FAA Airworthiness Assurance NDI Validation Center Operated by Sandia National Laboratories

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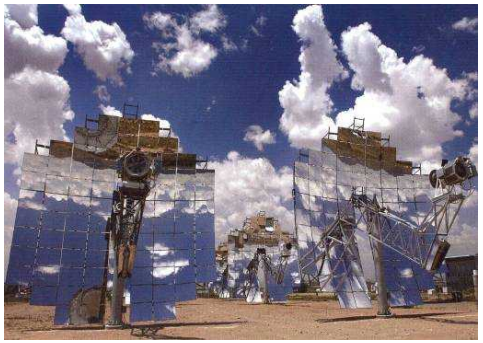
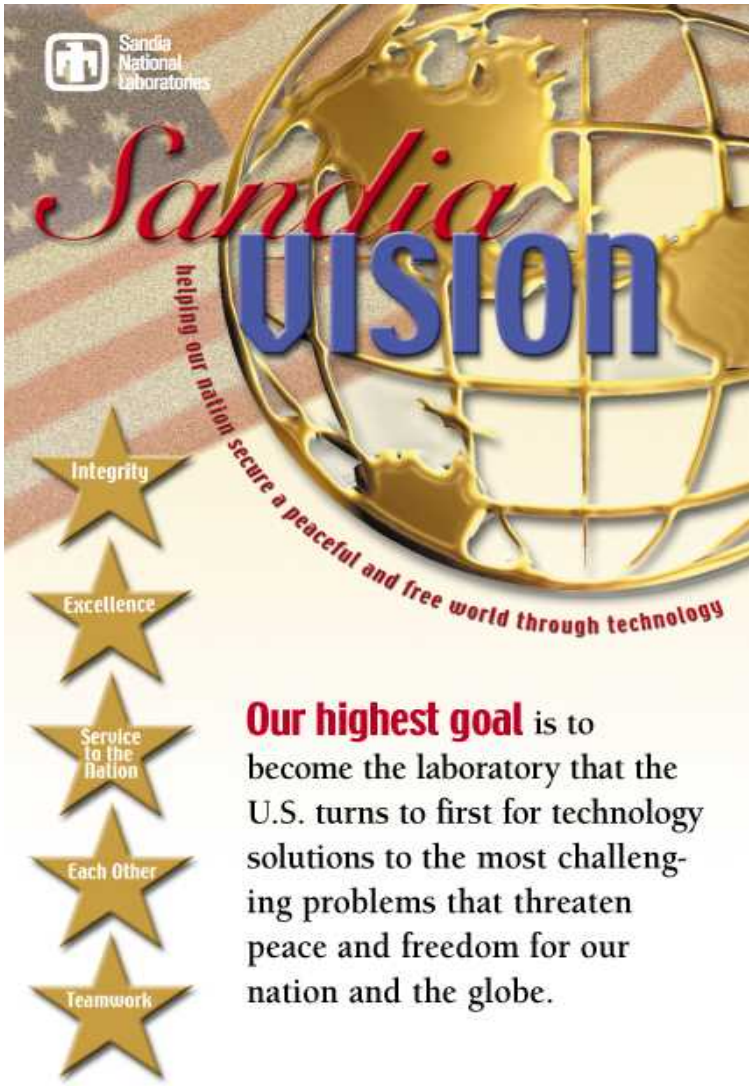
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

What is Sandia National Labs?

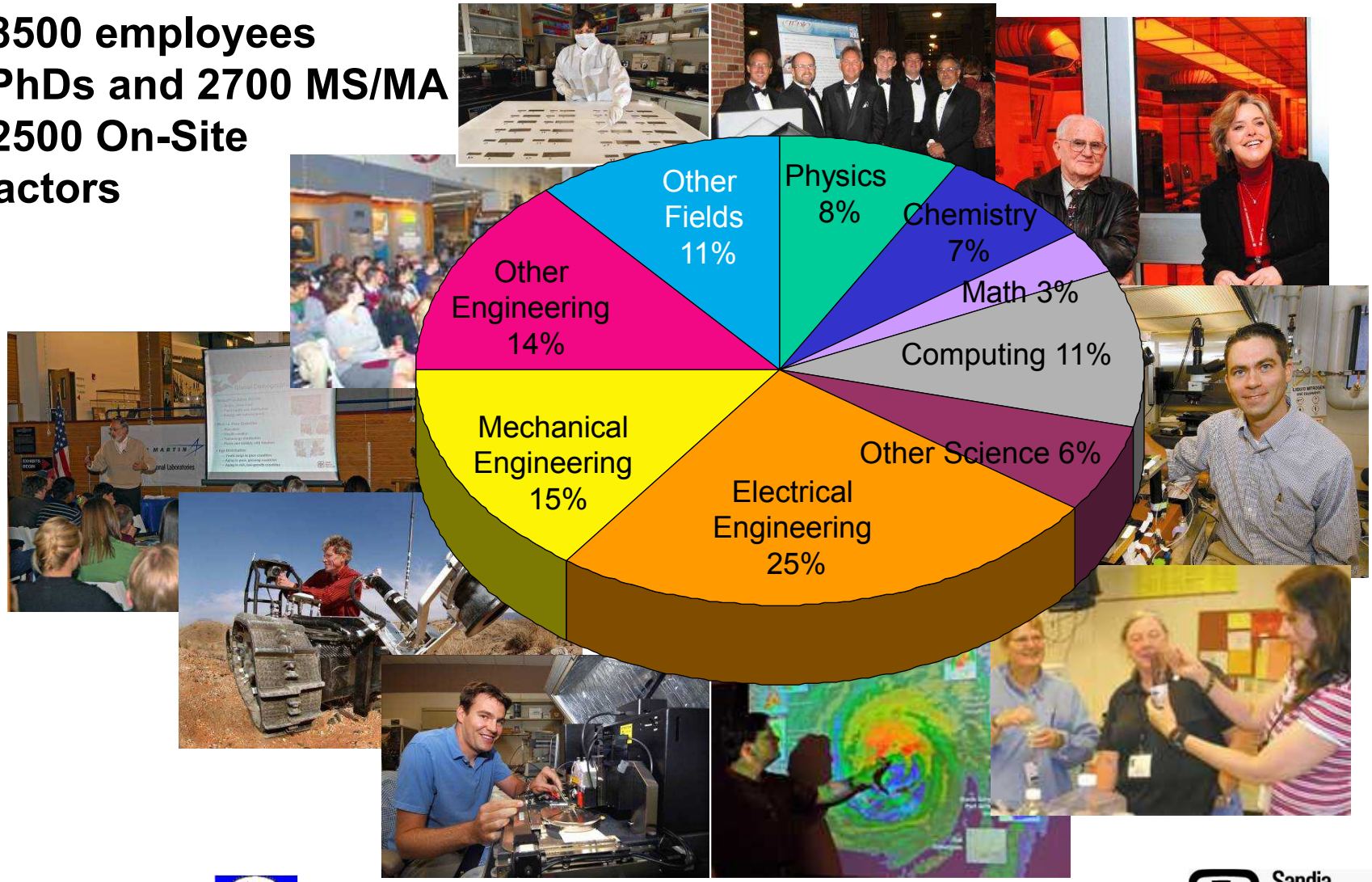
- National security laboratory
- Core mission in nuclear weapons
- Broader mission in science and technology to meet national security needs





Sandia People

Over 8500 employees
1500 PhDs and 2700 MS/MA
Over 2500 On-Site Contractors

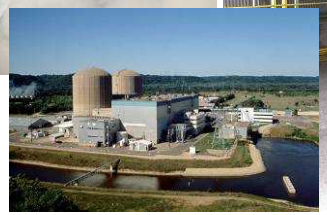


Strategic Management Groups

Integrated Technologies and Systems
Three Management Units

- *Energy, Resources, and Nonproliferation*
- *Homeland Security*
- *Defense Systems & Assessments*



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Nuclear Weapons
One Management Unit

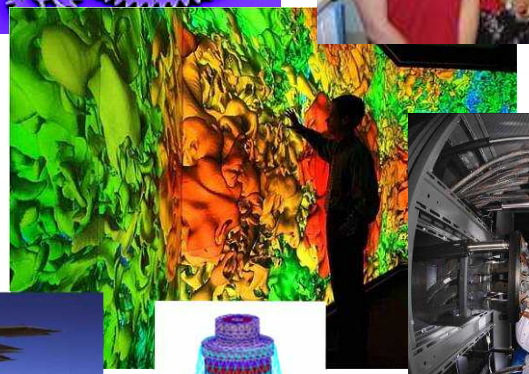
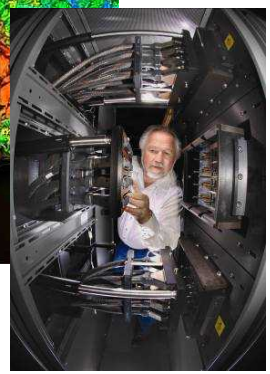
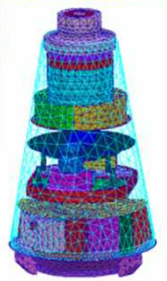
- *Nuclear Weapons*




Laboratory Transformation
Two Management Units

- *Integrated Enabling Services*
- *Science, Technology, and Engineering*



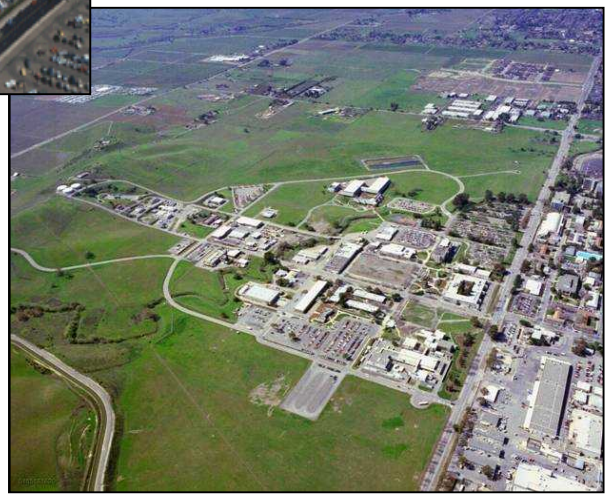
Sandia National Laboratories

Sandia Labs Has Distributed Facilities to Meet National Needs

Kauai Test Facility, Hawaii

Albuquerque, New Mexico

WIPP, New Mexico



Livermore, California

Tonopah Test Range, Nevada

Pantex, Texas

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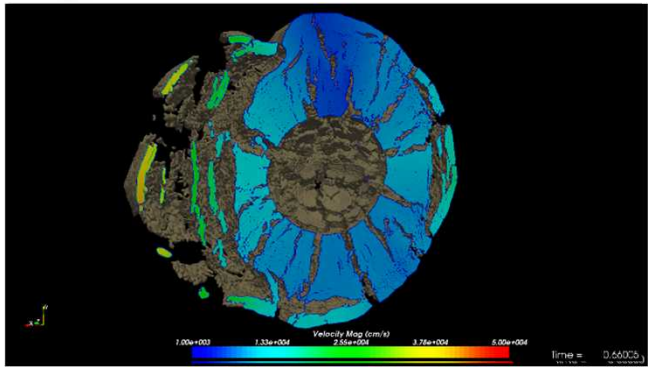
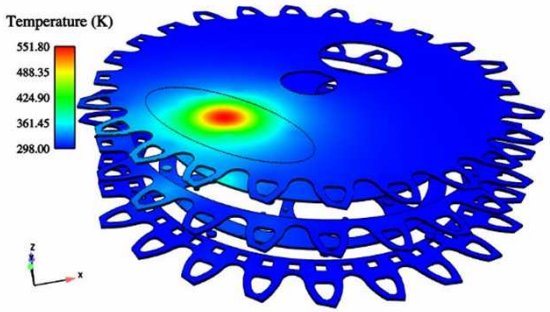
Sandia National Laboratories

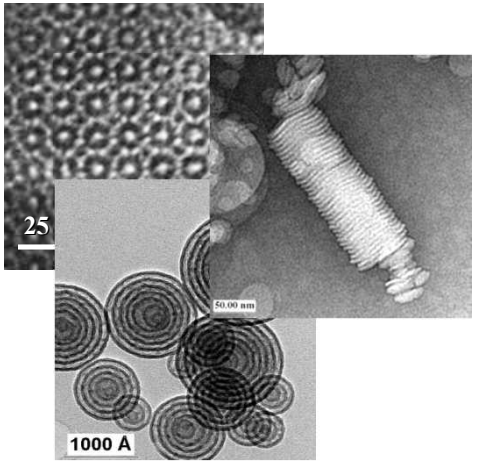
Our Mission Focus Relies on Strong Science and Engineering



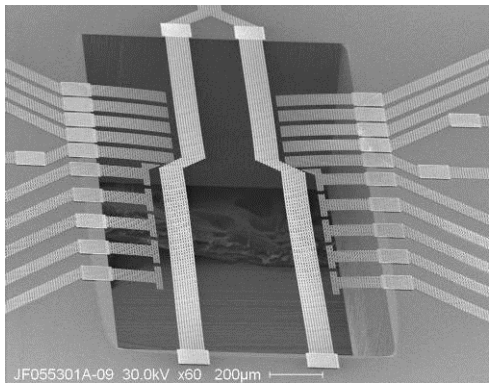
Computational and Information sciences



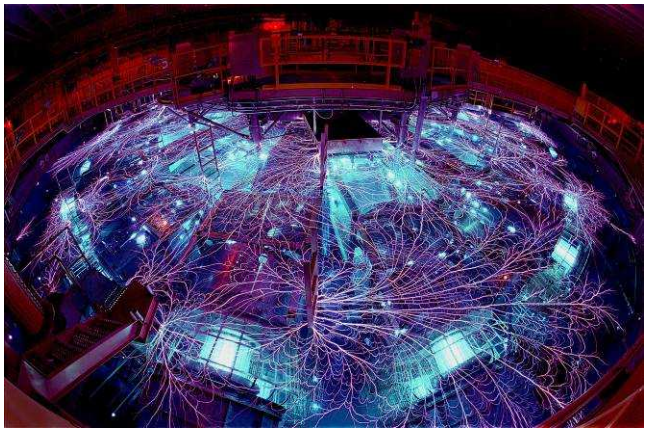
Engineering Sciences



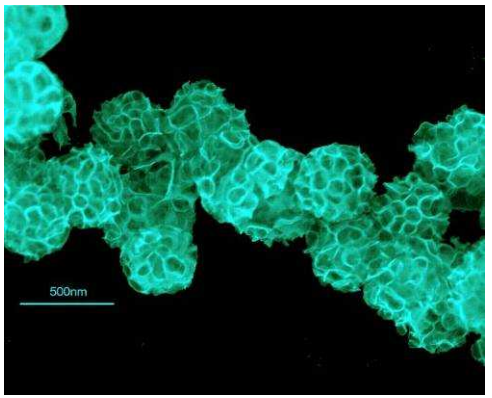
Materials Science and Technology



Microelectronics and Photonics



Pulsed Power



Biotechnology

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Sandia performs other nationally important work when its capabilities can make significant contributions

- Vulnerabilities of critical infrastructures
- Risk assessment methodologies

- Safety of transportation Systems
- Aging studies and diagnostics

- Environmental studies

- Anti-crime and anti-terrorism technology

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FAA Airworthiness Assurance Center

- Initiated in 1988 under the Aviation Safety Act
- Provides a mechanism to develop, evaluate, and bring new aircraft technologies to market
- Partnerships with industry, academia, and government

B737-200
Test Bed

Fairchild Metro II
Test Bed

AANC Objectives

- Enhance aircraft safety and reliability
- Aid in the development of advanced aircraft designs and maintenance techniques
- Provide our customers with comprehensive, independent, and qualitative evaluations of new and enhanced inspection, maintenance, and repair techniques
- Facilitate the transfer of effective technologies into the aviation industry
- Support FAA rulemaking process by providing guidance on content & necessary tools to meet requirements or recommendations of FARs, ADs, ACs, SBs, SSIDs, CPCP, and WFD
- Coordinate with and respond to Airworthiness Assurance Working Group (AAWG) in support of FAA Aviation Rulemaking Advisory Committee (ARAC)

AANC Programs Cover a Wide Array of Airworthiness Assurance Issues

Sandia Charter with FAA includes:

Adv. Materials & Structures	Crashworthiness
Inspection, Maint., Repair	Landing Gears
Propulsion & Fuel Systems	Nonstructural Systems

Sample Advisory Circulars Supported by AANC Project Information:

- *AC 91-60A "Continued Airworthiness of Older Airplanes"*
- *AC 120-16C "Continued Airworthiness Maintenance Programs"*
- *AC 135-10A "Approved Aircraft Inspection Program"*
- *AC 125-1, 129-4 "Maint. & Operation of Aircraft Under FAR Part 125/129"*
- *AC 91-56B "Struc. Integrity Program for Transport Airplanes"*

Summary of Programs

- **Federal Aviation Administration**
  - Airworthiness Assurance Center
    - Airframe Inspection, Maintenance, and Repair
    - Advanced Materials and Health Monitoring
    - Non-Structural Systems (Flight Controls, Wiring, Engines)
    - Smoke Transport Code Development
    - Specialty Alloys for Propulsion Applications
- **Dept. of Defense** - Air Force, Navy, Army
- **US Coast Guard, Civil Aviation Industry, US Forest Service**
- **DoE Defense and Energy Programs**
- **NASA** – Space Shuttle and Aging Aircraft
- **Private Industry** – e.g. Boeing, Bell Helicopter, Lockheed-Martin, Exxon, General Motors
- **Universities** – WSU, NWU, NC A&T, ISU, UW, NMSU

AANC - Teaming for Success

Teams have incorporated over 150 agencies

DC-9 Tee Cap
Northwestern University
Northwest Airlines
Douglas Aircraft
SAIC Ultralmage

Rotorcraft Inspection
Bell Helicopter
Sikorsky Aircraft
Petroleum Helicopters
Army/Navy
Olympus

Sensor & NDI Development
Boeing
General Electric
Delta Air Lines
Northwest Airlines
Jentek
Innovative Materials Testing

Engine Bearing Cleaning
GE Engines
Lewis Corporation
MRC Bearings

Halon Bottle Tester
Air Transport Association
Walter Kidde
Pacific Scientific
Physical Acoustics

Widespread Fatigue Damage
Boeing Commercial Aircraft
Delta Air Lines
NRC Canada
Iowa State University

Boron Epoxy Repairs
Boeing
Lockheed-Martin
Delta Air Lines
Federal Express
Textron
Air Force

NDI of Advanced Composite Structures
Boeing Commercial Aircraft
Airbus
United Airlines
Delta Air Lines
American Airlines
Air France
Lufthansa
Wichita State University
North Carolina A&T

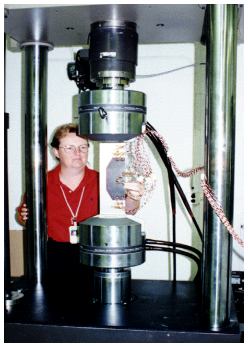
Commuter Program
Cessna
Raytheon
Fairchild
Northwestern University

MOI for Corrosion Inspection
Boeing Commercial Aircraft
United Airlines
Physical Research Inc.

Summary of AANC Accomplishments and Work to Address Aviation Safety Concerns

Halon Bottle Tester

Fatigue Tests on Composite Specimens



Thermal Wave Imaging

AANC Multidisciplinary Projects

L-1011 Composite Doubler

DC-9 T-cap Inspection

USCG Window Post Inspection

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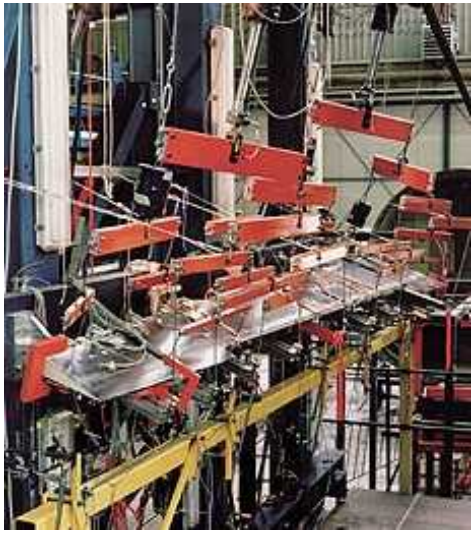
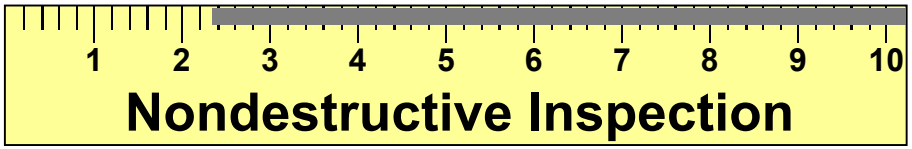
Required Relationship Between Structural Integrity and Inspection Sensitivity



Detectable Flaw Size



Allowable Flaw Size

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DC-9 Wingbox Tee Cap Inspection

DC-9 Wingbox Tee Cap Crack Inspection

- Ultrasonic technique replaces visual inspection
- Eliminates need for exposure to hazardous material in a confined space
- Doubles inspection area and increases resolution
- **Produced AMOC for Boeing AD while providing better NDI information**
- **Aging Aircraft FAR & SSID**

***Before* - 800 hours Visual Inspection**

***After* - 80 hours**

Northwest Airlines Inspector scanning DC-9 Tee Cap with new ultrasonic technique

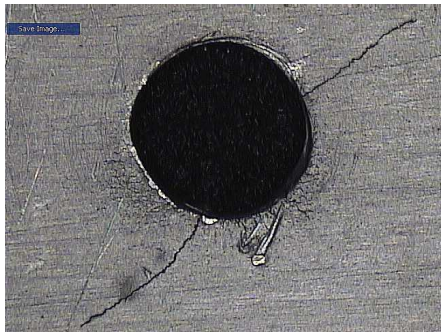
Repair of Commercial Aircraft Using Bonded Composite Doublers

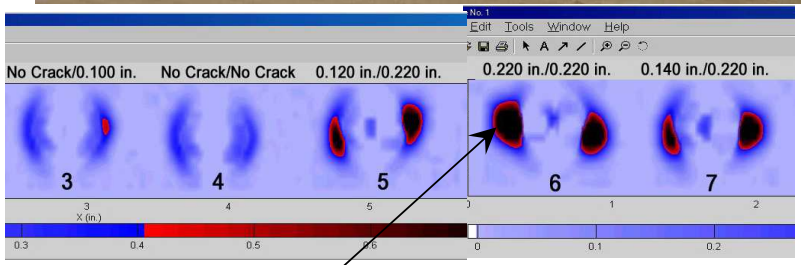
- Safely introduced new aircraft repair technology that provides both engineering and economic benefits
- Entire process, including advanced inspection methods, is aiding Service Life Extension Programs
- Produced Boeing Structural Repair & NDT Manual revisions and FAA guidelines to assure continued airworthiness; AMOC for AD 94-05-01
- Aging Aircraft FAR & associated ACs

Technology proven to be viable for the commercial aircraft industry - Pilot Programs, Boeing NDI and SRM Manual revisions

Widespread Fatigue Damage

- **Response to AAWG and ARAC request**
- **Understand WFD phenomena through lab and field studies; aging aircraft teardown inspections**
- **Advanced NDI has produced order of magnitude improvements to create risk management options**
- **Program is producing guidelines for assessing continued airworthiness**
- **Effort supports NPRM regulations in Widespread Fatigue Damage (FAA-2006-24281) & Damage Tolerance Data for Repairs & Alterations (FAA-2005-21693)**

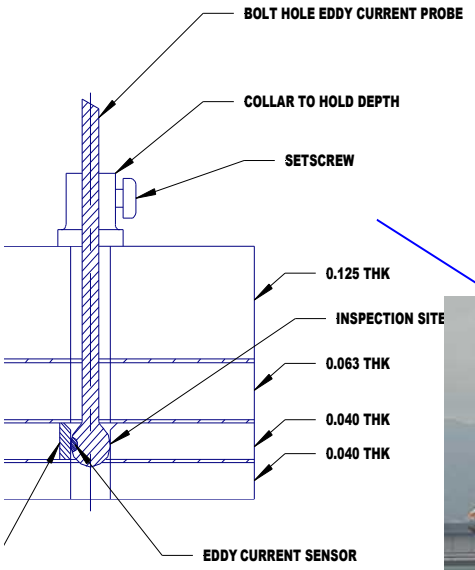




Fatigue Cracks

Quick Response Project – Emergency Inspection of B727 Cargo Door Modification

- Modification from passenger to cargo door covered lap splice joints involved in crack terminating action (AD 91-06-06 from Aloha accident)
- Program requested NDI method for immediate application to avoid grounding cargo fleet of 727 aircraft
- Bolt hole eddy current method was developed and validated
- **Inspection was incorporated into Boeing Alert Service Bulletin & approved as Alternate Means of Compliance for AD T98-23-51 and AD 99-04-22**



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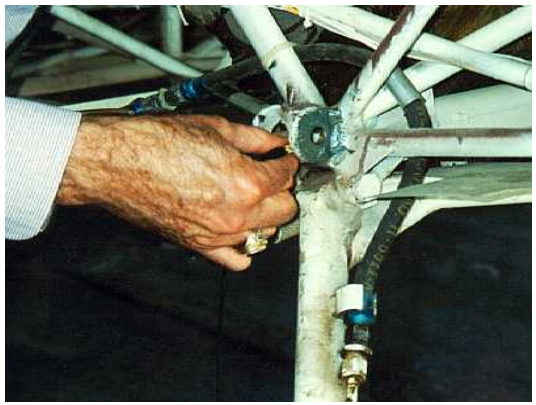
Quick Response Project – Emergency Inspection of General Aviation Fuselage Attachment

- Aircraft accident resulted in discovery of systemic corrosion problem in Piper aircraft
- Developed & validated P-E ultrasonic inspection for spar-to-fuselage attachment
- Inspection procedure was incorporated into AD 93-21-12 as means to comply with inspection requirements
- Aging Aircraft FAR and SSID

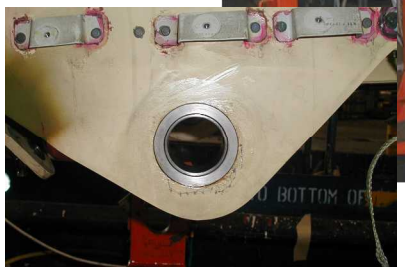


Quick Response Project for NTSB – AA587 Crash Investigation

- Developed inspection method to address post-accident AD
- Ongoing support for Airbus Alert SB (rudder)

MAUS MIA C-Scan of Airbus Rudder

Developed P-E UT inspection – added for carbon laminate lug



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Commuter NDI Program

Supporting Commuter SSID Advisory Document

- **Development and implementation of new NDI techniques allows aging commuter fleets to safely extend the life of their aircraft**
- **Move beyond visual – advanced NDI reduces inspection times/costs and lengthens the required inspection intervals**
- **Aging Aircraft FAR; information for AC-135-7, FAR 135**

Inspection of lower wing spar testbed (Fairchild SA226)

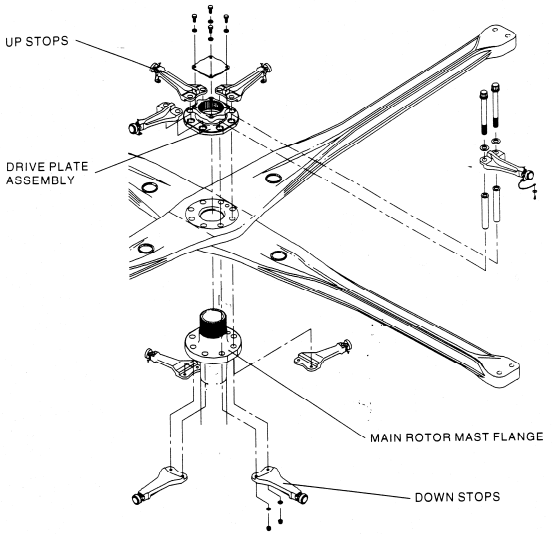
Field testing of eddy current inspection being completed on SA226 aircraft

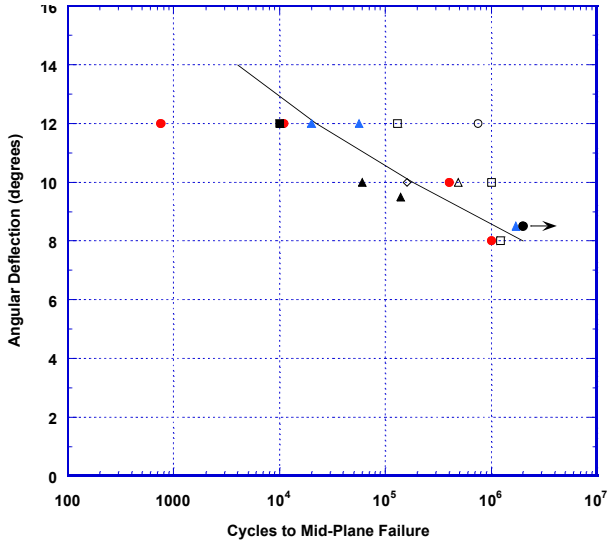
Detect 0.100” cracks in 3rd, 4th, and 5th layer of spar assembly

Rotorcraft Inspection & Damage Tolerance Program

- Allows advanced rotorcraft design concepts to be safely integrated into routine use
- Produce regulatory measures to meet new NDI demands stemming from damage tolerance analysis approach
- Results integrated into maintenance depots (training, procedures)
- **Supports Aging Aircraft FAR and design per DT FAR (14 CFR 29.571); AC 29-2C; AC 27-1B**

Damage Tolerance & NDI Assessment of Composite Rotor Hubs





Cycles to onset of delamination in high cycle fatigue) environment

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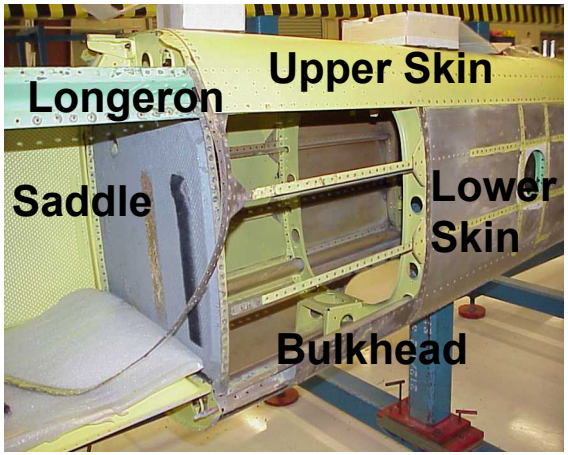
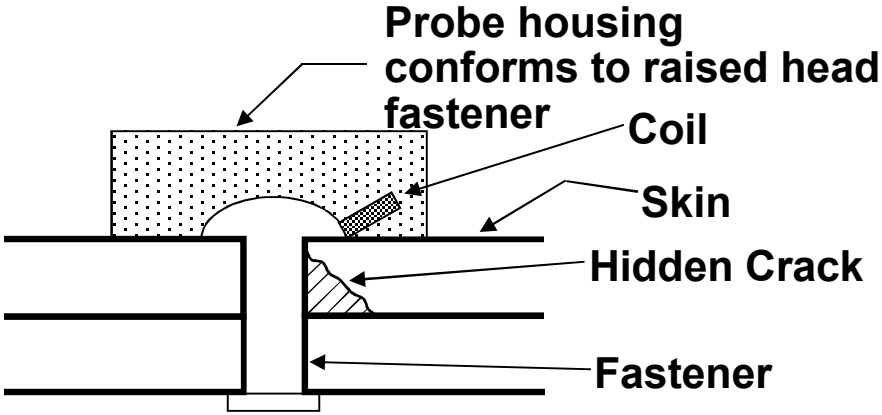
Rotorcraft Inspection & Damage Tolerance Program

Flaw Detection Studies - Cracks (high cycle fatigue) and Corrosion (multi-layered joints)



- Dual frequency EC method can detect <10% corrosion (0.002" th. loss)
- Custom probes developed to detect cracks under raised head fasteners
- Enhances safety, reduces repair costs, eliminates need to remove fasteners for inspections
- Aging Aircraft/DT FAR; 8300.12 Flight Standard Infor. Bulletin on corrosion

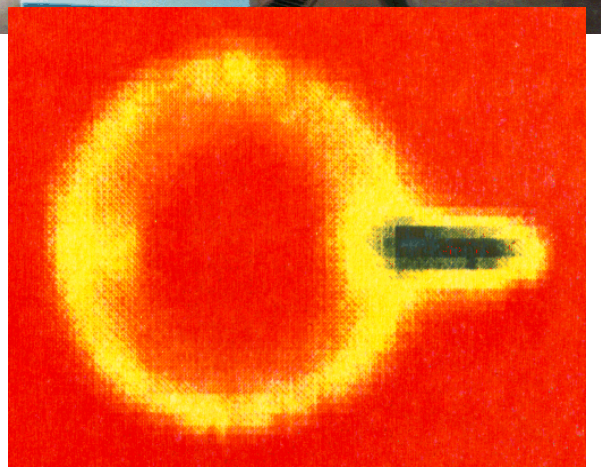
Training for Beta Site Testing at PHI



Angled Surface Crack

Eddy Current Inspection Reliability Experiment

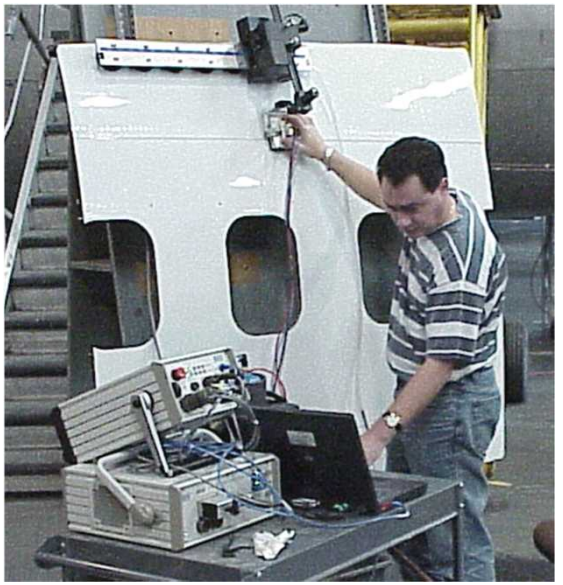
- Evaluated the performance of conventional eddy current devices at aircraft maintenance depots to detect fuselage cracks
- Demonstrated the need for better imaging capabilities to interpret eddy current measurements
- Led to development of new imaging technologies which will allow operators with less expertise to use the technology
- Supports AD 91-06-06 (terminating action) & subsequent Boeing Alert SB 737-53A1224 (AD 99-04-22)



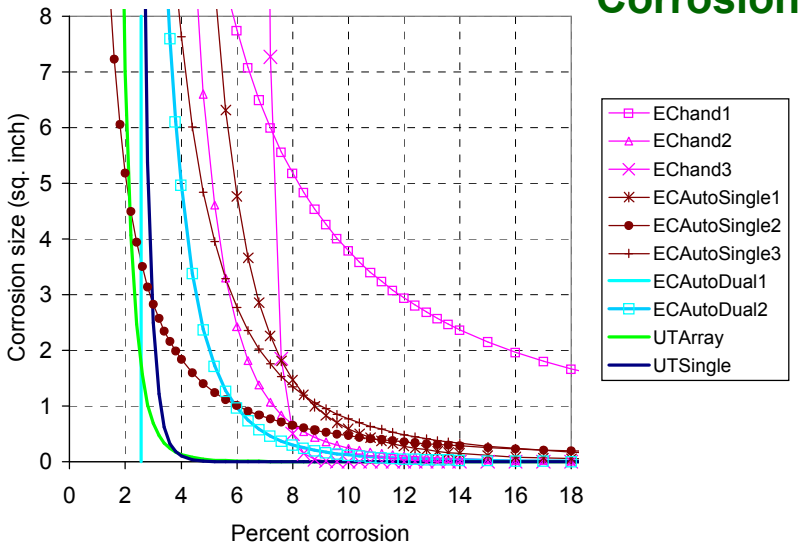
Eddy current imaging technology for crack length measurement

NDI Validation Experiment - Detection of Hidden Corrosion

- **Response to AAWG and ARAC request**
- **Assess the performance of conventional and emerging NDI techniques & integrate equipment into aircraft maintenance depots**
- **Aid NDI development, directs application to appropriate inspections**
- **Support Aging Aircraft FAR, 8300.12 Flight Standard Infor. Bulletin on corrosion, and corrosion inspection SSIDs**



RD Tech Performing Blind Corrosion Detection Study



Probability of Flaw Detection Contours

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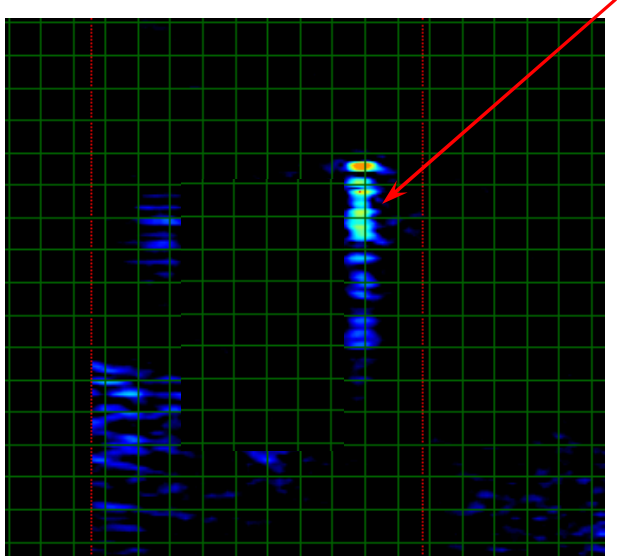
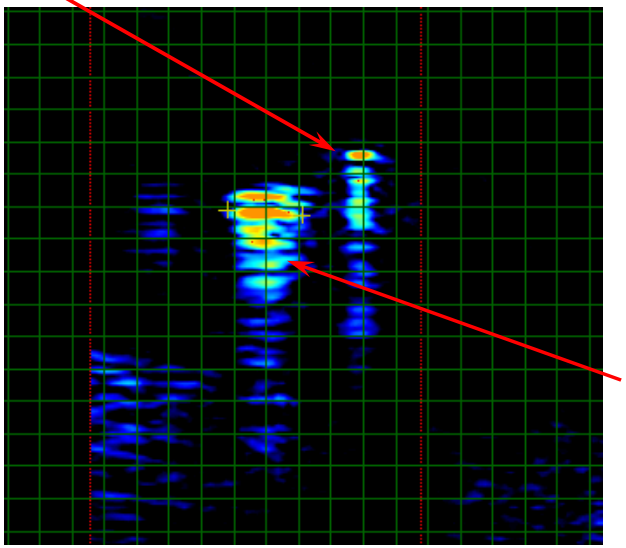
Linear Array Ultrasonics



Rivet with no crack



Rivet with crack

Composite Initiatives


A380 Section 19


A380 Center Wing Box


A340 HTP Skin


A380 Pressure Bulkhead

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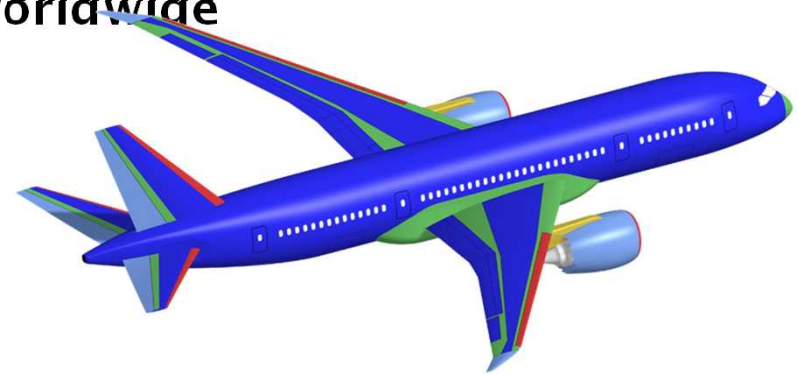
Composite Inspections & Reference Standards

- Industry-wide composite reference standards developed to support damage assessment & inspection
- SAE Aerospace Recommended Practices (ARP 5605 & 5606) - adopted into Boeing and Airbus NDT Manuals
- Improve inspections of composite structures via introduction of advanced NDI methods
- Provides consistent approach to composite inspections - harmonized approach by OEMs worldwide

Optimized NDT Reference Standards



Composite Structures on Boeing 787 Aircraft

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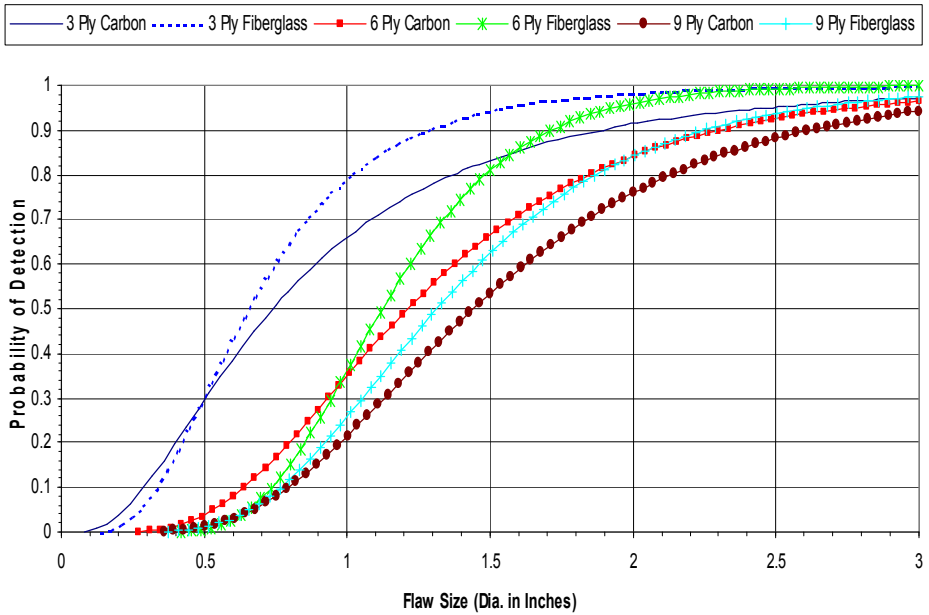
Assessing Composite Inspections

Composite Flaw Detection Experiment

Participation from over 25 airlines and maintenance depots

Industry-wide performance curves generated to quantify:

- **how well current inspection techniques are able to reliably find flaws in composite honeycomb structure**
- **the degree of improvements possible through the integration of more advanced NDI techniques and procedures.**



NDI technology insertion to support Aging Aircraft FAR & SSID program and provide proactive approach for next-generation aircraft

Experiment to Assess Flaw Detection Performance

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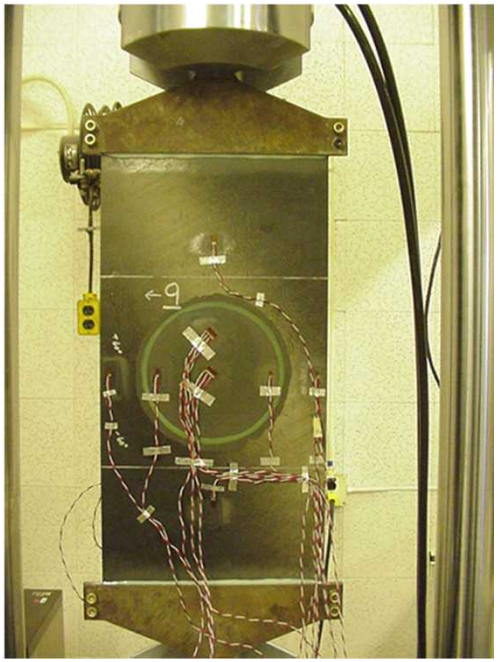
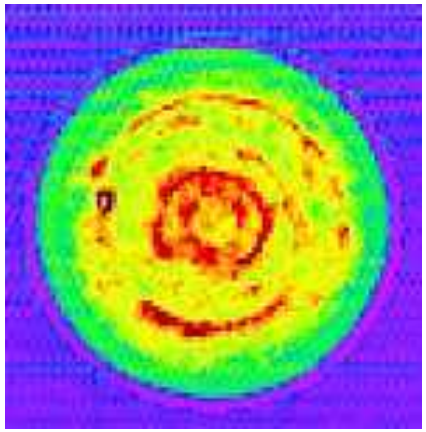
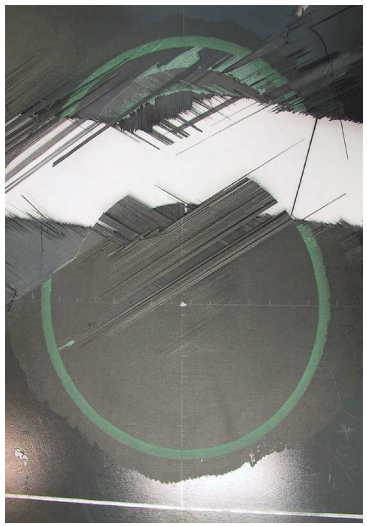
Composite NDI & Laminate Repair Systems – Compare Mechanical & NDI Performance

Joint program with North Carolina A&T

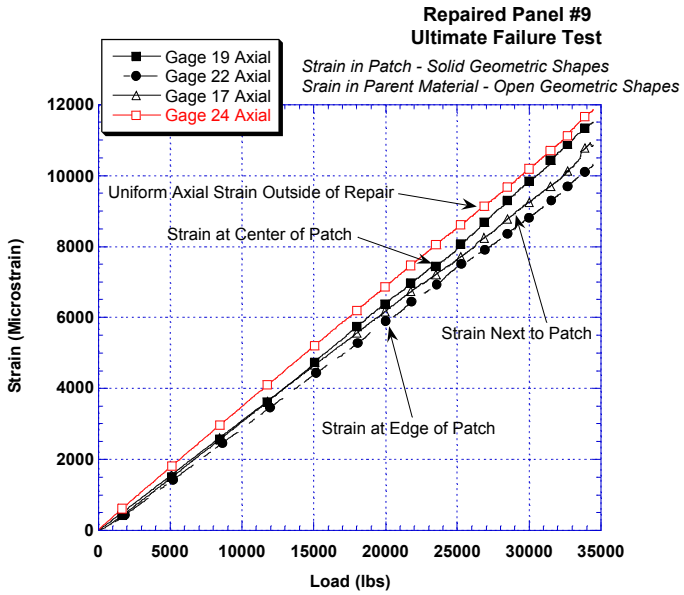






Strain field & repair efficiency assessment vs. NDI findings

Comprehensive evaluation of composite repair and associated NDI technology to ensure proper mesh between structural integrity & flaw detection



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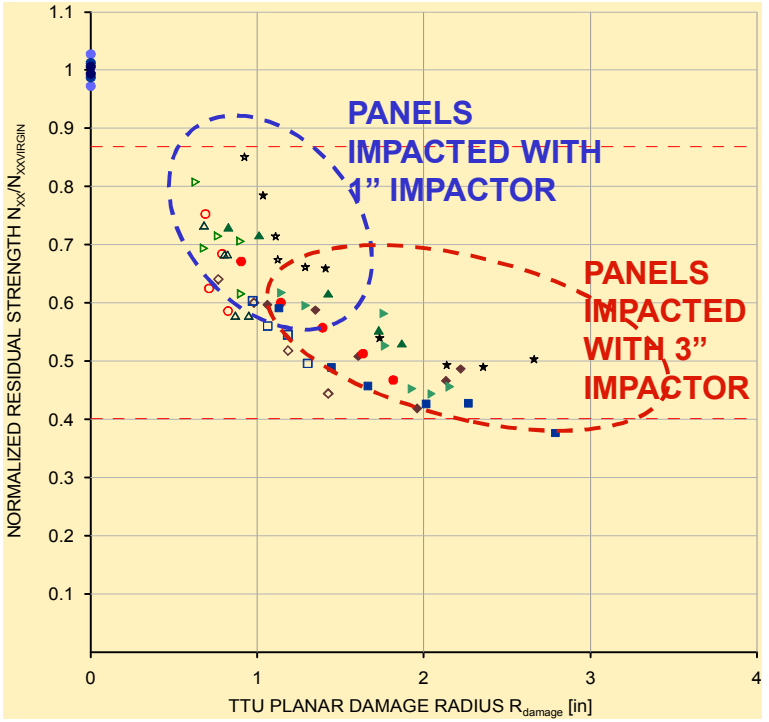
Impact, Repair & Damage Tolerance of Airframe Composites

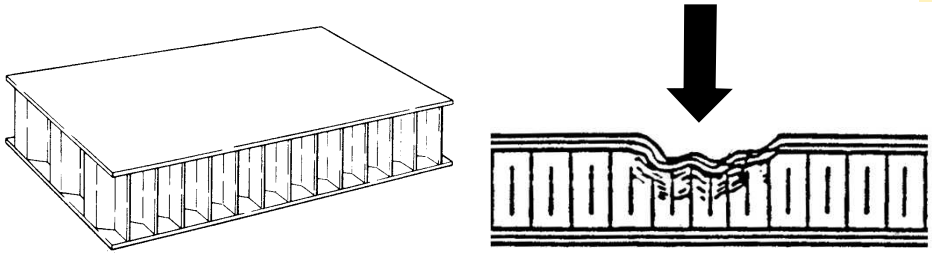
Joint program with Wichita State NIAR & Boeing

Goals and Objectives:

- To understand critical impact threats, residual strength and reliable inspection methods for aircraft sandwich designs
- Damage tolerance guidelines for AC revisions and/or ongoing certification programs
- Correlation of field damage detection with residual strength
- Evaluation of repair strength and NDI



Relation Between NDI Flaw Detection/Sizing And Residual Strength



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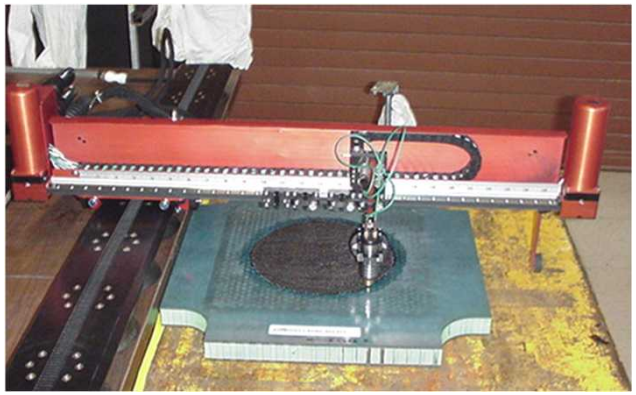
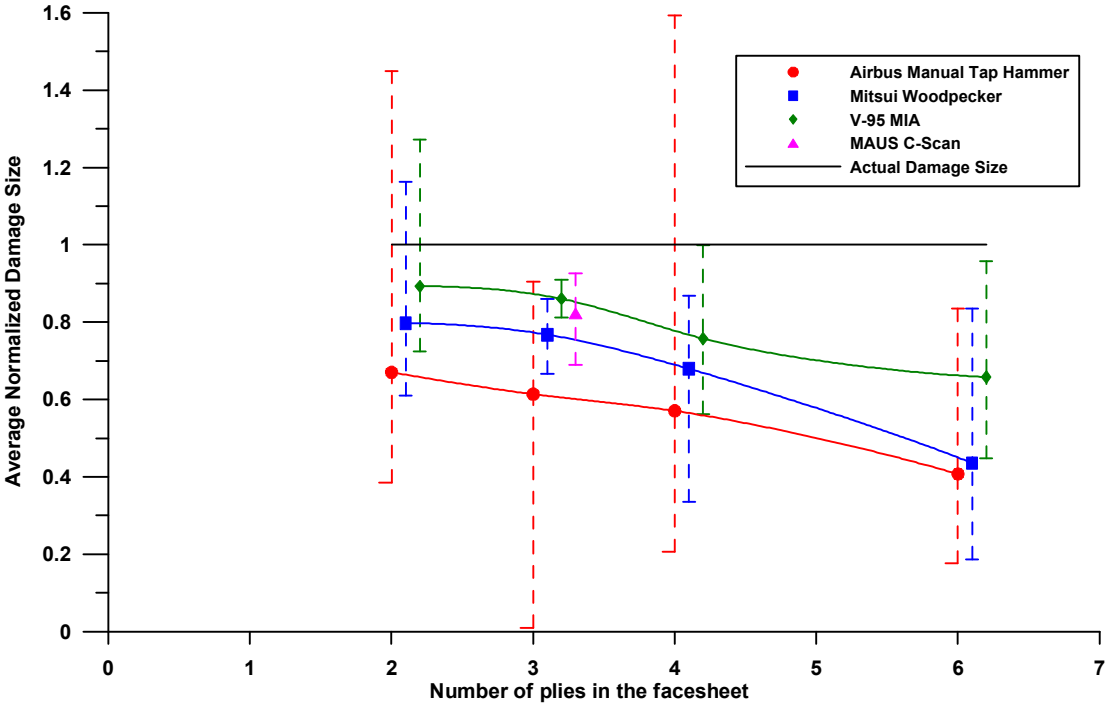
Impact, Repair & Damage Tolerance of Airframe Composites (cont.)



MAUS Inspections of Repaired Composite Sandwich Structures

Supports DT rulemaking (including 14 CFR 29.571), composite repair design and inspection (SSIDs)



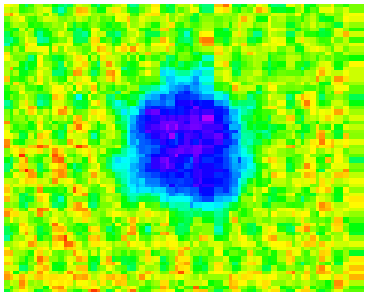


Image of Impact Damage

EVALUATION OF FIELD INSPECTION TECHNIQUES FOR IMPACT DAMAGE DETECTION

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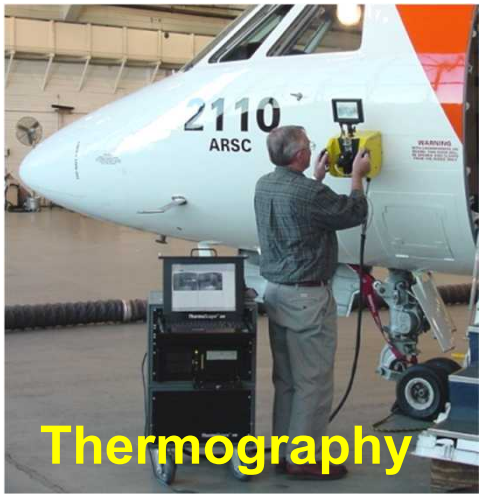
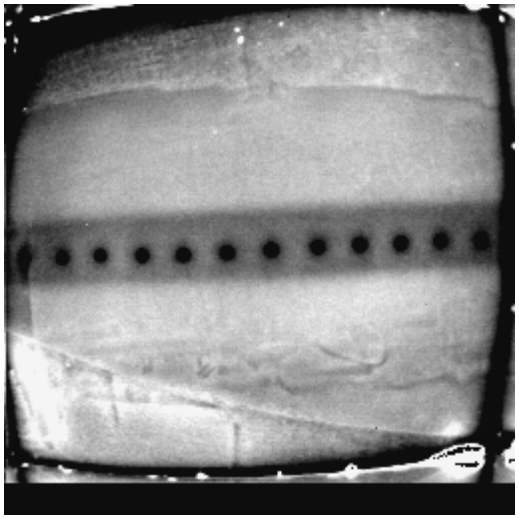
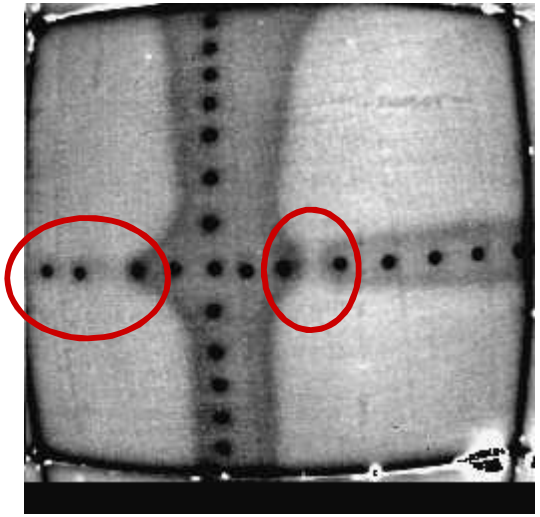
Fuselage Inspection Using Pulsed Thermography

- Improved corrosion & disbond detection
- Developed in partnership with (CASR) Wayne State Univ., Boeing and Northwest Airlines
- Boeing-approved method (NDI Manual revision) for fuselage disbond detection; addresses AD for over 2000 aircraft





Bonded Doubler

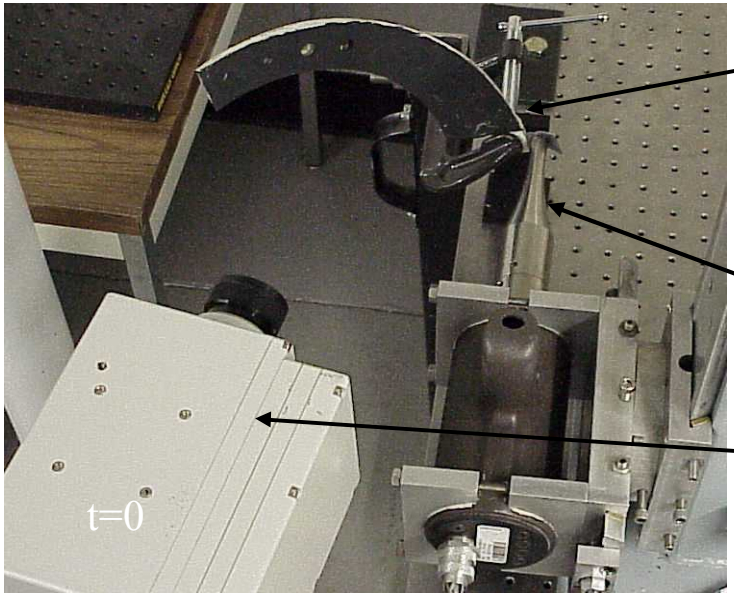


Disbonded/Bonded Doubler

Sonic Thermography for Crack Detection

Has found niche in engine parts where cracks are invisible to traditional dye penetrant methods

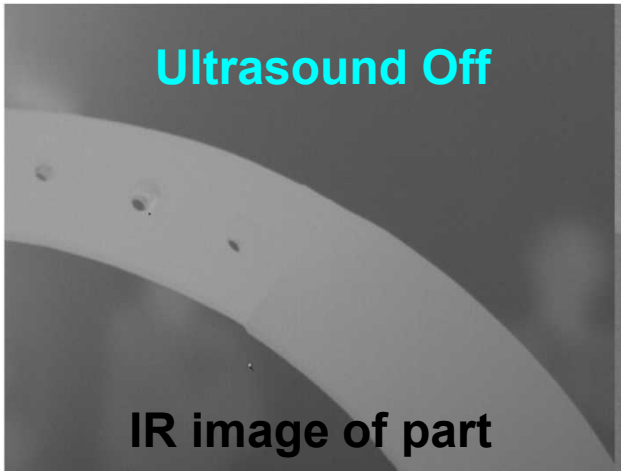
(supports AC 33.14-1)



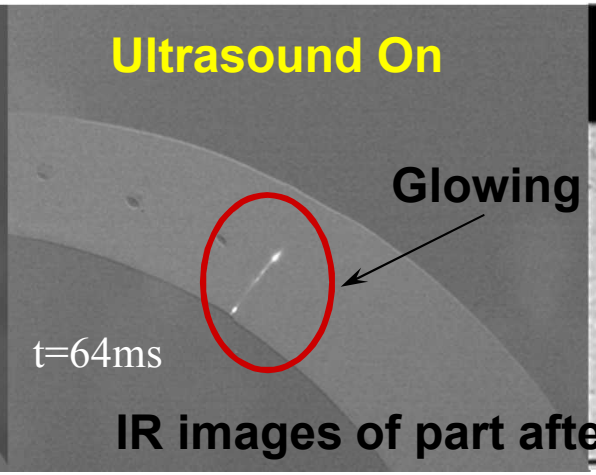
Part being inspected

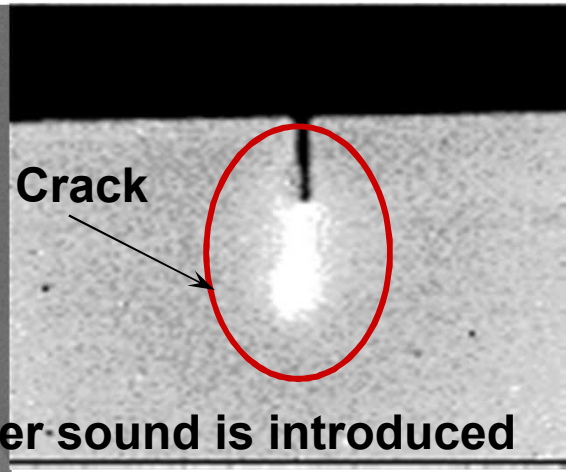
20 kHz
Ultrasonic Source

Infrared Camera



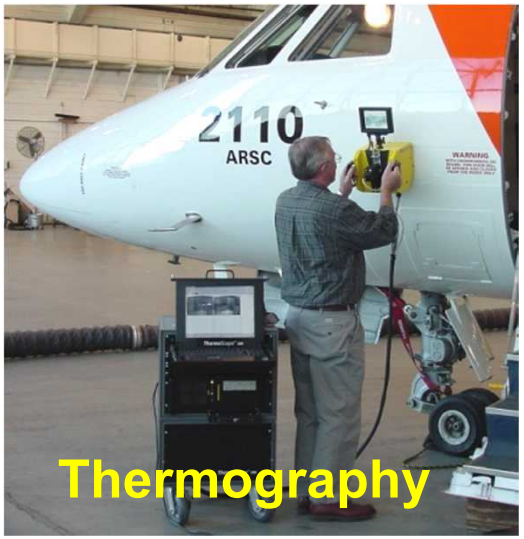
IR image of part

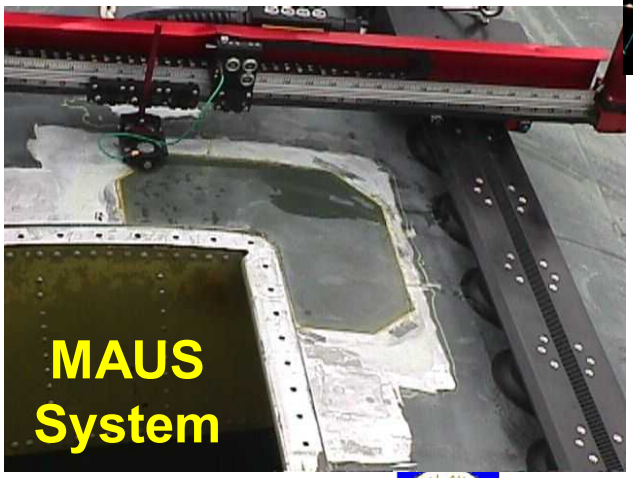




IR images of part after sound is introduced

Wide Area and C-Scan Inspection Methods





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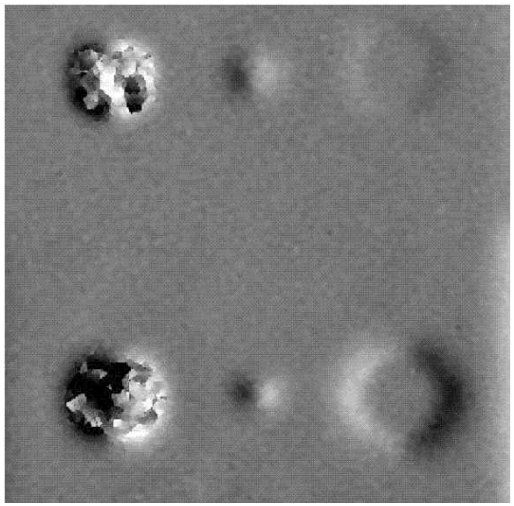
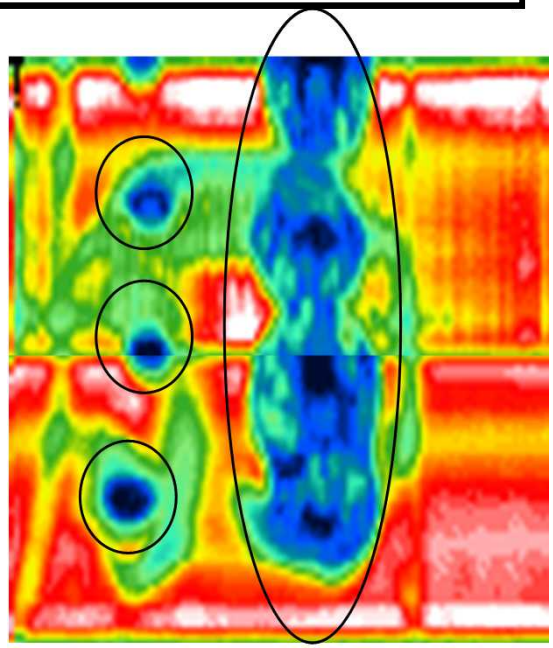
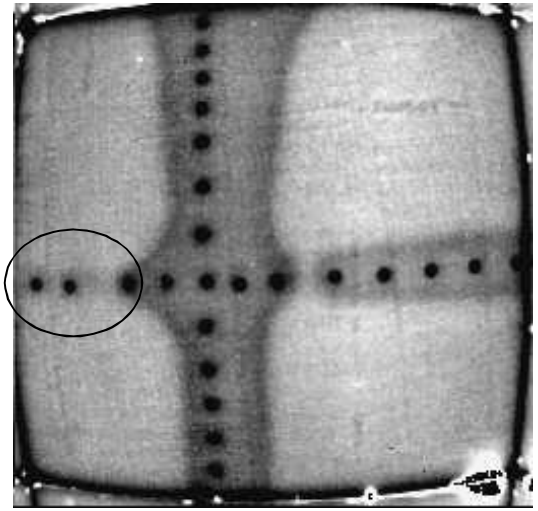
Sample C-Scan Images Showing Presence of Flaws

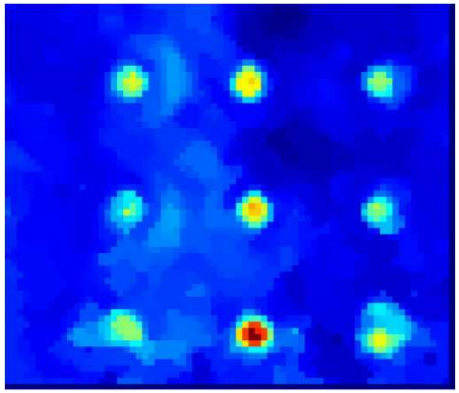
Shearography (LTI) Image



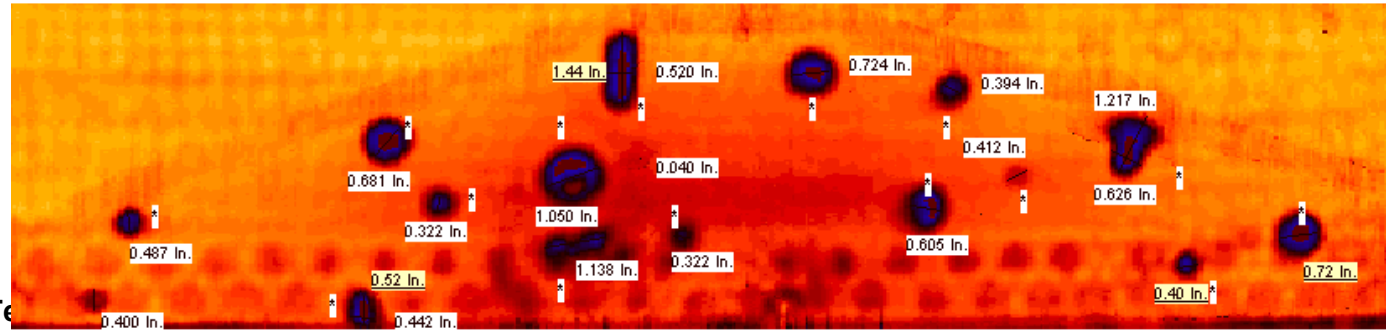


Thermography (TWI) Image





SAM Image



MAUS Image

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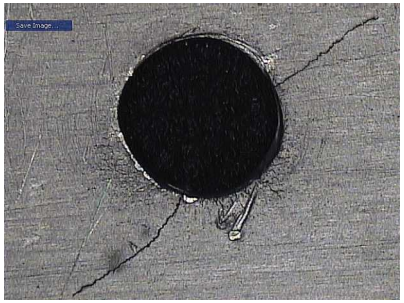
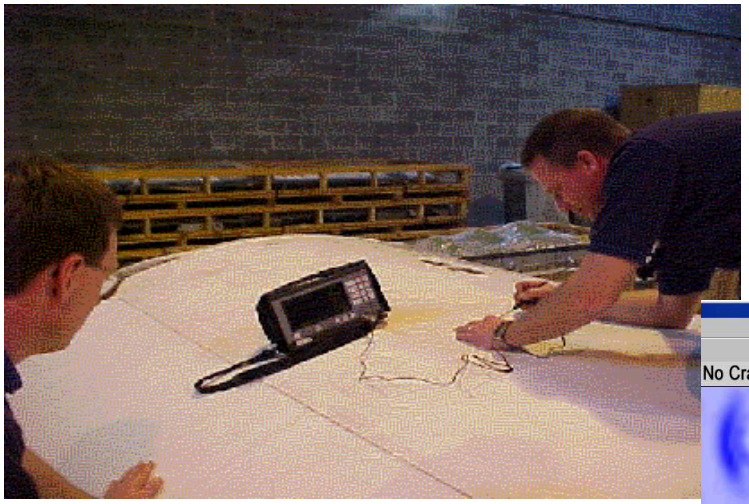
AANC – Addressing Tomorrow's Concerns

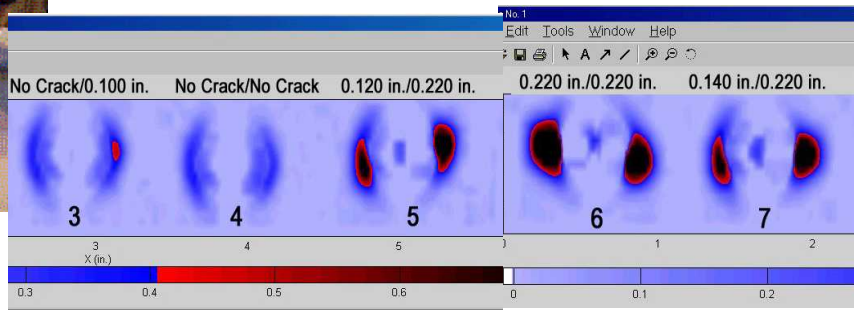
Proactive approach to improve transportation safety and support aviation industry while growing private companies in a wide range of industries

Widespread Fatigue Damage



- **Understand WFD phenomena through lab and field studies**
- **Advanced NDI has produced order of magnitude improvements to create risk management options**





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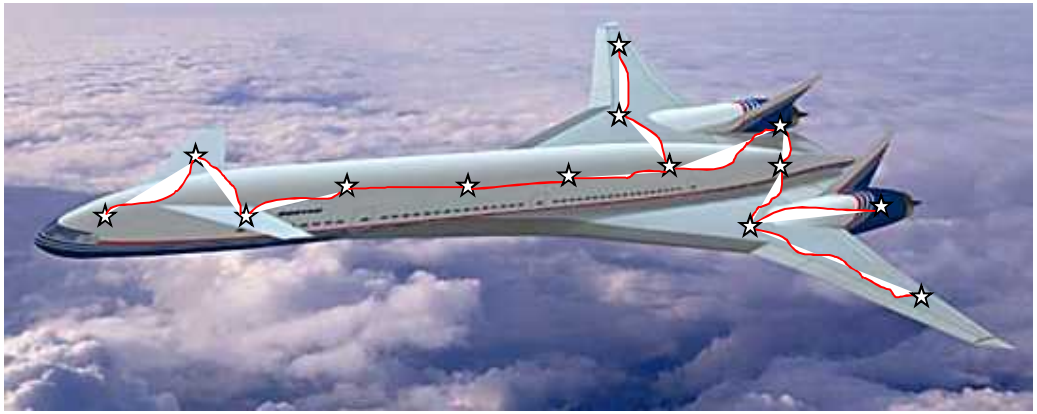
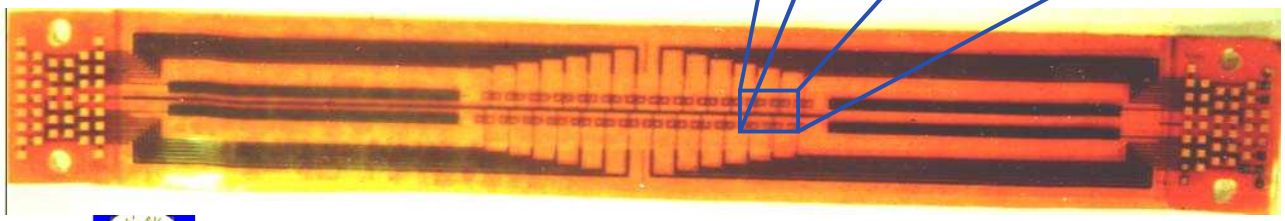
Distributed Sensor Networks for Structural Health Monitoring

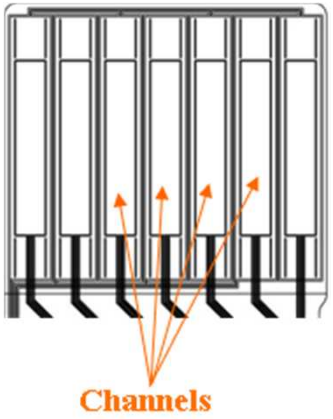
- In-situ sensors for rapid, remote (real-time) monitoring
- Allows for condition-based maintenance
- Evolution of rotorcraft HUMS – supports Damage Tolerance (DT) Data for Repairs & Alterations (FAA-2005-21693) & Aging Aircraft FARs; SSIDs

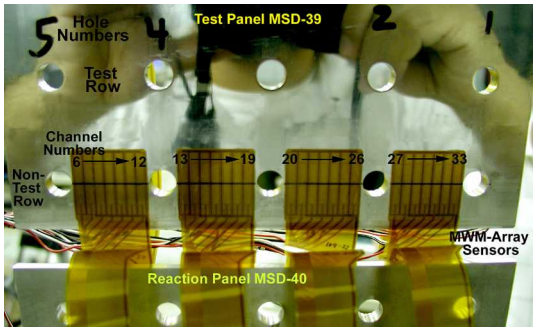


Flexible Eddy Current Array

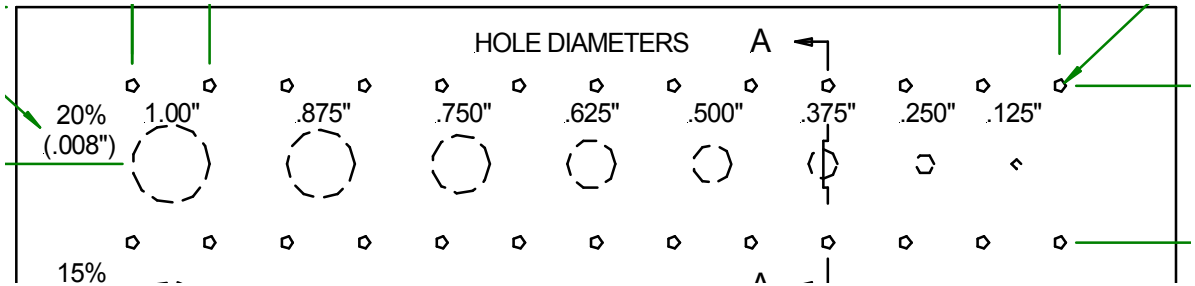


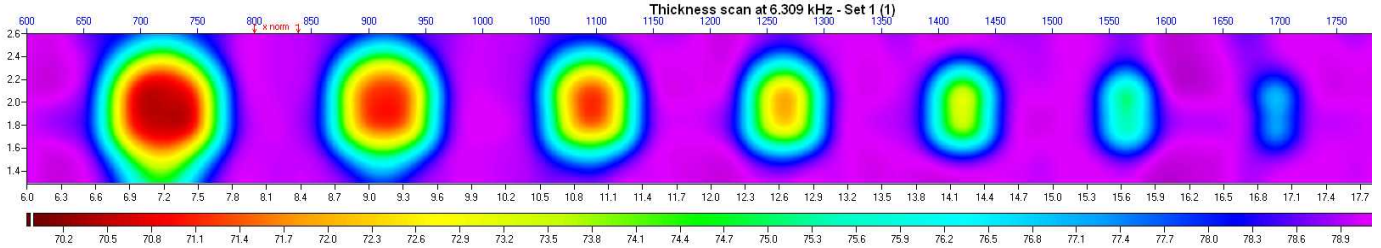
Corrosion Imaging with MWM Mountable Sensors





Multi-Channel MWM Arrays





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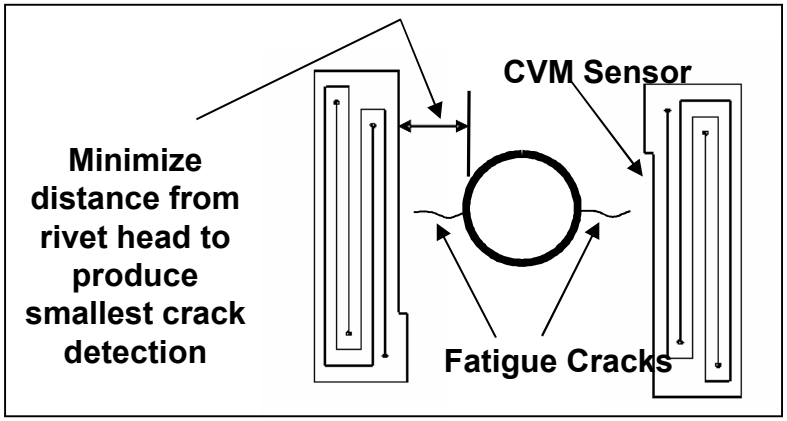
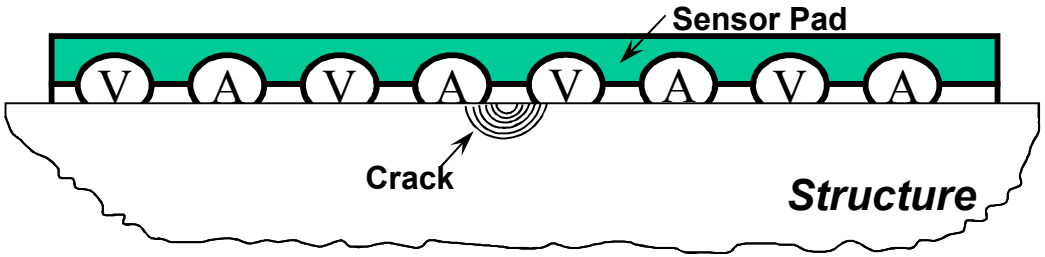
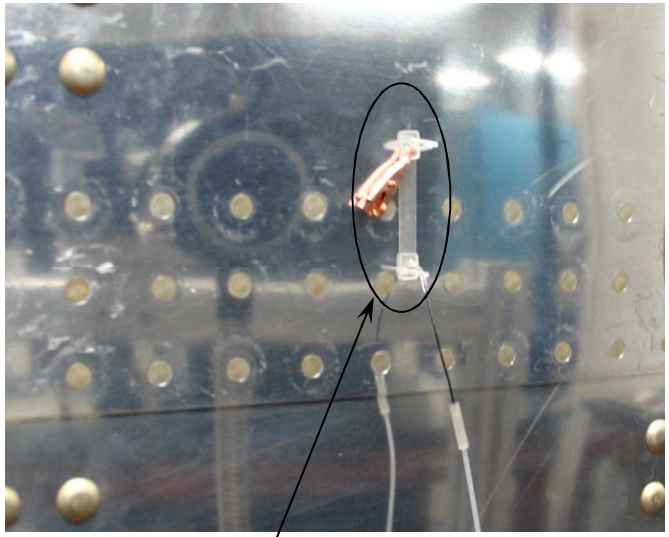
Comparative Vacuum Monitoring System

- Sensors with fine channels on the adhesive face - applies a vacuum to a thin film sensor with embedded galleries open to the surface
- Leakage path between the atmospheric and vacuum galleries producing a measurable change in the vacuum level
- Doesn't require electrical excitation or couplant/contact
- 90% Probability of Flaw Detection level = 0.025" L cracks

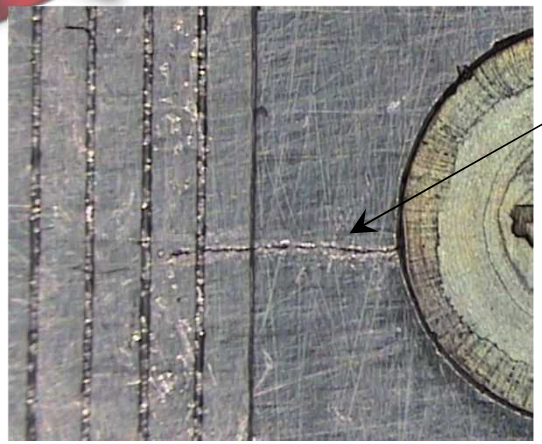




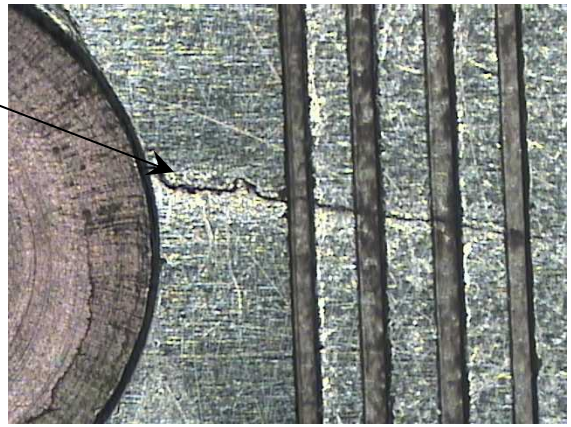


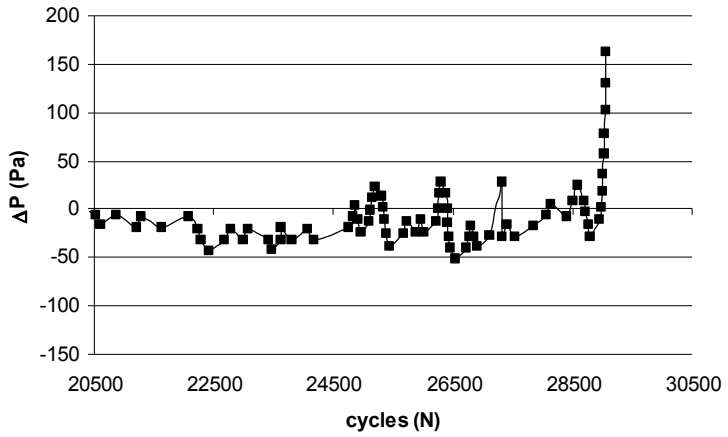
CVM Sensor Adjacent to Crack Initiation Site

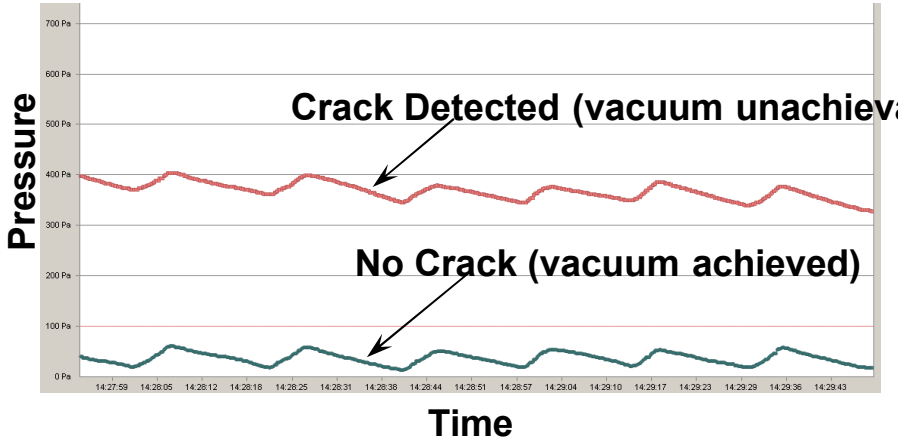
Comparative Vacuum Monitoring System



Fatigue crack engaging CVM sensors







CVM introduced into Boeing NDI Standard Practices Manual – first embedded sensor approved for in-situ structural health monitoring (Aging Aircraft FAR; AMOC to ADs)

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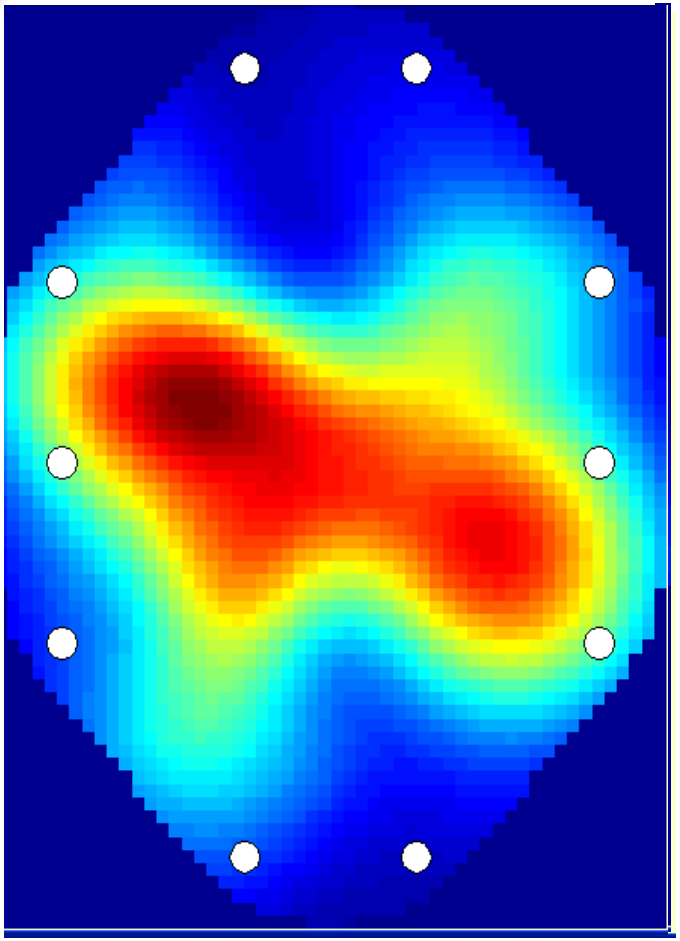
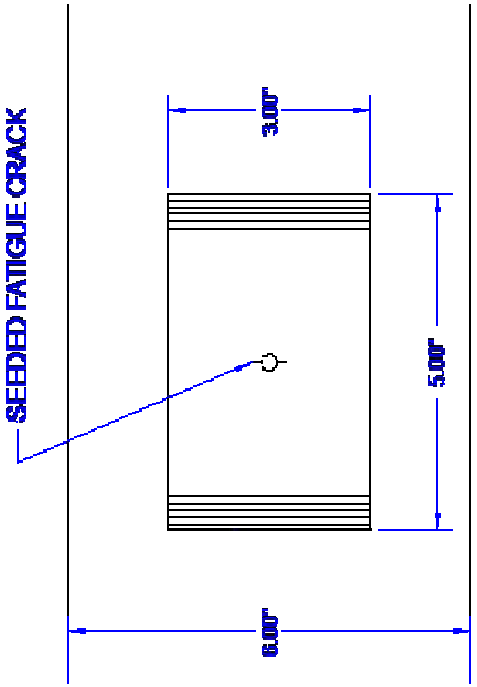
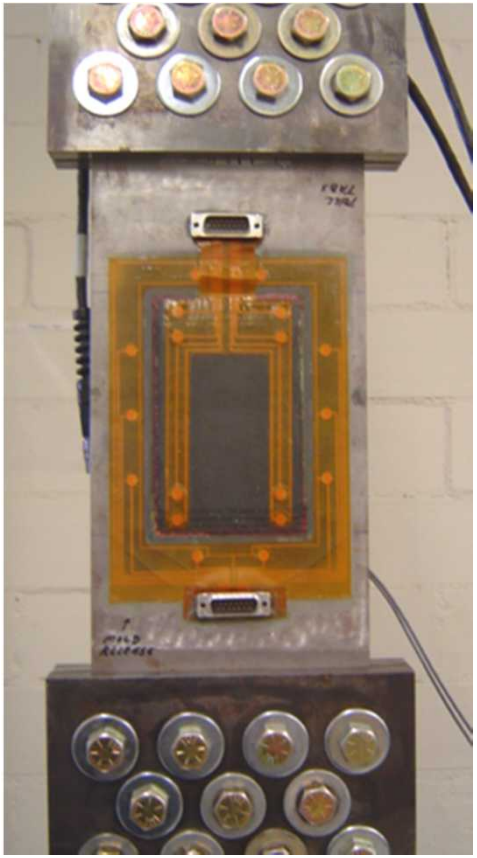
Crack Detection & Growth Monitoring with Piezoelectric Sensors



87K Cycles





PZT crack length estimates within 5% of measured

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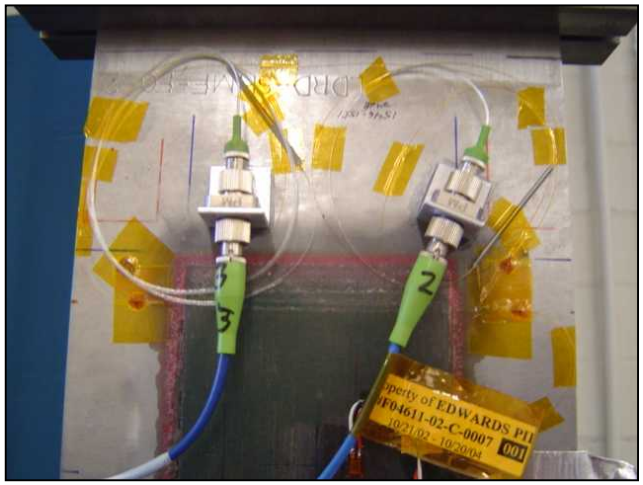
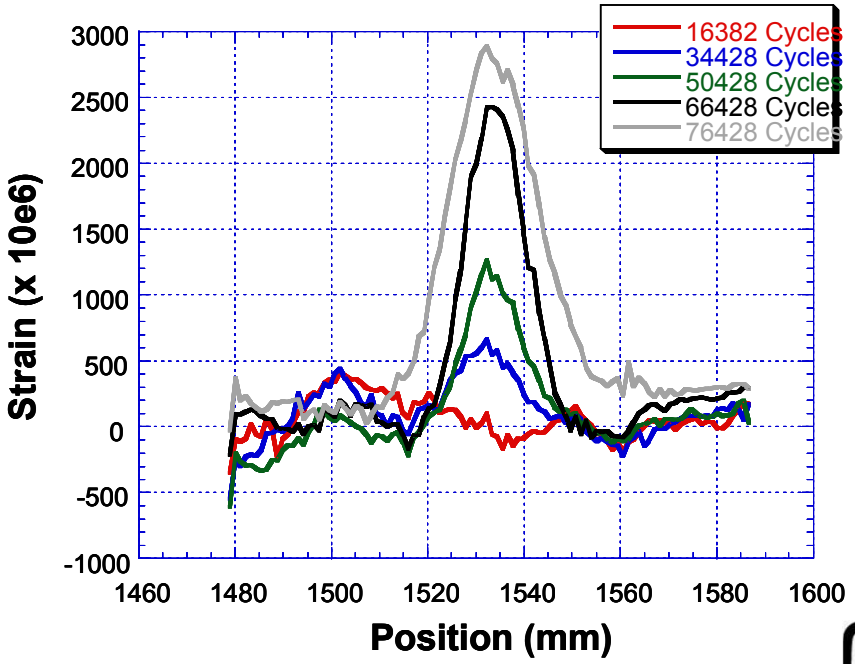
Health Monitoring with Fiber Optic Sensors

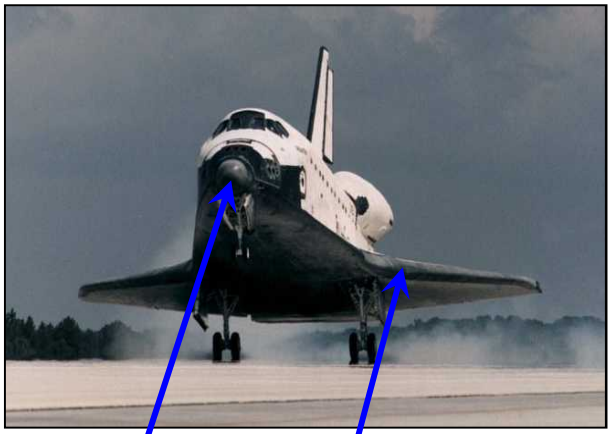


Axial Strain Distribution Along Sensor D as a Crack Tip Approaches



Pulse-Echo Ultrasonic Method for Health Monitoring of Space Shuttle Thermal Protection System

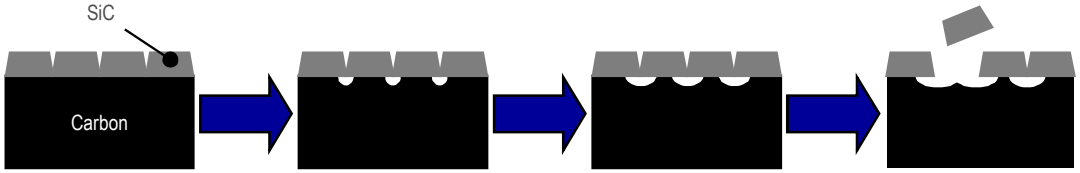
- **Example of FAA AANC expertise applied to solve NASA problem**

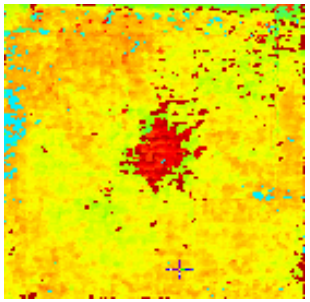


Wing Leading Edge & Nose Cap RCC Panels

Photo of Impact - RCC Front Surface

SiC Coating Loss Mechanism via Convective Mass Loss





UT Image of Flaw

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AANC Work in Other Industries

Tailor successful aviation technology to meet the needs of other industries

Exxon/Syncrude

Composite repair & structural health monitoring

US Auto (Ford, GM, Chrysler)

Production of stiffer and stronger automobile bodies using advanced bonding methods

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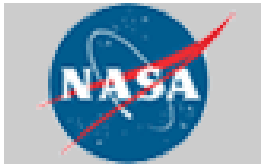
AANC Meets the Needs of FAA While Aiding and Leveraging Programs with DoD, NASA & Private Industry



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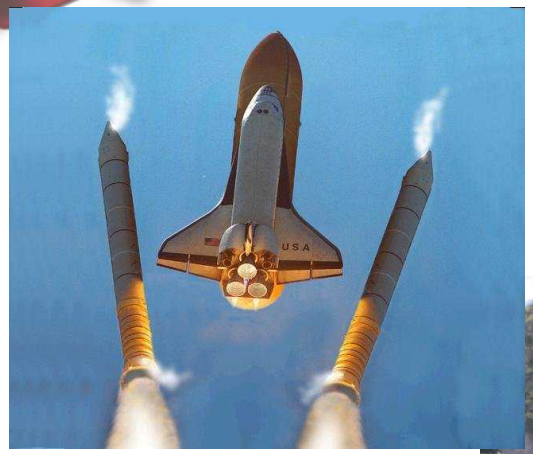

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Wide Range of Uses for AANC Technology

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