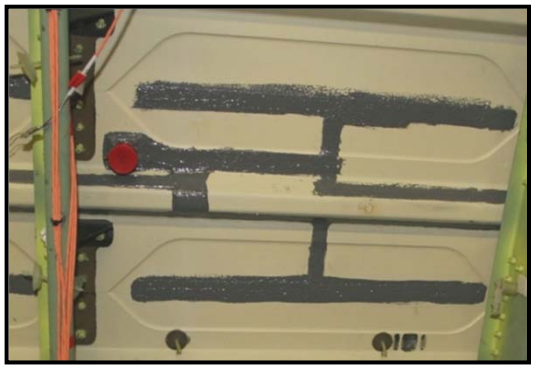
Sensor Installation

Requirement Issue
Verify robust sensor installation process.



Surface Preparation

Application Process of Acousto Ultrasonic Sensors in CFRP Fuselage Skin



Sealant Application & Sensor Connection

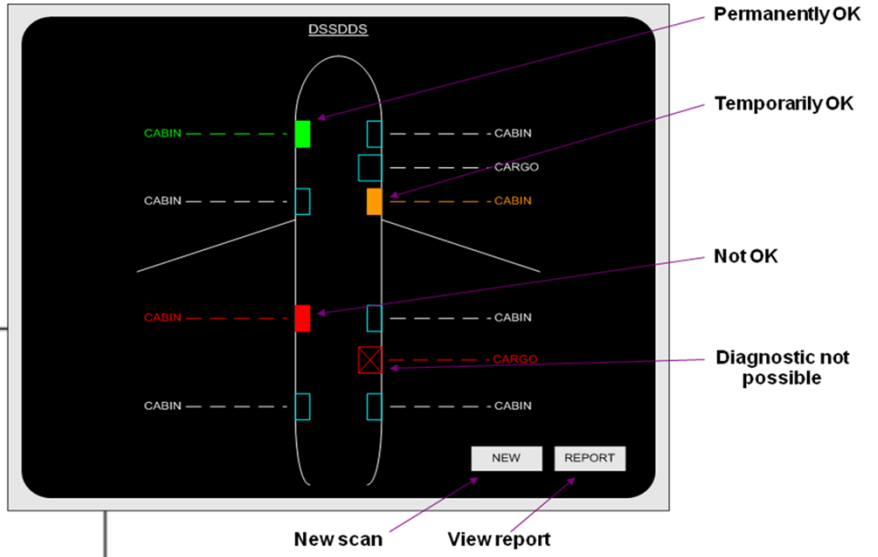
Vacuum bagging

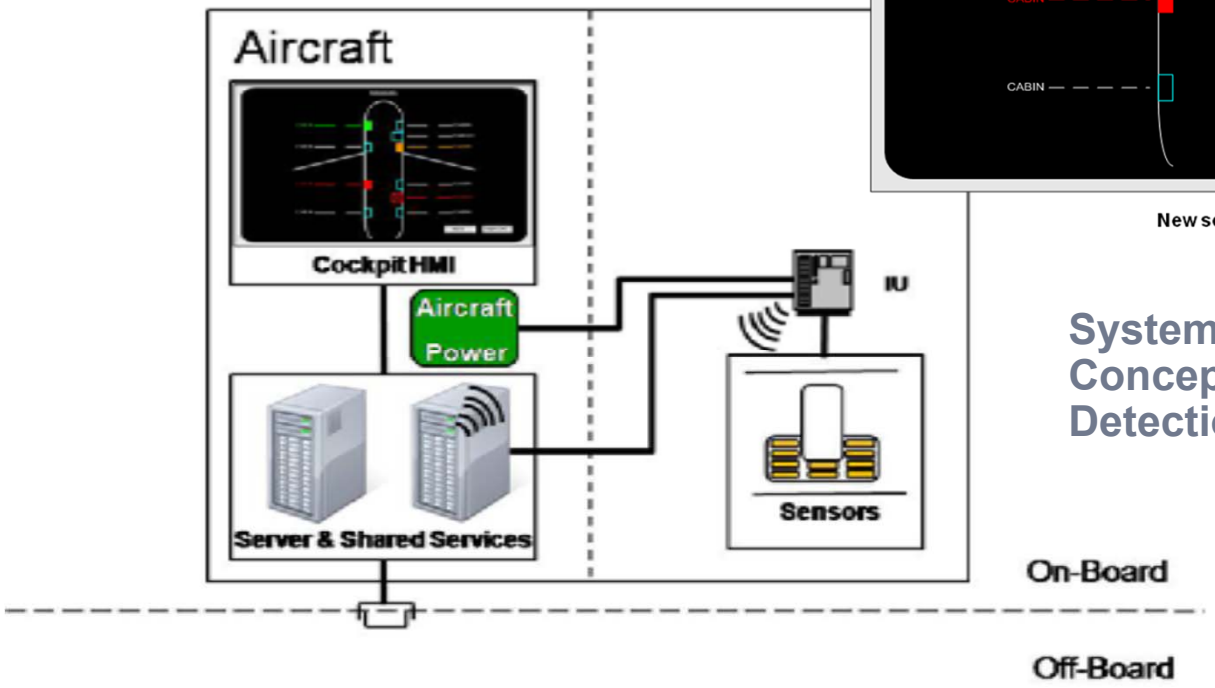
Sensor Application

Systems

Requirement Issue

Define SHM system architecture with respect to aircraft system architecture





System Architecture Integration Concept: Impact Damage Detection System

Contents

Basics for V&V: Standards

	Standard	Focus	Organization
1	Overall V&V Process	Standardize worldwide V&V approach	Worldwide Standardization Organizations - WWSO (e.g. SAE)
2	SHM Usage	Define usage of SHM for maintenance & design	Aerospace Regulators
3	Sensor Quality	Establish Sensor Quality Standards	WWSO (e.g. ISO)
4	Sensor application and protection	Establish and standardize installation processes for sensors	OEM
5	System integration	Establish and standardize system integration processes	System Integrators

1st – Overall V&V Approach: SHM Guidebook

The overall V&V approach for Fixed Wing Aircraft is described in the

SAE ARP6461

Guidelines for Implementation of SHM on Fixed Wing Aircraft

Purpose of the guidelines:

- Provide guidance on the implementation of SHM in aircraft applications
- Provide information on structural maintenance practices and provide guidance on how SHM can be incorporated within or as modifications to current maintenance and airworthiness documents.
- Standardize and harmonize worldwide understanding about SHM (including terminology).
- Provide basic requirements to guide SHM technology development.
- Recommend certification matters that are relevant to SHM
- **Describe the V&V process**

Published in September 2013 !

2nd - SHM Usage – Scheduled Maintenance

Example: MSG 3

The term S-SHM is introduced as a new scheduled structure maintenance task level in MSG-3:

Scheduled SHM (S-SHM):
S-SHM is the act to use/run/read out a SHM device at an interval set at a fixed schedule

SHM is distinguished from other structure maintenance:

Structure maintenance tasks are:
- *General Visual Inspection (GVI)*
- *Detailed Inspection (DET)*
- *Special Detailed Inspection (SDI)*
- *Scheduled SHM (S-SHM)*

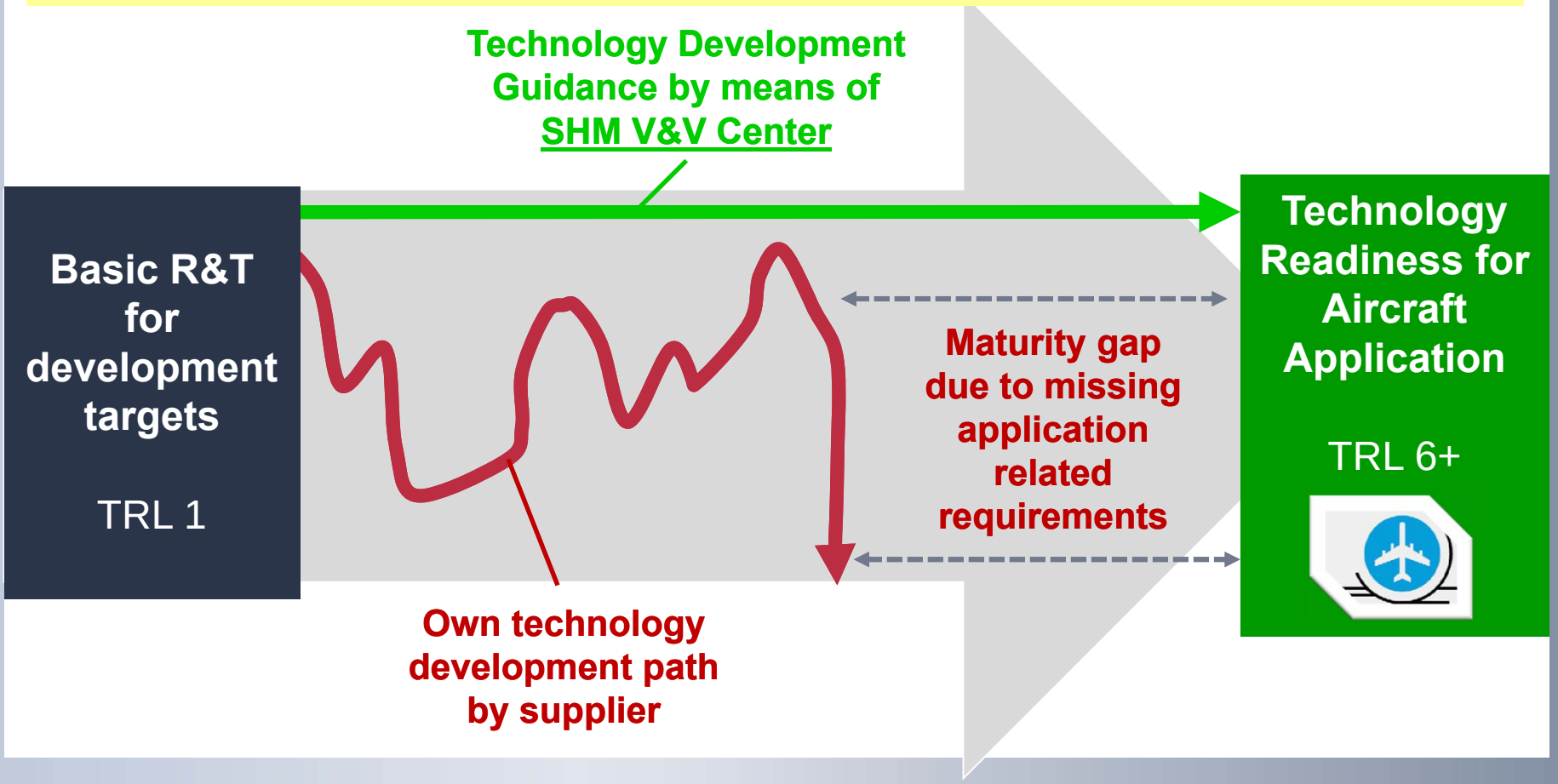
Next Standardization activities

- Quality Standards for Sensors — Missing / partial available
  - Essential Standard to ease Sensor system selection
  - Needed for major SHM sensor families
  - Subject to Public Standard
- Sensor Application Standards — Missing / partial available
  - Process Standardization to apply and protect Sensors
  - Subject to OEM or public Standard
- System Integration Standards — Pending
  - Only needed if existing Standards do not cover the Integration

But how will Standards and a Guided Technology Development be connected?

...via a SHM V&V Center at Airbus M&P

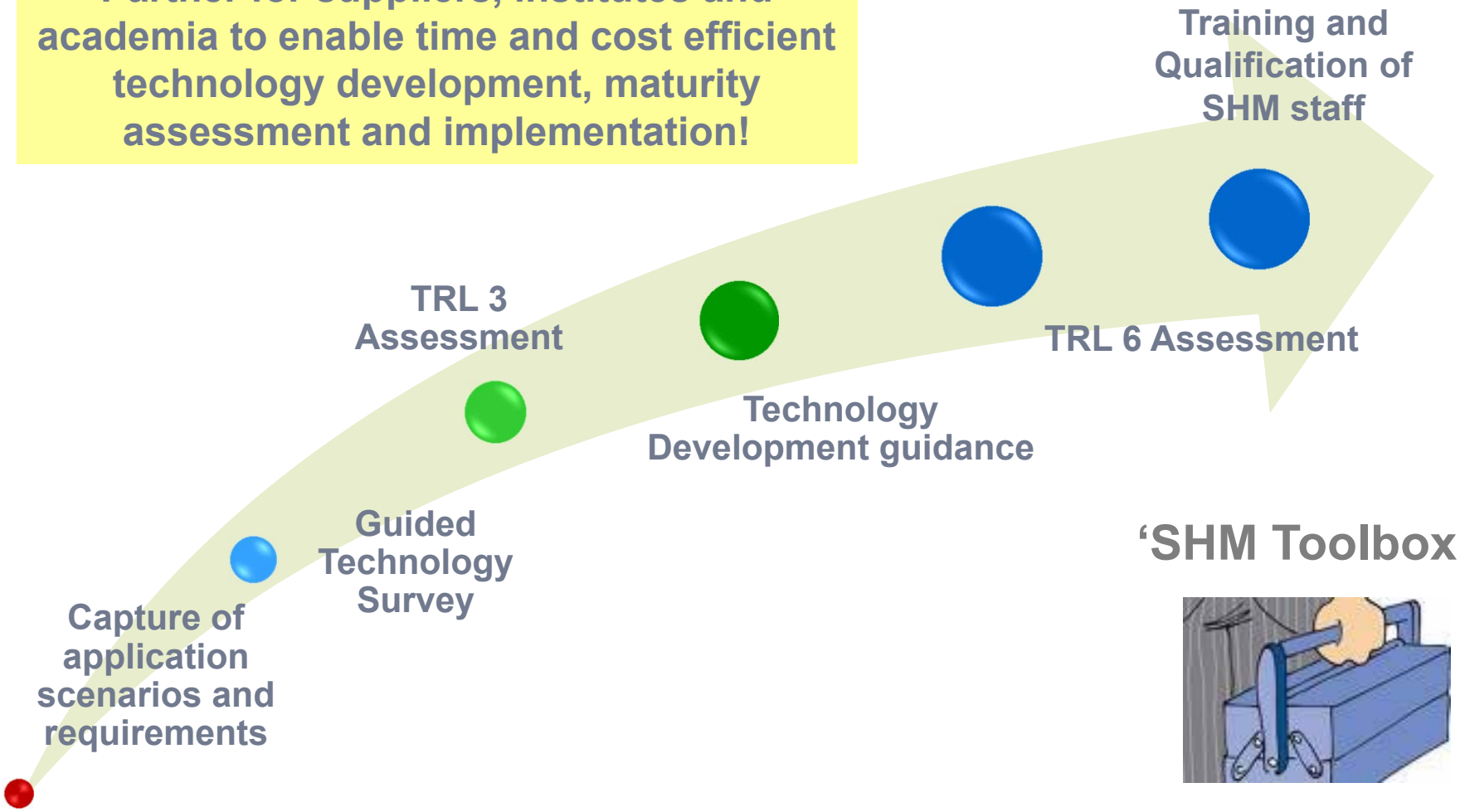
State of the art: SHM technology development and maturity assessment is time and cost consuming!



SHM V&V Center at Airbus M&P – Scope

Under preparation

Partner for suppliers, institutes and academia to enable time and cost efficient technology development, maturity assessment and implementation!



'SHM Toolbox'

How will the approach be transferred into reality?

New EADS Company for NDT & SHM

EADS has founded a new company to provide all kind of NDT **and SHM** services

TESTIA
AN EADS COMPANY

for

- EADS Business Units (Airbus, Eurocopter, etc.)
- Suppliers to Airbus and other EADS BUs
- Airlines and MRO
- Institutes & Universities
- NDT&SHM Equipment Manufacturer

AIRBUS

Testia & SHM

TESTIA AN EADS COMPANY

Testia is a Service, Training & Solution Provider for SHM

- Application & installation of sensors and systems
- Development of SHM solutions for Aerospace & other industries
- Training related to SHM
- Reseller and service company for SHM technologies
- Consultancy

AIRBUS

Testia & „SHM V&V“

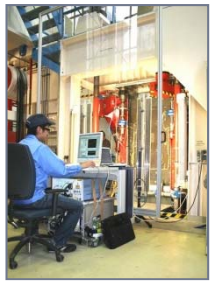
Testia will be a major partner to mature SHM technologies and applications

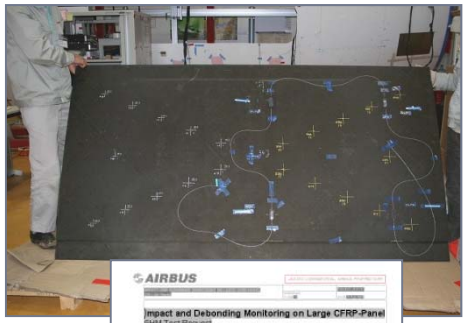
Testia intends to operate a Airbus SHM V&V Center

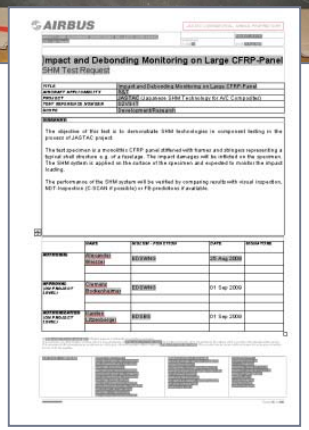
- Entrance point for Airbus V&V requests
- Determine and validate the requirements for applications
- Enable system provider the maturation of their technology in accordance to Airbus and the SAE ARP-6461 (SHM Guidebook) requirements
- Involve worldwide partner to perform required verification tests

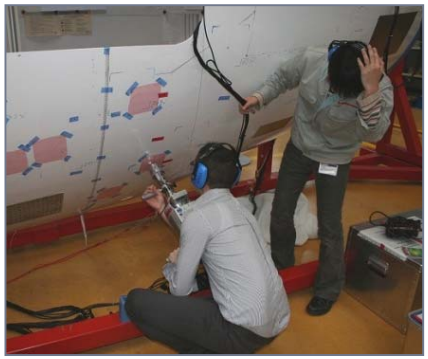
JASTAC Project

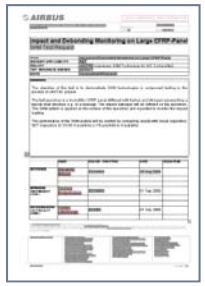
Example: Verification of Detection Capability











Component / Full-Scale / Flight Test — *Airbus*

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Test Request — *Airbus*

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SHM Test Request — *Airbus*

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SHM Application & Test Procedure — *Supplier/Testia*

↓

SHM Application & Test — *Airbus & Supplier/Testia*

↓

Test Report — *Supplier/Testia*

↓

Verification — *Airbus & Supplier/Testia*

AIRBUS

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Conclusion

- SHM is key enabler for best aircraft operability and revolutionary structure design and on its way to application.
- SHM development process and maturity assessment established to minimise development time and cost.
- Join our guided development network in order to realise SHM and deploy its benefits together !