

# NDT of Composites at NIAR (ATLAS)

Steven Lee, and Waruna Seneviratne

2023 Airlines for America NDT Forum  
Denver, Co



WICHITA STATE UNIVERSITY





**NIAR**



# NDT of Composites at NIAR (ATLAS)

## Inspection Team

### NIAR

Waruna Seneviratne, PhD

Steven Lee

Jasvinder Malli

Kalle Smith



WICHITA STATE UNIVERSITY

# Manufacturing Engineering Education



Develop a multi-disciplinary manufacturing environment and an engineering education program to prepare engineers and educators for the *Factory of the Future* and to aid current workforce in seamlessly adapting to advancements in the workplace.



- Future

- Create a pipeline of “industry-ready” future engineers for advanced manufacturing processes
- Machine learning and artificial intelligence
- Advanced materials and processes

- Present

- Work with industry solving current manufacturing problems
- Exposure to industry challenges

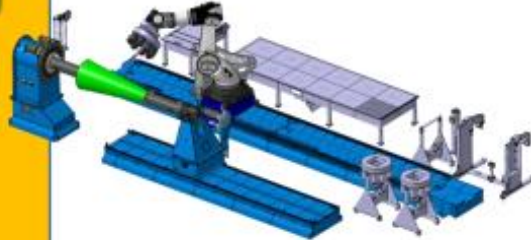
- Past

- Develop workforce training programs for advanced manufacturing technologies
- Create new job opportunities for current workforce



## Automated Manufacturing

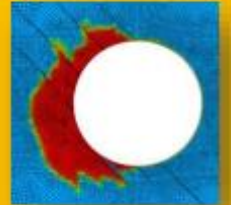
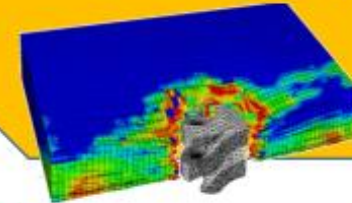
- Automated Fiber Placement
  - Thermoset, Thermoplastic, Dry Fiber, and CMC
- Press Forming
  - Compression-, Injection-, and Over-Molding
- Thermoplastic Welding
  - Resistance, Induction, and Ultrasonic



**ATLAS**  
 ADVANCED TECHNOLOGIES LAB FOR  
 AEROSPACE SYSTEMS

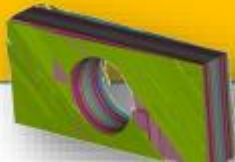
## Computer-Aided Simulations & Analysis

- Manufacturing Simulations
- Process Modeling
- Discrete Damage Modeling
- Stress Analysis



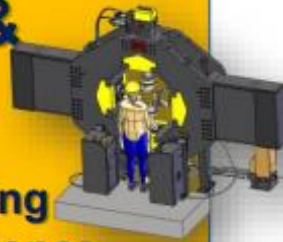
## High-Fidelity Inspections

- X-Ray CT (XCT)
- MAUS (UT)
- Acoustic Emission (AE)
- Pulse Thermography (PT)
- Laser Shearography (LS)
- Digital Image Correlation (DIC)

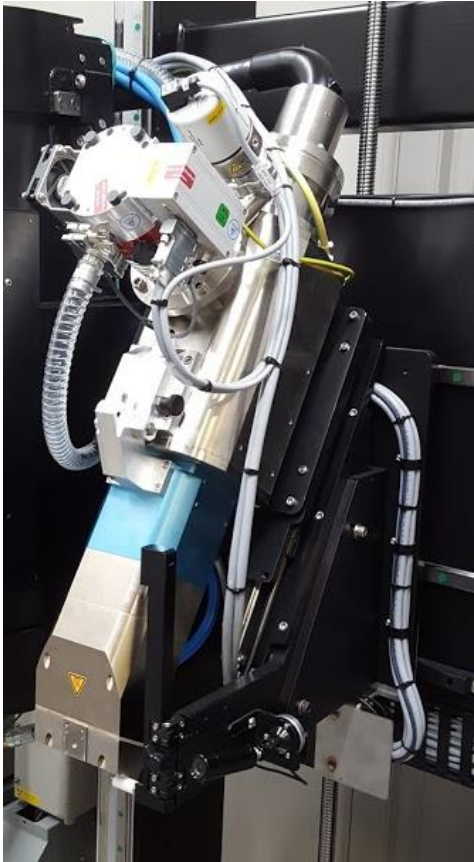


## Structural Test & Evaluations

- Axial-Torsion Biaxial Testing
- Durability & Damage Tolerance
- Structural Health Monitoring
- Aging Evaluations and Life Extension
- Repair Evaluations



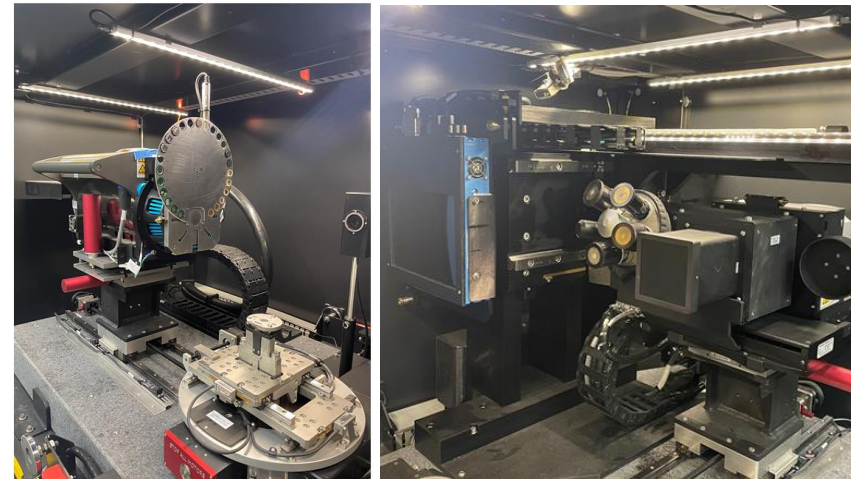
# NSI System Components



- NSI X7000 with ability to accommodate a 60" x 60" part in radiation shielded enclosure.
- X ray tube
  - 225kV Microfocus (6  $\mu$ m) for low attenuating / low density materials e.g. Carbon Fiber Composites.
  - 450 kV Minifocus for high attenuating / high density materials e.g. Metals
- Detector
  - Varian Lo8 flat-panel detector 16" x 16"
  - Linear Diode Array (LDA) allows high precision data acquisition
- Overall 3 different source + detector combinations:
  - 225kV + flat panel
  - 450 kV + (flat panel or LDA)

# Zeiss System Components

- Zeiss X-Radia 520 Versa
- Micro-CT
  - Lowest: 70 Nanometer (0.07 microns)
  - Highest: 100 Micron resolution
- X ray tube
  - 30 to 160 Kv
  - 10W maximum
- Detector
  - Objectives 0.4X, 4X, 20X, 40X
  - Flat Panel



# CAMUS 3D System Ultrasonic

- Innerspec Camus 3D
- Phased Array Ultrasonics
  - 64 Element Array with umbrella
  - 16 Thermal Cameras on truss
  - Two-50" tv's
  - 24 skids for water recirculation
  - Vicon Tracker Software



# MAUS Inspection System

- **MAUS V**

- **Single Element Pulse Echo**
- **64 Element Phased Array**
- **Resonance Scanning**
- **Pitch Catch**
- **Mechanical Impedance**
- **Capability for Eddy Current**





# Infrared Thermography

- **Thermal Wave Imaging Pulsed Thermography**

- Camera FLIR X8500SC
- 25mm lens 1280x1024 FOV: 10.5x8.4”
- 17mm lens 1200x870 FOV: 13.2x9.6”
- High Frequency Frame Rate of 180Hz
- 14 Bit Digital Image
- Windowing down FPA can induce higher frame rates
- 12um pixel pitch

- **FLIR T400**

- 320x240
- -4F-662F
- 8x continuous zoom

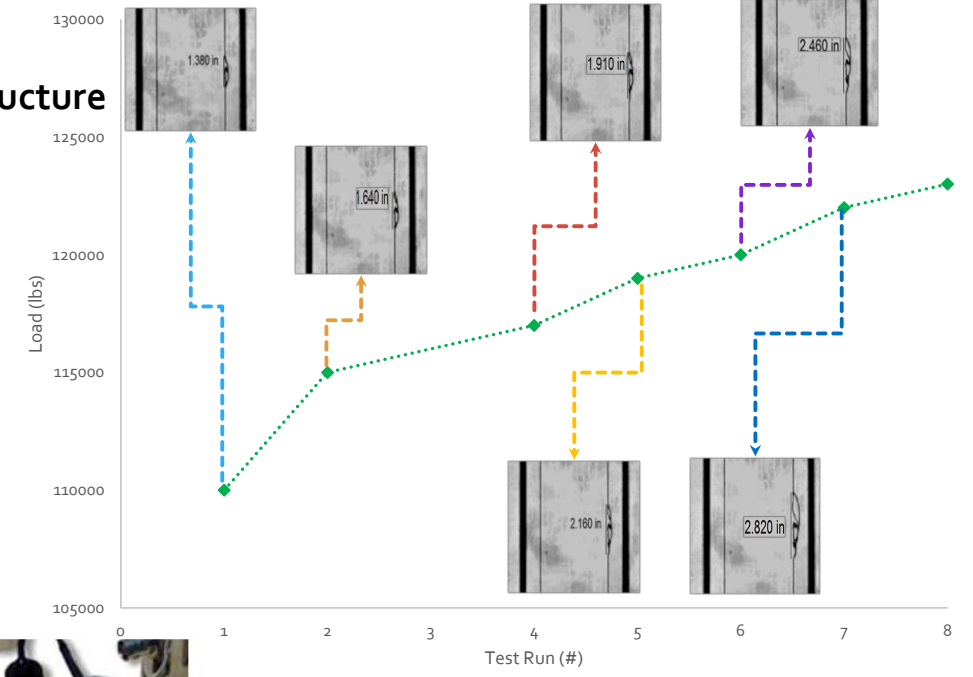
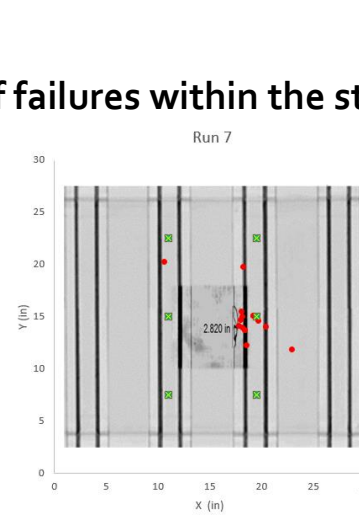


FLIR T400



# Acoustic Emission Testing

- Acoustic Emission Principle
  - AE system detects transient elastic waves generated by the rapid energy release from the microstructural changes
- Implementations
  - Real time, in-situ inspection for instant detection of failures within the structure
  - Failure location triangulation
  - Structural Health Monitoring (SHM)
- AE System Apparatus
  - Sensors: PICO, NANO, R15I, R6I
  - Preamplifiers: 2/4/6
  - Computer: Express-96 Chassis
  - Data acquisition & Post Processing : AEwin software & NOESIS software

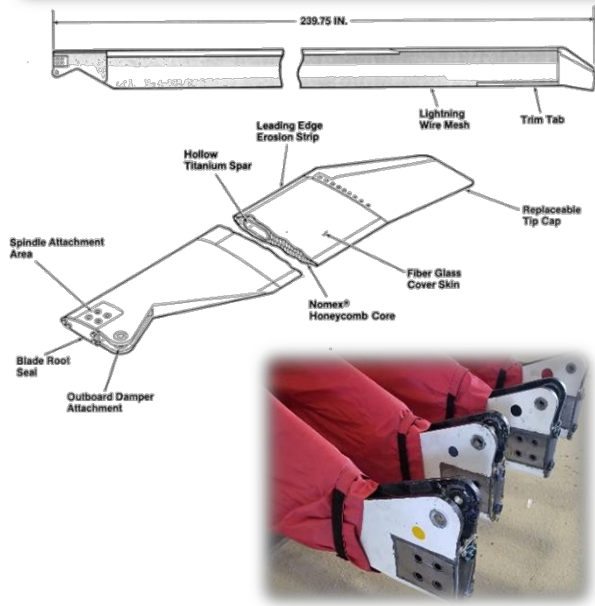


# Programs

- Our NDI team supports a magnitude of research programs for private industries, federal and state. As of lately some our primary focus has been in the support of multiple Federal Aviation Administration (FAA) programs of aged in-service structures.
  - **FAA-RBT Evaluation of Aged Structural Bonds on Rotor Blades.**
  - **FAA-777 Inspection and Teardown of Aged In-Service Composite Structures**
  - **FAA-ISR Inspection and Teardown of Aged In-Service Bonded Repairs**

# FAA-RBT Technical approach

## Phase I: Main Rotor Blade Acquisition

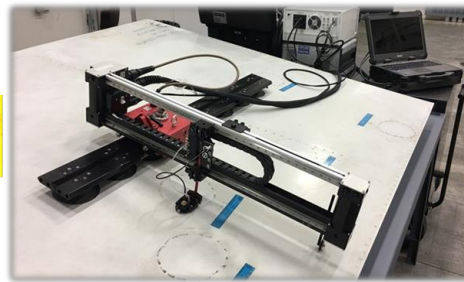
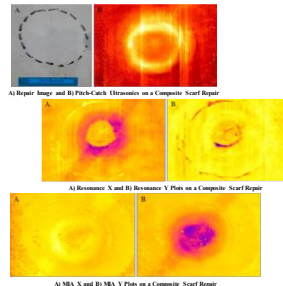
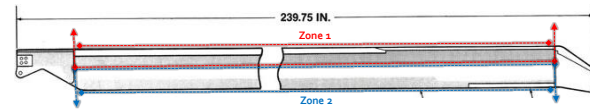


## Phase II: NIAR Inspections

### Receiving Inspection: Defect and Damage Evaluation

- Visual
- Resonance
- Mechanical Impedance
- Phased Array
- Laser Shearography
- Pulsed Thermography

### NDI Report: Damage Maps, Repairs, etc.

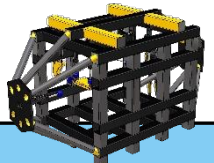


## Phase III: Teardown / Detailed Inspections / Testing

- Inboard: Cuff / Pocket
- Leading Edge: Abrasion Strip
- Pocket Mid-span

### Teardown: ROI Determines Testing [2-Blades]

- Mechanical Testing
  - Specimen: SCB, FRP
  - Element: 4PT Flex, etc.
- Detailed NDI
  - XCT
  - Photomicrographs
- Physical Testing
  - Porosity
  - Tg
  - DOC



### Full Scale Testing [2-Blades] Focus on Initial NDI and Areas Found in Element Tests

- Component Testing: Inboard Section
- Teardown: Outboard Section

- Strain Survey
- Fatigue

## Final Report: Document Findings

# Rotor Blade Aquisition

- **Blades Acquired**

- Sikorsky S-92
  - A044-00411
  - A044-00190

- **Inspections**

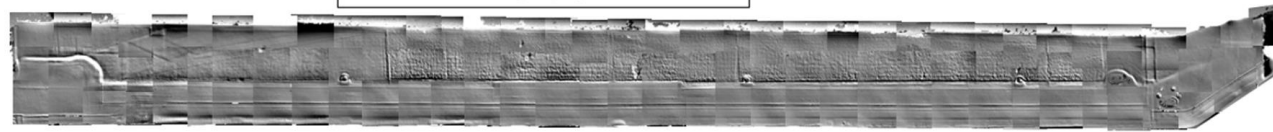
- Both Blades Complete



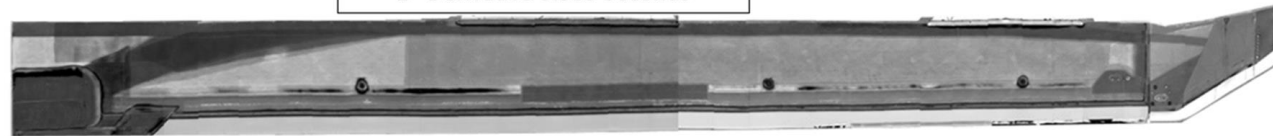
**Lower Surface**



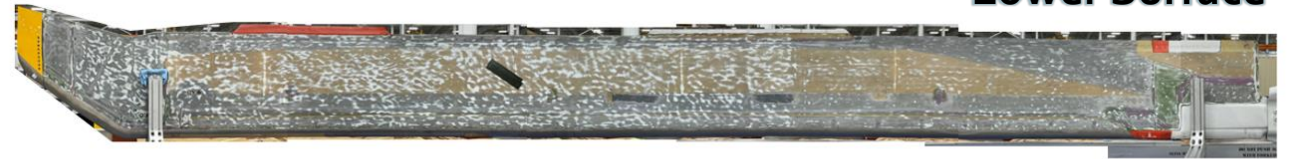
Shearography Data



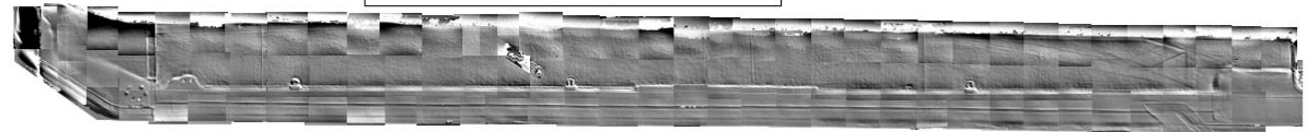
1<sup>st</sup> Derivative 0.533 Seconds



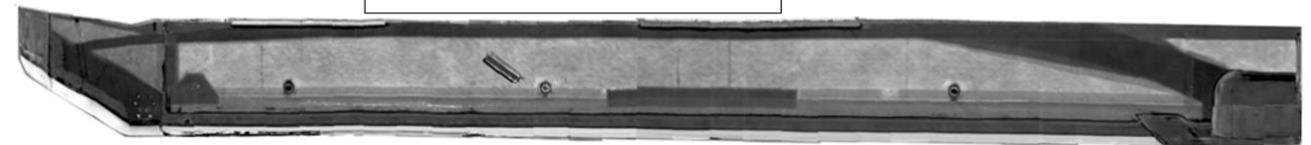
**Lower Surface**



Shearography Data



1<sup>st</sup> Derivative 0.533 Seconds



# Research Planning

## A. Sikorsky S-76A



### Blade Details

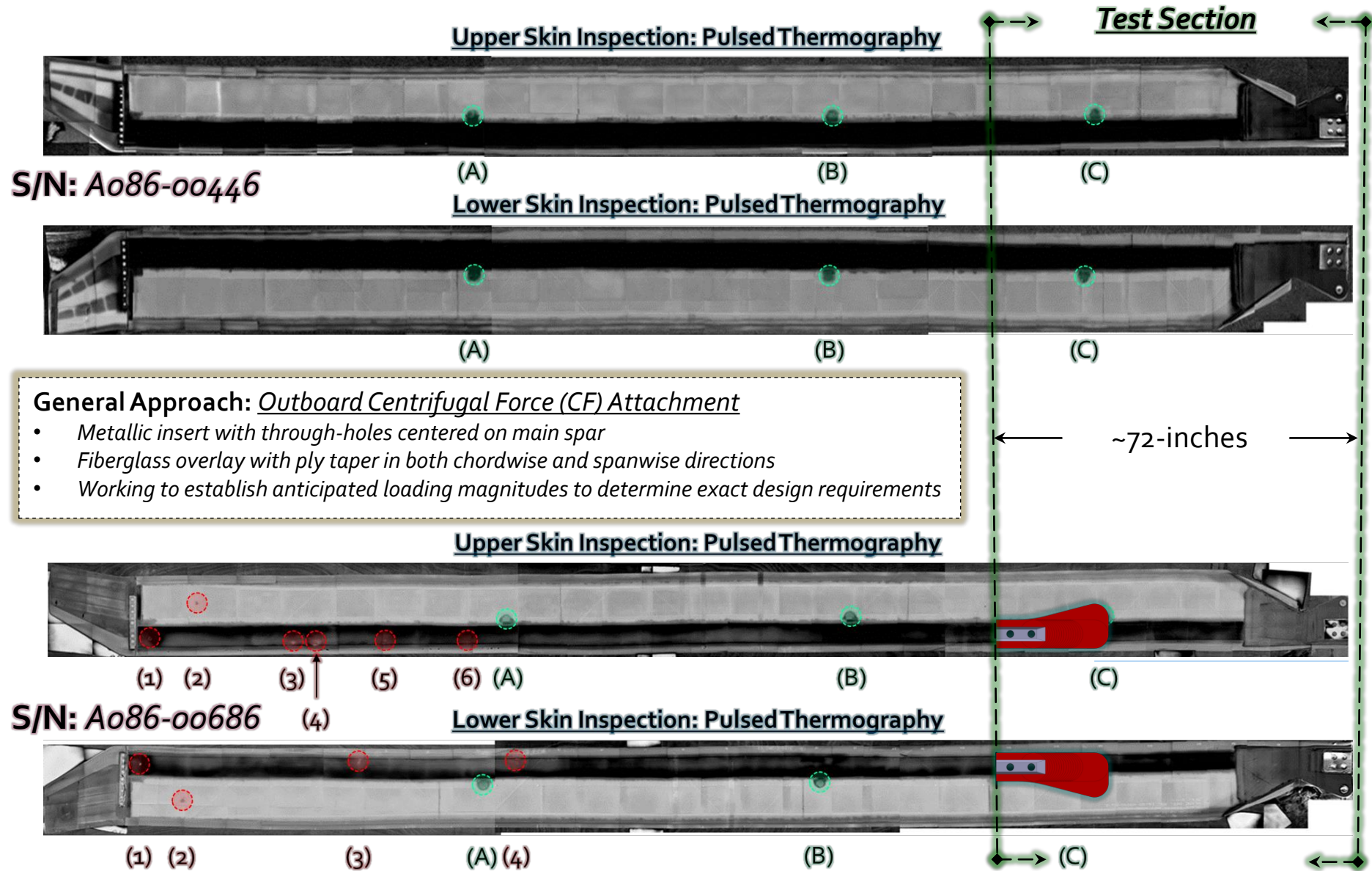
- **Quantity**
  - Two main rotor blades
- **Historical Information**
  - Hours: 3,274

### Status

- **Inspections**
  - Shearography: **Complete**
  - Thermography: **Complete**
  - Ultrasonics: **Complete**

### Path Forward

- **Teardown**
  - Root-end extraction
  - Preparation for F.S. testing
- **Testing**
  - Strain surveys
  - Fixture validation

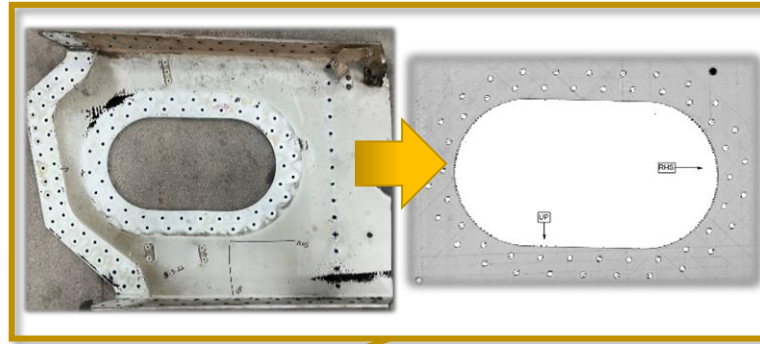


# FAA-777 Component Level NDI

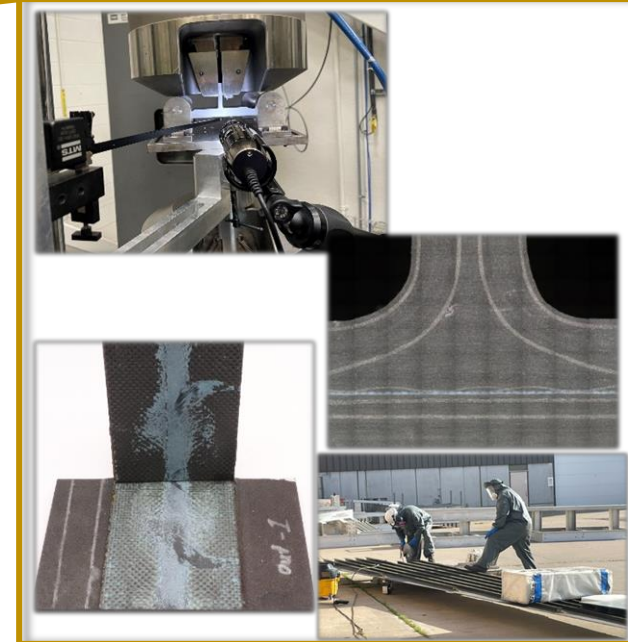
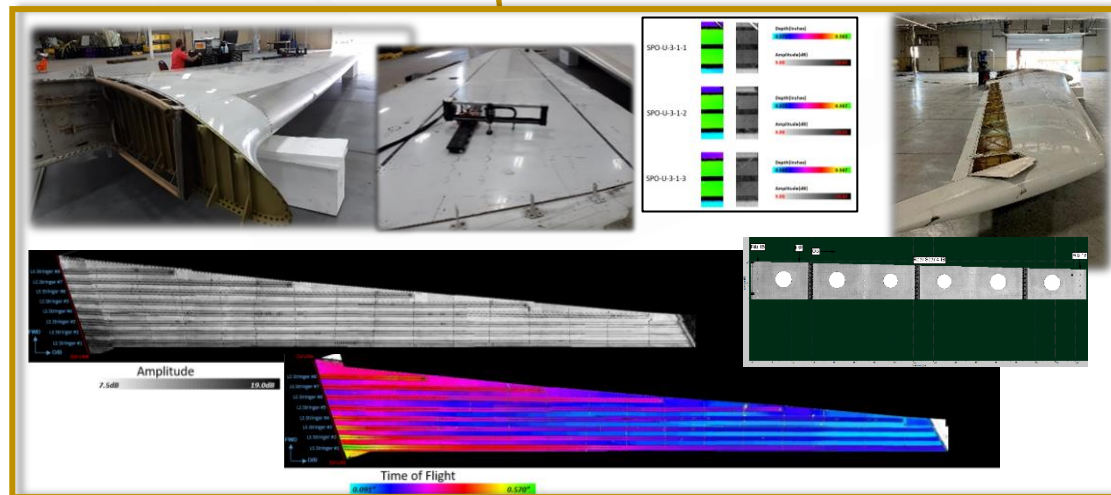
Disassembly



Receiving



Cut Location

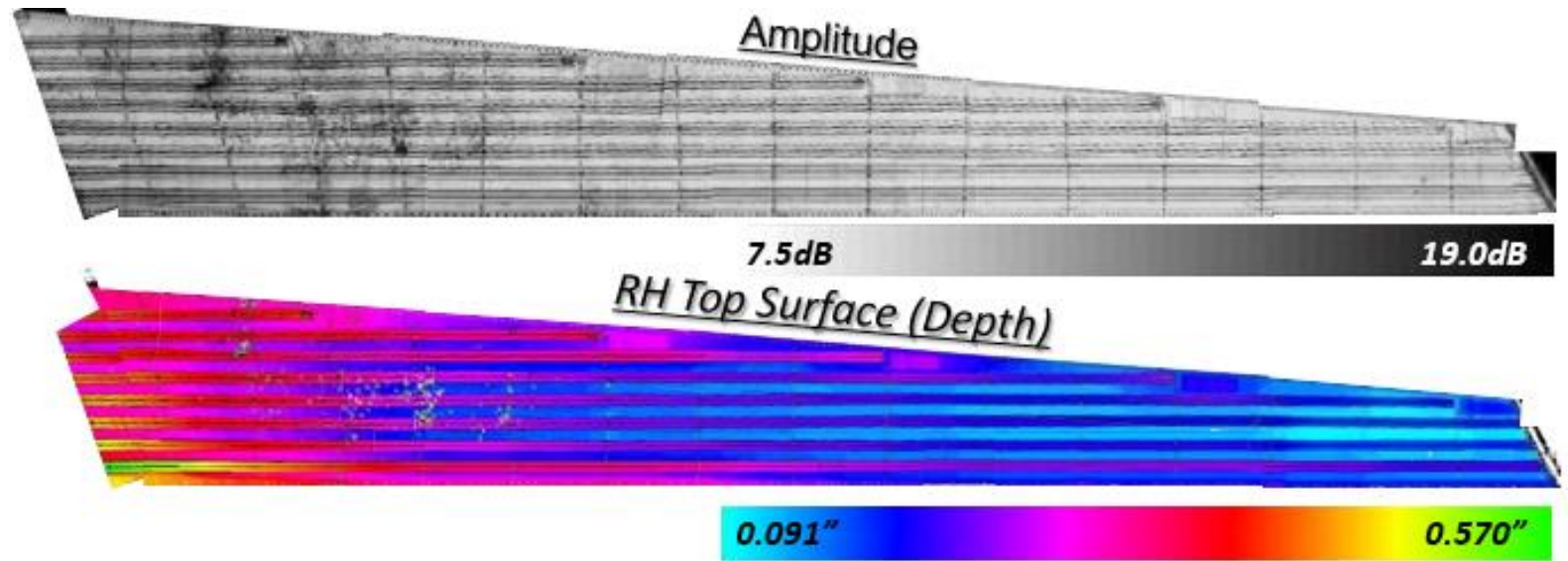


# Component Level NDI

**Goal:** Evaluate structural component using high-fidelity non-destructive inspection methodologies for initial screening and defect mapping.

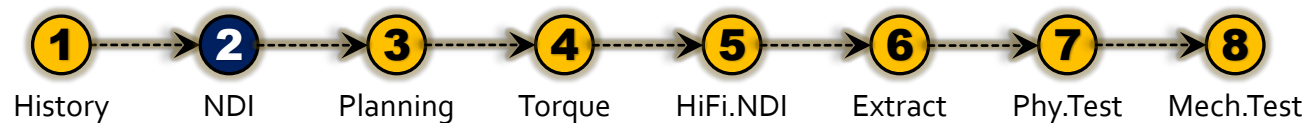
## • Approach

- Ultrasonic Pulse Echo
- MAUS



## • Observations

- Loss of data toward the inboard section of the scan due to surface roughness of the specimen.
- No major defect indications found on the global scan level.



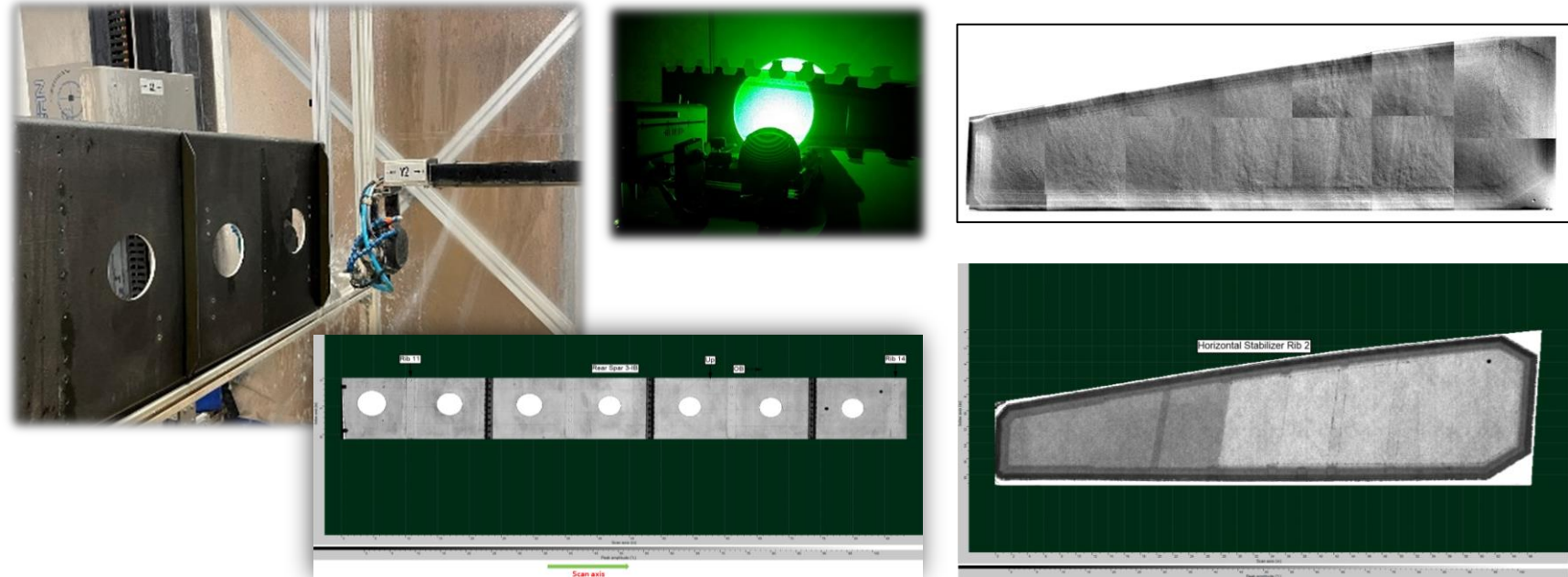


# Component Level NDI

**Goal:** Evaluate highly-loaded elements for defects and/or damages due to aging or in-service loading of the composite structure.

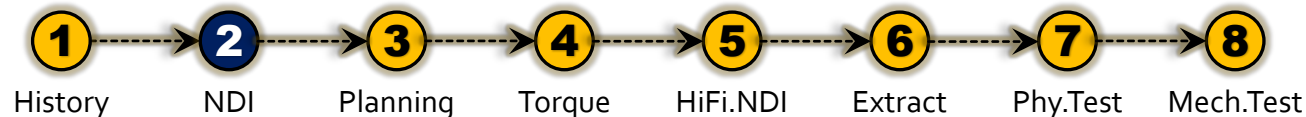
## • Approach

- Ultrasonics
- Infrared Thermography
- Laser Shearography
- Microscopy
- X-ray CT



## • Observations

- No major deviations to note from the component baselines due to defects found in the composite structure.



## Questions?

- **Waruna Seneviratne – ATLAS**
  - Contact: [Waruna.seneviratne@idp.wichita.edu](mailto:Waruna.seneviratne@idp.wichita.edu)
- **Steven Lee – ATLAS**
  - Contact: [steven.lee@idp.wichita.edu](mailto:steven.lee@idp.wichita.edu)

# FAA/AANC HISTORY and ASSETS

Presented to: A4A NDT Forum  
By: Paul Swindell  
Date: Sept 19, 2023



Federal Aviation  
Administration



# Airworthiness Assurance NDI Validation Center (AANC) A Unique FAA Facility



**Albuquerque International Airport  
Operated for the FAA by Sandia National Laboratories  
Dedicated in February 1993**

## Full Scale NDI Test-Beds at the FAA's AANC



**DOUGLAS DC-9**



**DASSAULT FALCONJET**



**BOEING 727**



**BOEING 737-200**



**BOEING 747-100**



**BELL UH-1**



**BELL TH-57**



**FAIRCHILD METRO 226**



**AIRBUS 310 RUDDER**

# FAA AANC Small Panels For NDI Validation Studies

Allows quantitative assessments of NDI Methods



**Small Crack/WFD Panels**



**Solid Laminates**



**Lap Joint Corrosion**



**Composite Honeycomb**

## Sample AANC Labs in the Sandia Tech Area



**Ultrasonic Test – Immersion Test Facility**

**AANC Test Specimen Library – engineered test specimens, complete aircraft test beds, sections cut from aircraft (> \$5M value)**



**Portable NDI Equipment  
(> \$1M value)**



# AANC Quick Response NDI Capability

## Example: American Airlines Flight 587 Investigation

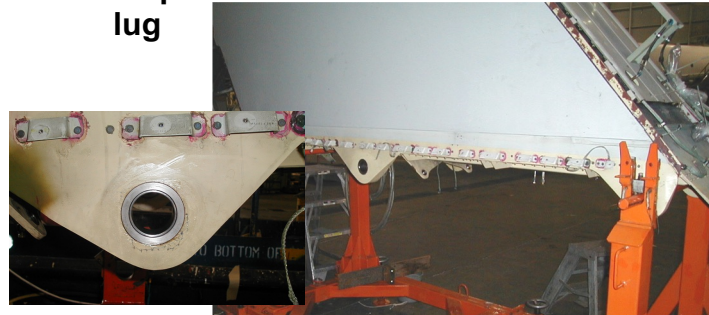
- Assisted development of inspection method to address post-accident AD
- Ongoing support for Airbus Alert Service Bulletin (rudder)



### MAUS MIA C-Scan of Airbus Rudder



Developed Pulse-Echo Ultrasonic inspection – added for carbon laminate lug

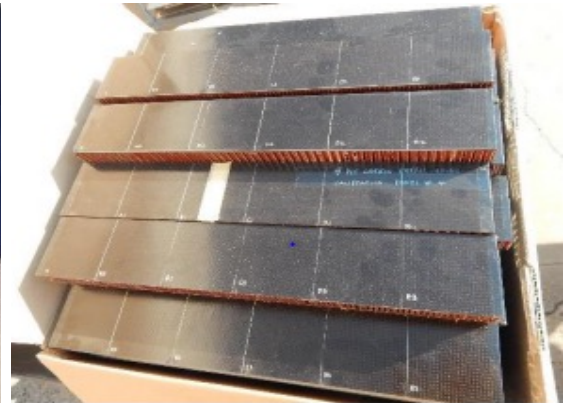
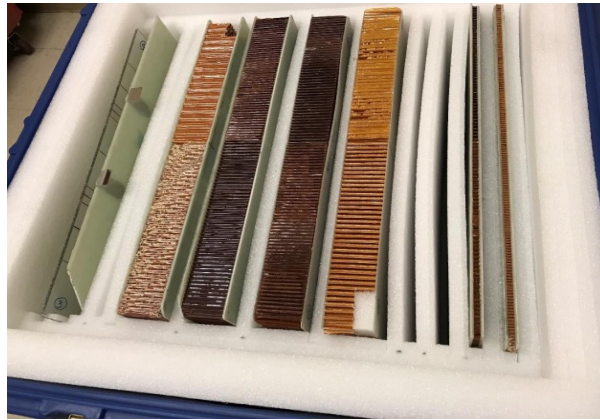
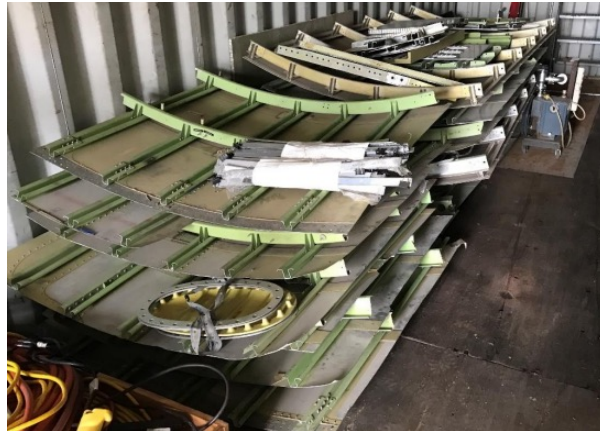




# AANC Test Specimen Library

Large A/C control surfaces  
Large skin/structure panels  
Robinson rotorcraft blades  
787 composite panels with impact damage  
Honeycomb panels  
Skin panels with substructure  
Assorted aircraft components  
ECIRE frames POD experiment  
ECIRE bolt hole POD experiment  
cases of POD experiments  
composite bonded doubler/rotorcraft golden pod sets  
EC Inspection Reliability POD Set  
Corrosion POD set  
Wing crack POD  
Solid Composite Laminate POD  
Honeycomb POD  
Assorted composite laminate NDI specimens  
Honeycomb NDI specimens  
Composite Impact NDI specimens  
NDI ref stds/composite corrosion NDI specimens  
composite weak bond specimens  
scarfed composite specimen  
composite honeycomb impact damage  
Cessna wing crack specimen  
Bell damage detection/Robinson accident  
microcrack specimens for penetrant/mag particle  
Engine Ti and Inconel specimens  
Rotor CVM and PZT specimens  
Embraer PZT specimens  
NDT reference standards-cracks and thickness metals  
NDT reference standards-composite  
Composite specimens  
Rotorcraft composite Hub/composite doublers  
Lap splice with corrosion  
Goodrich hidden tire damage  
NASA shuttle heat shield





FAA contract ended

AANC closed

Assets moved to NIAR

Assets to be relocated to FAA Tech Center 2023

Material will be available for Industry Use

Test NDI new equipment

Airline NDI training

Contact Danielle Stephens

# QUESTIONS?

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**FAA**

