OLYMPUS

Your Vision, Our Future

Ultrasonic phased-array for aircraft maintenance

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Amsterdam, November 2009

RD TECH PANAMETRICS-NDT NDT engineering corporation NORTEC SONIC

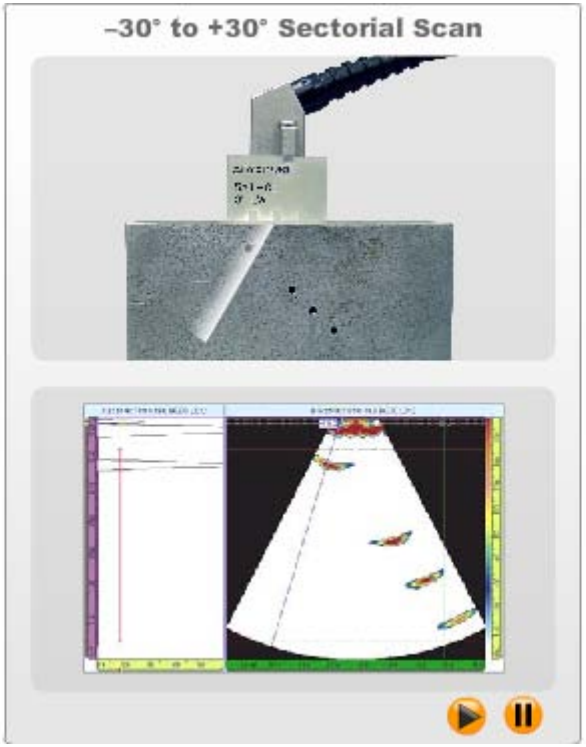
Innovation in NDT™

Presentation plan

- Principle review of ultrasonic phased-array
- Boeing 737: Scribe line inspection
- Airbus 320: Inspection of wing top skin panel for corrosion
- Airbus 380 GLARE inspection with ultrasonic phased-array
- Composite inspection
- F-5, T-38: Automated Fastener holes inspection scanner

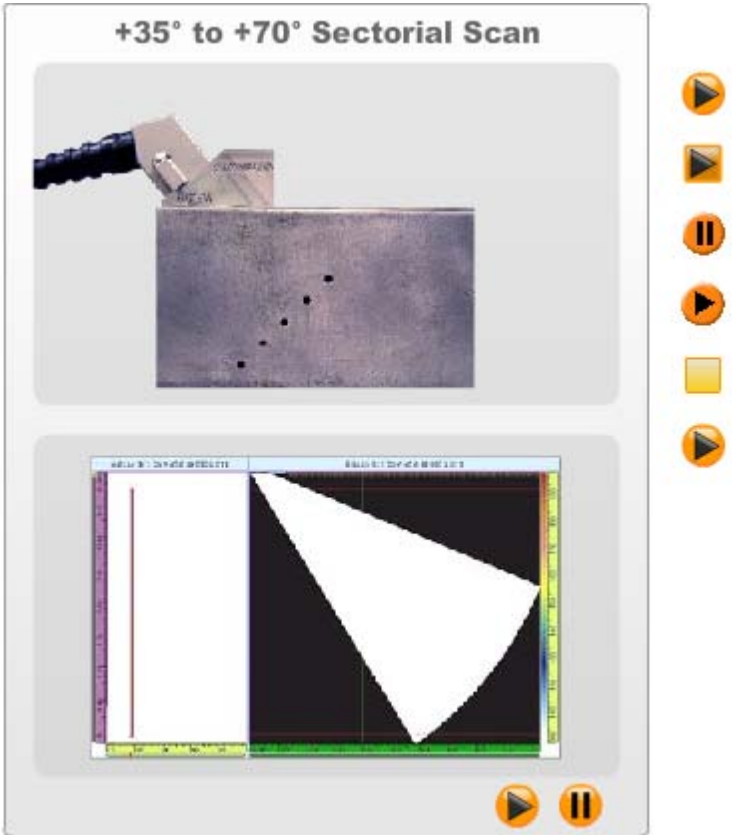
Omniscan MX capabilities: Sector scan

- Ex: Sweeping angles from -30 to 30 LW



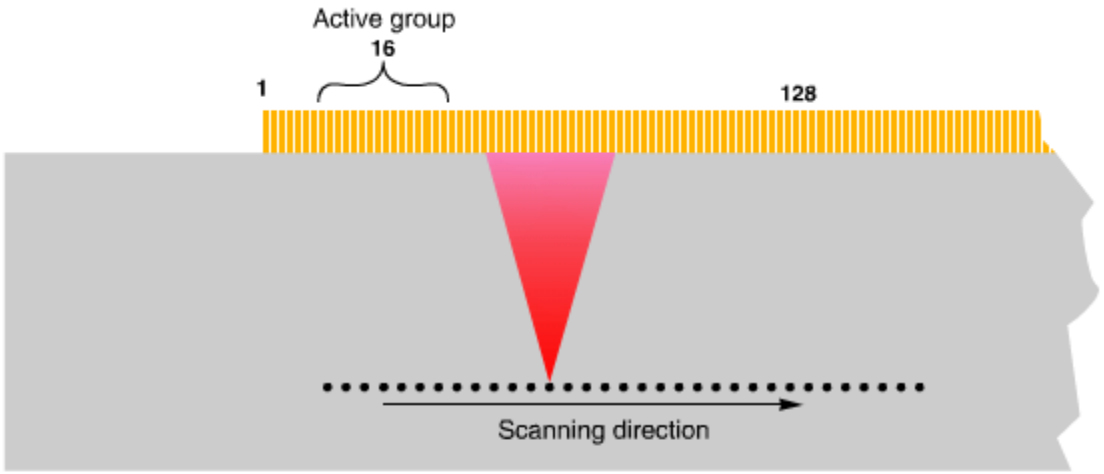
Omniscan MX capabilities: Sector scan

- Ex: Sweeping angles from 35 to 70 SW



Omniscan MX capabilities: Linear scan

- Ex: Linear scan at 0 LW



Modular unit: Omniscan MX

Portable modular instrument
Modules available:
- Ultrasonic phased-array
- Eddy current array
- UT 2, 8 channels
- EC 4 channels

Equipment – OmniScan MX-PA

- Portable, Light, and battery operated
- Very simple to set up and use
- **Multiple C-scan options**
- A-scan and C-scan data storage
- Linear array up to 128 mm wide
- Compatible with all linear array probes available on the market
- C-Scan instrument for integration
- NDT Remote control compatible
- Up to 6000 A-Scans recorded per sec.
- Typical inspection rate: 60 m^2/hr with 1 mm resolution
- 30 times faster than conventional UT
- **16:128 PA module allows for quick swapping between PA and UT for prove-up and defect sizing**

Boeing NTM procedures with the OmniScan PA

- **Boeing 737, 747, 757, 767 (CMN NDT part 4, July 2008)**
  - **Fuselage skin scribe mark**
  - **Omniscan PA + PA probe**

- **Boeing DC-9 (NTM DC9-32A350, dec 2004)**
  - **Inspection of landing gear**
  - **Omniscan PA + PA probe**

- **Boeing 787 (NTM 51-00-09, August 2008)**
  - **Procedure to examine bonded repairs in BMS 8-276 solid laminate structures**
  - **Omniscan PA + Glider + 3.5L64-NWI + wedge**

- **Boeing 787 (NTM 51-00-07, August 2008)**
  - **Procedure to find delaminations and skin-to-stiffeners disbond in BMS 8-276 solid laminate structures**
  - **Omniscan PA + Glider + 5L64-NWI + wedge**

Airbus NTM procedures with the OmniScan PA

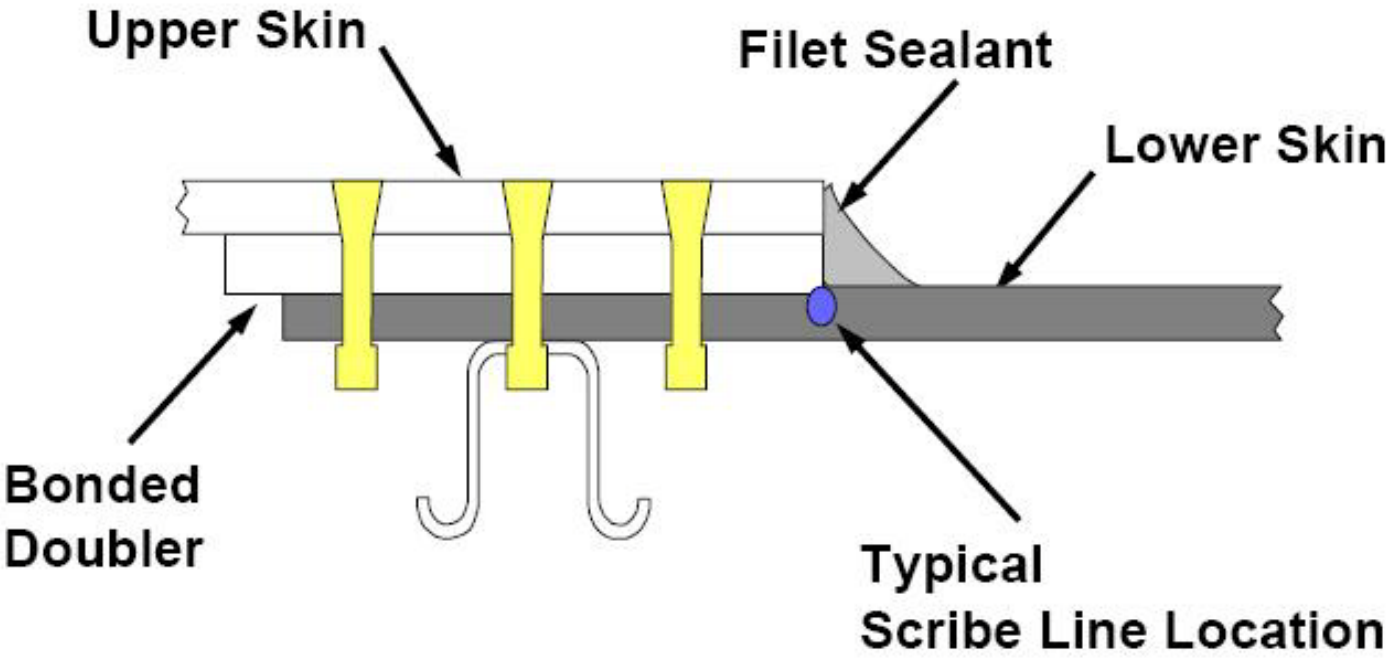
- **Airbus 380 (NTM A380-51-10-23, Sept. 2008)**
  - General ultrasonic phased-array procedure for the inspection of GLARE structures
  - Omniscan PA + 2L128I3 and 1L64 + waterboxes
- **Airbus A340-500-600 (NTM A340 57-18-16, July 07)**
  - Center wing box, rear vertical cross radius at FR47, radius in upper area
  - Omniscan PA + PA probe
- **Airbus 300-600 (NTM A300-57-035 July 07)**
  - Inspection procedure is for the gear rib forward attachment lug for the main landing gear
  - Omniscan PA + 10L32-A1 probe
- **Airbus 318/319/320/321(NTM 57-29-07, March 2009)**
  - Inspection of wing top skin panel for corrosion
  - Omniscan PA + wheel probe

- Scribe mark inspection with ultrasonic phased-array

Scribe line background

- Flight Standards Information Bulletin for Airworthiness (FSAW 03-10B) issued on November 2003 titled: Fuselage Skin “Scribe Mark” Damage on Boeing 737 Aircraft
- Reports:
- Damage has been reported along fuselage skin lap joints, butt joints, and other areas of several aircraft caused by the use of sharp tools used during paint and sealant removal
- Use of sharp instruments can result in lines scribed in the fuselage skin
- ***Lines scribed in the pressurized skin, if undetected, can result in cracks and possibly lead to widespread fatigue damage.*** I
- All commercial aircrafts who went to a repaint and sealant removal process are susceptible to have scribe marks

Boeing 737 configuration



Picture of a scribe mark:

Existing inspection methods

- Visual
- Eddy current
- Conventional UT

Advantages of phased-array

- No paint removal (huge time saving)
- Sector scan imaging
- Omniscan PA easy to operate
- The smallest configuration of the Omniscan PA 16:16 is enough (economic)

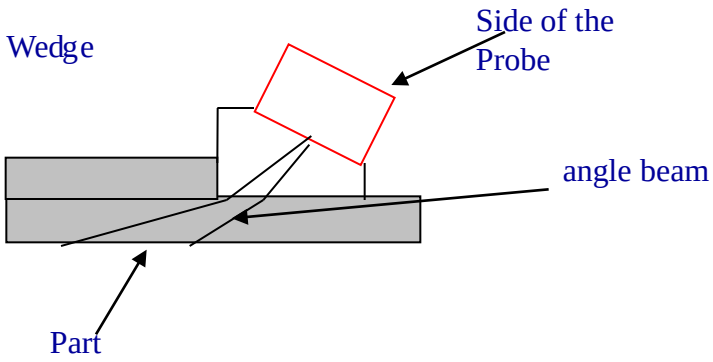
Search for defect

- 0.200 inches (5.08 mm) long (or more)
- Are in the forward and aft direction
- Are 50% of the skin thickness in skins that are from 0.032 to 0.044 inch (0.81 to 1.10 mm) thick
- On the outer surface of the skin and in an area that begins approximately 0.030 inches (0.76 mm) above the lower edge of the upper skin and continues to 0.063 inches (1.60 mm) below the lower edge of the upper skin.

(courtesy of Southwest Airlines)

Scribe line inspection

- The phased-array probe used is an **off-the-shelf** probe,
- The frequency of the probe is 10 MHz
- Mounted on a wedge
- Sector scan range from 60 to 85 SW
- No encoder needed

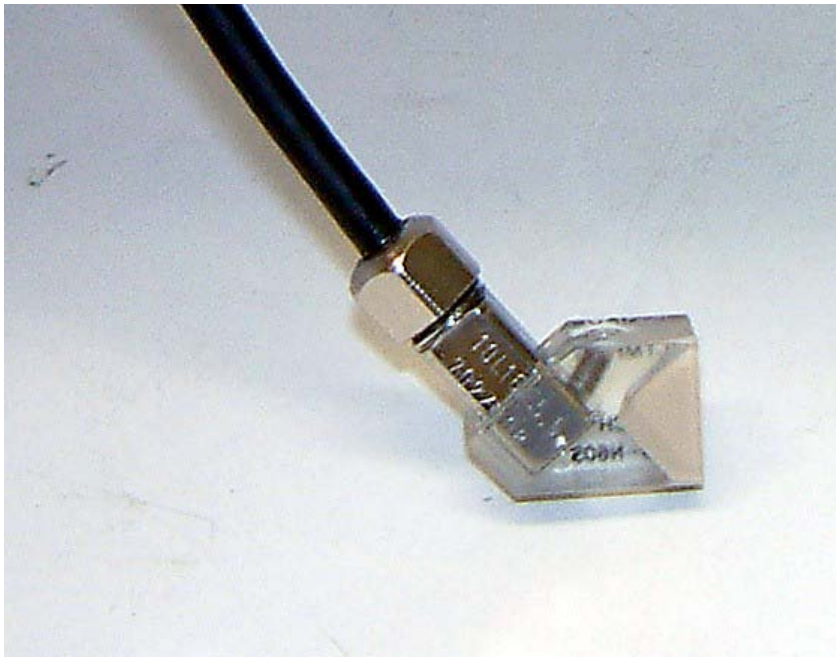


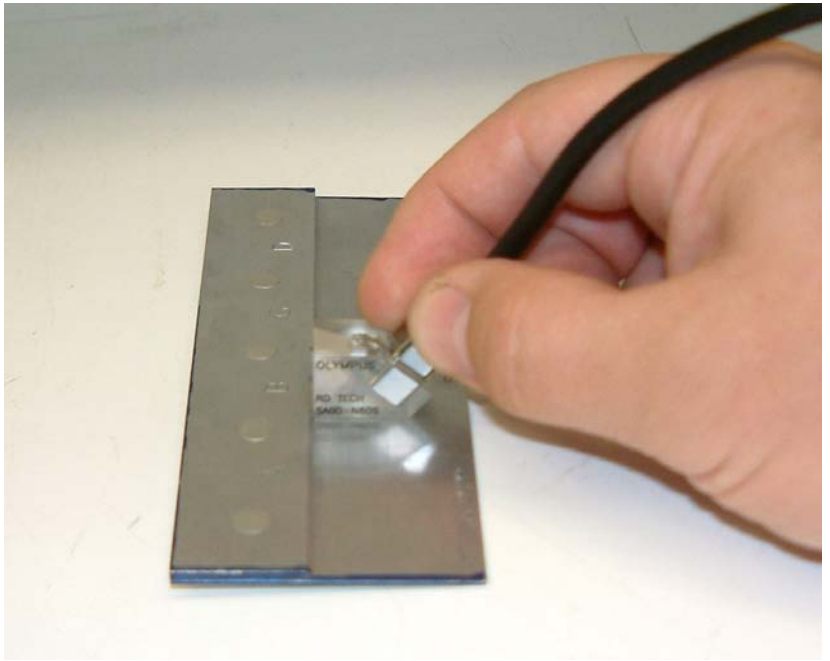
The Probe

The probe decided upon is a 10MHz, 16 element, each element is only 0.31mm wide giving a total aperture size of 6mm.

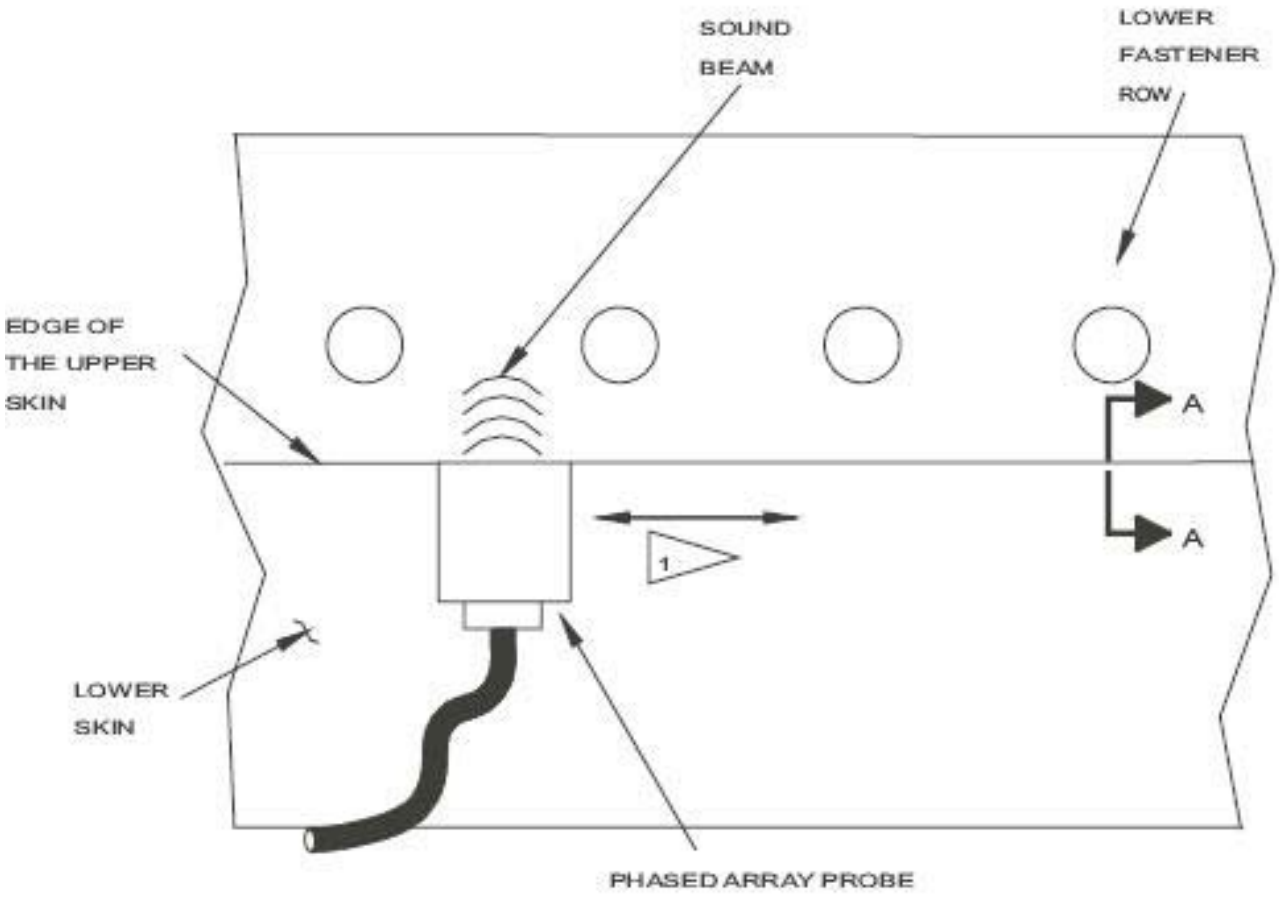
- The small element size provides a good steering capability
- The small total aperture size provides a short near field

The Probe

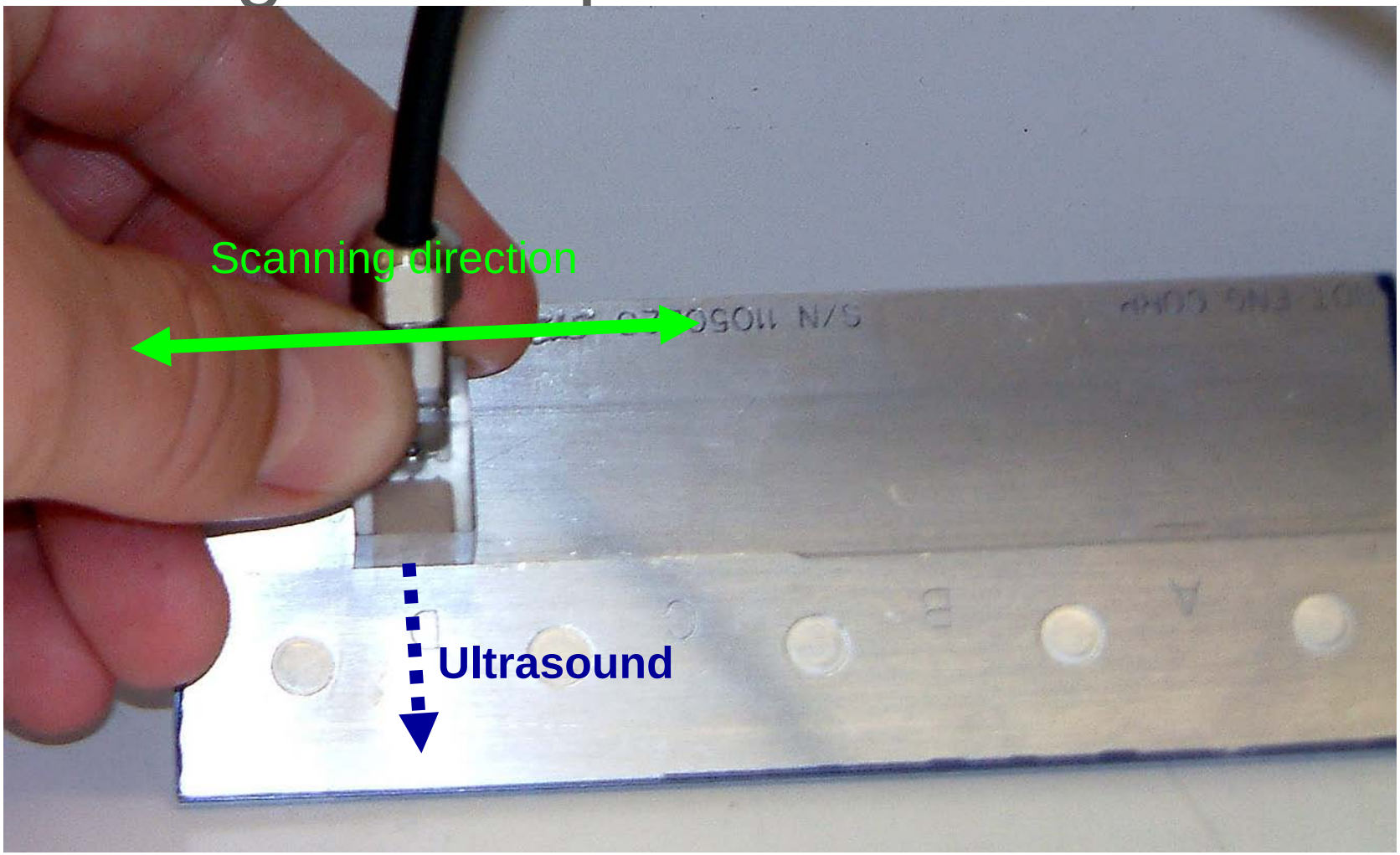




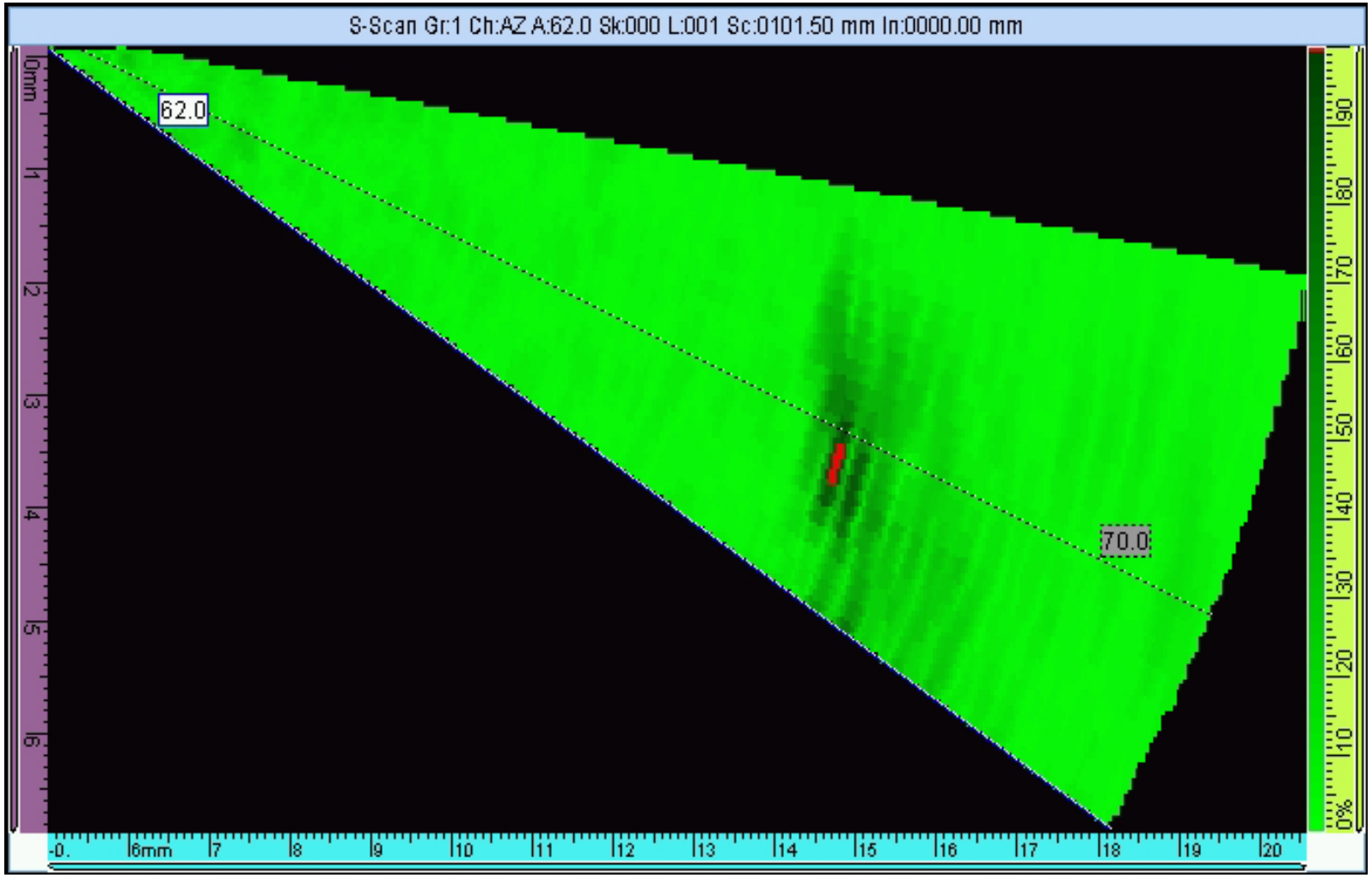
Scribe line inspection



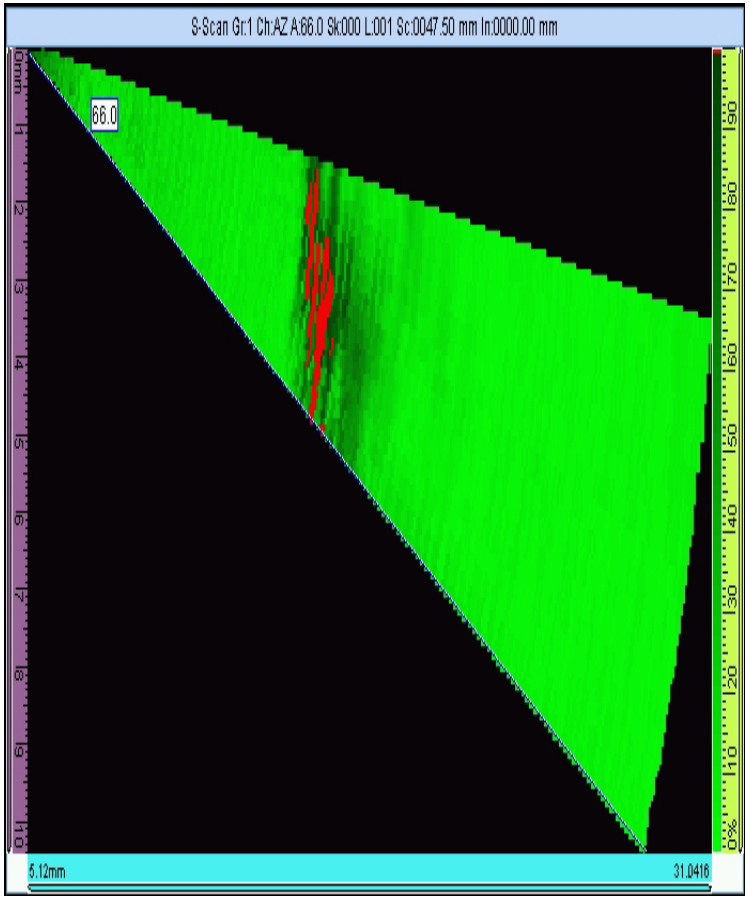
Scanning technique



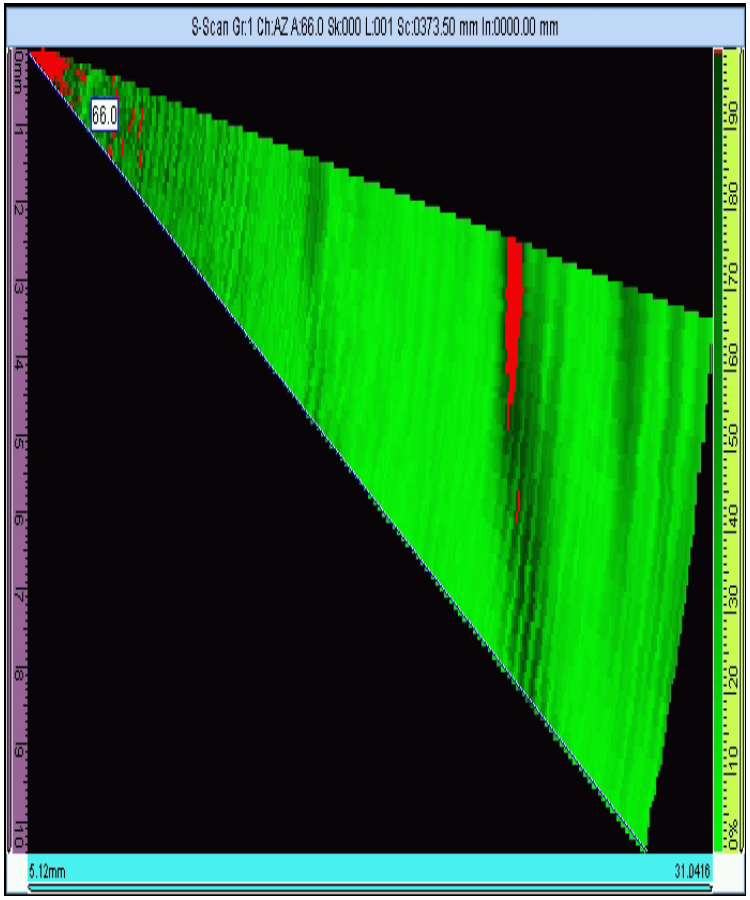
Typical scribe mark indication



Omniscan PA imaging



Scribe mark indication



Fastener hole indication

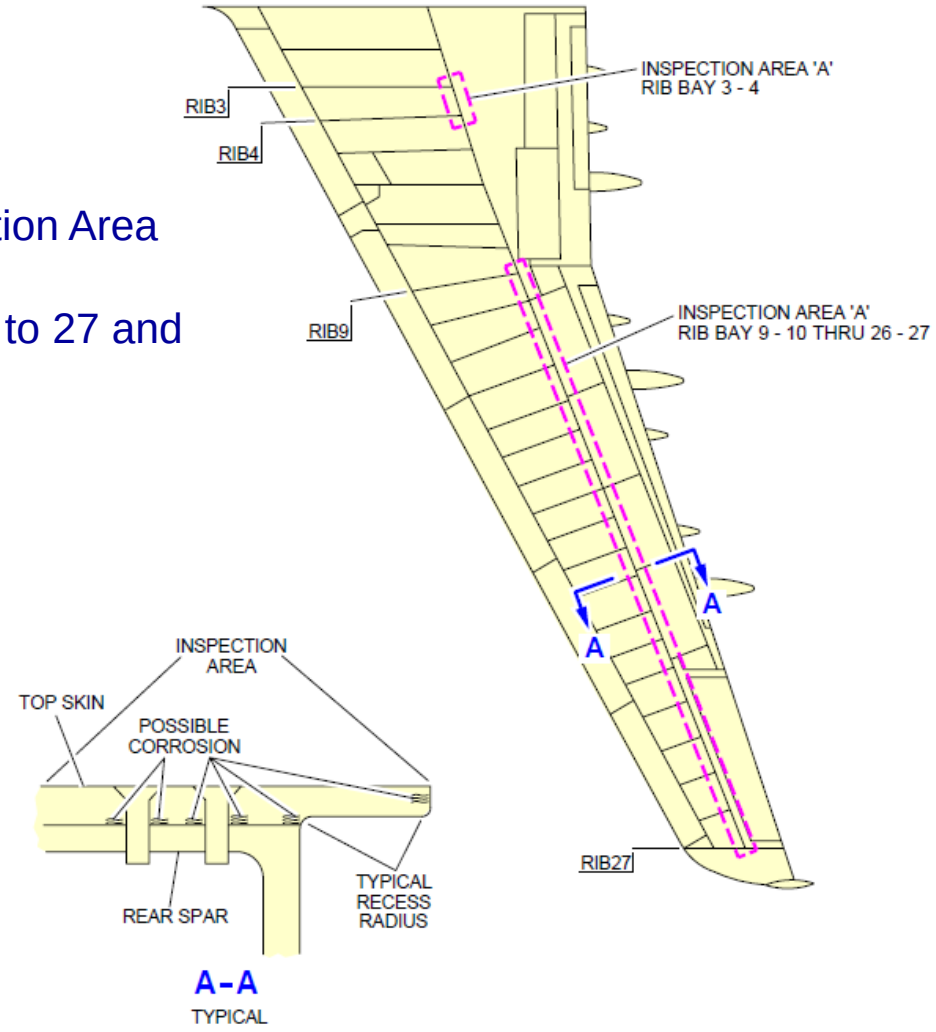
Conclusions about scribe mark

- Inspection for scribe mark can be done without paint removal
- Extremely fast payback
- Omniscan PA referenced in the Boeing NTM manuals for the whole fleet
- Hundreds of NDT operators trained for this inspection
- In use by the most of the airliners like Delta, KLM, Southwest, USAir, Northwest, British Airways, Lufthansa, SAS, …

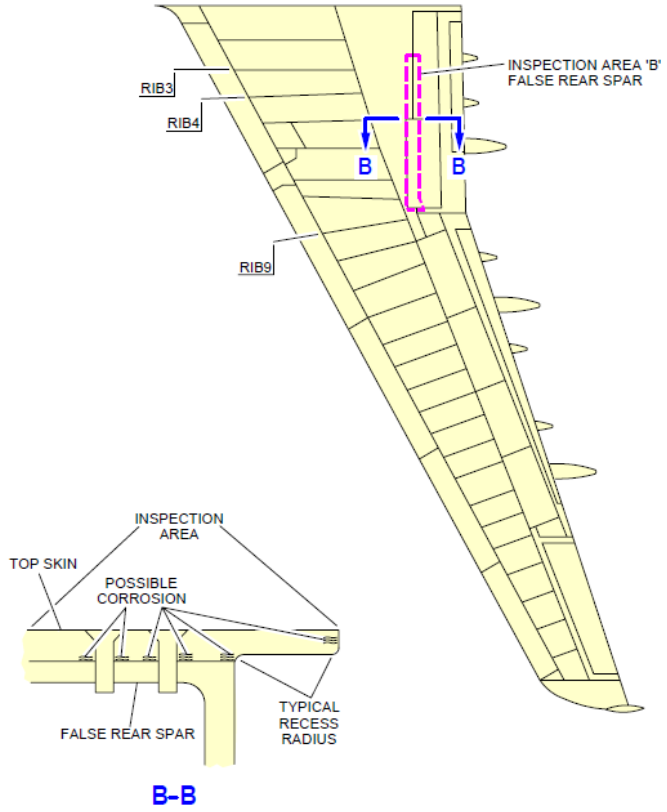
- Airbus 320: **Inspection of wing top skin panel for corrosion**

Inspection zones

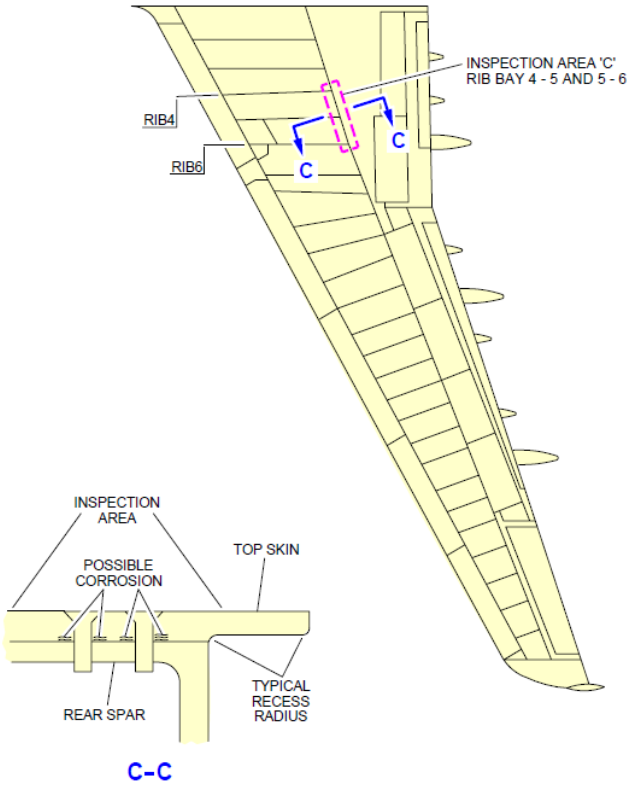
Rear Spar Inspection Area Between
Ribs 3 to 6 and 9 to 27 and Possible Damage



Inspection zones



Between the traling edge and the forward fastener row of the false rear spar



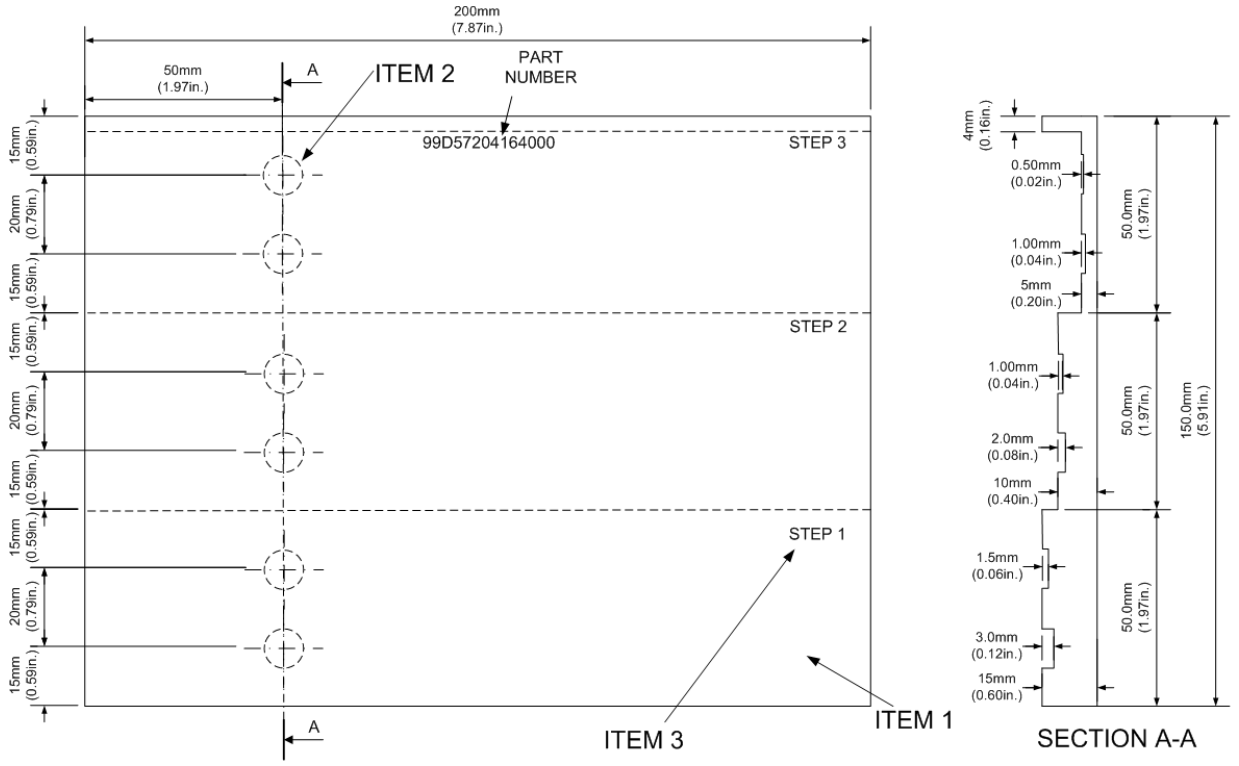
Between the forward fastener row and aft fastener row of the rear spar in Rib Bays 4-5 and 5-6

Equipment used

Ultrasonic phased-array wheel probe including:
50 mm long PA probe
5 MHz,
64 elements, 0.8 mm pitch

Omniscan PA
16:128
A, B, Cscan imaging

Calibration sample



ITEM	NOMENCLATURE	QTY	MATERIAL / REMARKS
1	CALIBRATION STANDARD	1	Al 7150T651 or similar
2	ARTIFICIAL DEFECTS	6	10mm DIA SPOTFACES AT 0.5mm AND 1.0mm DEPTHS
3	LABEL	4	USE 3mm (1.20in.) HIGH CHARACTERS TO MINIMUM DEPTH. FILL IN BLACK.

NOTES

PAINT TOP SURFACE WITH PRIMER (MATERIAL NO. 16-006) AND FINISH WITH TOP COAT (MATERIAL NO 16-018).

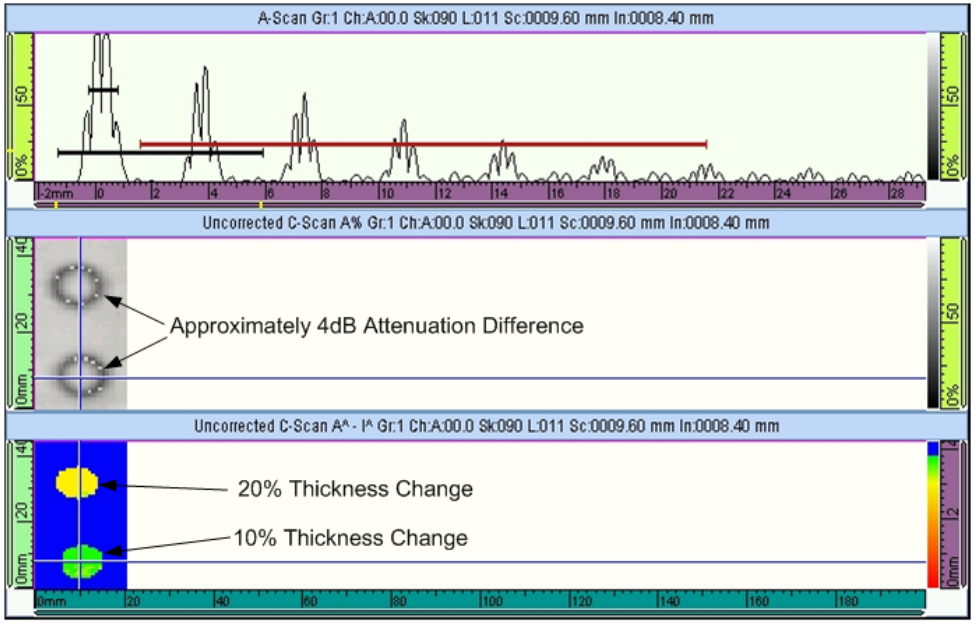
AFTER PAINTING ENGRAVE PART NUMBER AND STEP IDENTIFICATIONS. USE 3mm (0.12in.) HIGH CHARACTERS TO MINIMUM DEPTH. FILL IN BLACK.

DIMENSIONS IN MILLIMETRES (INCHES IN BRACKETS)
SPOTFACE MILLED TO A TOLERANCE OF +/- 0.05mm (0.002in).
ALL OTHER TOLERANCES +/- 0.20(0.008in).

Calibration

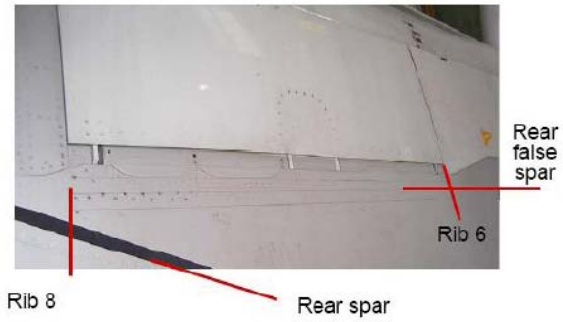
Equipment calibration:

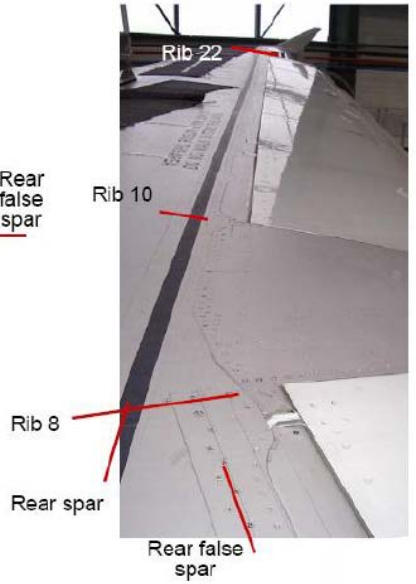
- -calibrate array for element sensitivity
- -calibrate array for defect sensitivity using the reference standard

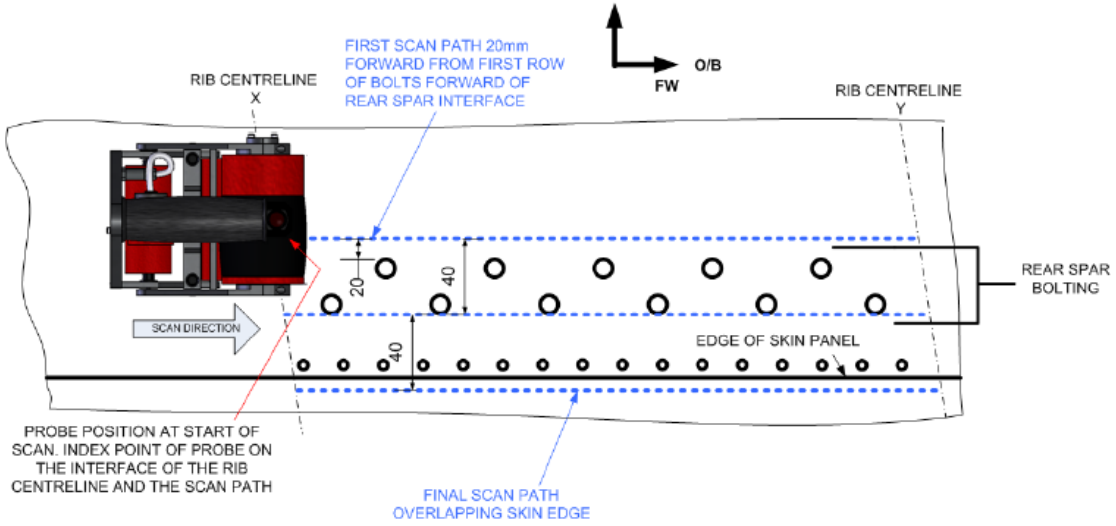


Instrument display:
Ascan,
Cscan Amplitude
Cscan Time-of-Flight

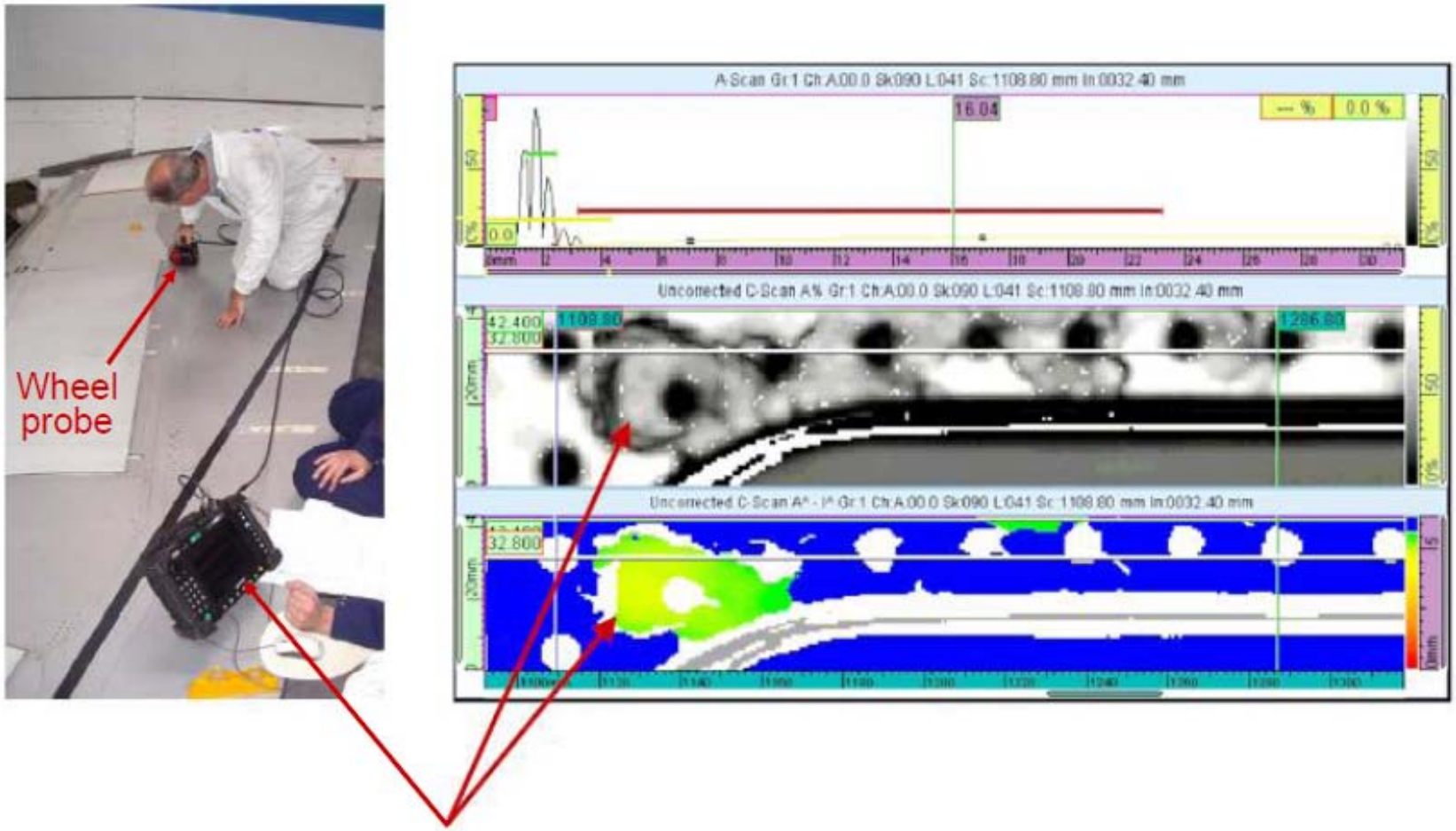
Use configuration







Life example



Corrosion indication Read on the Omniscan screen

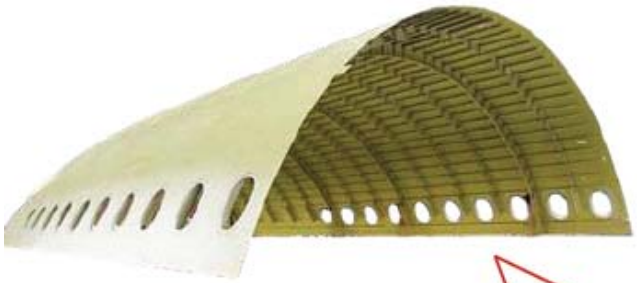
Screen display of corrosion detection

Conclusions

- Indications that shows a backwall echo reduction of 4 dbwith a corresponding change of 10% of the material thickness shall be classified as corrosion and reported
- Depth range of corrosion is measured
- Size of the corrosion area is measured
- The scan file is archived for later use

- Airbus 380 GLARE inspection with ultrasonic phased-array

Use of GLARE in the A380



Crown Panels (FWD & AFT Fuselage) :
GLARE®

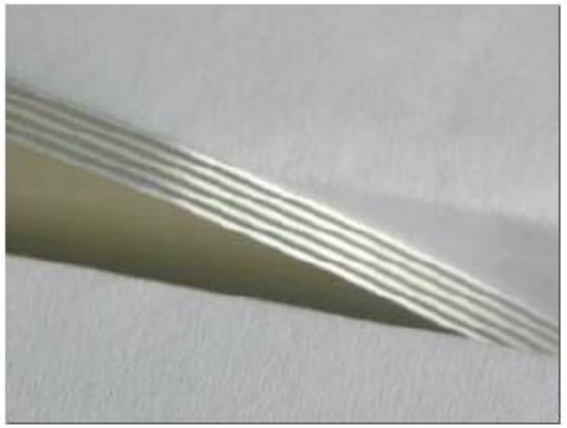
Vertical stabilizer leading edge:
GLARE®

Horizontal Stabilizer Leading Edge
D-nose skin : GLARE®

Fuselage Skin & Wings :
aluminum alloys

- GLARE® : LAMINATE MADE UP OF ALUMINIUM SHEET AND GLASS FIBRE LAYERS.

GLAss fiber REinforced aluminum (GLARE®):
member of the Fiber Metal Laminates (FML) family



Material 2024 T3 - thickness 0.3 or 0.4 mm
(0.5 mm in passenger door corners)
(Single-sided clad material is used only for the external surface of the aircraft)

Aluminum alloy layer

Glass fiber prepreg layer

Aluminum alloy layer

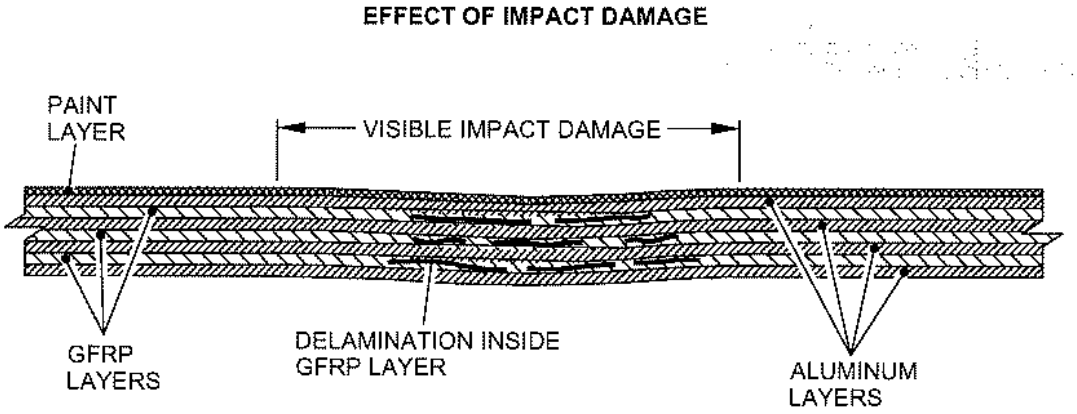
Glass fiber prepreg layer

Aluminum alloy layer

Material S2 glass fiber and FM 94 epoxy resin. Each layer has from two to four plies of thickness 0.125 mm each.

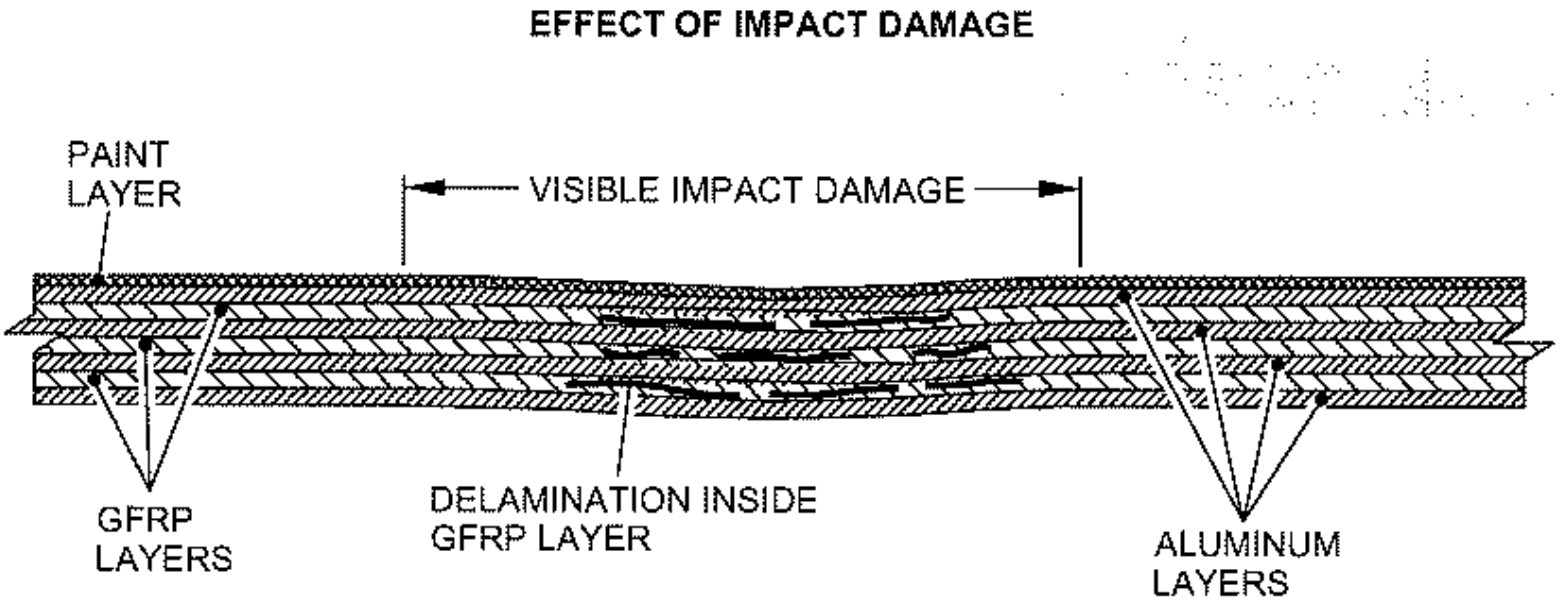
Typical damage

- Delaminations and disbounds due to:
  - Impact (stone impact, dropped tools, bird strike, ground equipment
  - Overheating
  - Ligthning strikes



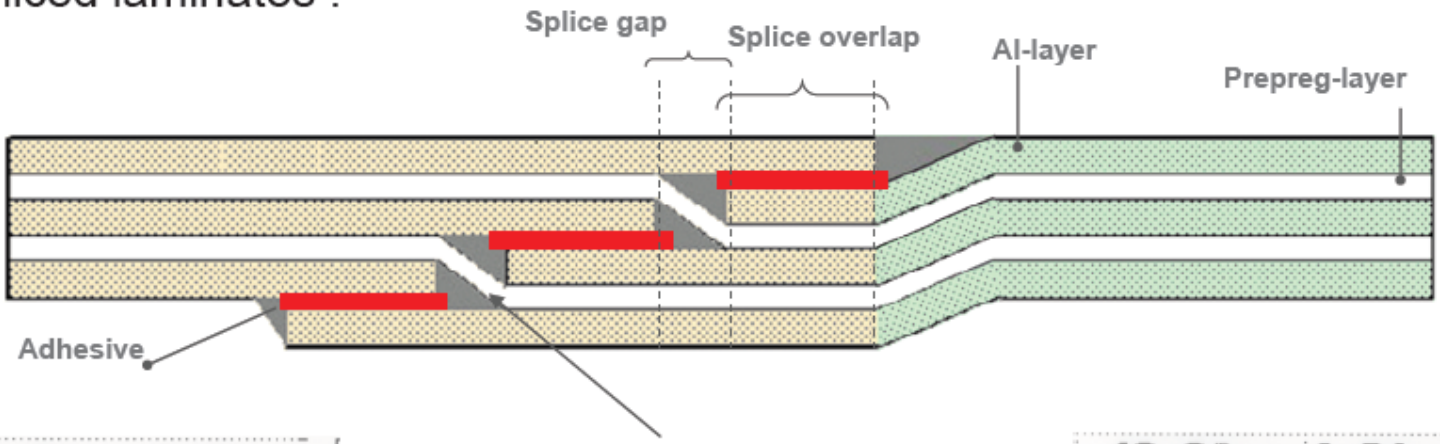
- The inspection is done after visible detection of damages

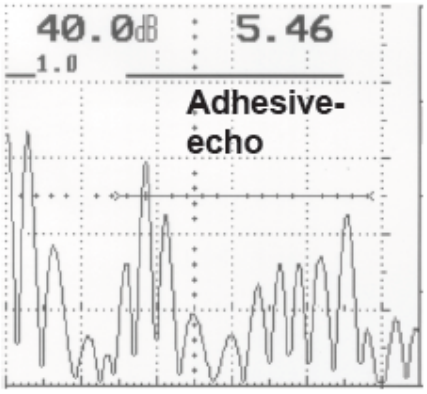
Possible defect locations



- Investigations with phased-array-UT showed the advantages of this technology

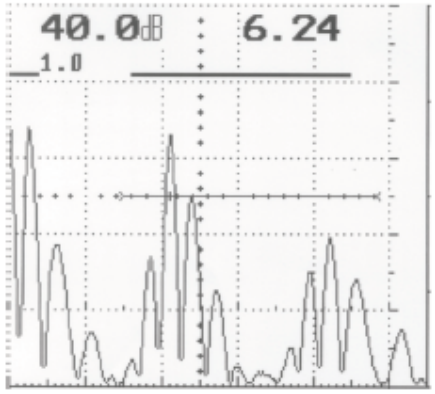
- Spliced laminates :





Splice gap area (flowless)

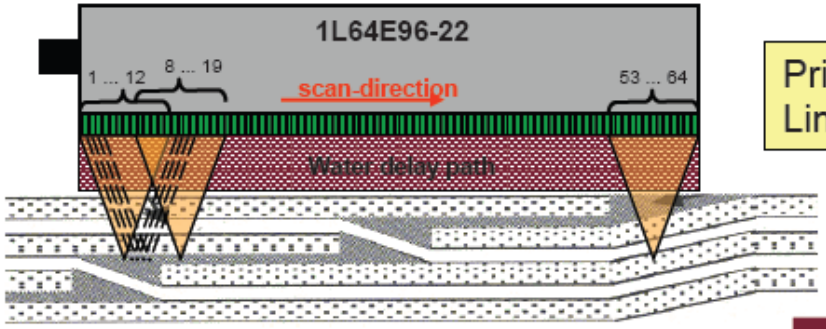
- Most difficult case is for splice gap : adhesive echo looks like defect echo
  - need to refer to drawings
  - need for alternative solution



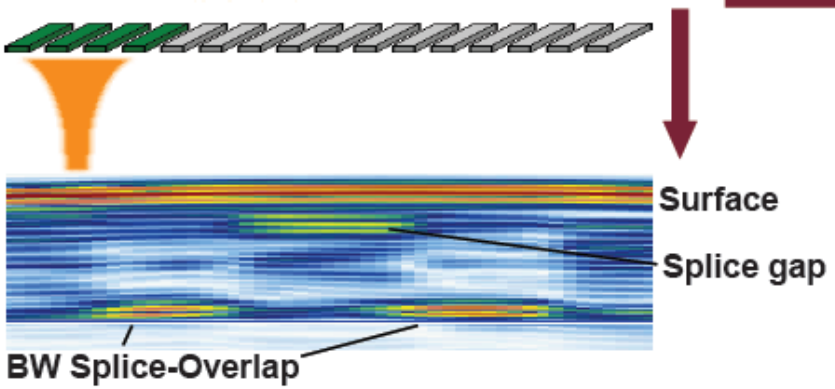
Splice Overlap area (defect)

- Inspection of a splice area by means of a Phased-Array linear-scan

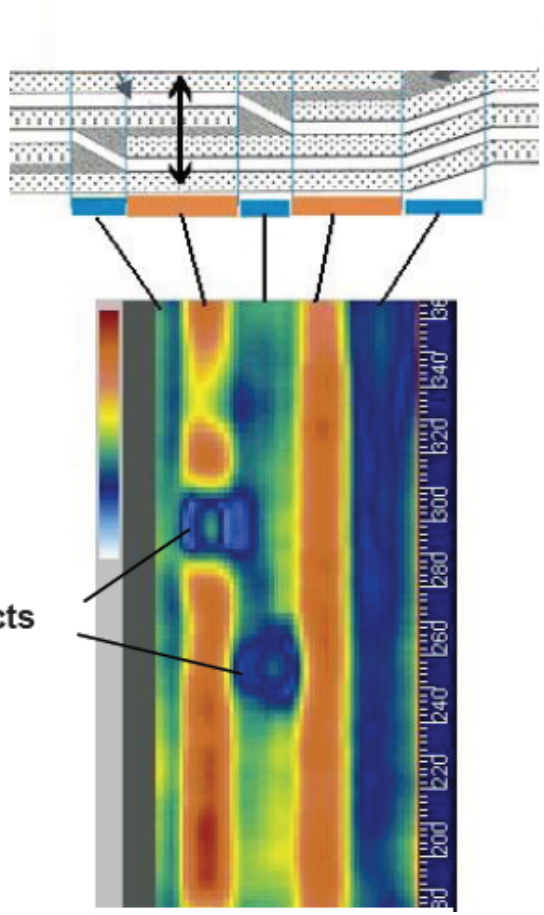
1L64E96-22 *LINEAR ARRAY* : 1MHz, 64 Elements (Array: 96mm x 22mm) Active Elements:12, Step-with: 1 Element, Effective scan-length: 78mm, el. Focus: BW



Principle of the Linear scan



B-Scan of a splice area



C-Scan of a Splice area

Conclusions about GLARE inspection

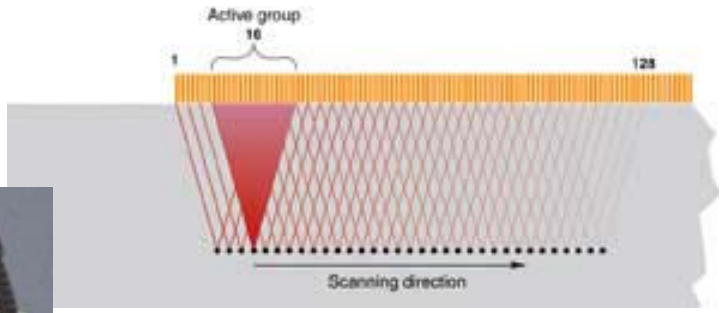
- Ultrasonic phased-array detects delamination and disbounds in the structures
- Cscan imaging improves reliability of the inspection
- Use of linear array probe assures full coverage detection

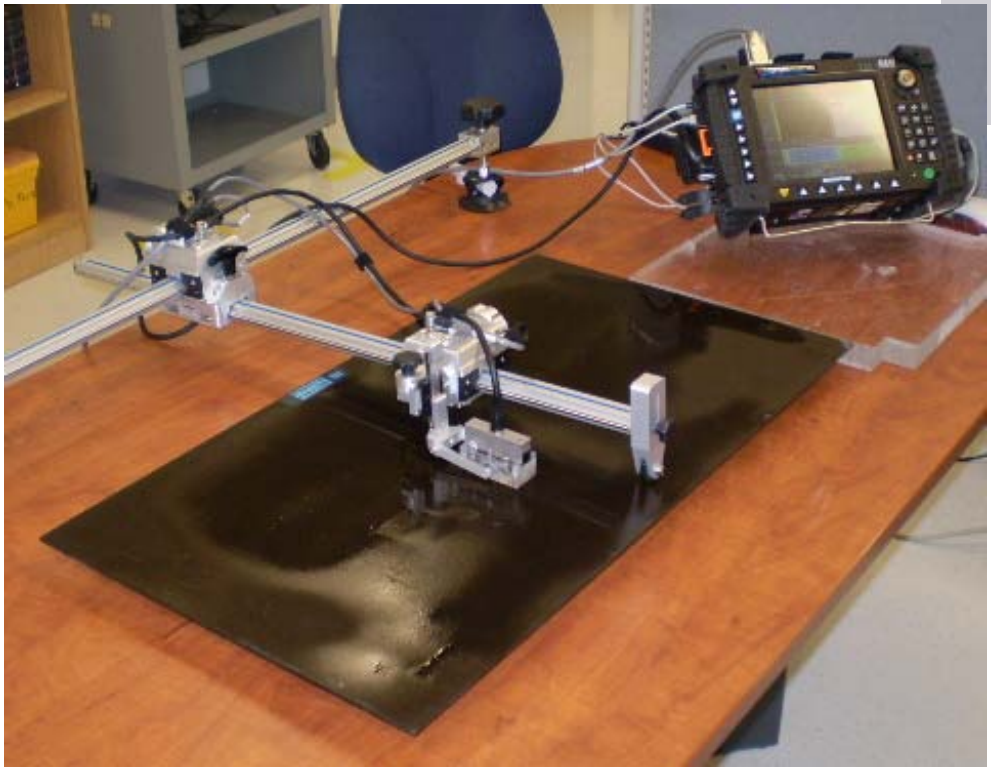
Composite inspection during maintenance

- Efficient data acquisition of large surface areas requires the following elements.
  - Acquisition unit allowing for two-axis data acquisition and C-scans.
  - UT array probe (PA or paint brush)
  - Coupling medium
    - » Wedge with thin film of water
  - Scanning system
    - » Manual portable scanner

Inspection Equipment

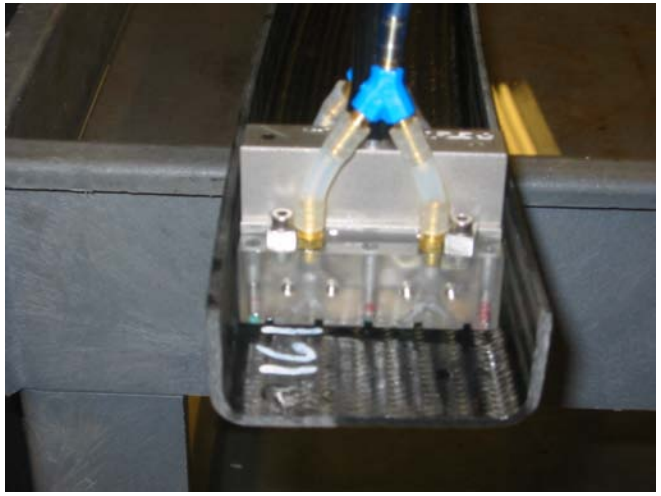
- Omniscan MX PA 16:128 – or – TomoView/FocusLT
- Phased Array probes and wedges
- Conventional ultrasound probes and wedges
- Scanners (GLIDER) and encoders

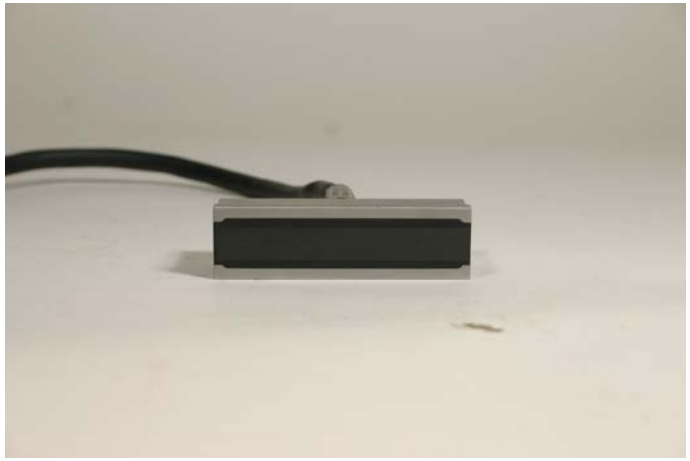




Near Wall Inspection (NWI) probe and wedge

- Near wall inspection probe (no dead zone on the edges of the probe
- 1 mm wall on each side
- 64 mm long – 64 elements of 1 mm pitch -
- 3.5 and 5 MHz versions
- NWI Hard wedge with water inputs





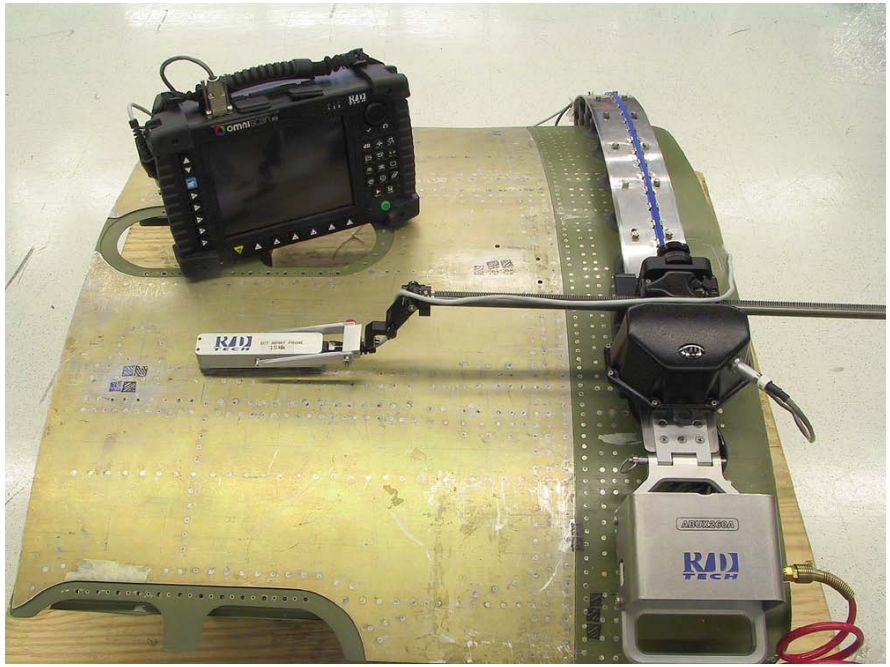
- The OmniScan® PA, the Glider™ and the 5L64 probe are referenced for C-scan inspections on the Boeing 787(Dreamliner) for both damage detection and bonded repair inspection of composite parts.

GLIDER specifications

- Cscan scanner for area 12 in x 12 in (300 mm x 300 mm) (other lengths available)
- 2 axes, 2 encoders, X-Y
- Encoder: no contact with the part.
- Encoder resolution: 0.5 mm, 0.020 in
- Index: variable minimum:0.5 mm, 0.020 in
- Bonding fixture: 2 manual succion cups (no need for compressor)
- Radius: concave and convex 40 cm to 1 m (flat) ; 16 in to 400 in (flat)
- Can be used with UT PA, conventionnel UT, Eddy current, ECA, bond tester, etc…
- Can accommodate water supply
- Easy to manipulate and deploy
- To be used by one operator.

Flexible scanner

Travel distance X:940 mm, Y:530 mm
Encoder resolution: 0.1 mm
Minimum curvature on X: 355 mm



Version with ventury, it requires compressor

New version with manual succion cups

Conclusions about ultrasonic phased-array

- Deployed in the field for many applications
- Referenced in procedures for aircraft maintenance
- Affordable
- Hundreds of aircraft inspectors trained to use Omniscan PA

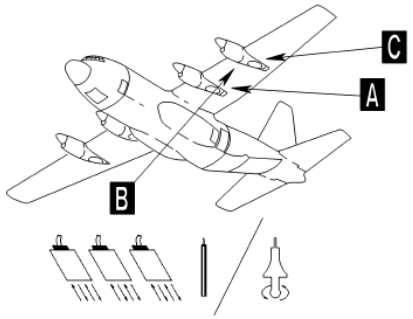
- Military applications

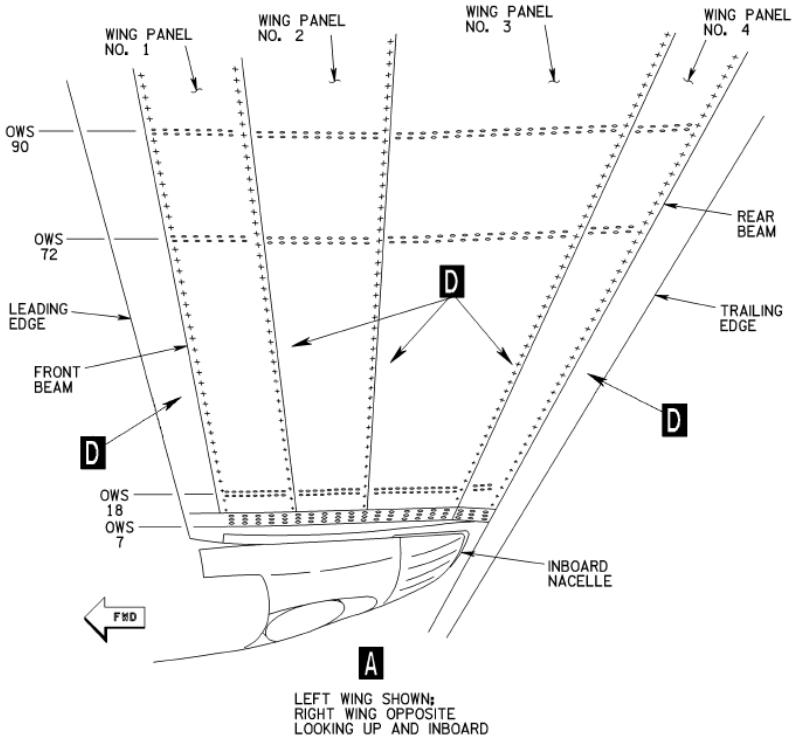
- C130
- NDI OF OUTER WING LOWER SURFACE PANEL GENERAL SPANWISE SPLICES

Inspection configuration

NDI of Outer Wing Lower Surface
Panel-to-Panel and Fwd/Aft
Panel-to-Beam Cap

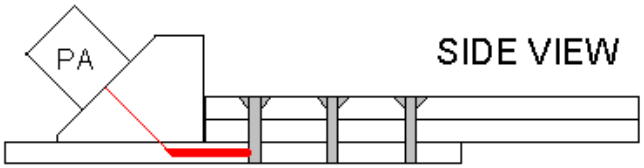
Span-wise Splices OWS 7-300.

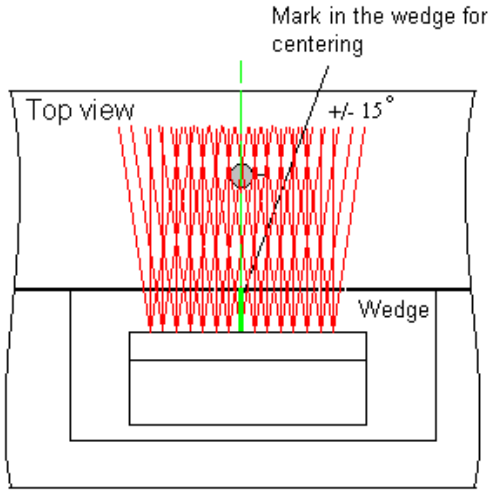


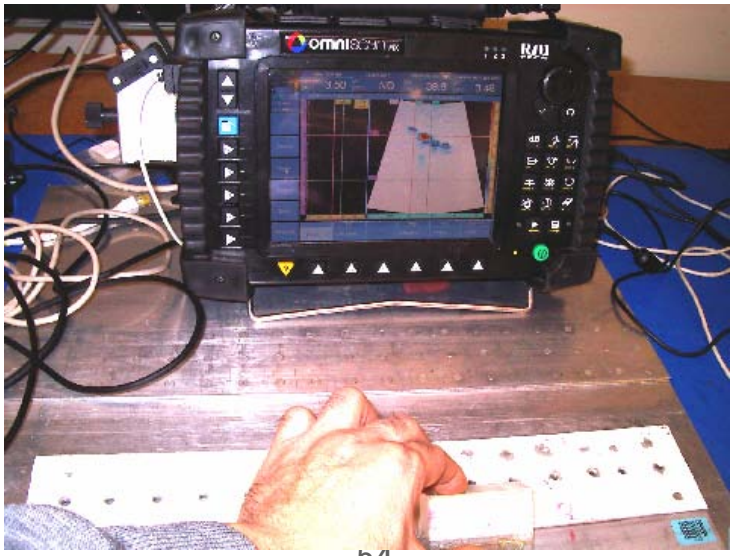


C130J-NDI-57-50-013-1R2

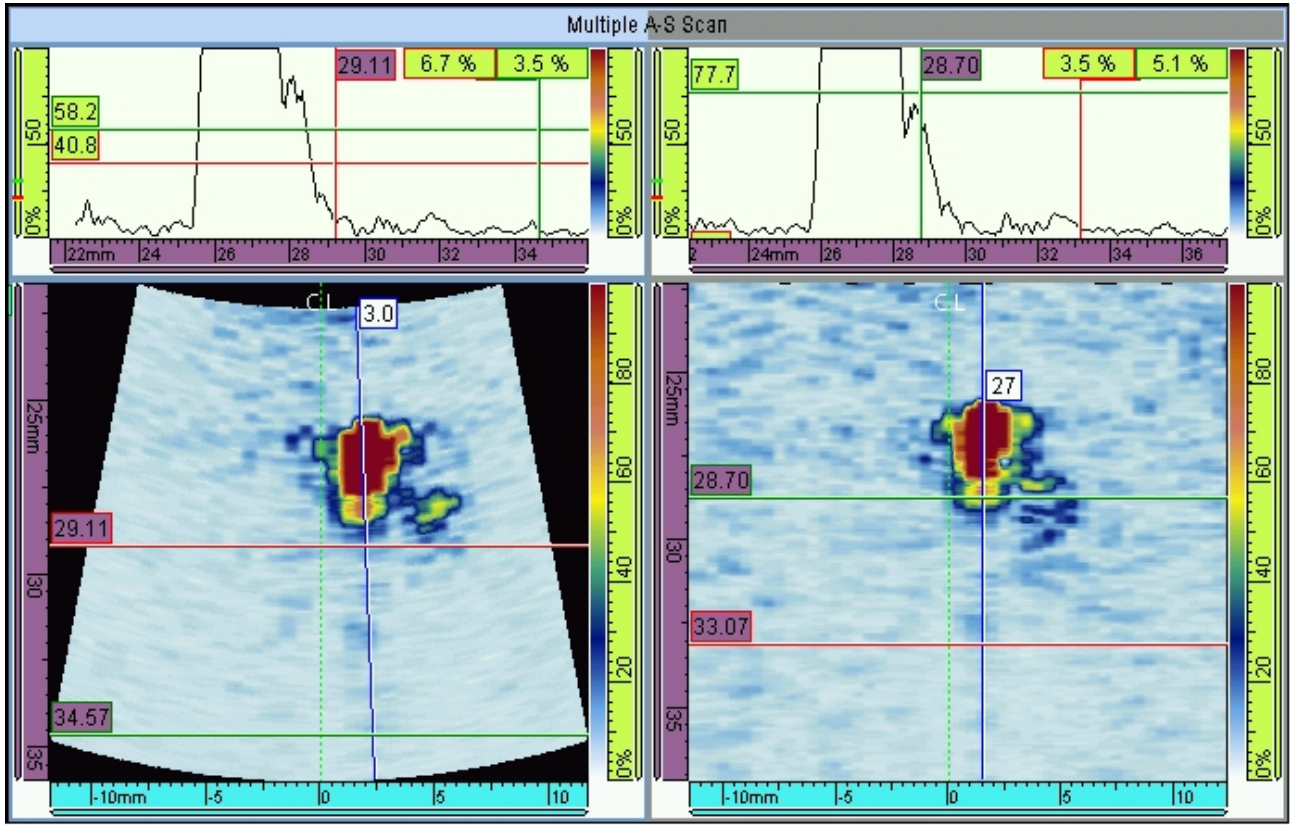
Inspection configuration





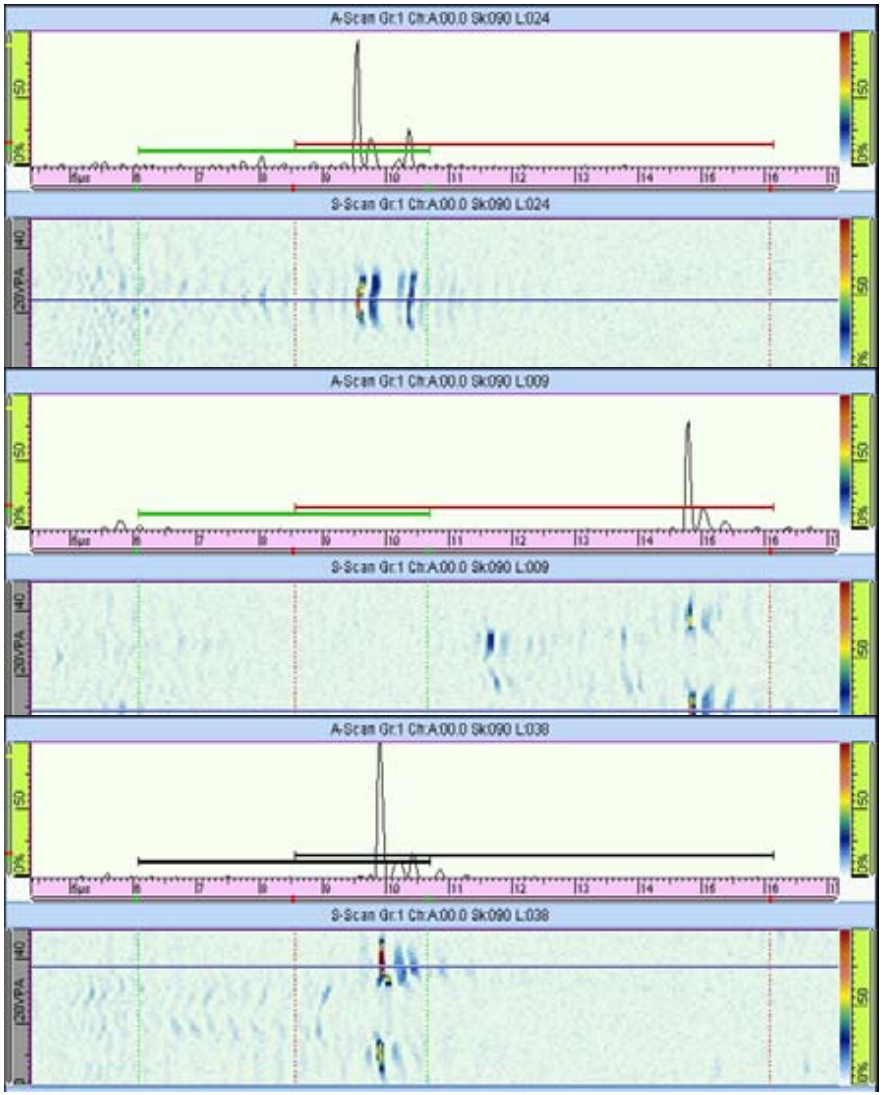


Scan plan



On the left, sector scan

On the right, linear scan 76 SW across the rivet line

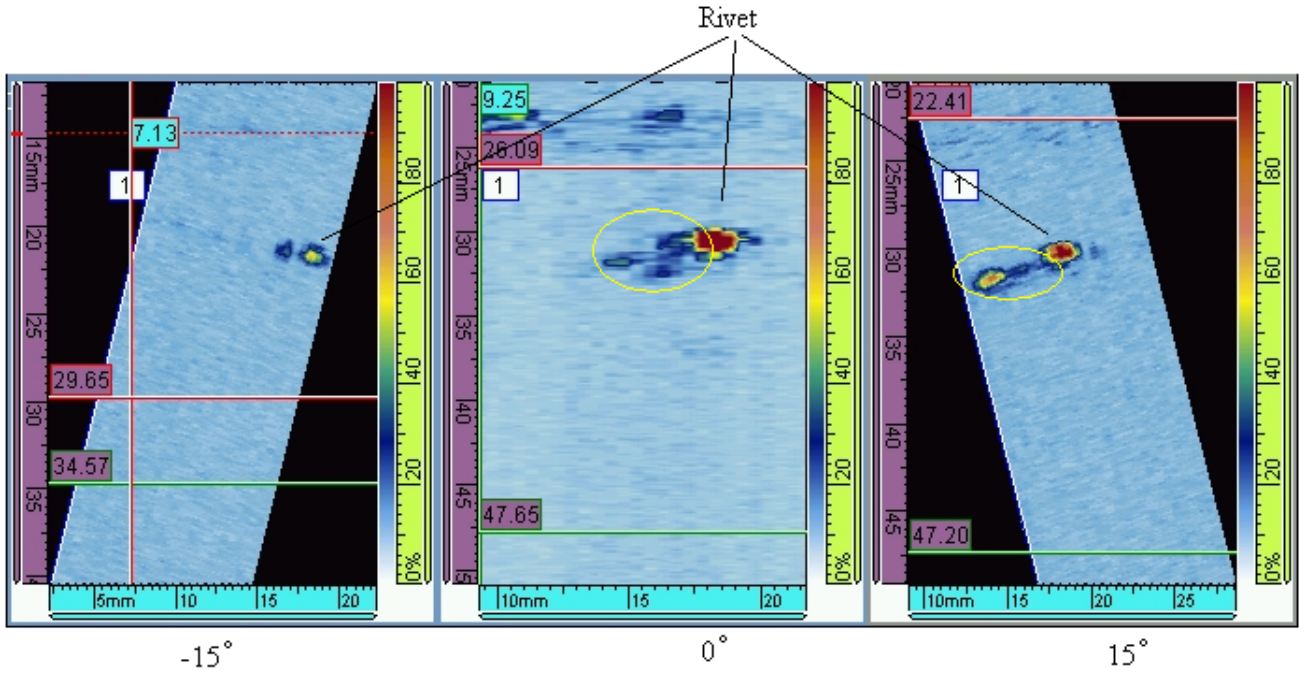


Signal from fastener hole

Signal from near-side notch

Signal from far-side notch

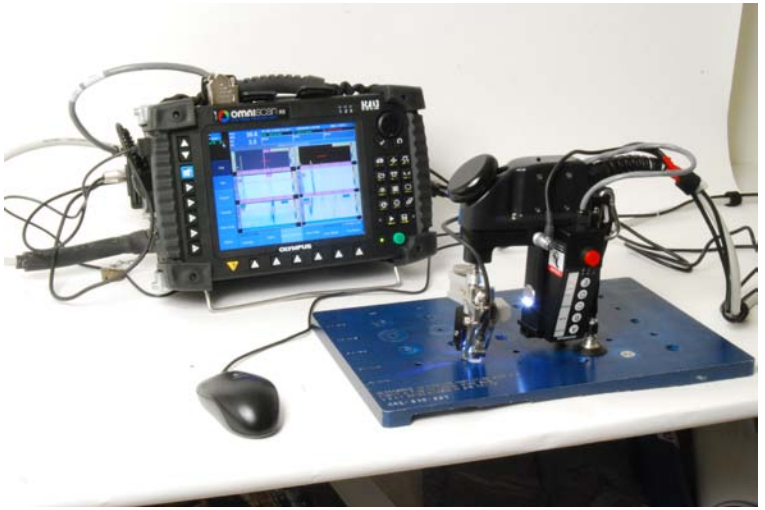
Some results



Rivet with oblique crack detected
at 15 deg skew angle and undetected
with 0 skew angle

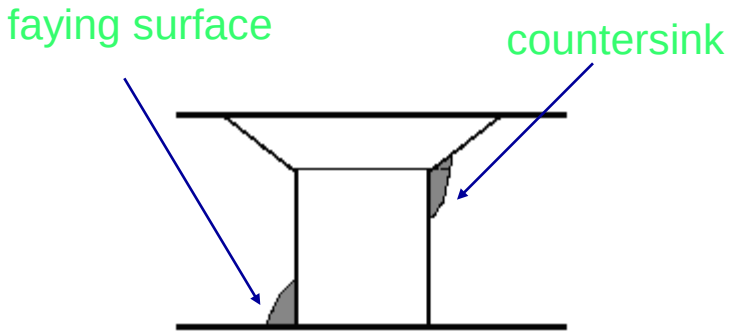
AFIS: **A**utomated **F**astener-holes **I**nspection **S**ystem

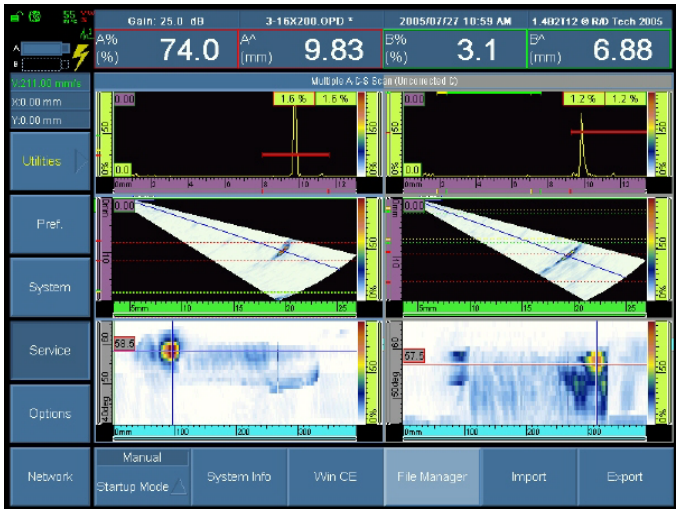
- Developed for the USAF under the contract FA8202-05-C-0035
- AFIS detects notches located at the faying surface and the countersink around the fastener holes on aircraft structures without fastener removal
- ROTOSCAN replacement
- AFIS in a portable battery operated automated system
- AFIS is adaptation of the famous Omniscan MX – Portable phased-array unit



Inspection requirements

- 360 degrees around the fastener holes
- Without removing the fastener
- Notches located at the countersink and faying surface
- 0.05 in round EDM notches
- Inspection time less than 1 min



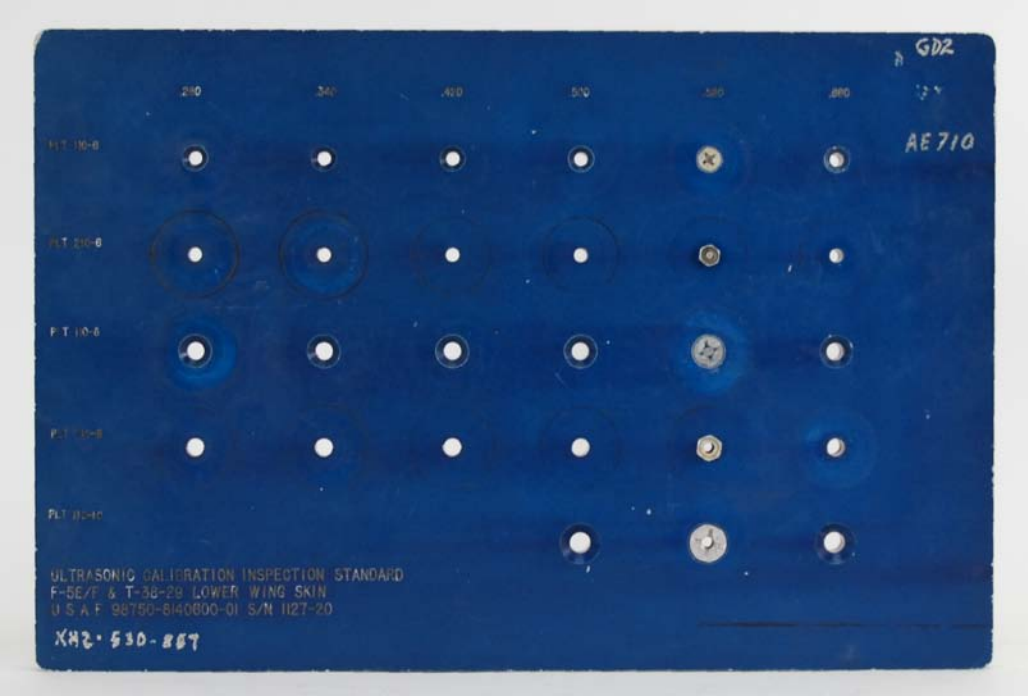


Inspection range

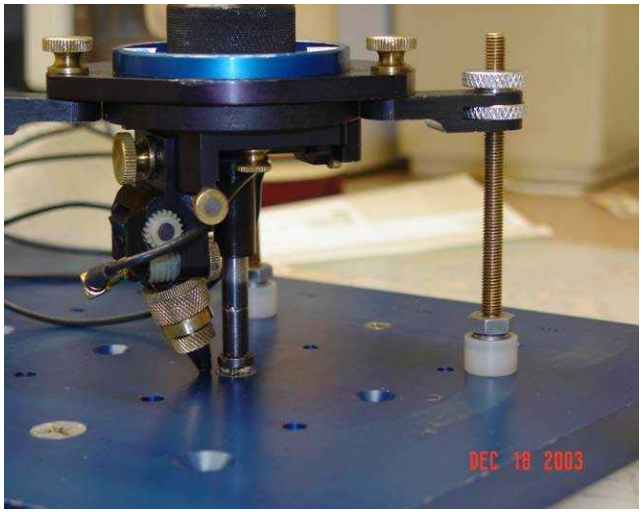
Fastener hole diameter (in)	Min. Skin Thickness(in)	Max. Skin Thickness(in)
3/16	0.18	0.70
1/4	0.18	0.70
5/16	0.45	0.68

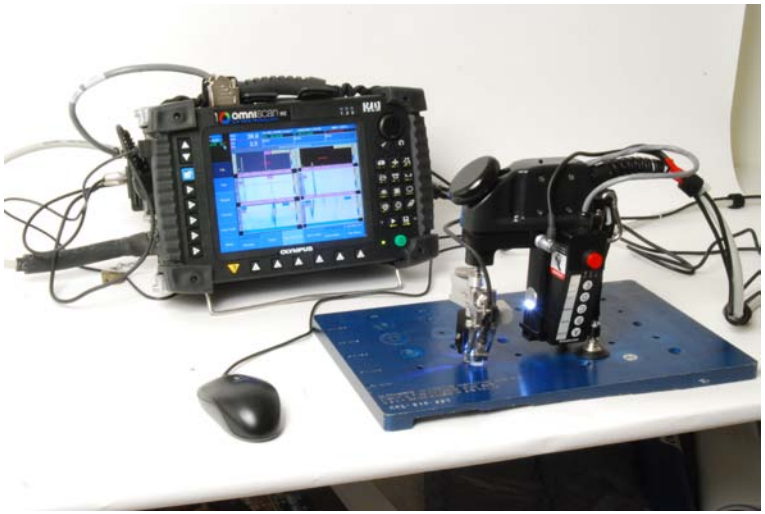
Calibration standards

EDM notches: 0.05 in (round)
Holes with countersink (flat fastener heads)
Holes without countersink (raised fastener heads)
Removable fasteners (Philips head)



Replacing the UT Rotoscan with the AFIS





Rotoscan

Manual
Conventional UT
Analysis with waveform

No archieved data
Probe angles changed manually
One beam for each region (countersink, faying surface)

AFIS

Automated
UT phased-array
Analysis with Cscan and Bscan images and waveform
Archived dataes
Electronic sector scan
Simultaneous sector scan for each region

AFIS configurations

- Actually, AFIS is configured for
  - T-38; flushed fastener heads
  - F-5; flushed and raised fastener heads
- It can be configured for other fleets

Solution concept:

- Ultrasonic phased-array instrument:
  - **Omniscan MX**

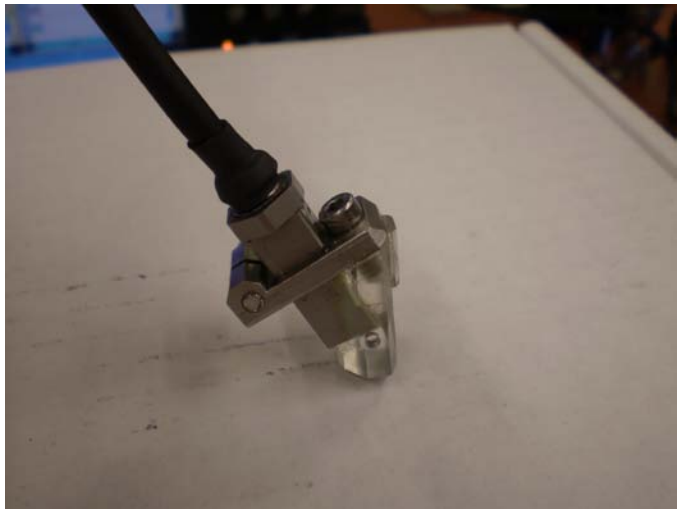
- One small phased-array probe

- One portable 360 degrees scanner

- One motion driver

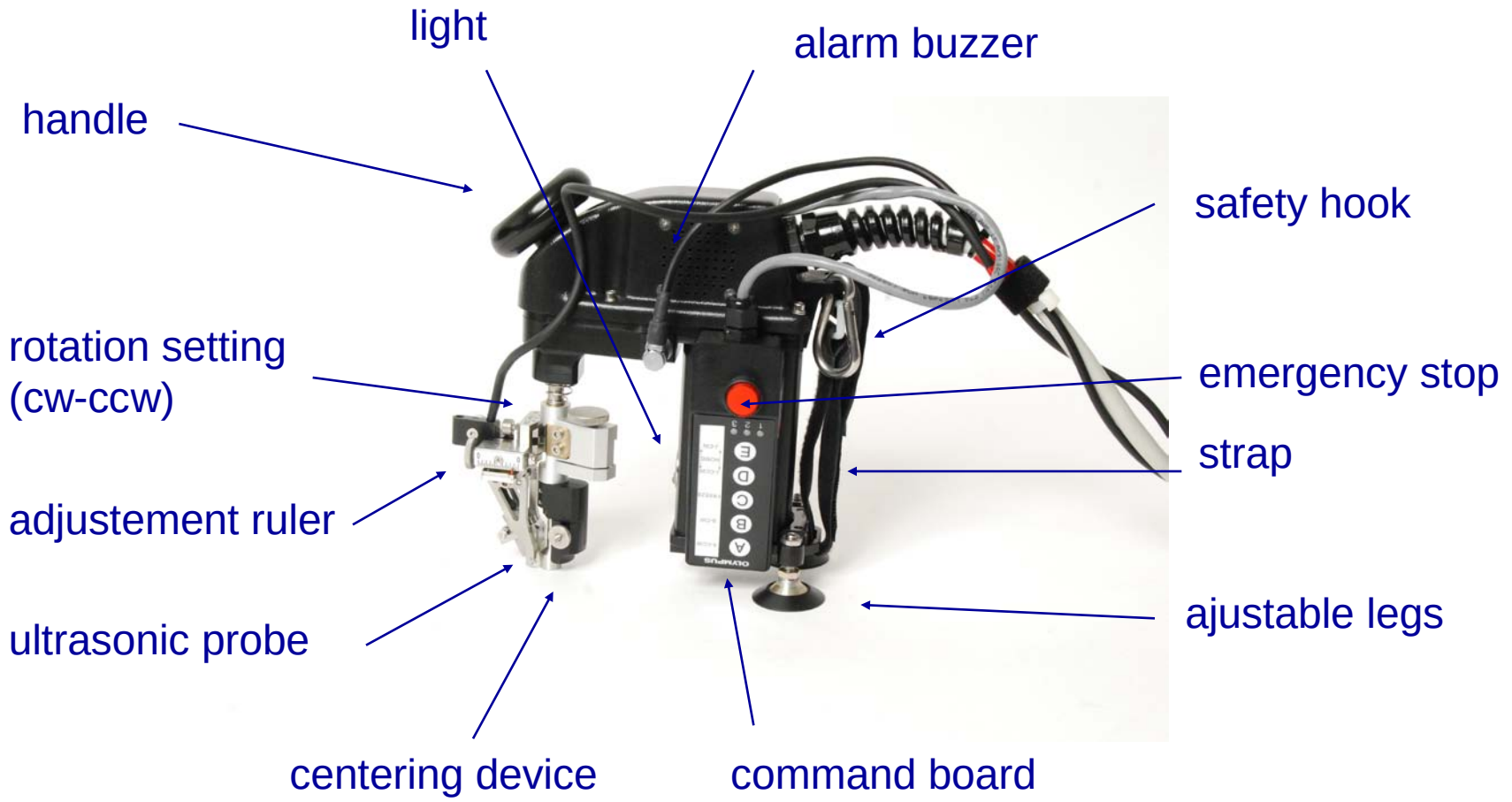
AFIS phased-array probe

- Frequency: 10 MHz
- Qty of elements: 16 elements
- Steering capabilities: 30 to 80 SW
- Wedge with very small footprint to access close to the fastener head



Probe 10L16-A00

AFIS scanner



AFIS scanner

- Weight: 2 lbs
- Size: 7 in x 6 in x 3 in

AFIS motion driver

- 1 axis motion drive
- Piggy backed to the Omniscan
- Fully compatible with the Omniscan

Automated Fastener-holes Inspection System: Operation mode

Probe rotation around the fastener hole

2 sectors inspected with different set-ups (gate, gain, etc) countersink and faying surface

Automated Fastener-holes Inspection System: Operation mode

Sequence:

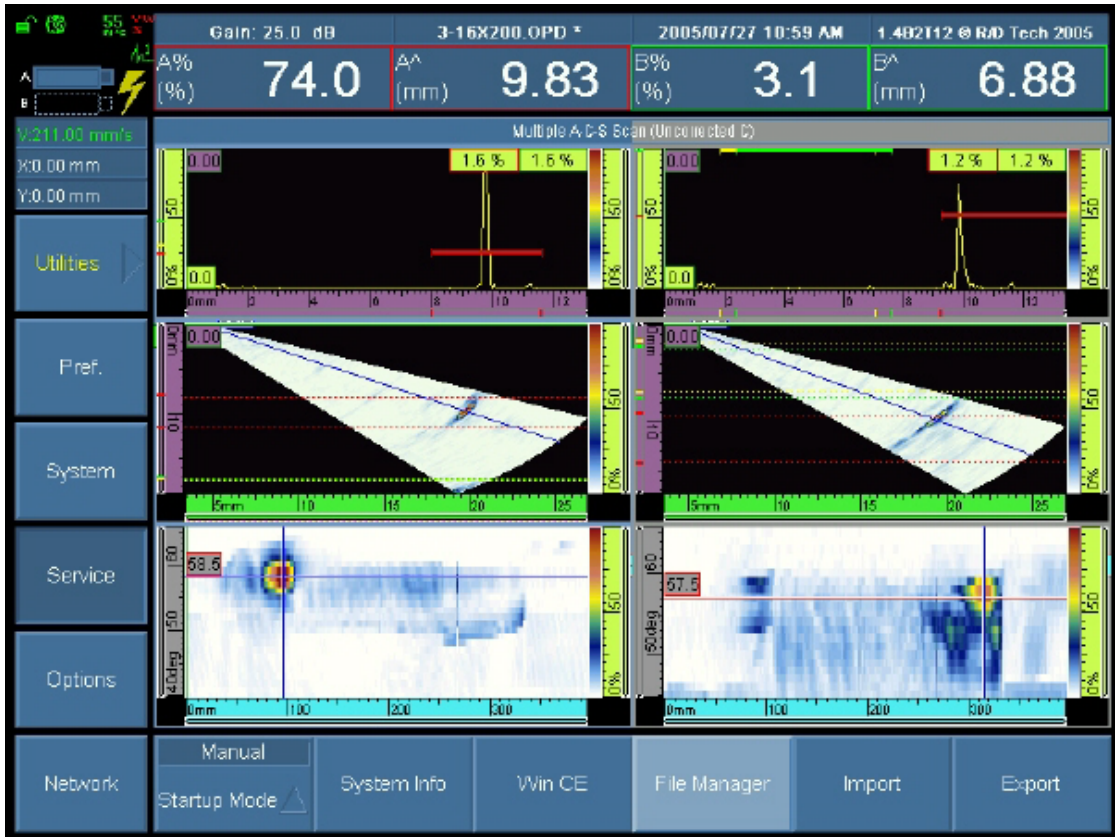
Coupling
Scanner positioning
Homing
Inspection
Freeze
Analysis

Results: Hole diam: 3/16 in; thickness: 0.2 in

Ascan:

Sector scan:

C-scan:

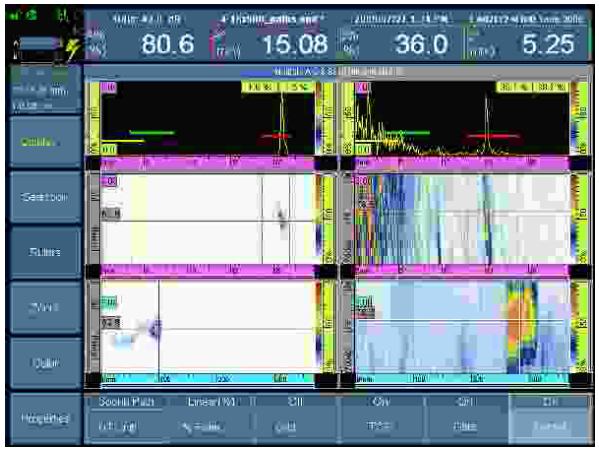


Faying surface
SNR > 20 db

Countersink
SNR> 20 db

Results for thick samples

Diameter: 3/16 in
Thickness: .5 in



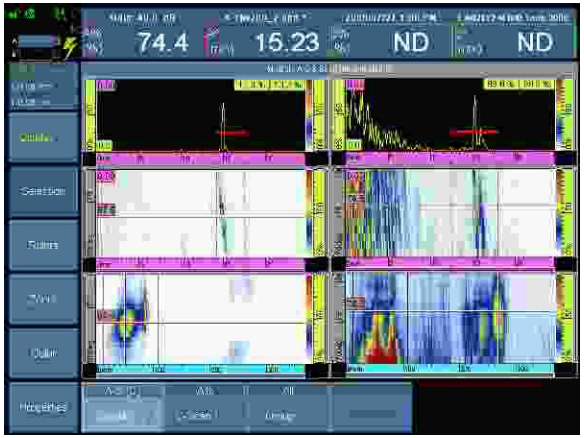
Diameter: 1/4 in
Thickness: .5 in

Diameter: 5/16 in
Thickness: .5 in

Detection of all notches located at the countersink and faying surface with high SNR

Results for thin samples

Diameter: 3/16 in
Thickness: .2 in



Diameter: 1/4 in
Thickness: .2 in

Diameter: 5/16 in
Thickness: .4 in

Detection of all notches located at the countersink and faying surface with high SNR

Conclusion

- AFIS detects all notches within the desired range of thickness and diameter
- Detection with very high SNR
- Inspection done in less than 30 sec for each fastener holes
- Less operator dependant (because automated)
- Reliable (image and pre-defined setting reduce risk of error)
- Easy to use
- Can be configured for other fleets than T-38 and F-5

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