"Science @ MCC"

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Presentation Outline

- **"The NDTonAIR" project**
- **Investigated applications**
  - Ultrasonic Inspection
    - ☛ Wing Gear Rib 6 Crack in the A33F
  - Active Thermography
    - ☛ Water ingress
    - ☛ RR Air Intake Noise Panel
    - ☛ Loose rivets
- **Future works and Conclusions**

The NDTonAIR Project

Beneficiaries (Recruiting & Training):

Univ. Perugia (IT) – Coord. Prof P. Burrascano

Brussels Airlines (BE) – Mr J. Reynaert

CEA-List (FR) – Dr D. Premel, Dr C. Rebaud

Fraunhofer IKTS (DE) – Dr B. Koehler

Kaunas KTU (LT)- Profs R.Kazis, L. Mazeika, E. Jasiuniene

KU Leuven (BE) – Profs M.Wevers , C. Gloriuex, H. Pfeiffer

Univ. de Nantes (FR) – Prof G. Berthiau

Univ. of Newcastle (UK) – Prof G.Y. Tian

RECENDT (AT) – Dr P. Burgholzer

TWI Limited (UK) – Dr S. Soua

Univ. of Warwick (UK) – Profs D.Hutchins ,S. Dixon

Partners (Secondment & Training):

Univ. Calabria (IT) – **Chair of the supervisory board Prof M. Ricci**

Manager Dr S. Laureti

Univ. Cassino (IT)

COTESA (GE)

Dresden TU (GE)

FH Upper Austria (AT)

JKU Linz (AT)

MDP (IT)

Univ. Paris Saclay (FR)

SIEMENS (GE)

X-Phase(IT)

The NDTonAIR Project

www.ndtonair.eu

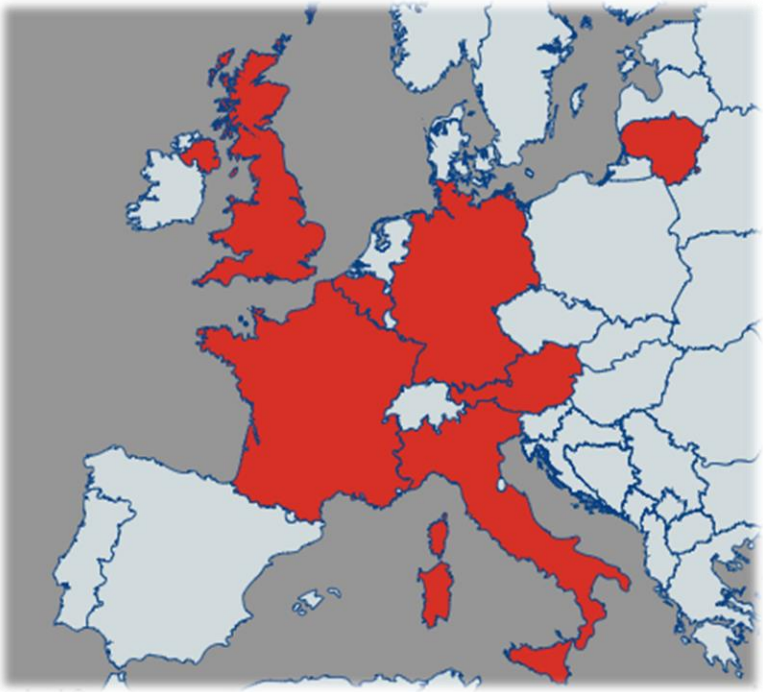
3.8 M€

4 years

15 PhD/ESR's

- Development of new NDT & SHM methods
- Promotion of (non-)scientific collaboration
- Training of aviation NDT experts

Foster
academic & industrial
collaboration



Investigated applications

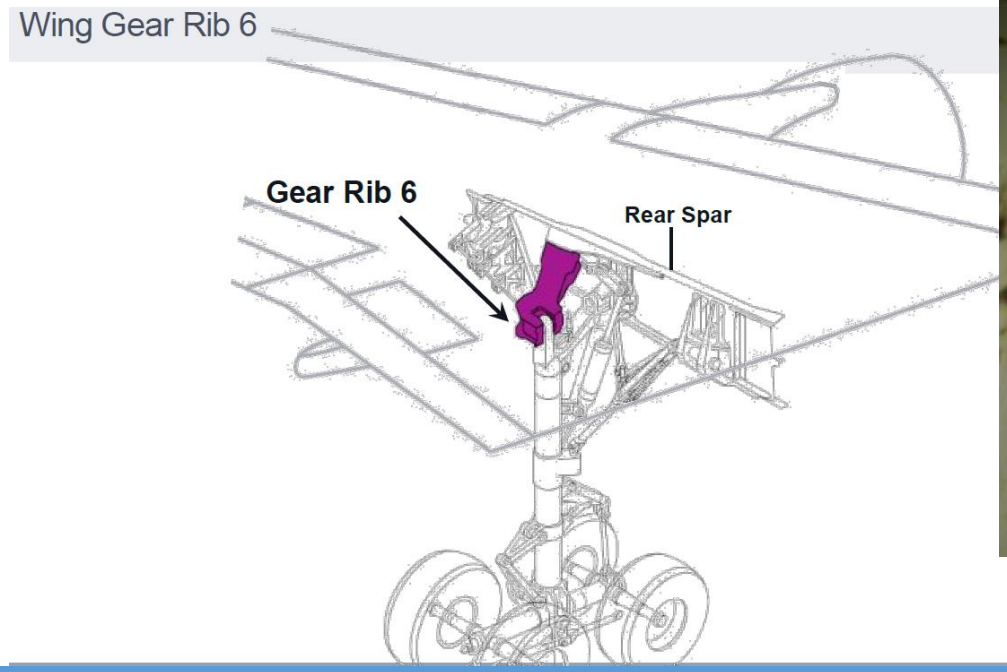
- **Ultrasonic Inspection**
  - 👉 **Wing Gear Rib 6 Crack in the A33F**
- Active Thermography
  - 👉 Water ingress
  - 👉 RR Air Intake Noise Panel
  - 👉 Loose rivets

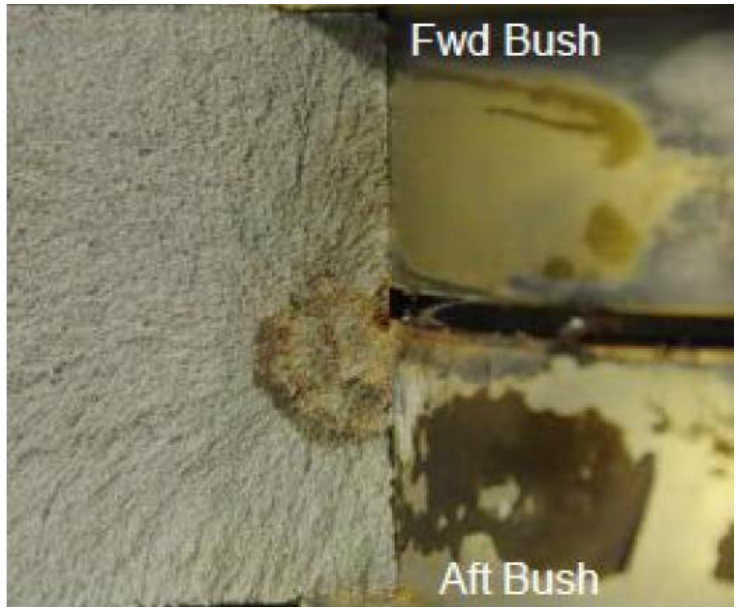
Wing Gear Rib 6 Crack in the A33F - AIRBUS

➢ **Standard maintenance procedure: REMOVAL OF LANDING GEAR**

Assumptions:

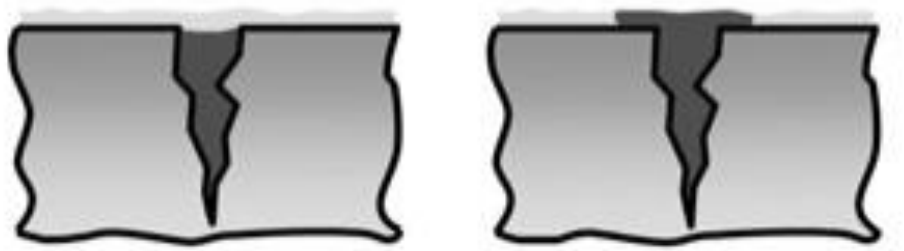
- Crack propagation from the inside;
- Initial starting point of crack between FWD and AFT Bush (see picture below);
- Small cracks only detected with Eddy Current after removal of Landing Gear;
- Visual inspection only enough when crack propagated through the whole structure;





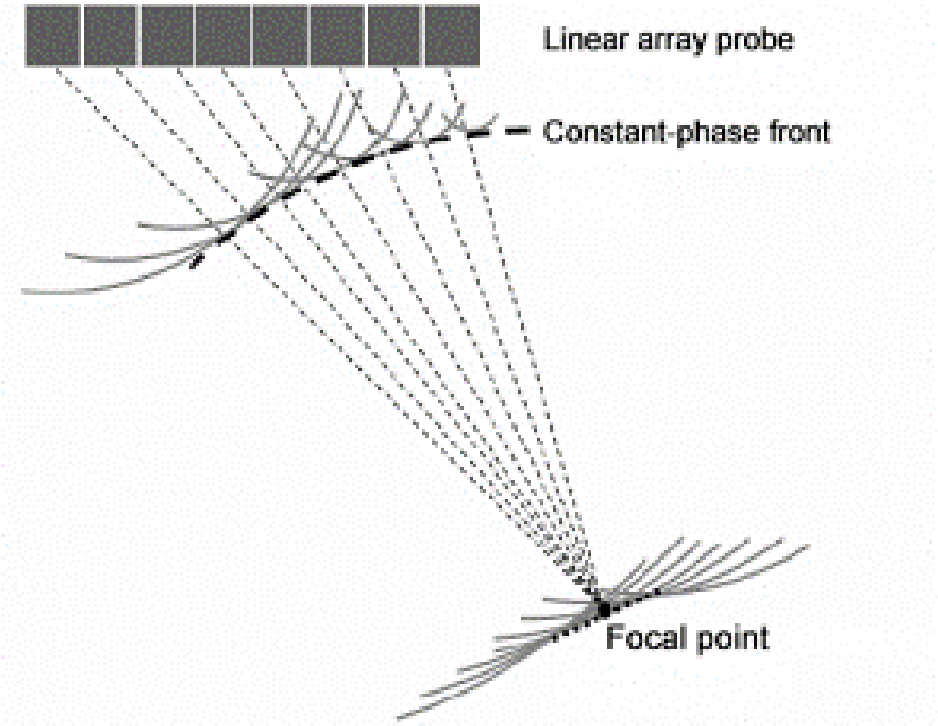
Wing Gear Rib 6 Crack in the A33F - AIRBUS

Standard maintenance procedure



- Inspection of moved bushes
- If grease and/or bushes are moving, then:
  - Landing Gear (LG) removal;
  - Dye penetrant inspection;

Proposed Inspection Method: Ultrasonic Phased Array



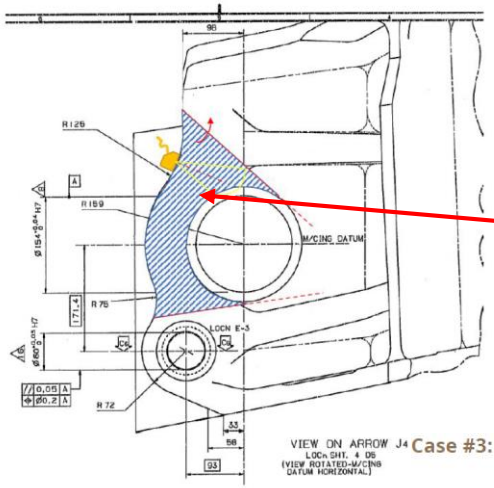
- Inspection of moved bushes
- If grease and/or bushes moved:
  - ~~landing gear removal~~
  - PAUT inspection

Wing Gear Rib 6 Crack in the A33F - AIRBUS

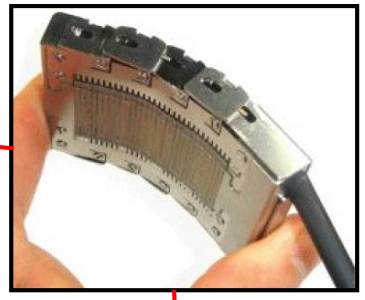
- **Standard maintenance procedure: <u>REMOVAL OF LANDING GEAR → Time consuming!!</u>**

PROPOSED SOLUTION: Phased-Array Ultrasound without landing gear removal!

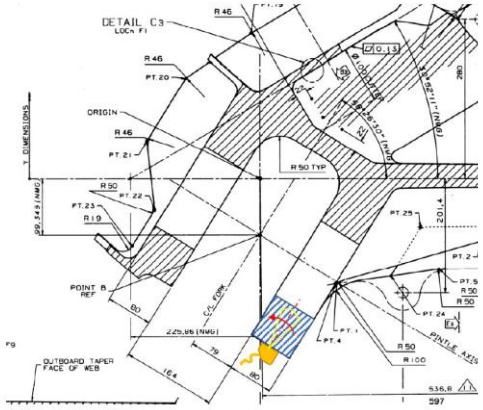
Case #1: Inspection from the front face of the Rib



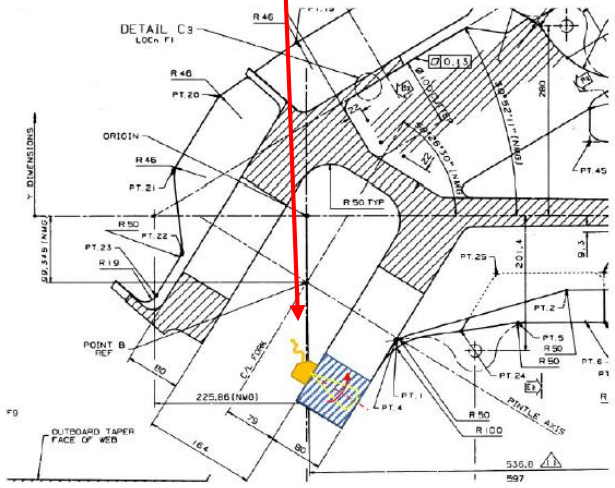
Phased-Array Probe



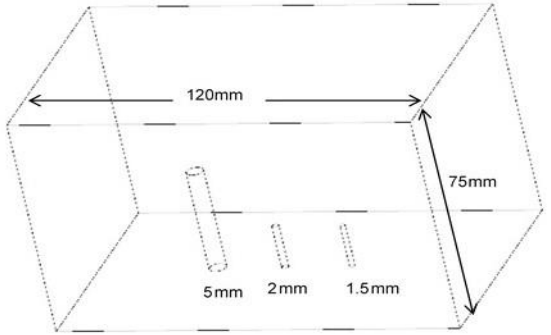
Case #2: Inspection from the front face of the Rib



Case #3: Inspection from the inner and/or outer surface of the Rib

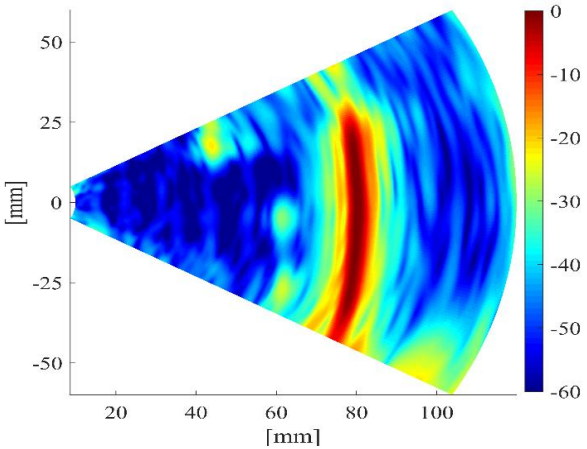


Our proposal: Pulse-compression Phased-Array system



Advantages over standard Phased-array systems:

- The use of advanced input signals and processing (coded signals and pulse-compression) provides a higher detectability!



Wing Gear Rib 6 Crack in the A33F - AIRBUS

PROPOSED SOLUTION: Pulse-compression Phased-Array Ultrasonic testing without landing gear removal!

- LG replacement: **c.a. 25 k€**
- 6 weeks **unscheduled Aircraft on ground** (AOG) 1000 k€ pax compensation for Brussel Airlines
- 750 k€ wet leased A/C

→ c.a. 1.75 M€ of saving per effected A/C

Actual state of the investigation:

1. Received Rib from Lufthansa Technik
2. Performing FE simulations
3. Performing measurements on REAL Rib!
4. Go to the hangar and measure in REAL environment!

SAFETY

NOTE: the aim is NOT to replace current inspection methodology but to provide a handy tool for more frequents inspections!!

Investigated applications

- Ultrasonic Inspection
  - 👉 Wing Gear Rib 6 Crack in the A33F
- **Active Thermography**
  - 👉 **Water ingress**
  - 👉 RR Air Intake Noise Panel
  - 👉 Loose rivets

Water Ingress detection with Thermography

AIRBUS

CUSTOMIZATION	AIRCRAFT TYPES	DOCTYPES	REVISION DATE	TITLE	TAIL NUMBER - MSN - FSN
	A330 A340	NTM	01-Apr-2019	51-10-25-290-801-A01 - General Procedure for Thermography Inspection to detect Trapped Water in Honeycomb Structures mounted Vertically for Ambient Temperatures between 10° C and 35° C (50° F and 95° F) - Procedure A	

***** ON A/C MSN ALL***

TASK 51-10-25-290-801-A01
General Procedure for Thermography Inspection to detect Trapped Water in Honeycomb Structures mounted Vertically for Ambient Temperatures between 10° C and 35° C (50° F and 95° F) - Procedure A

1. Task Supporting Data

A. Area of Applicability

This procedure provides the general procedure for inspection of honeycomb sandwich structures with FRP layers and honeycomb core. There is a limitation to thicker top skins and honeycomb identification (See FIGURE 51-10-25-991-001).

This procedure is valid for all undisturbed honeycomb sandwich structures in the following configuration (See FIGURE 51-10-25-991-001):

- FRP top and bottom layers
- Layer thickness L = 0.4 mm – 1.5 mm (0.016 in – 0.059 in) (layer on the side to be inspected)
- Honeycomb:
  Honeycomb height H = 30 – 40 mm (1.18 in – 1.575 in) and cell size between 4.8 mm and 6.4 mm (0.189 in and 0.252 in)
  Minimum amount of fluid:
  At honeycomb height H = 30 mm (1.18 in) = > 6 ml fluid
  At honeycomb height H = 40 mm (1.575 in) = > 6 ml fluid

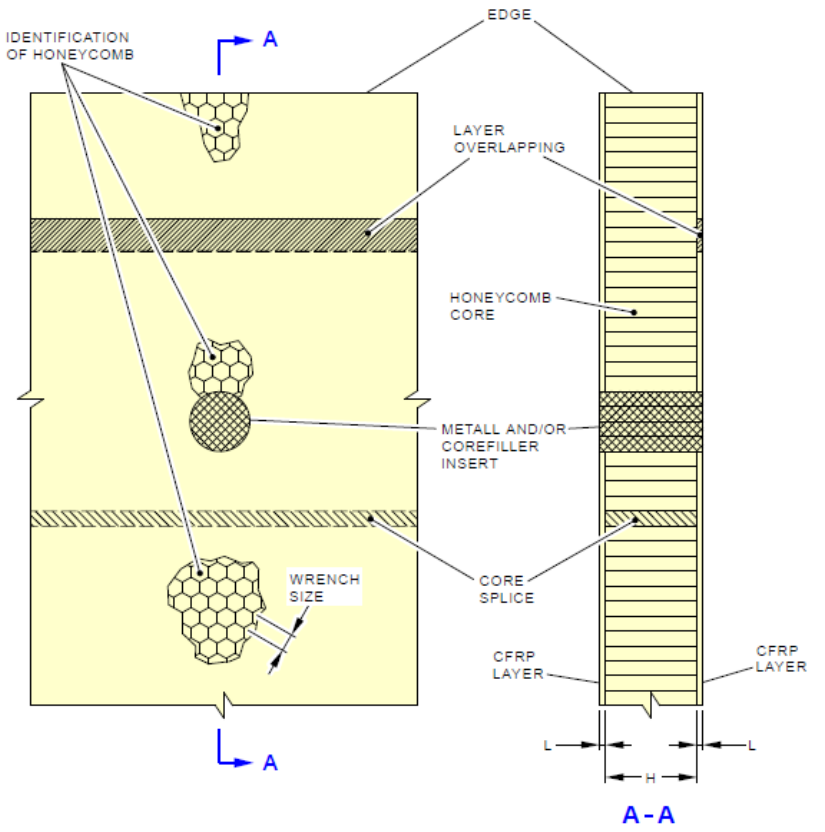
NOTE: Repaired areas are not testable
Repaired areas (outer skin repairs and core repairs) are normally not visible at the rudder structure. For identification of the repaired areas see the test results of the thermography inspection according to task 55-40-50-290-801.

B. Description of Possible Damage

(1) Different Damage Types
- Honeycomb cells containing more than 50% of trapped fluid per cell in areas equal to or greater than 200 mm² (0.310 in²) in size (See FIGURE 51-10-25-991-002).
- The filled honeycomb cells must lie next to each other (See FIGURE 51-10-25-991-002).
- The minimum distance or extent from all edges must be 15 mm (0.591 in) (See FIGURE 51-10-25-991-002).

C. Job Set-Up Information

(1) Tooling:



NOTE:
L = LAYER THICKNESS
H = HONEYCOMB HEIGHT

MATERIAL	WEIGHT	WRENCH SIZE
HONEYCOMB	kg/m³	mm (in)

L_NT_511025_1_0010101_01_01

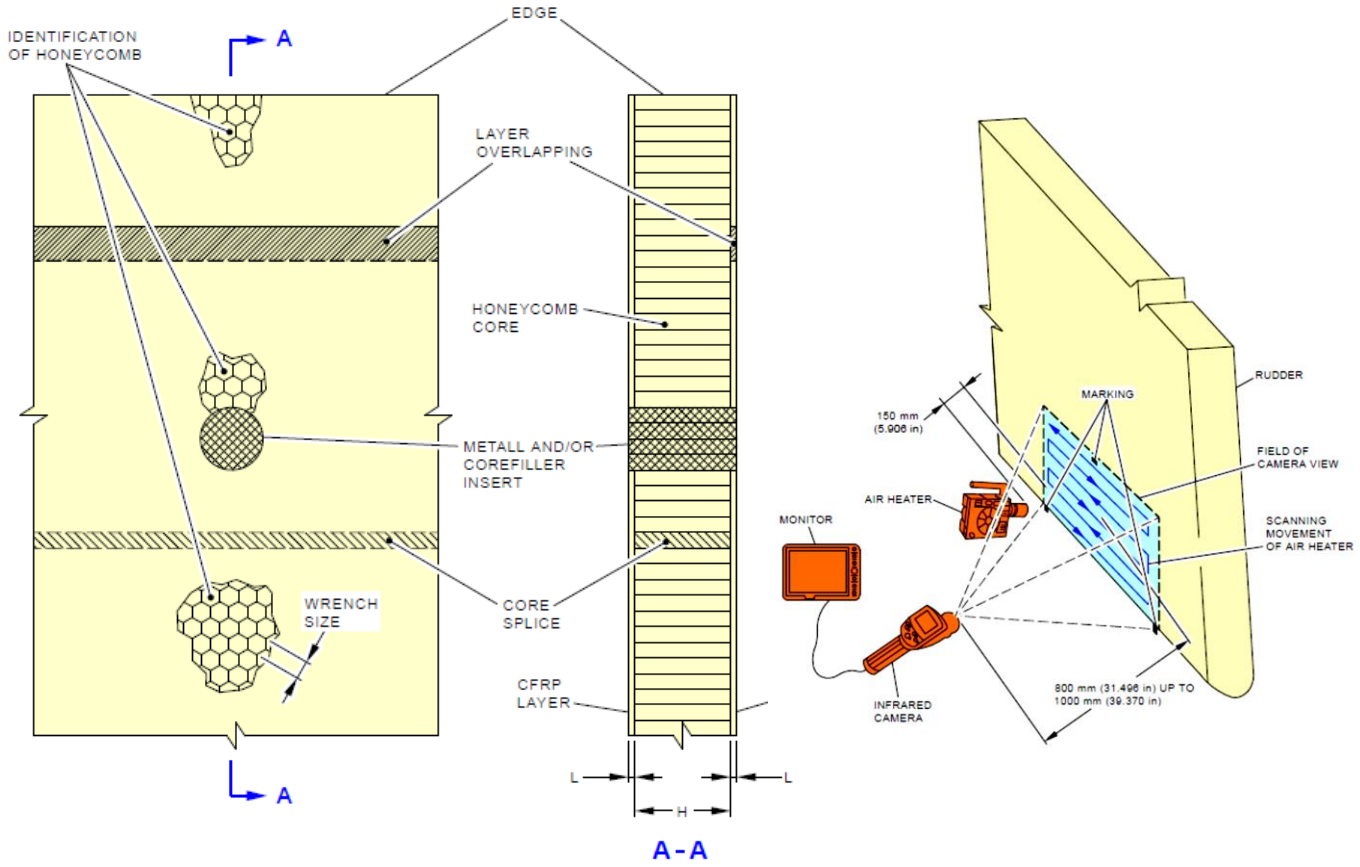
Figure 51-10-25-991-001-A (SHEET 1) - Inspection Area
**** ON A/C MSN ALL**

Water Ingress detection with Thermography

1. Task Supporting Data

   A. Area of Applicability

   This procedure provides the general procedure for inspection of honeycomb sandwich structures with FRP layers and honeycomb core. There is a limitation to thicker top skins and honeycomb identification (See FIGURE 51-10-25-991-001).



Limitations:

- Detectability of water ingress is limited to "relatively-thin" composite parts.
- Low detection capability - both standard heat modulation scheme (step-heating or long-pulse) and heat sources (air heater) are employed.
- The data is not saved, and the movement is left to the human being as well as the data assessment.

Water Ingress detection with Thermography

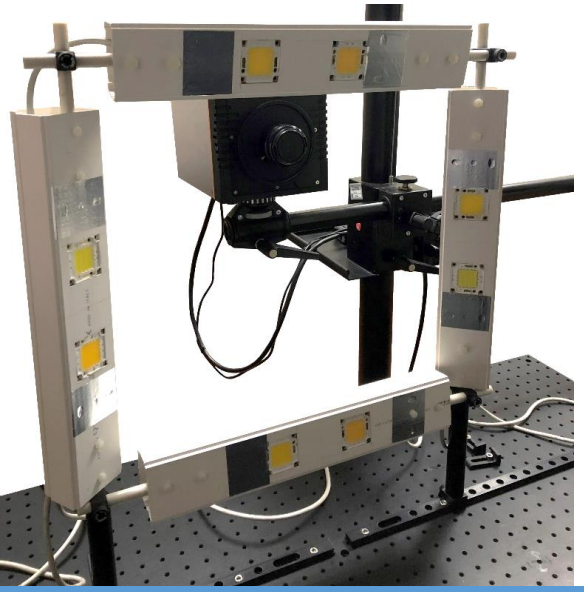
Proposed solutions:

- **Employing suitable heat sources (low power LED chips or halogen lamps), advanced heat modulation scheme and post-processing techniques for:**

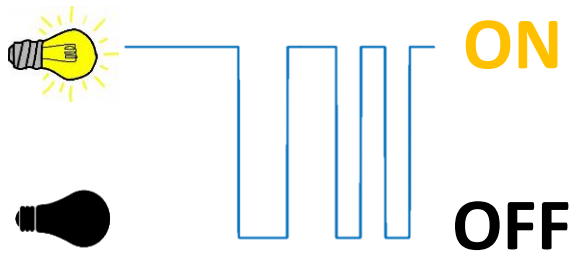
1) enhancing water ingress detection for thicker composite samples;

2) reducing power consumption.

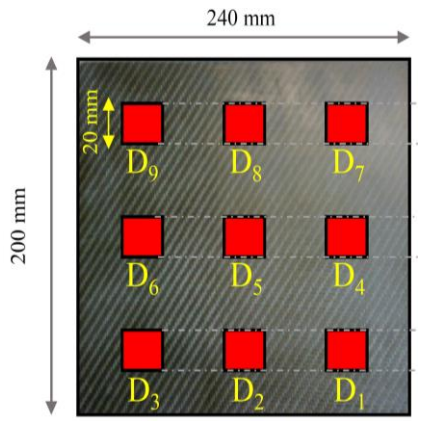
400W LEDs chips Thermography Setup

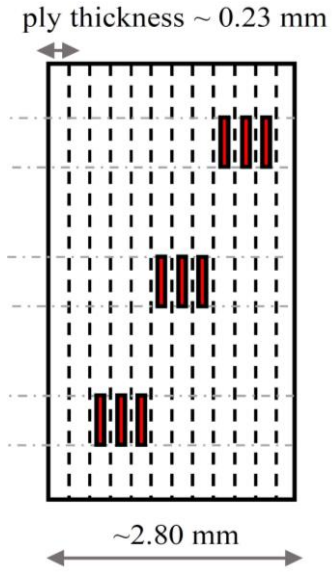


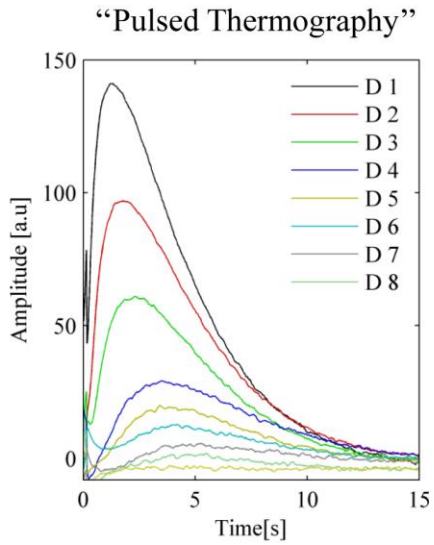
An example of coded-modulated modulation:

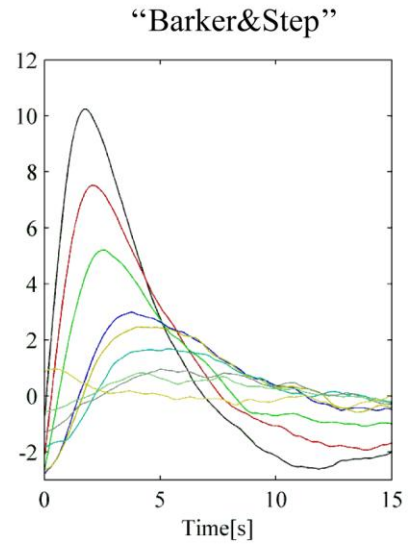


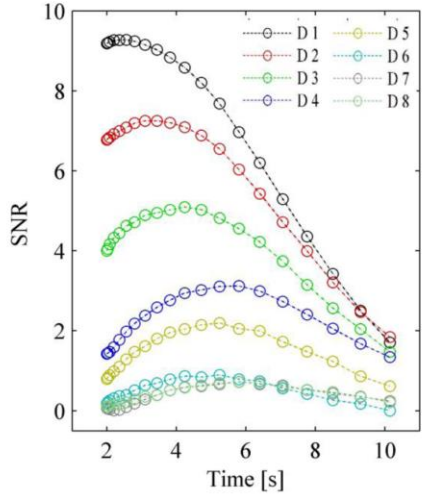
The effectiveness of the proposed methodology has been proved for CFRP inspection!

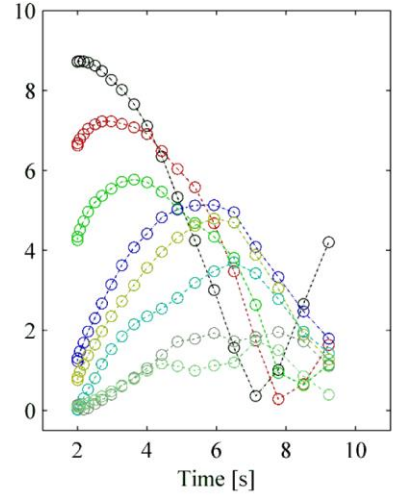












Water Ingress detection with Thermography

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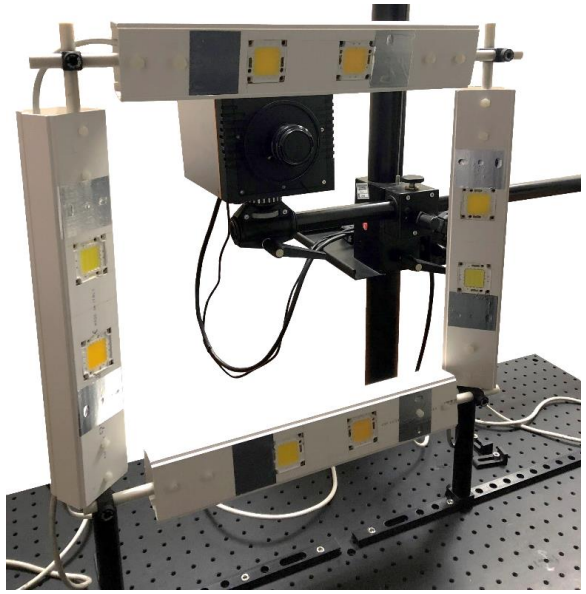


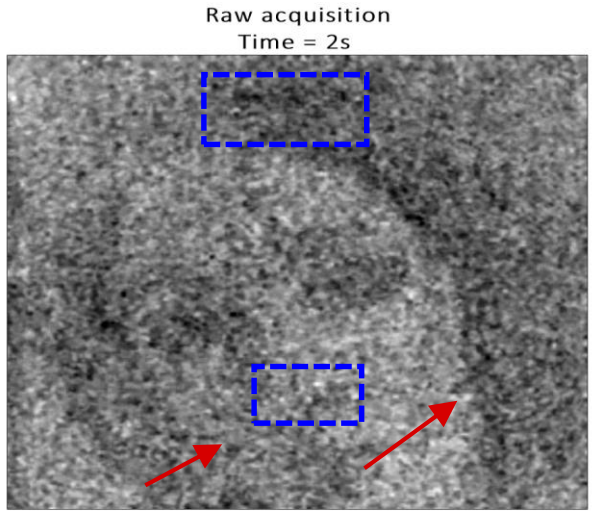
!!!

6 kJ flash head lamps (or even stronger) must be used with care!! Coded-modulated LED chips + Pulse-compression provides the same results, and even better in some cases, but with no risks for the user

!!!

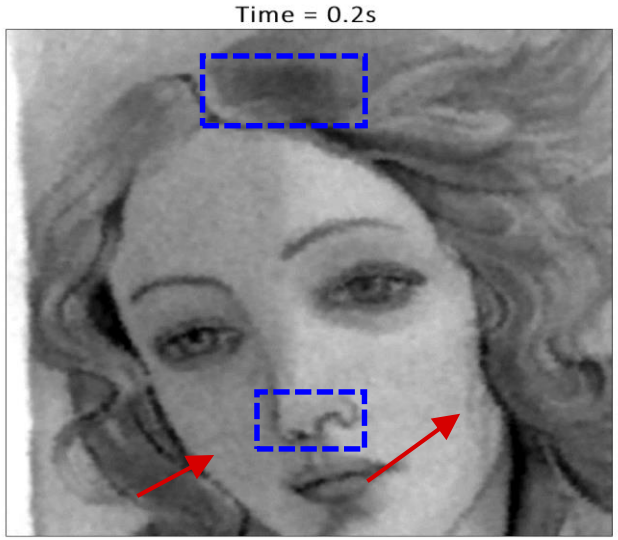
WITHOUT

Pulse-compression



WITH

Pulse-compression



Water Ingress detection with Thermography

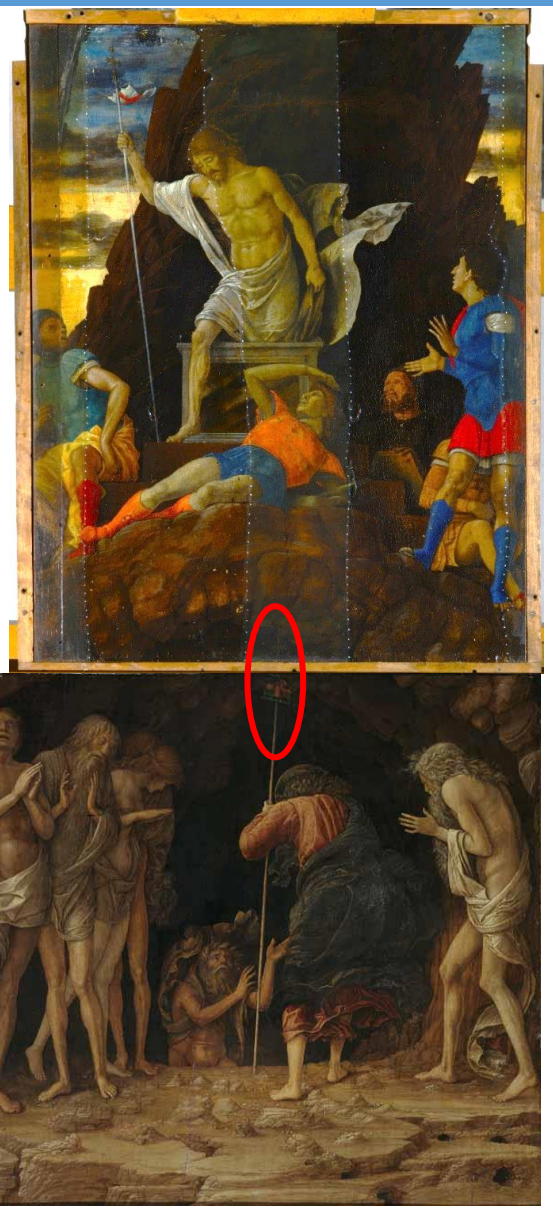
Pulse-compression Thermography example

"Resurrezione" – Andrea Mantegna
Accademia Carrara, Bergamo
Paintings on panel, end of 15th century
Recently re-attributed to Andrea Mantegna, as the upper half of a two-part paintings together with "Discesa di Cristo al limbo"

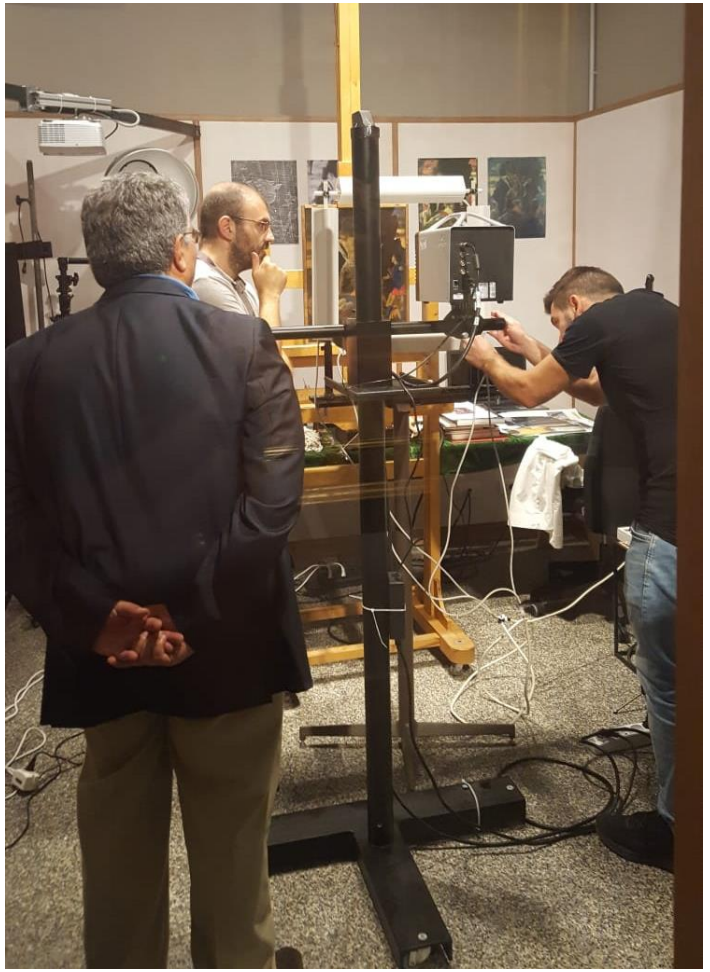
Measurements made on-site during the restoration process

Many indications from time-analysis of thermograms: wood grain structure, nails & grouts, cracks, preparation layer

Water Ingress detection with Thermography

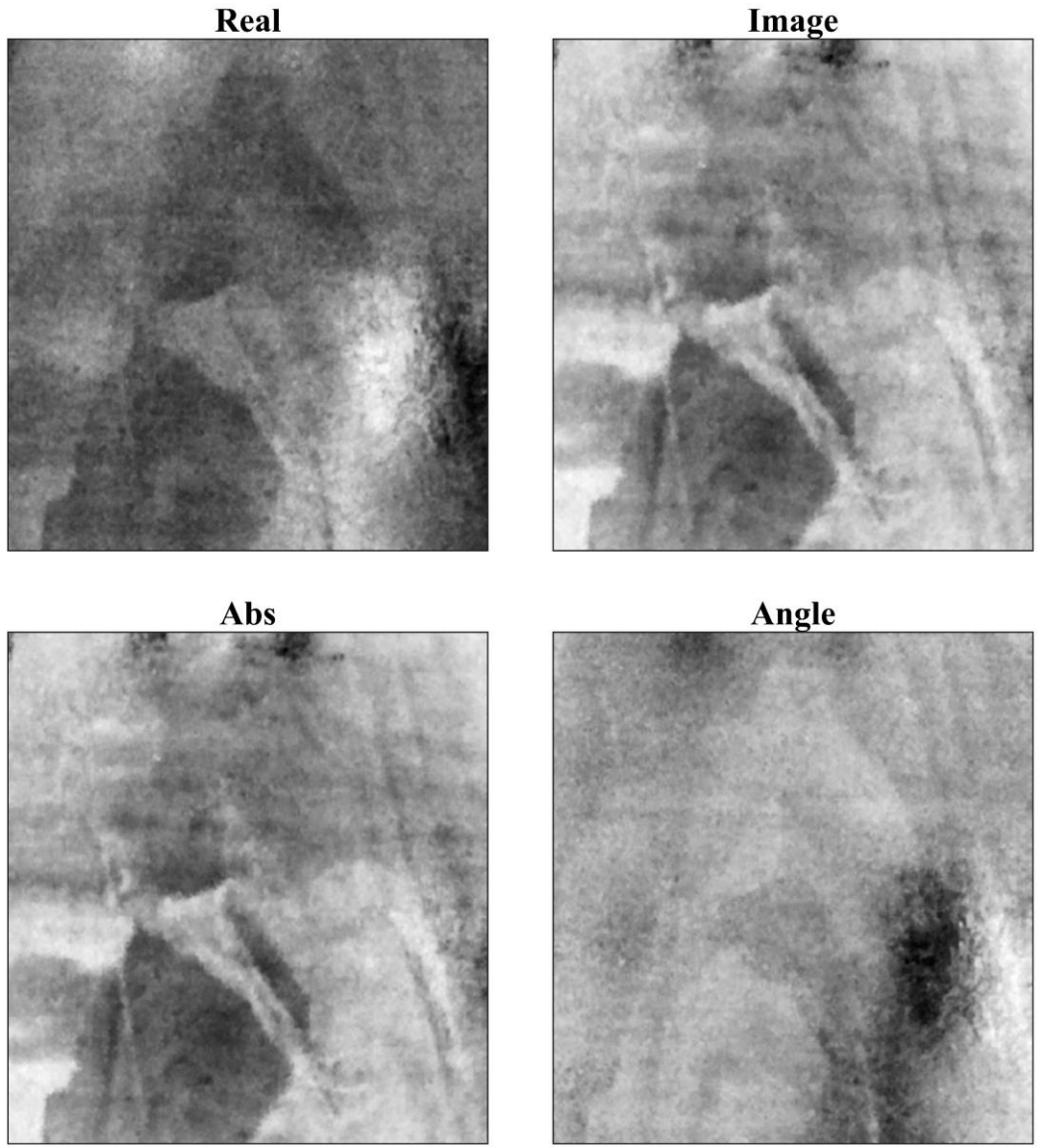


Sold for 30 milion € !



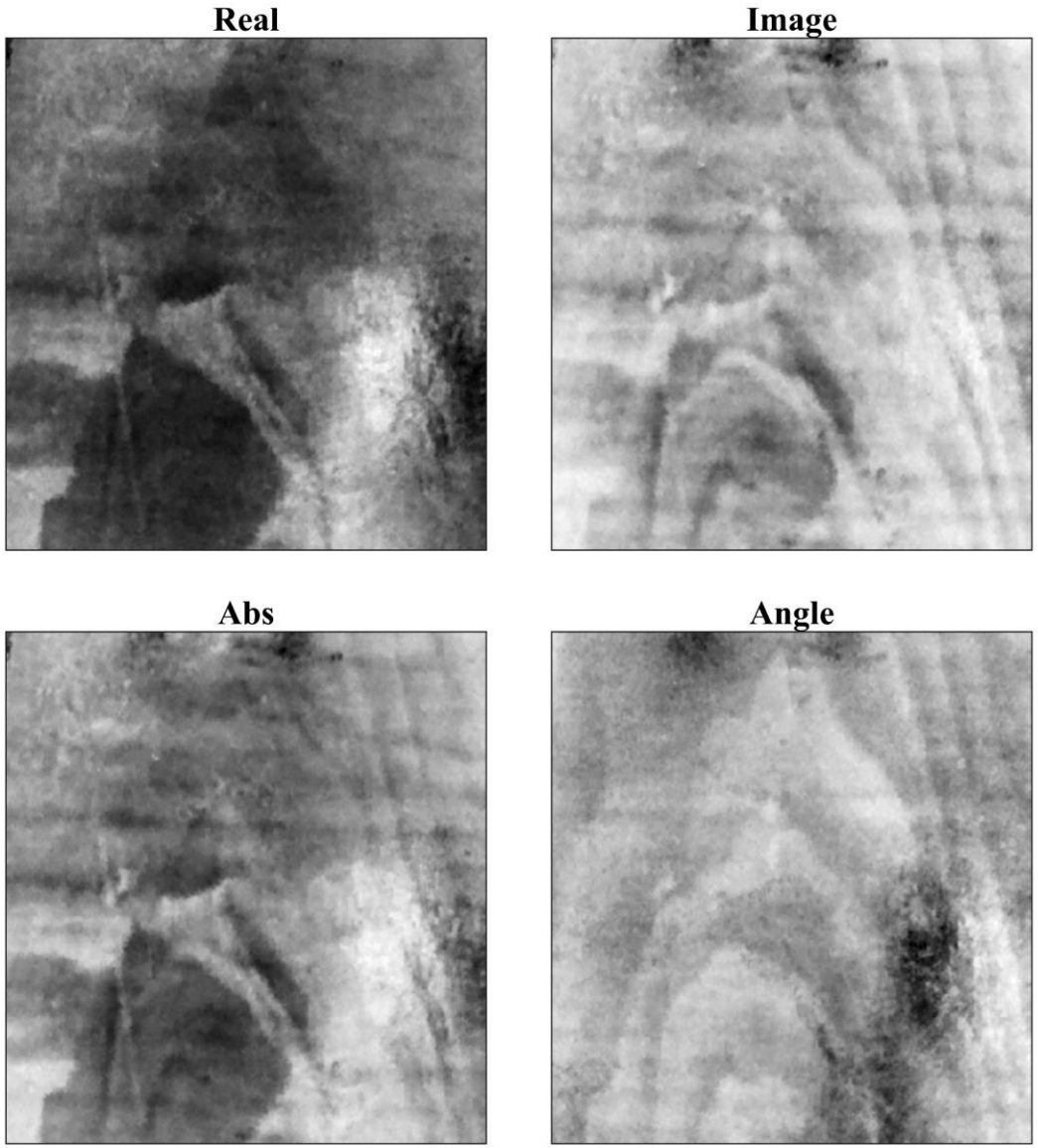
Water Ingress detection with Thermography

T= 0.10 s



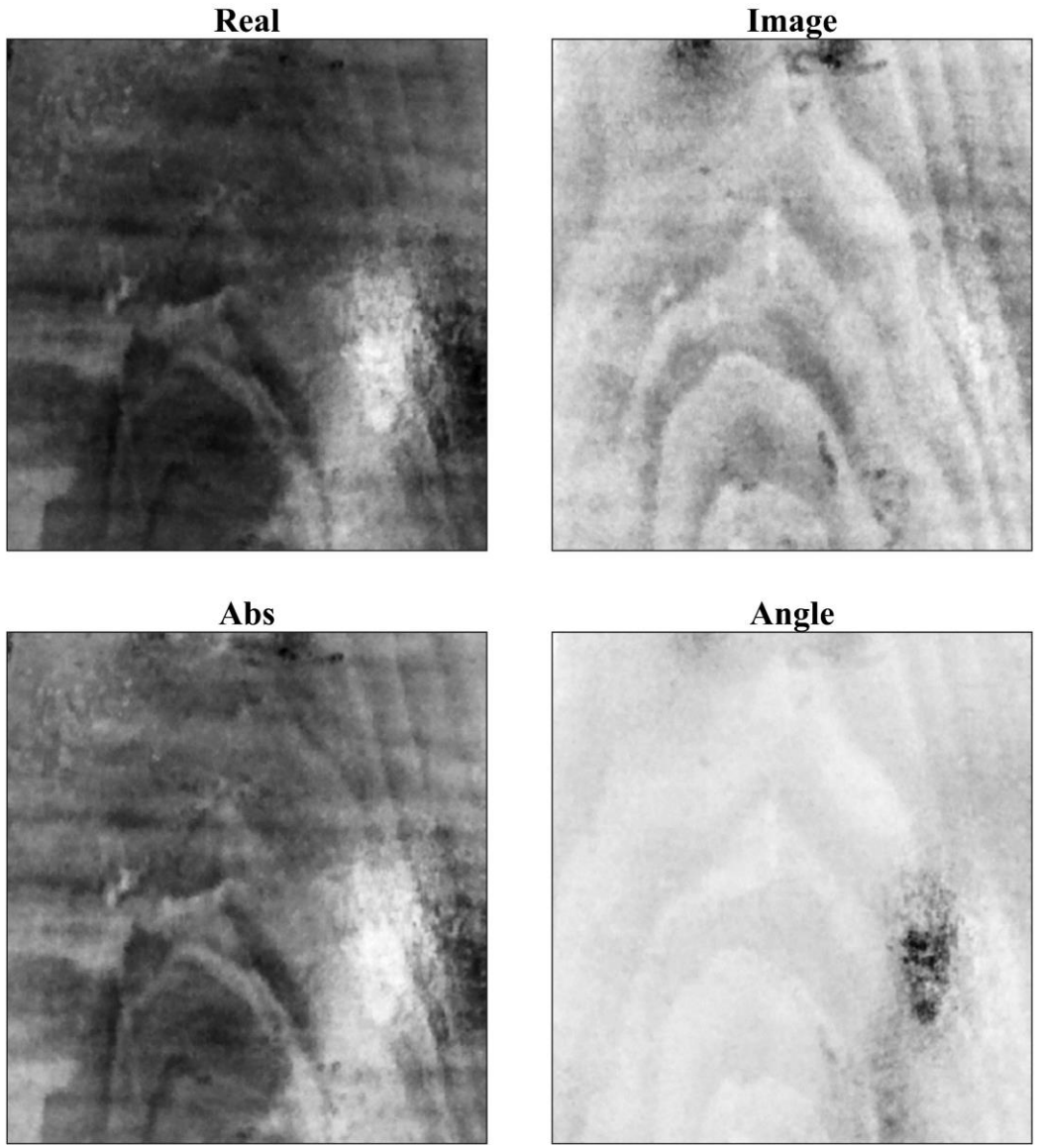
Water Ingress detection with Thermography

T= 0.35 s



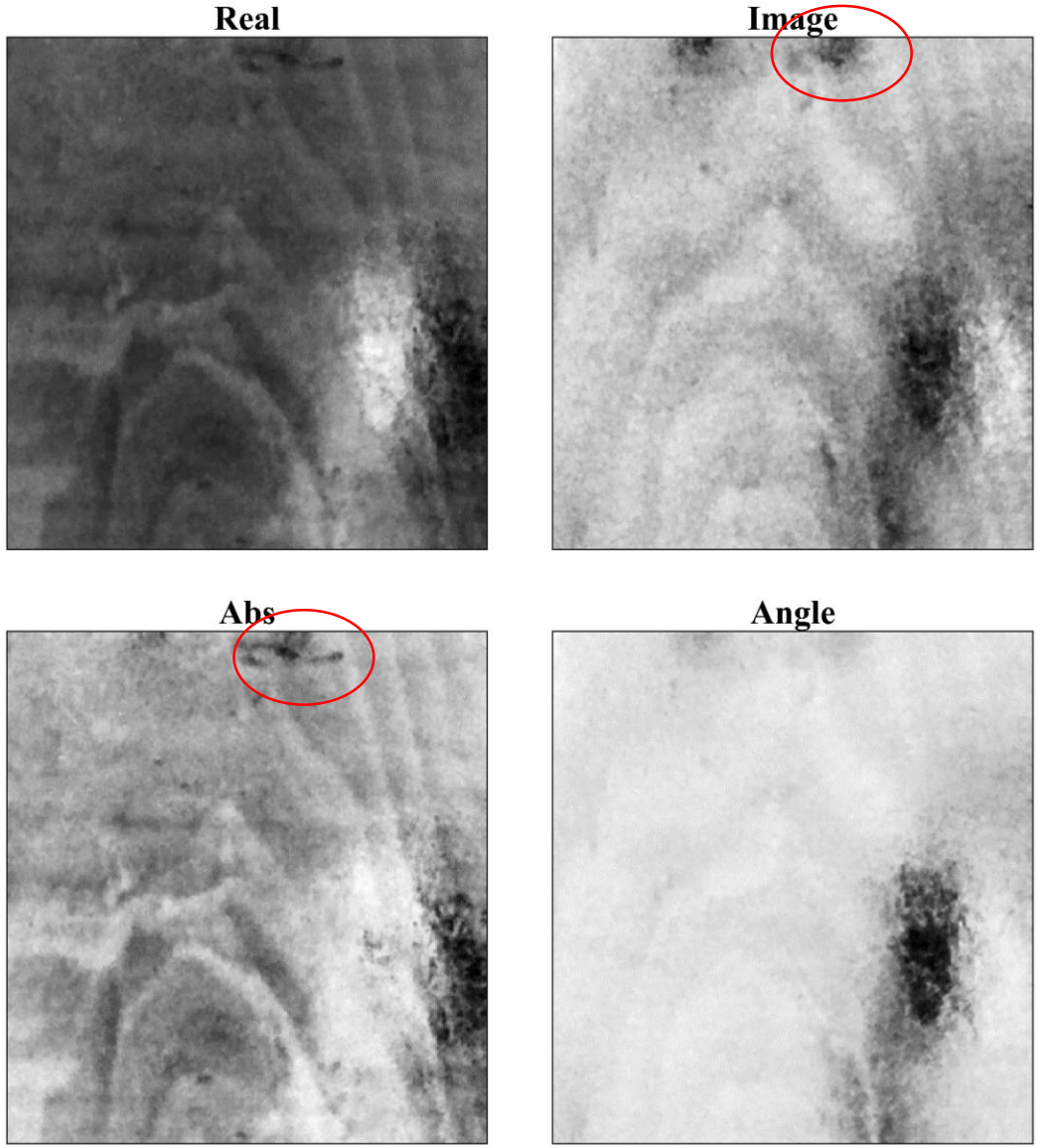
Water Ingress detection with Thermography

T= 0.60 s



Water Ingress detection with Thermography

T= 0.60 s

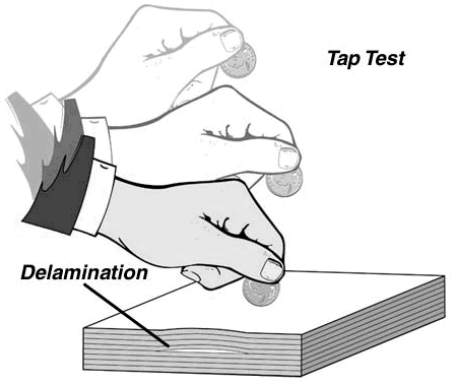


Investigated applications

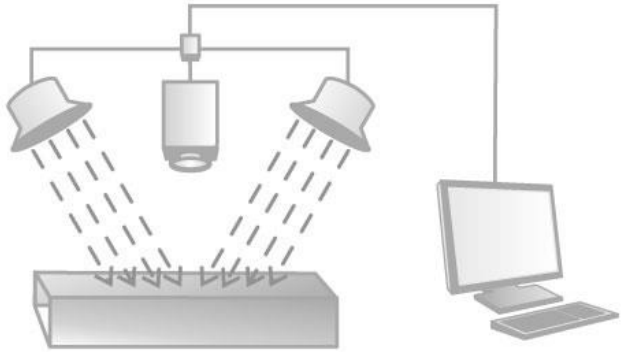
- Ultrasonic Inspection
  - 👉 Wing Gear Rib 6 Crack in the A33F
- **Active Thermography**
  - 👉 Water ingress
  - 👉 **RR Air Intake Noise Panel**
  - 👉 Loose rivets

Investigated applications: RR Air Intake Noise Panels

RR Air Intake Noise panels inspection (once per year)



- 10 h of work
- Hand-written records
- Accuracy is very subjective



- Inspection time: c.a. 30 min
- Automated inspection
- Objective Tomographic & Digital data
- Pixel Accuracy

- **95% time reduction for inspection!!!**

➢ Higher detection capability & more frequent inspections:

- big repairs → small repairs (-200 k€)
- Less likely to ground A/C!!!
- No spare part of inlet needed (~~70 k€~~/month) (rented)

SAFETY

95 % time saving → part of A-check?

Investigated applications

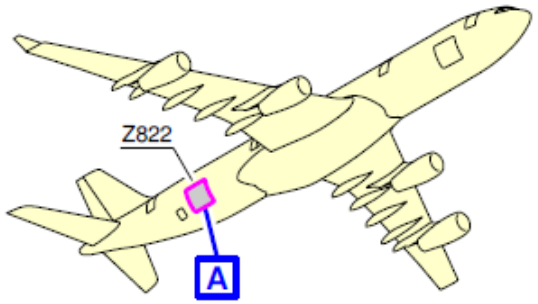
- Ultrasonic Inspection
  - ☛ Wing Gear Rib 6 Crack in the A33F
- **Active Thermography**
  - ☛ Water ingress
  - ☛ RR Air Intake Noise Panel
  - ☛ **Loose rivets**

Loose Rivets

MANDATORY MANDATORY MANDATORY

ATA SYSTEM: 52

TITLE: DOORS - AFT CARGO COMPARTMENT DOOR - INSPECT STRUCTURE FOR CRACKS AND LOOSE/LOST/SHEARED RIVETS



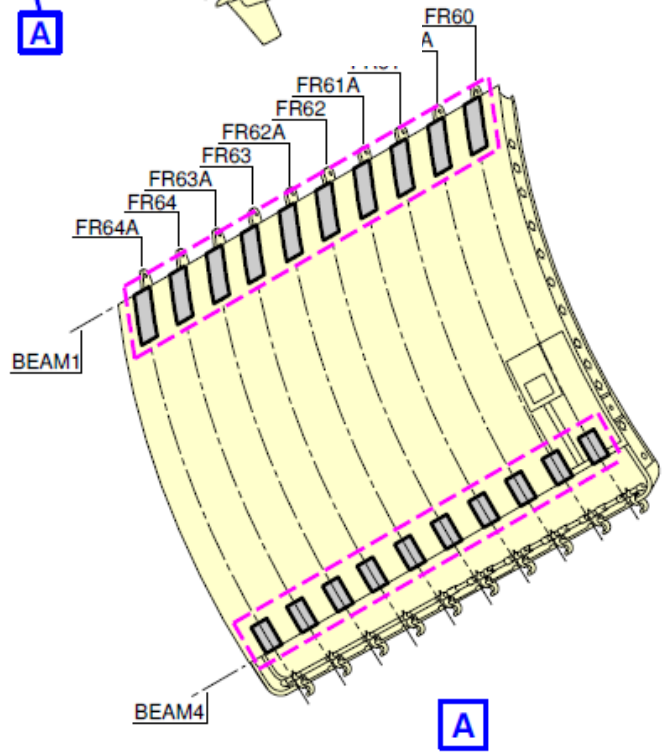
- Mandatory inspection of AFT Cargo Door

- Inspect visually Loose/Lost/Missing Fasters

(a) Do a Detailed inspection of the outer skin and inner surfaces of the AFT Cargo Compartment Door frame heads area at beam 1 for cracks, loose, sheared or missing fasteners at the subsequent locations in ac[illegible] NTM 51-90-00 and as shown on Fig. A-GBFAA Sheet 01, Fig. A-GBGAA Sheet 01, Fig. A-GBHAA Sheet 01 and Fig. A-GBJAA Sheet 01:

DESC 51-90-00-001 CONF A - General

1. General
   - A. Visual inspection procedures are among the simplest and most economical of all the nondestructive testing methods.
   - B. Optical instruments can be used to assist the inspection by magnifying discontinuities that are too small to be seen by the unaided eye.
   - C. Other instruments may also be used to inspect areas where the access is difficult.



Loose Rivets

MANDATORY MANDATORY MANDATORY

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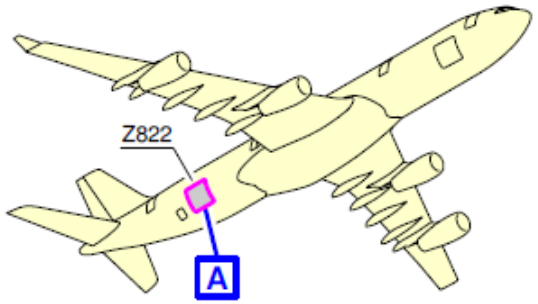
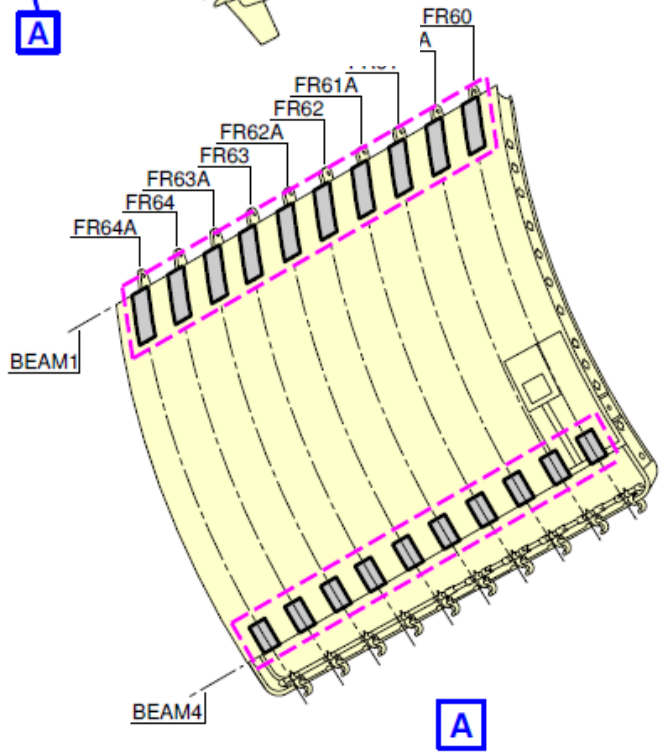
TITLE: DOORS - AFT CARGO COMPARTMENT DOOR - INSPECT STRUCTURE FOR CRACKS AND LOOSE/LOST/SHEARED RIVETS





- Mandatory inspection of AFT Cargo Door
- Inspect visually Loose/Lost/Missing Fasters
- Repetitive inspection ever 550 FC (flight cycle)

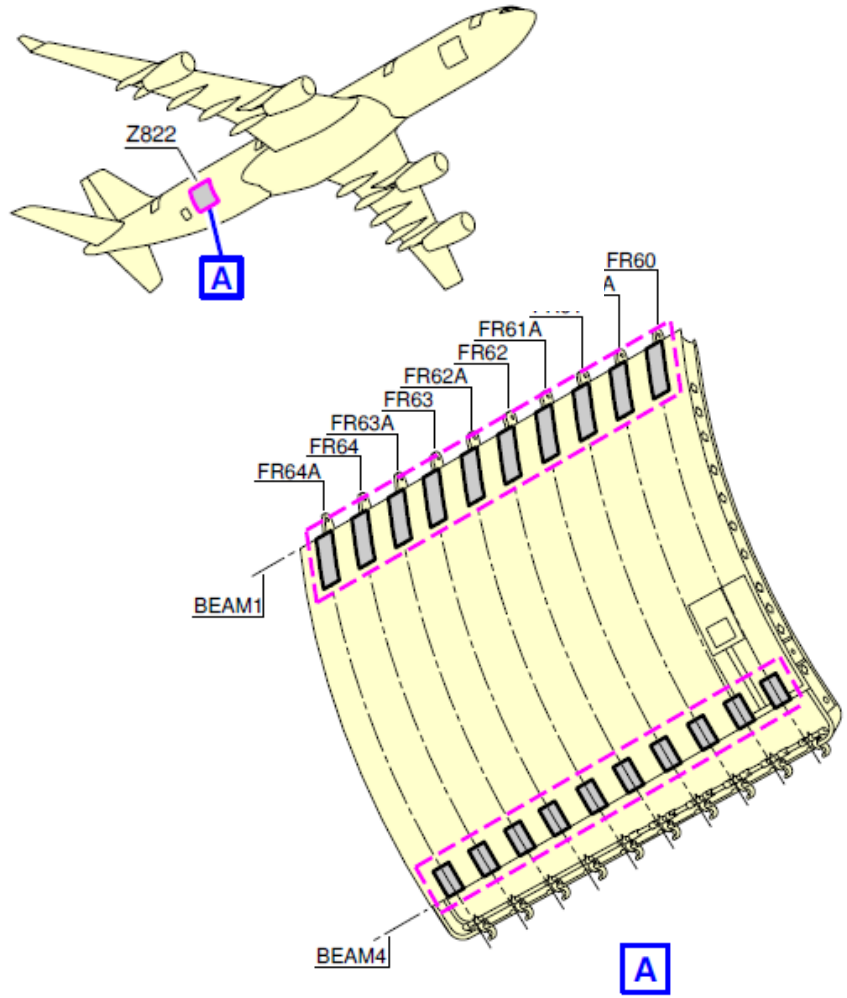
If no crack is found during the Special Detailed Inspection	Replace fasteners	Before next flight	None
	Repeat inspection	None	550 FC

2,5 FC/day -> <u>every 8 month!!!</u>

- <u>Costs:</u>

Loose Rivets

Task 525023-832-848-001: Inspection	
Identify the Part Number of the AFT Cargo Compartment Door	0.50
Do a Check and if necessary adjust the AFT Cargo Compartment Door Hook Gaps (only at first inspection)	1.00
Do a Detailed Inspection (DET) of the AFT Cargo Compartment Door Frame Fork Areas	2.00
Do A Detailed Inspection (DET) of the AFT Cargo Compartment Door Frame Head Areas	2.00
Do a Special Detailed Inspection (SDI) of the AFT Cargo Compartment Door Frame Fork Areas	6.00
Do a Special Detailed Inspection (SDI) of the AFT Cargo Compartment-Door Frame Head Areas	6.00
Repair the AFT Cargo Compartment Door Frame Fork Area Fastener Holes by Bushing	4.00
Replace the AFT Cargo Compartment Door Frame Fork	10.00
Do the Adjustment of the AFT Cargo Compartment Door Hook Gaps	5.00
Tests	1.00
Close-Up	1.00
TOTAL MANHOURS	39.50
ELAPSED TIME (HOURS)	39.50

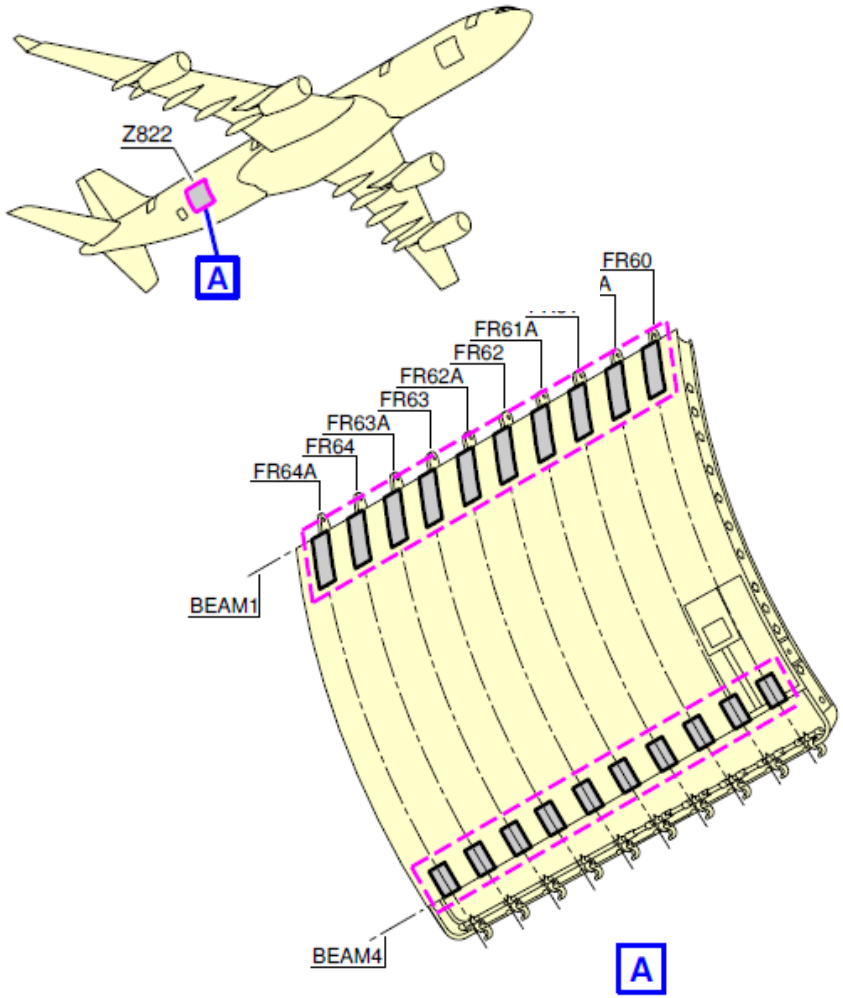


Loose Rivets

MANDATORY MANDATORY MANDATORY

ATA SYSTEM: 52

TITLE: DOORS - AFT CARGO COMPARTMENT DOOR - INSPECT STRUCTURE FOR CRACKS AND LOOSE/LOST/SHEARED RIVETS



- Mandatory inspection of AFT Cargo Door
- Inspect visually Loose/Lost/Missing Fasters
- Repetitive inspection ever 550 FC (flight cycle)

If no crack is found during the Special Detailed Inspection	Replace fasteners	Before next flight	None
	Repeat inspection	None	550 FC

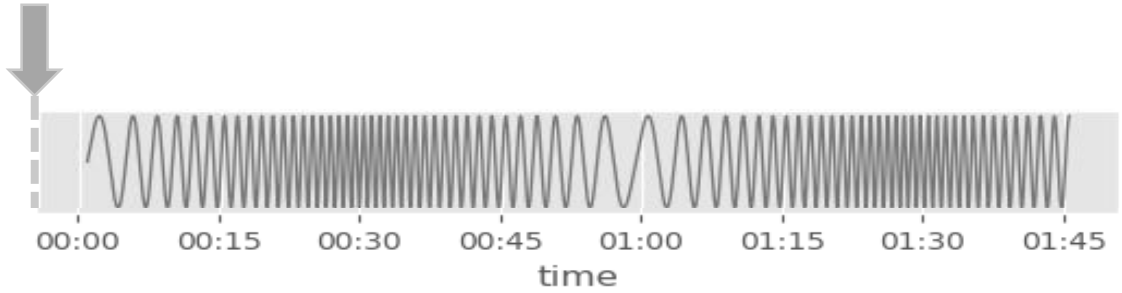
2,5 FC/day -> every 8 month!!!

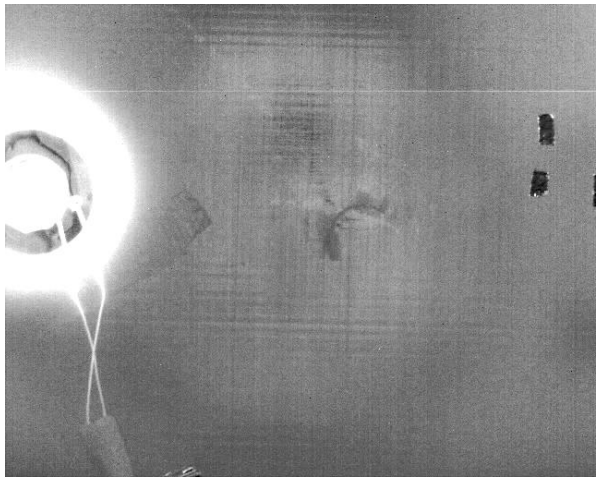
- Costs: 40 hours/door/aircraft/every eight month

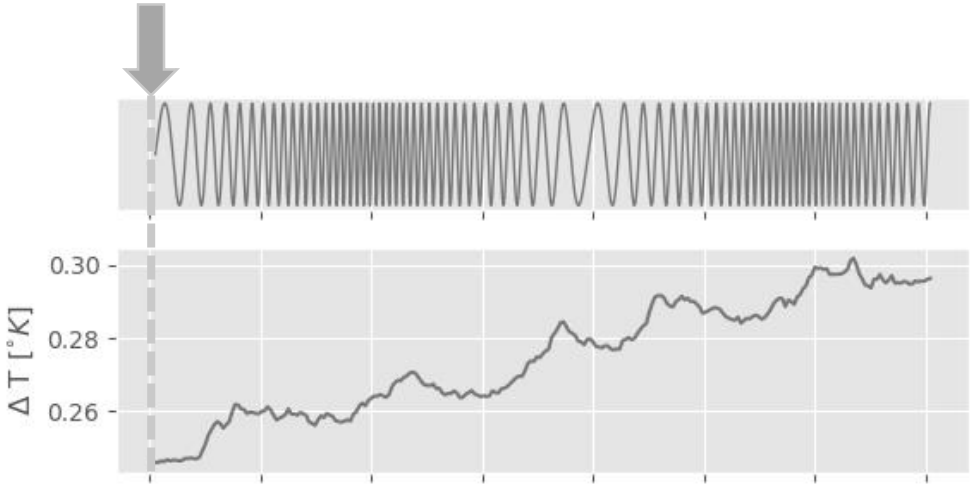
➢ BEL: 21 A/C x 2 doors x 8/12 month → 28 weeks

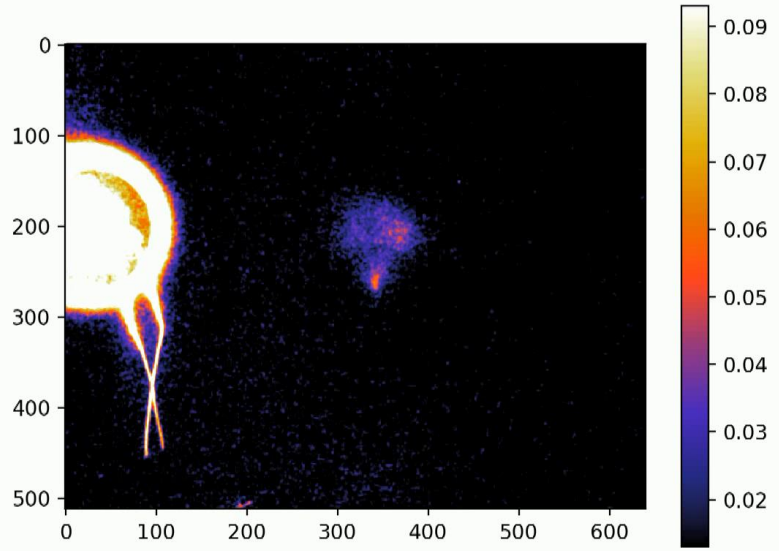
Loose Rivets

- **FLIR SC7000**
- **Glued PZT**
- **Sweep: 15-25 kHz**
- **10 images averaged**

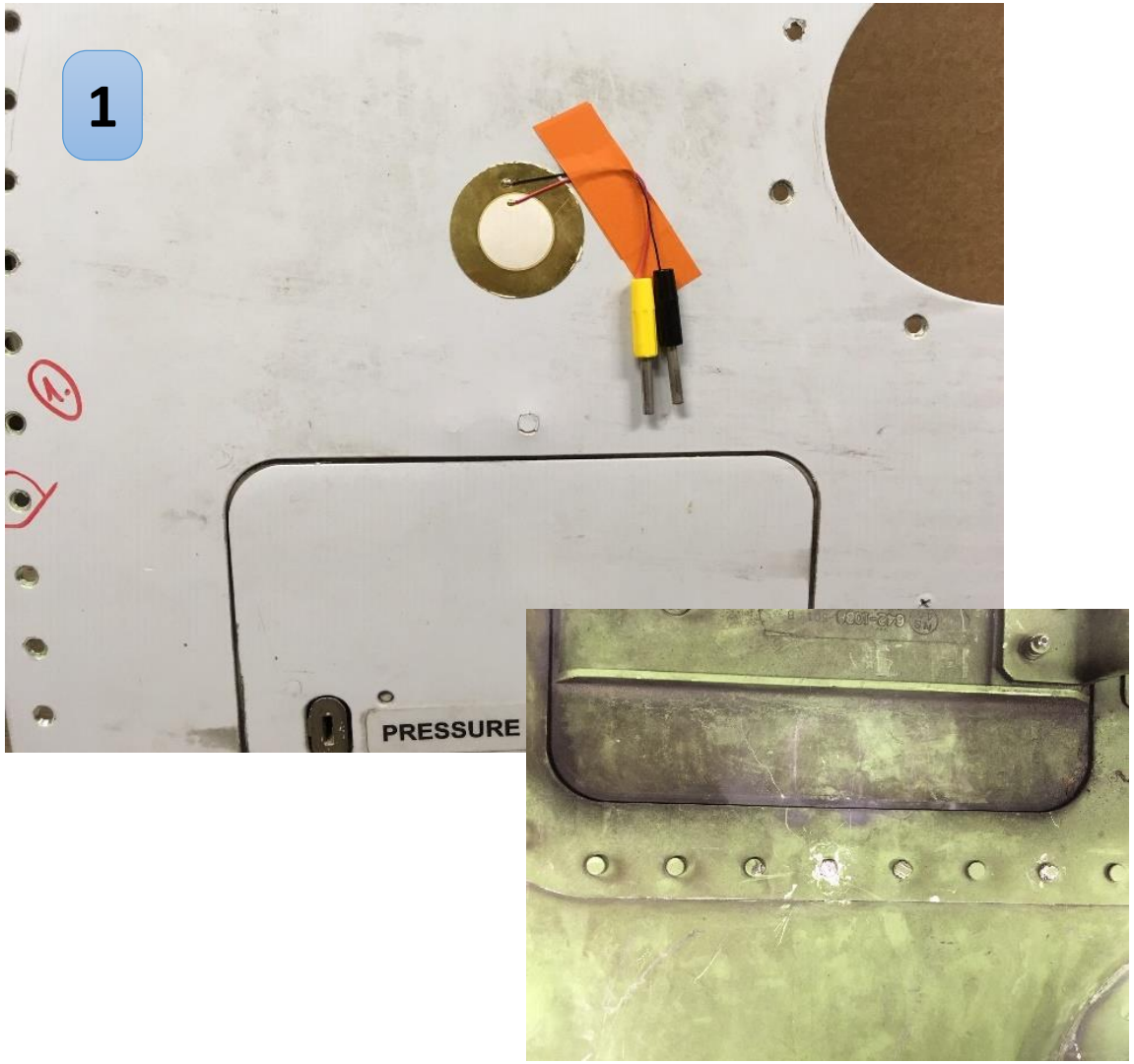




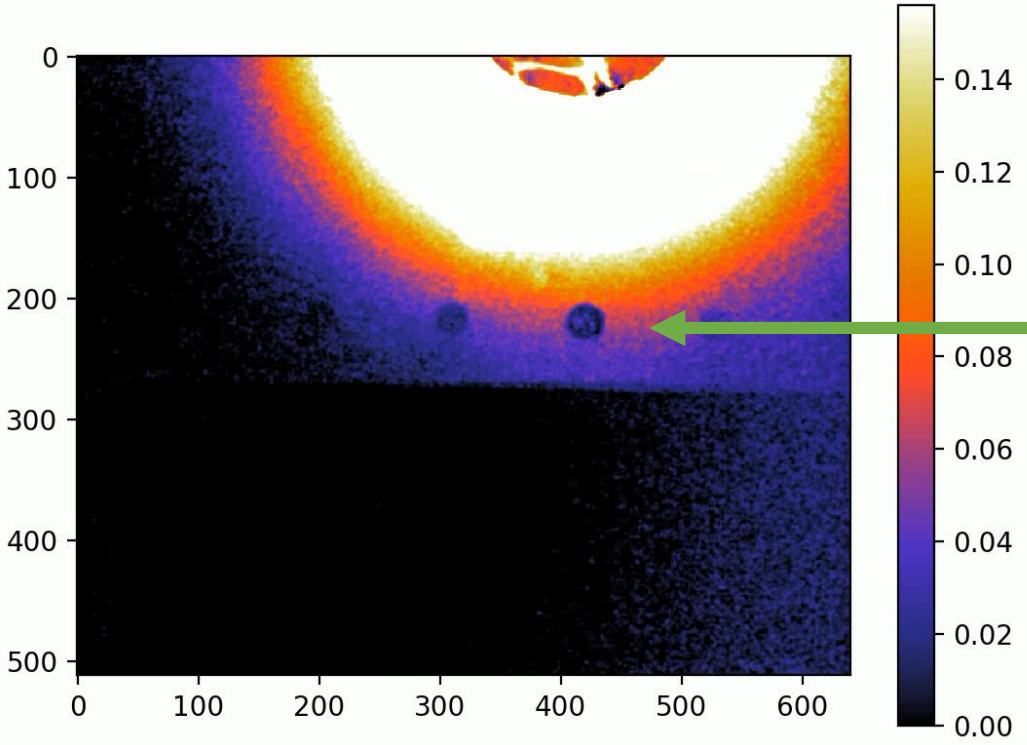


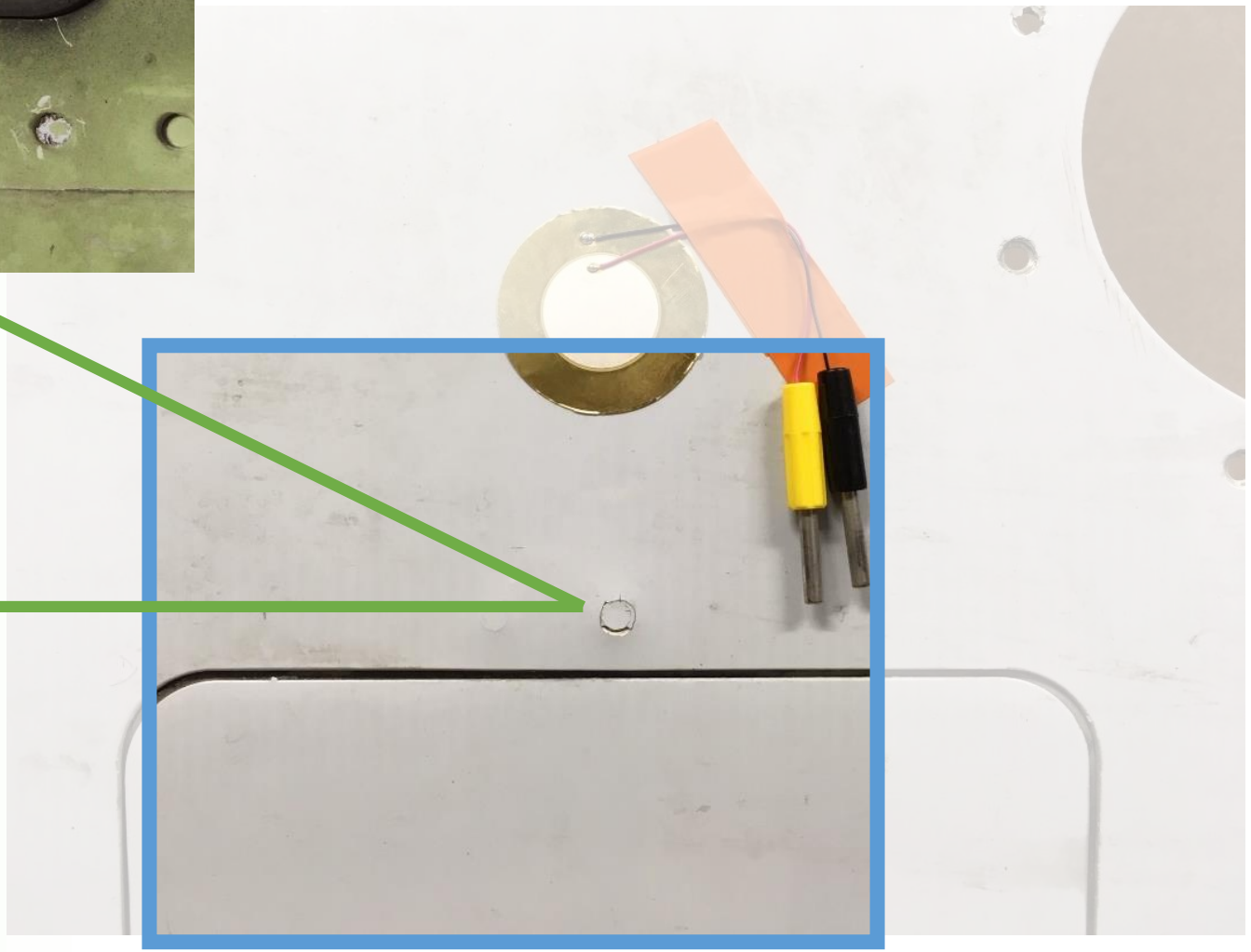


Loose Rivets

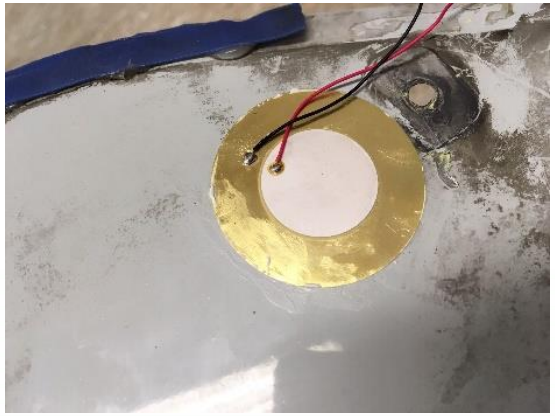


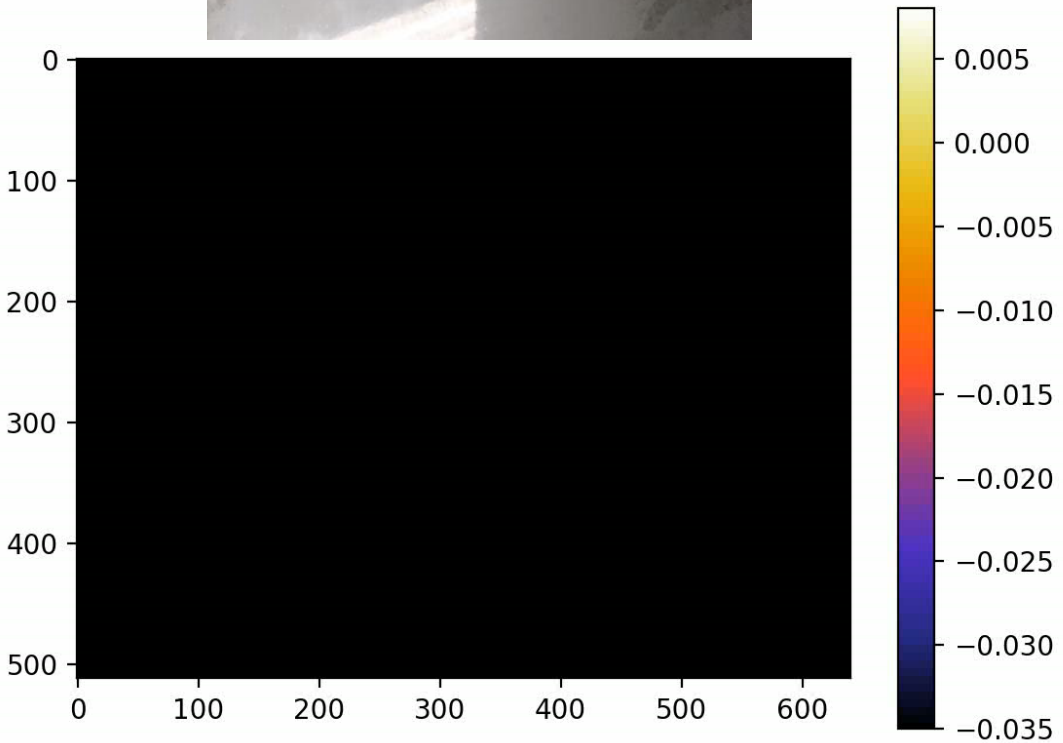
Loose Rivets

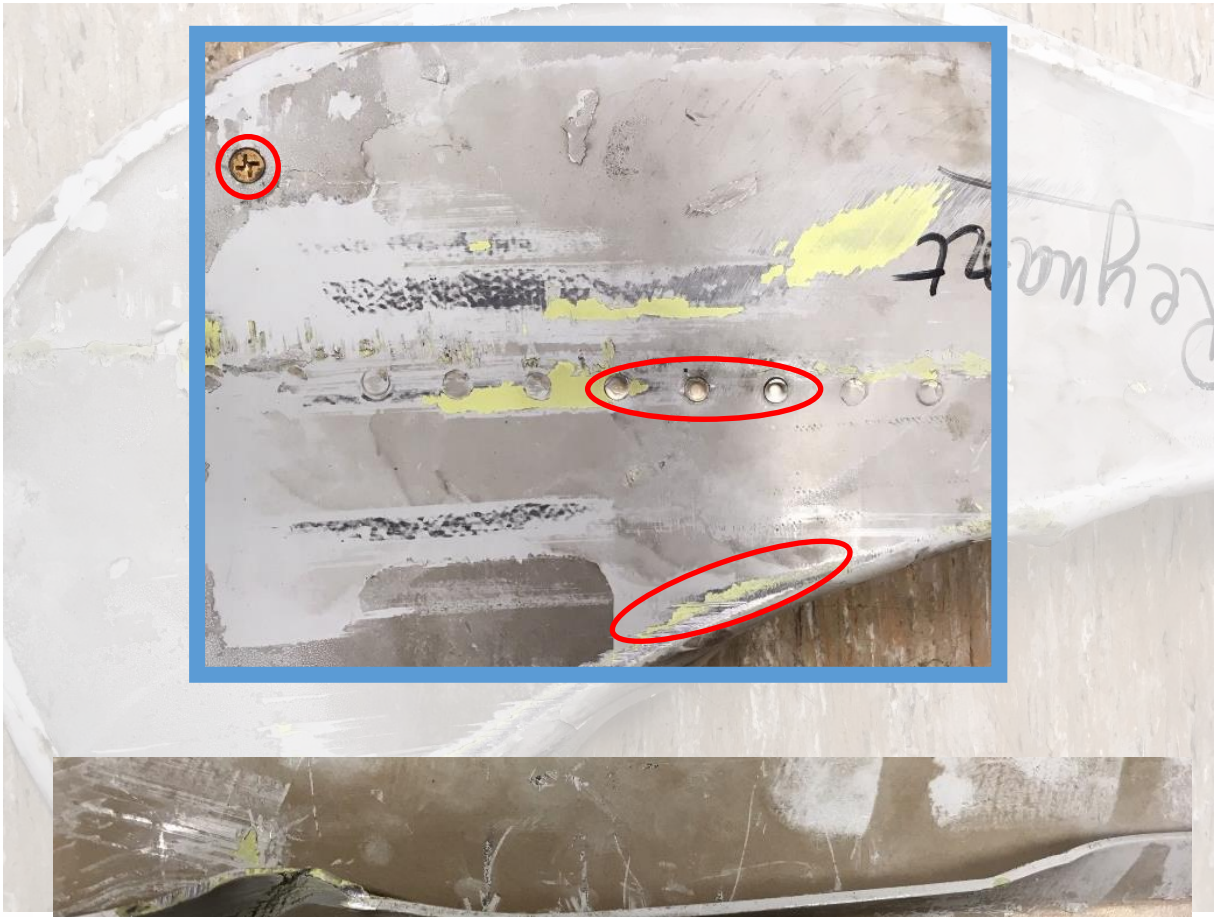




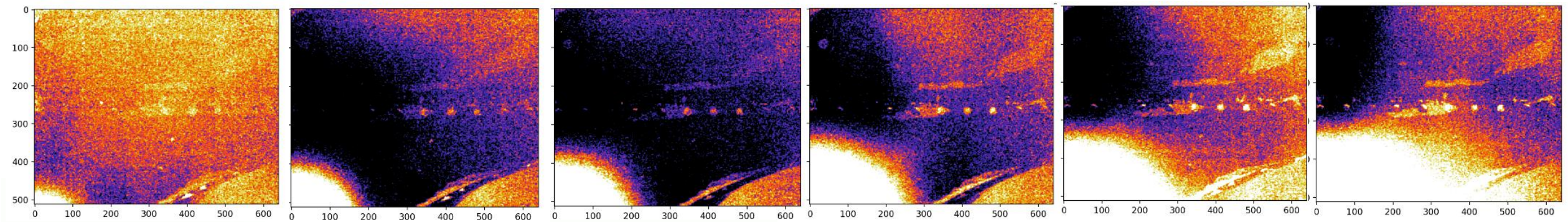
Loose Rivets

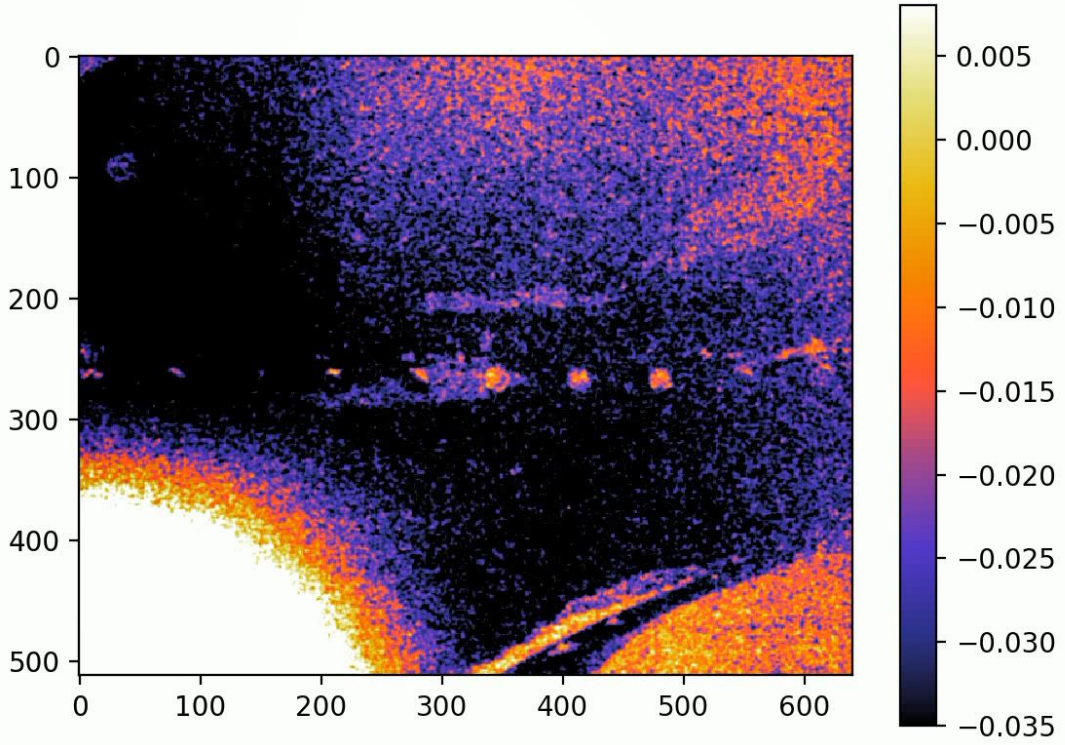




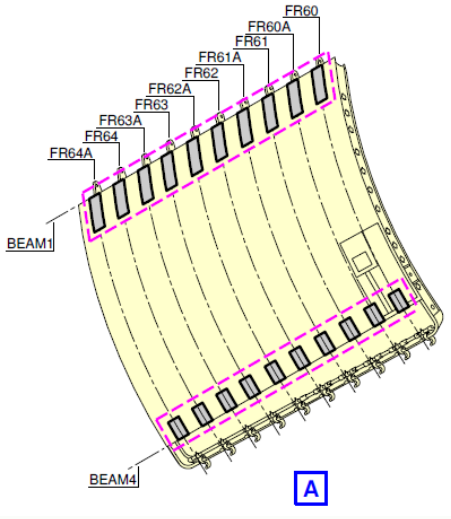


Loose Rivets





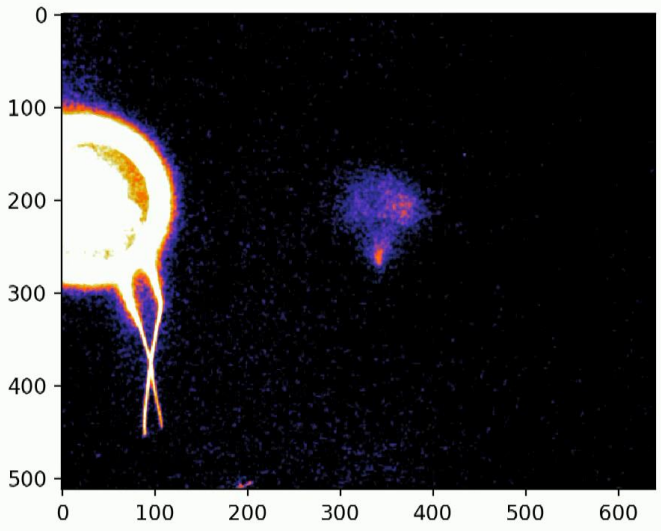
Conclusions

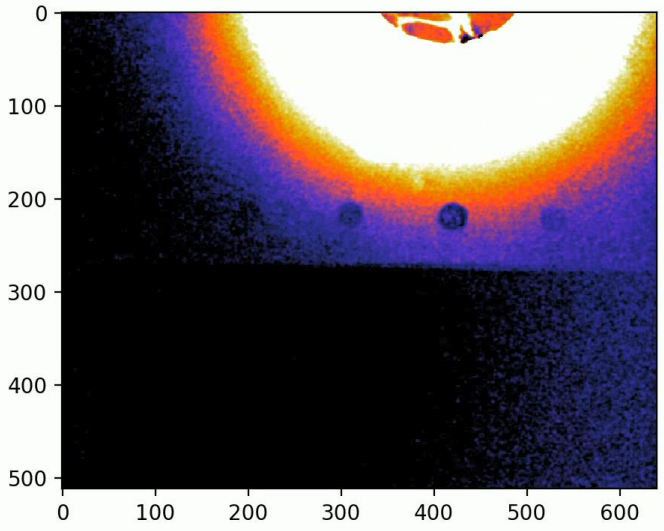


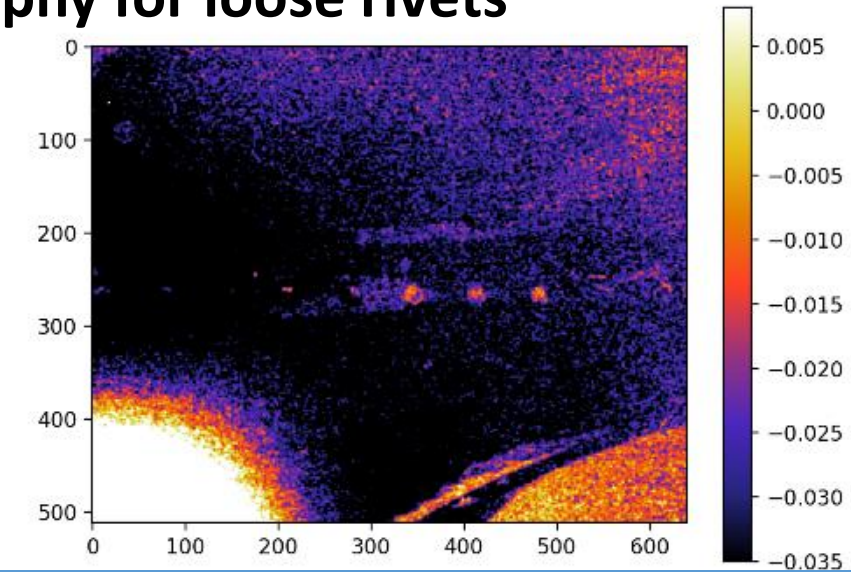
1. Immense need for innovative inspection methods
2. Science & Safety
3. Science & Safety & Cost Reduction
4. Need for more automatic detection method

RESUME OF THE PROPOSED METHODS:

- **Pulse-compression Phased Array for Rib inspection without LG removal**
- **Pulse-compression Thermography for water and noise panel inspection**
- **Ultrasonic-stimulated Thermography for loose rivets**







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Thanks for your attention!

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