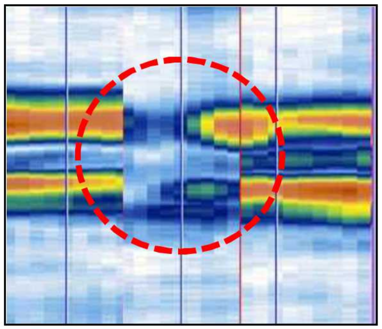
SAND2018-9338C

# Blade Reliability Collaborative – Evolving Advanced NDI: Health Monitoring for Enhanced In-Service Life & Accurate QA to Aid Wind Blade Production







**Dennis Roach, Ray Ely, Tom Rice, Josh Paquette**

**Wind Blade Reliability Center**

**Sandia National Labs**

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

# Rising Need for Wind Blade Inspections

- Rapid and steady increase in wind power installation

- Critical enablers to improve market competition with other electricity sources - *Dept. of Energy Wind Vision Roadmap* identifies need for continuing declines in wind power costs (blade availability) and improved reliability

- Increase wind farm availability and lower production costs by reducing unplanned maintenance - requires broader adoption of condition monitoring systems

- Better understanding of harsh environments combined with uncertainties in aging phenomena and Damage Tolerance of blades

- Blade maintenance is now a major issue because: 1) the number and age of wind blades in operation continues to grow, 2) larger blades have increased demand/need for more invasive repairs (vs. replacement), 3) operational loads/environment combined with seeded flaws creates the need for in-service inspections

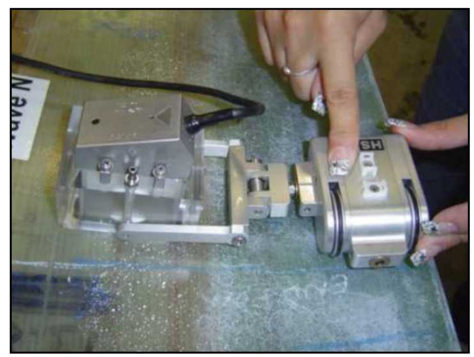
- Navigant Research estimates the cumulative global revenue for wind turbine inspection services will reach nearly $6 billion annually by 2024.

# Blade Reliability Collaborative - Objectives

***Create the ability for manufacturers to determine the quality of their product before it leaves the factory & to enhance the in-service inspection of wind blades***

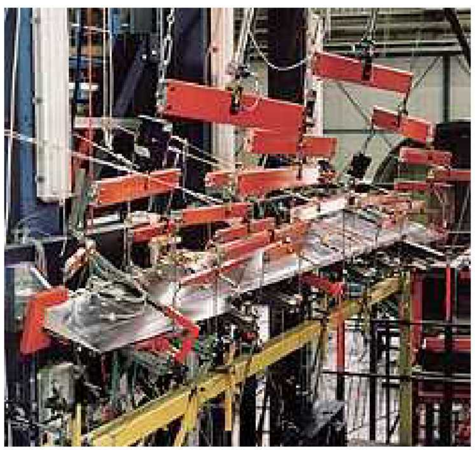
- **Develop, evaluate and validate the array of potential nondestructive inspection methods for the detection of flaws in composite wind turbine blades**
- **Plan and implement a national capability – including a physical presence and methodology - to comprehensively evaluate blade inspection techniques**
- **Produce optimum deployment of automated or semi-automated NDI to detect undesirable flaws in blades (time, cost, sensitivity)**
- **Transfer technology to industry through hardware and technology evaluation, inspector training, and procedure development**



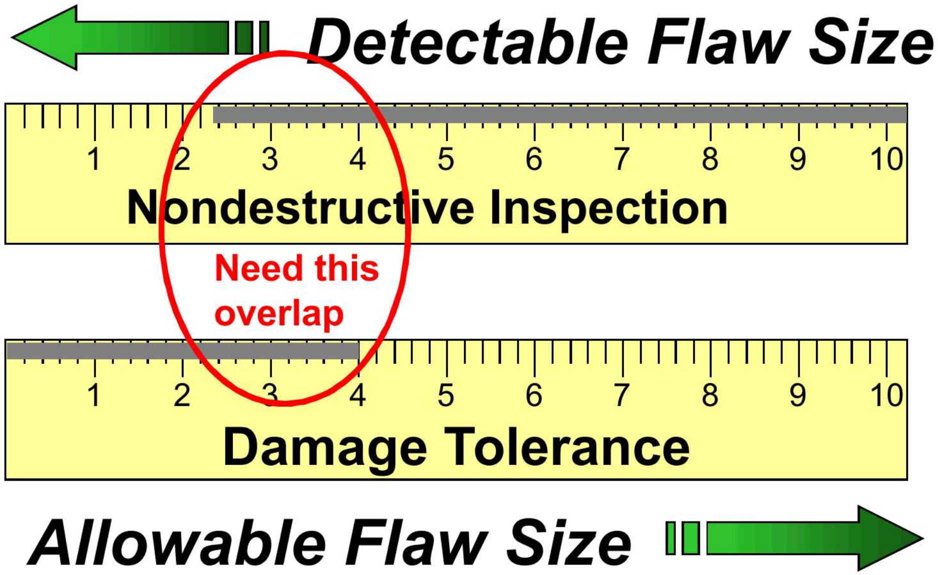


# Blade Reliability Collaborative – NDI Objective

***Create the ability for manufacturers to determine the quality of their product before it leaves the factory & to enhance the in-service inspection of wind blades***

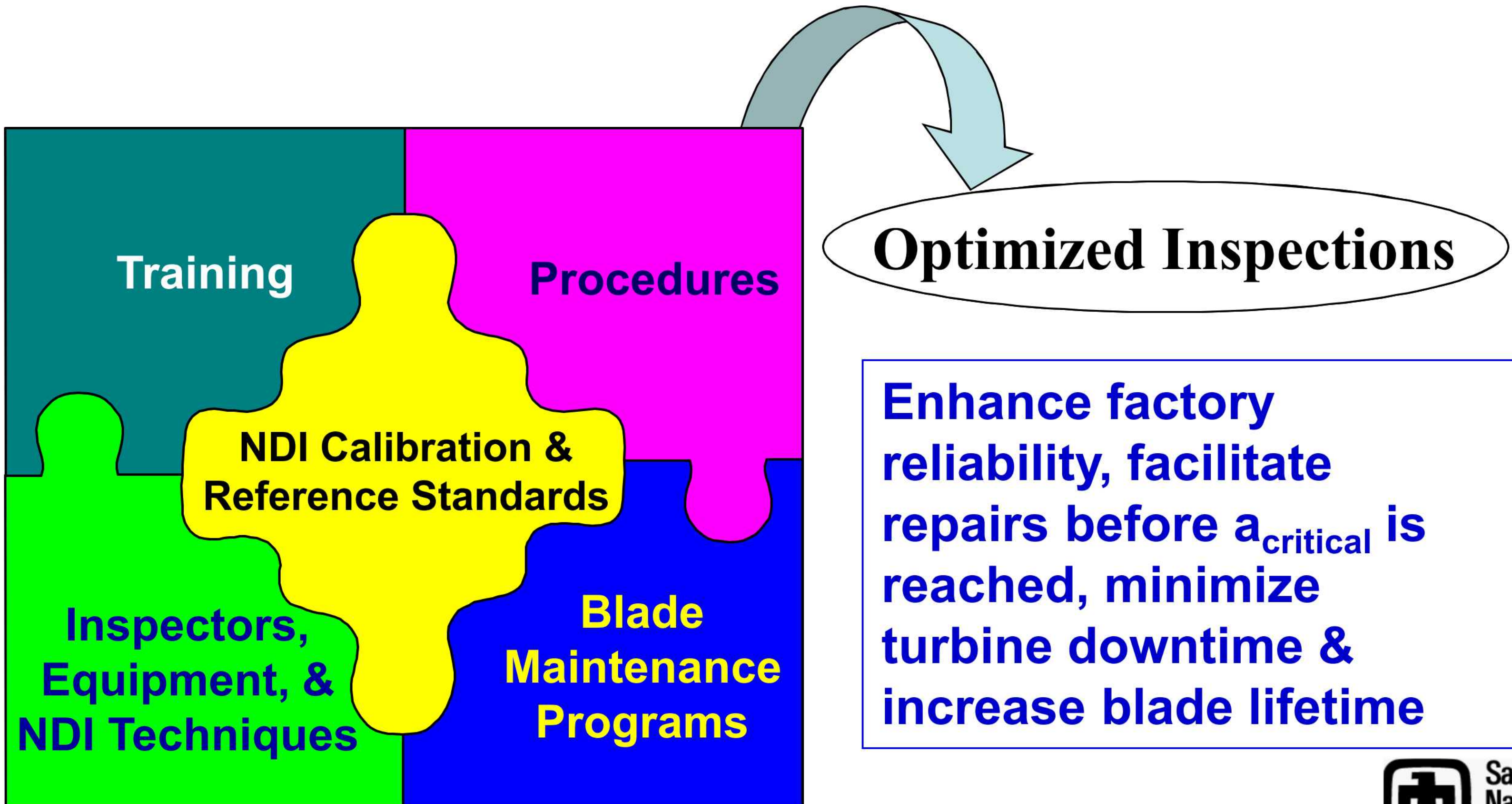


**Required Relationship Between Structural Integrity and Inspection Sensitivity**



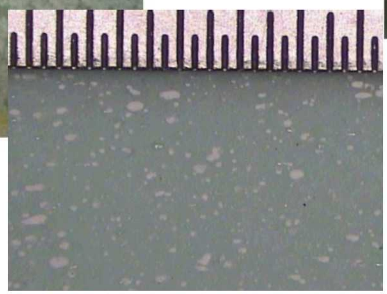
# Program Thrusts to Improve Wind NDI

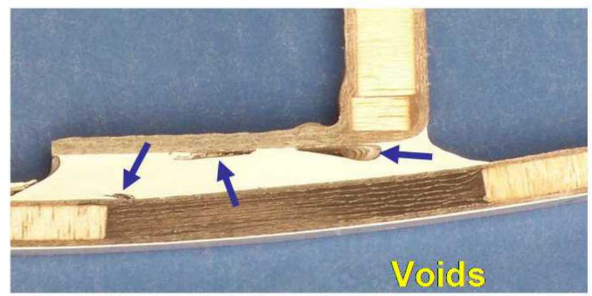
- Use of NDI reference standards to form sound basis of comparison & ensure proper equipment set-up
- Use of material property & calibration curves (attenuation, velocity)
- Human factors – adjust procedures
- Improved flaw detection: Hybrid inspection approach - stack multiple methods which address array of flaw types (data fusion)



# Inspection Areas and Flaw Types of Interest

**Flaws include: Ply Waves Delaminations, Adhesive Voids, Joint Disbonds, Snowflaking and Porosity**

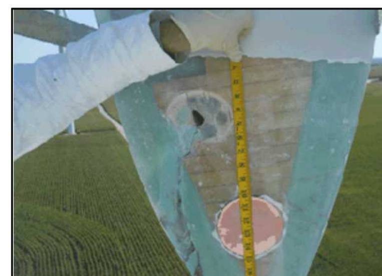



# In-Service Inspection of Blades Including Wind Blade Repairs

**Damage Sources -**
**Installation, Lightning Strike, Impact, Erosion, Overstress, Fatigue, Fabrication-Seeded, Environmental**

**Skin Laminate Fracture**

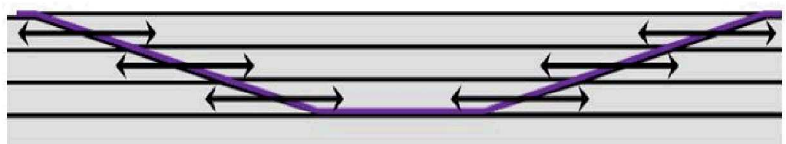

- **In-service NDI can improve blade reliability, minimize blade downtime & extend blade life**
- **Additional access & deployment challenges**
- **Post-repair inspections**



# Demand for More Extensive Wind Blade Repairs Requires Pre- and Post- Repair Inspection

- Requires the means to conduct in-service inspections up-tower
- NDI must go beyond visual surface indications and produce deep, subsurface damage assessments
- NDI must be rapid to minimize blade downtime

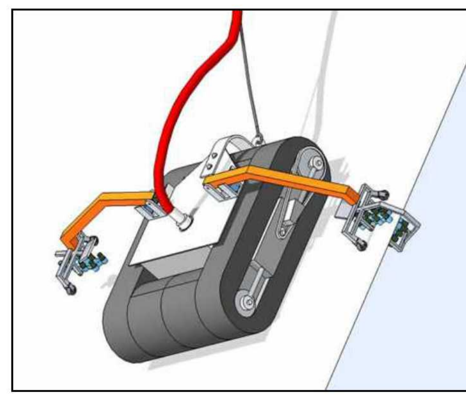
Severe Growth of Fiber Fracture

Scarfed Blade Repair Process

Lightning Strike Damage

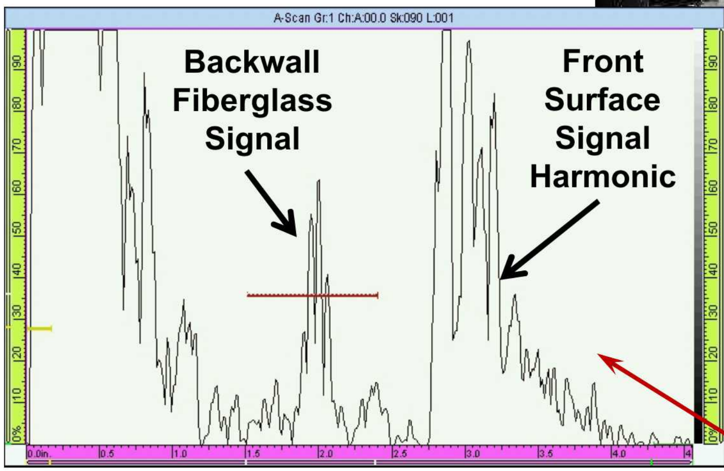
Drone- and Robot- Deployed NDI Systems

NNSA National Nuclear Security Administration

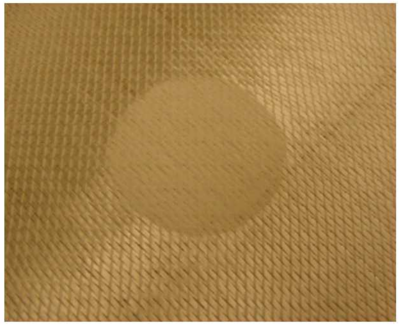
ries

# Overcome Inspection Challenges



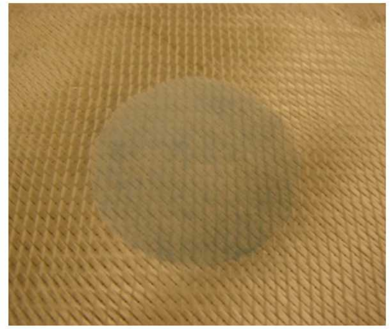

**Want to make NDI easier, quicker, more reliable and more sensitive**

# Different Flaw Types Engineered into NDI Performance Assessment Specimens

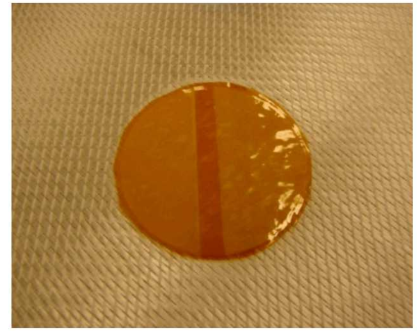


Glass Beads

Grease



Mold Release



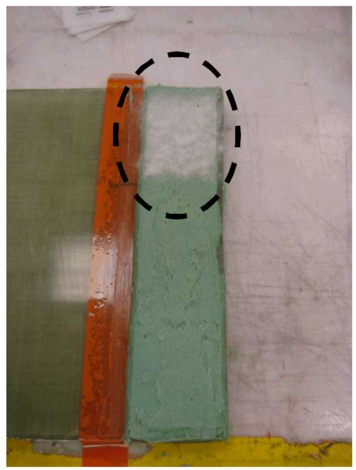
Pillow Insert

*Materials inserted into multiple layers*

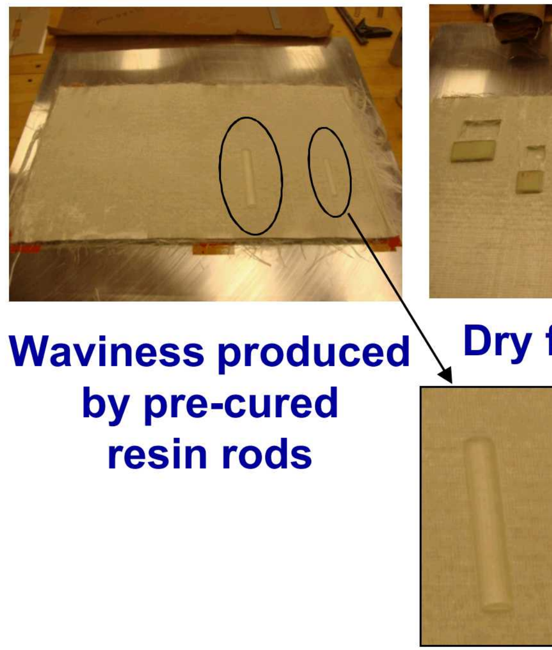
---

Voids in bond joint

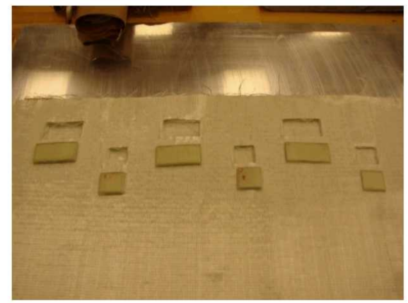
Pull tabs in bond joint



Glass beads In bond joint



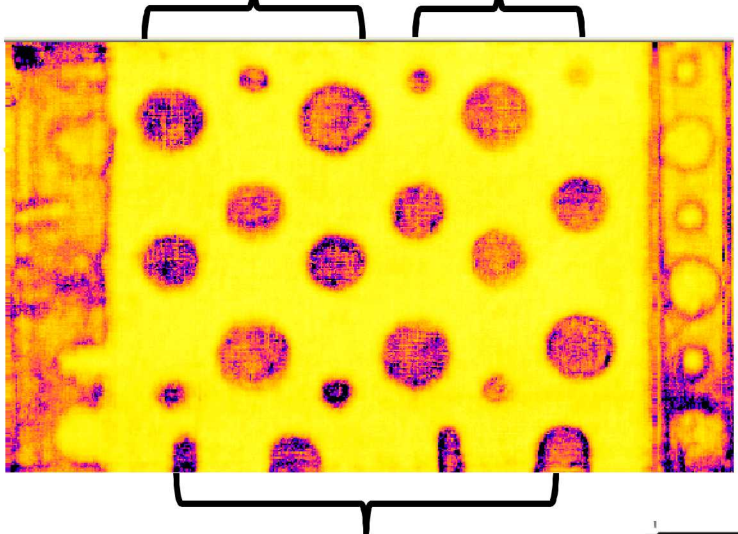
Waviness produced by pre-cured resin rods



Dry fabric areas

# MAUS P-E UT with Focused Probe (1 MHz/2”) and Adjustable Water Path

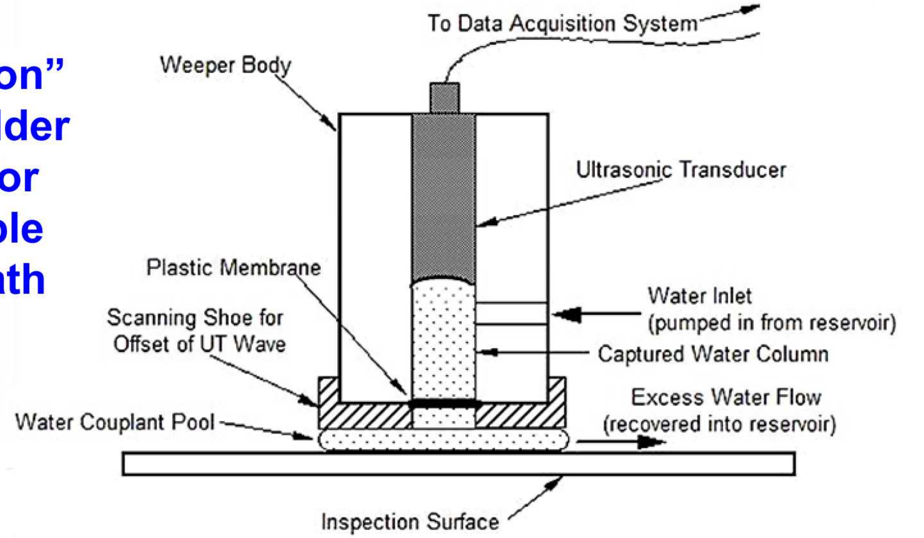
Flat Bottom Holes Pillow Inserts

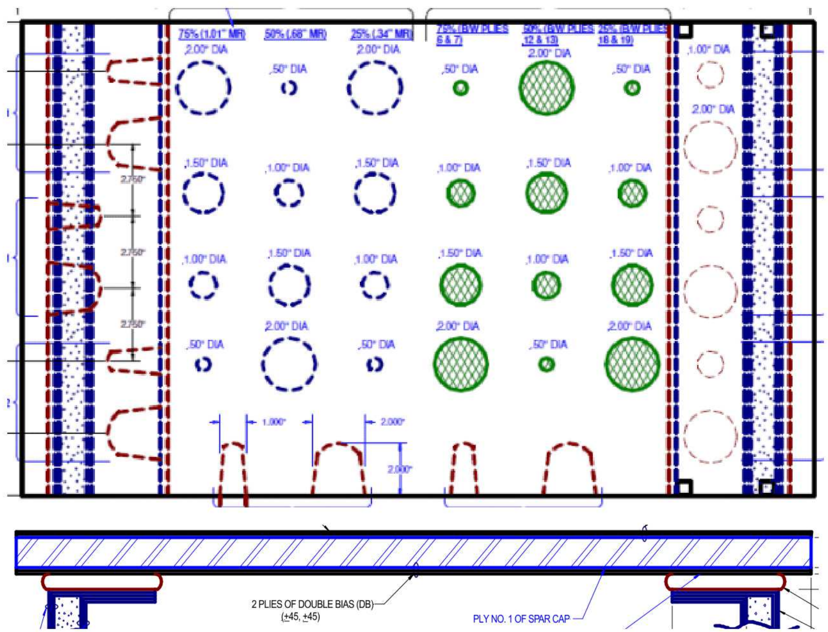


Pull Tabs

**REF-STD-6-202-250-SNL-1**

**New “Immersion” Probe Holder Allows for Adjustable Water Path**

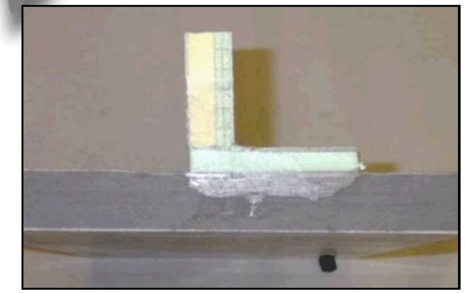


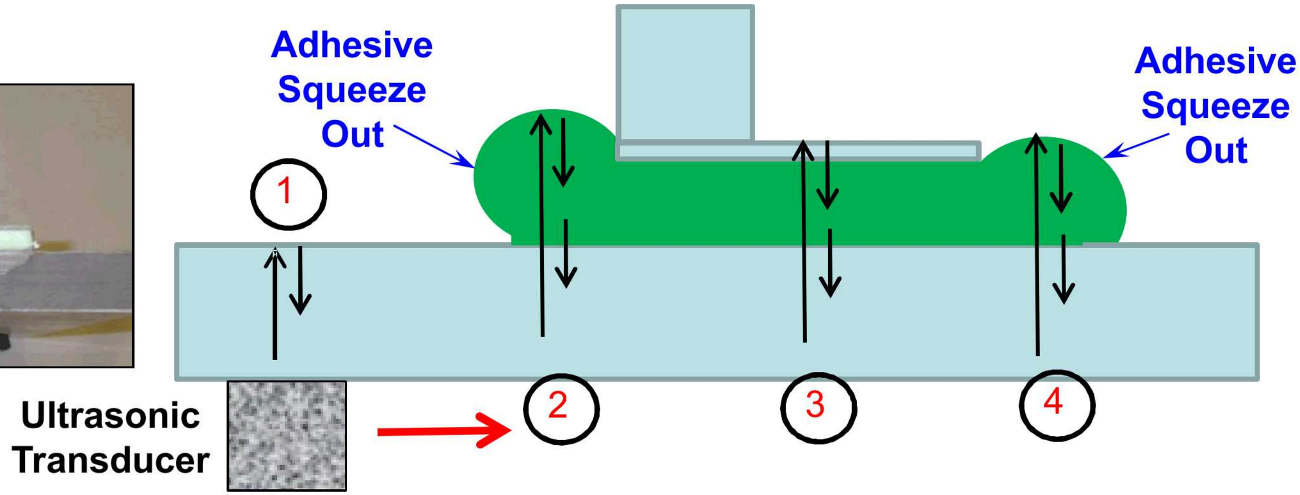



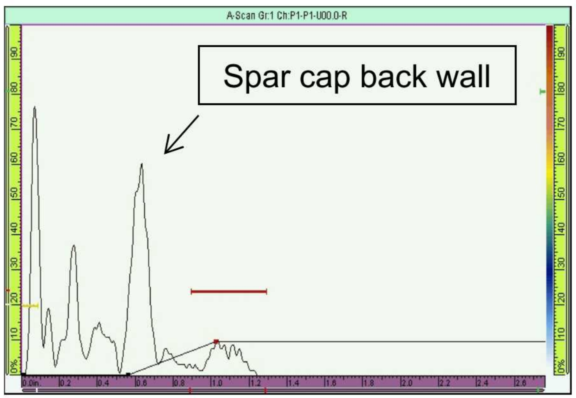

NNSA National Nuclear Security Administration

Sandia National Laboratories

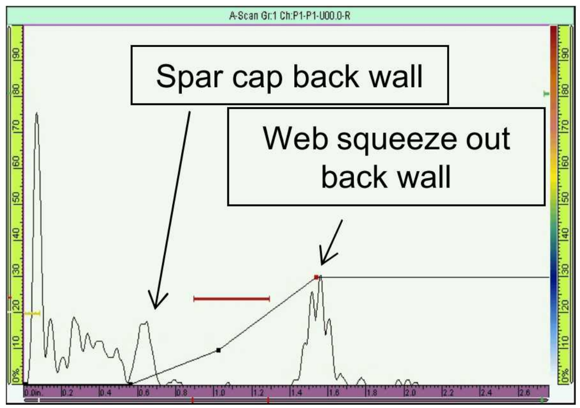
# Pulse-Echo Inspection of Bond Joint



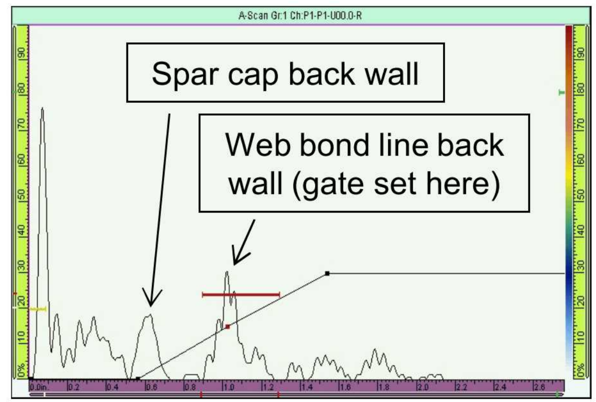



Spar Cap - 1

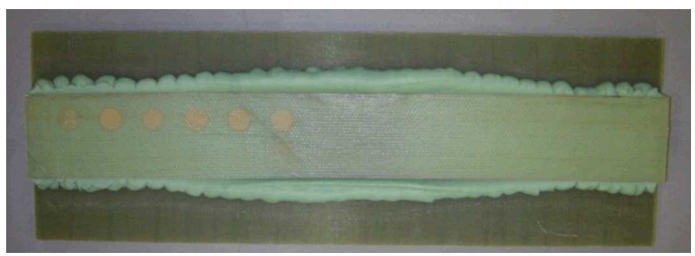



Web Squeeze Out- & 2 4




Web Bond Line- 3

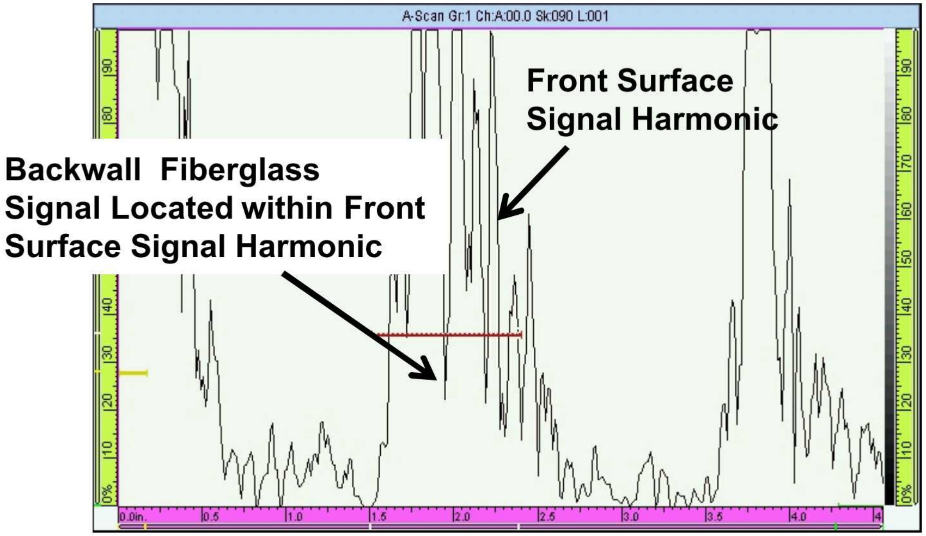
## A-Scan Signals



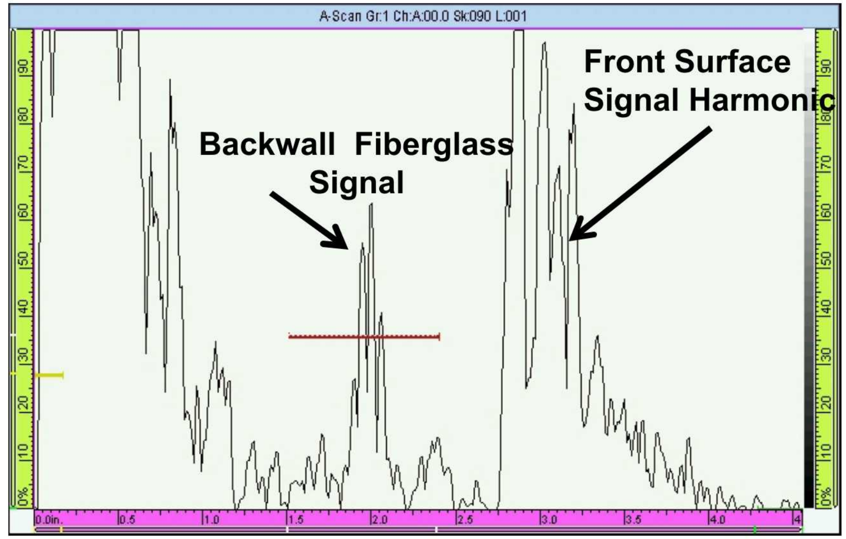
Sandia National Laboratories

# Design of Delay Lines to Avoid Signal Interference

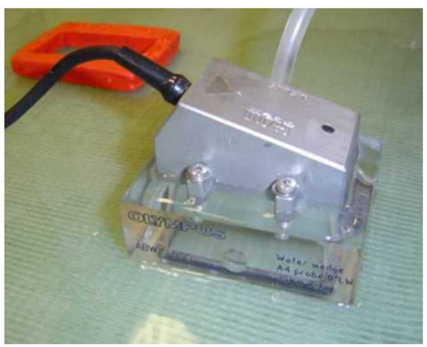
## Water Box Signal Analysis - 25mm compared to 40mm; Moves harmonic return signal outside area of interest.




25mm Delay




40mm Delay



1.5 MHz Phased Array UT Probe

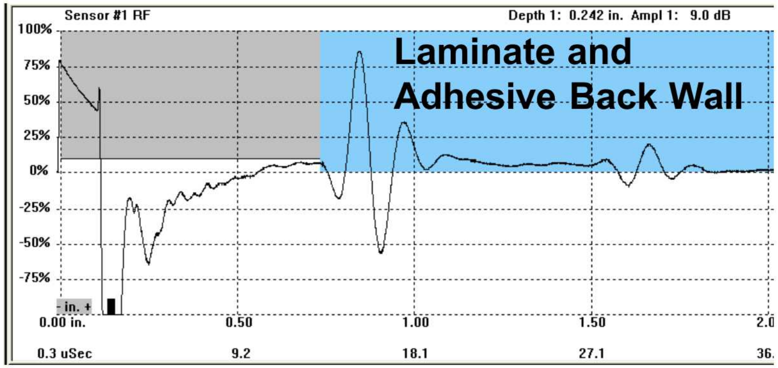
**Sandia has focused on a sealed couplant box that:**

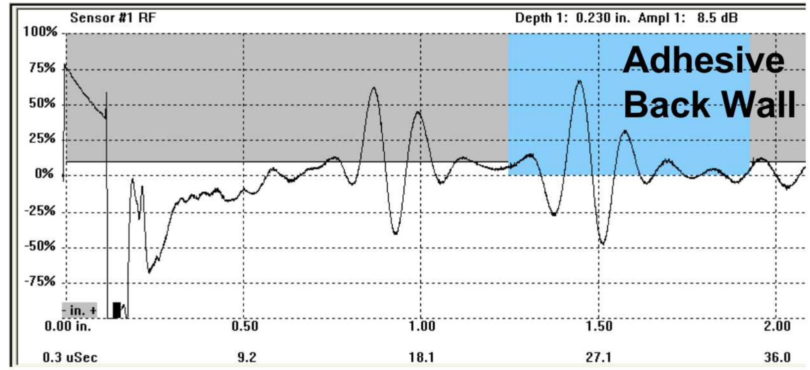
- **Adjusts to slight curvature in surfaces**
- **Eliminates water flow to open box**
- **Maximizes signal strength**
- **Accommodates necessary standoffs for signal clarity**
- **Easily saves scanned images for reference using a wheel encoder**

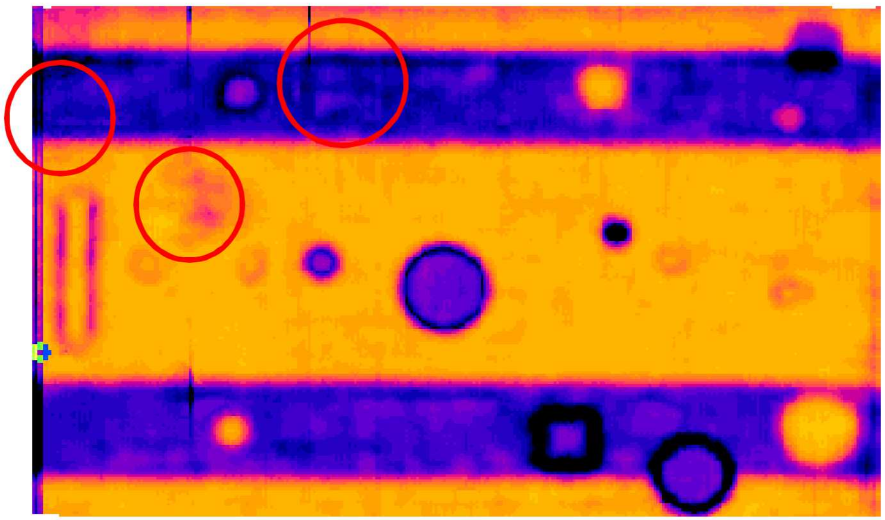
NNSA National Nuclear Security Administration

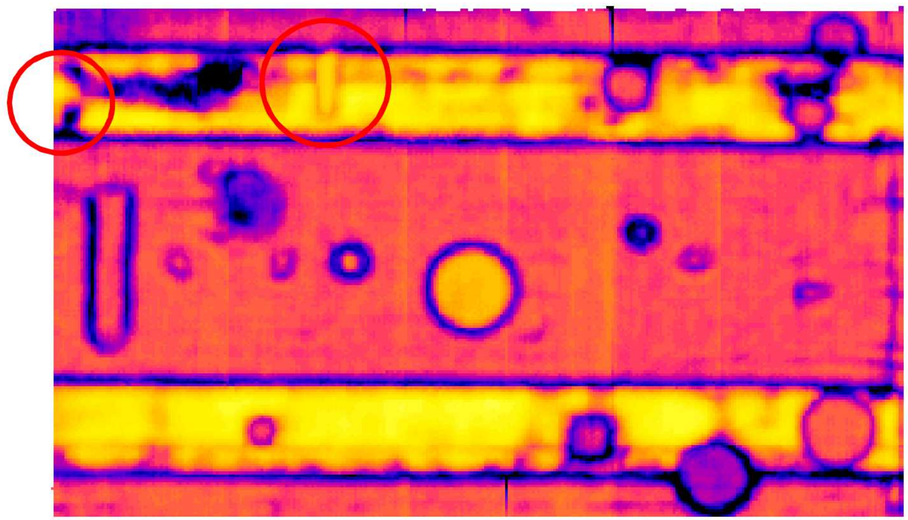
Sandia National Laboratories

# *Gate Setting Analysis*
# MAUS V 500 KHZ Contact Test C-Scan Results





**Defects at the shear web flange and adhesive layer may, or may not, be detected depending on gate settings and part thickness.**

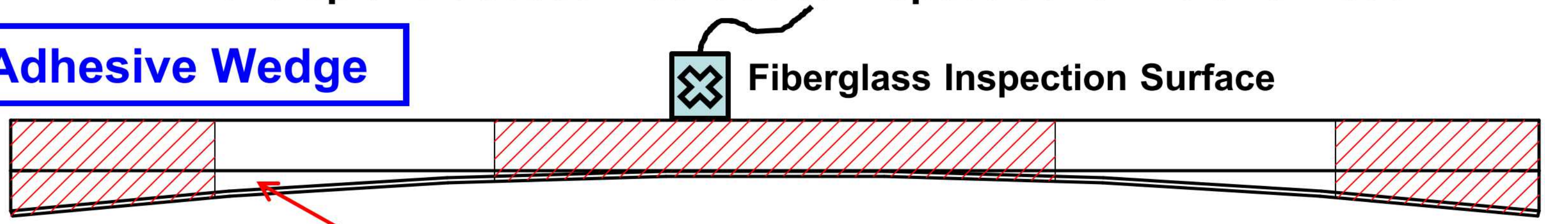
NNSA National Nuclear Security Administration

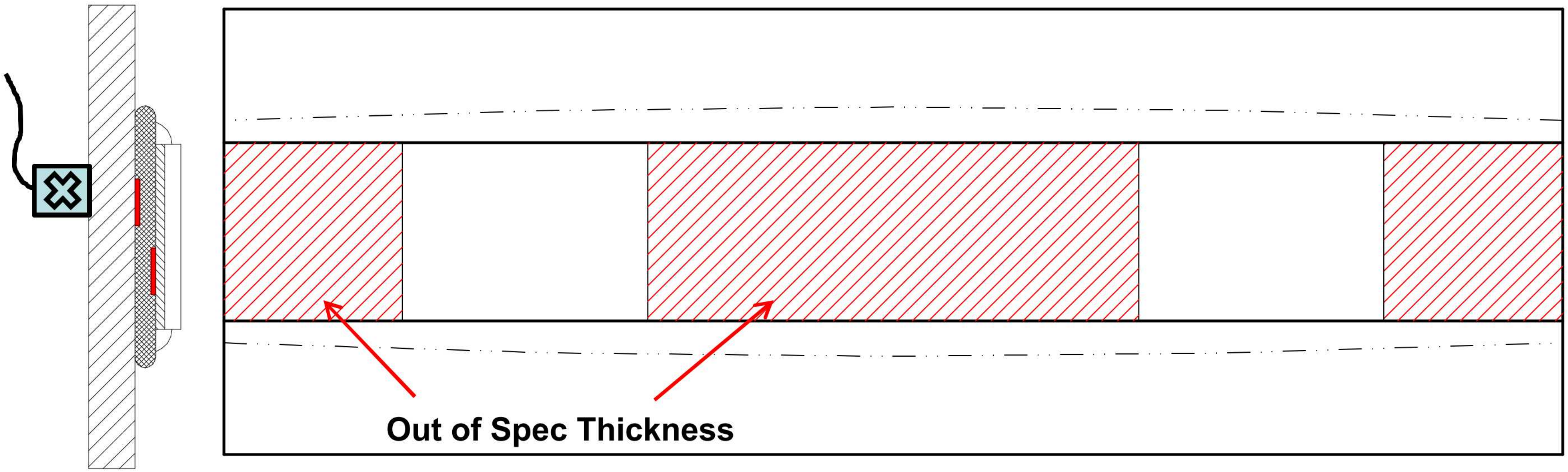
Sandia National Laboratories

# Adhesive Thickness Measurements with Phased Array UT

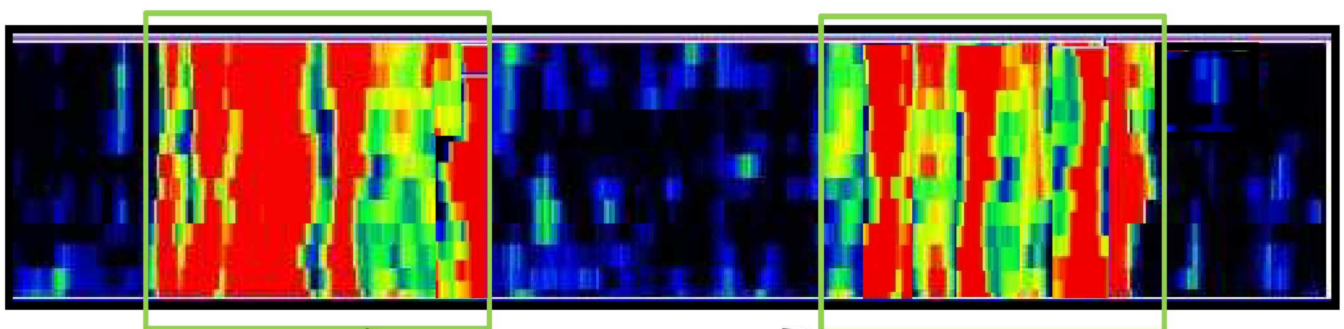
**Develop and assess methods to inspect bond line thickness**

## Tapered Adhesive Wedge



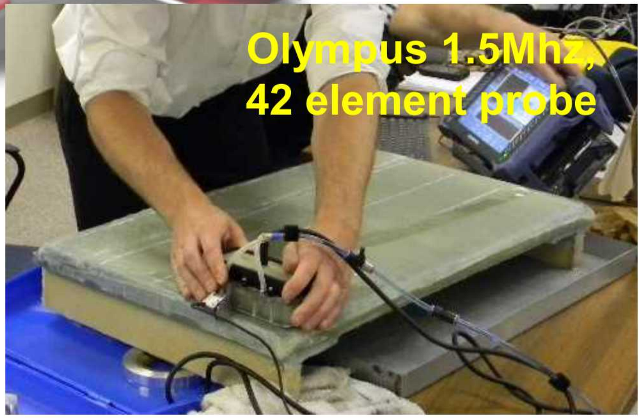

## Phased Array UT Results

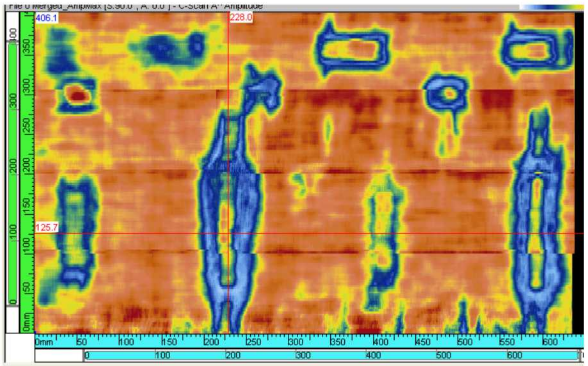


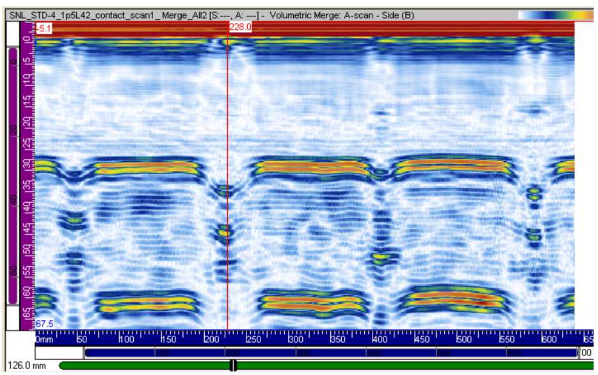

NNSA National Nuclear Security Administration

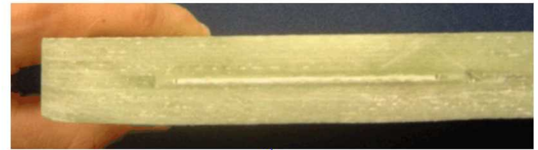
Sandia National Laboratories

# Phased Array UT – Display and Deployment



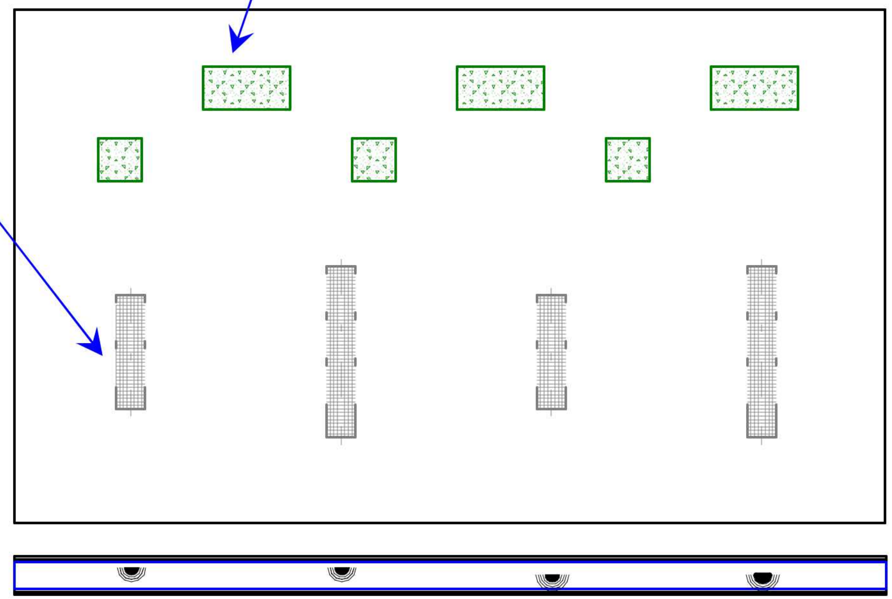




**Dry Fiber Areas**

**REF-STD-4-135-SNL-1 (wrinkles & dry areas)**

**Resin Rod Induced Waves**



# An Experiment to Assess Flaw Detection Performance in Wind Turbine Blades (POD)

## Purpose

- Generate industry-wide performance curves to quantify:
  - how well current inspection techniques are able to reliably find flaws in wind turbine blades (industry baseline)
  - the degree of improvements possible through integrating more advanced NDI techniques and procedures.

## Expected Results - evaluate performance attributes

1) accuracy & sensitivity (hits, misses, false calls, sizing)
2) versatility, portability, complexity, inspection time (human factors)
3) produce guideline documents to improve inspections
4) introduce advanced NDI where needed

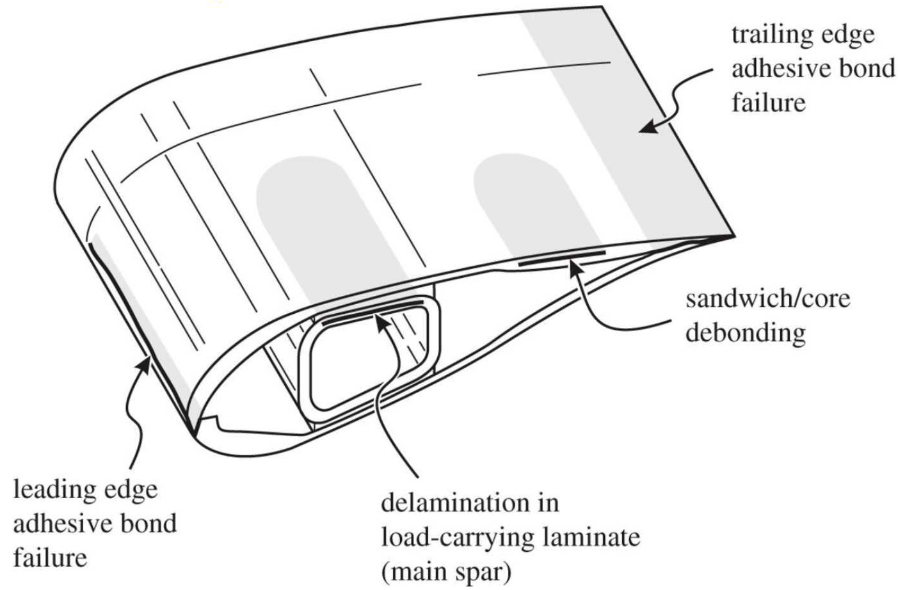
**Ensure representative blade construction and materials**

# Wind Blade NDI Probability of Detection Experiment

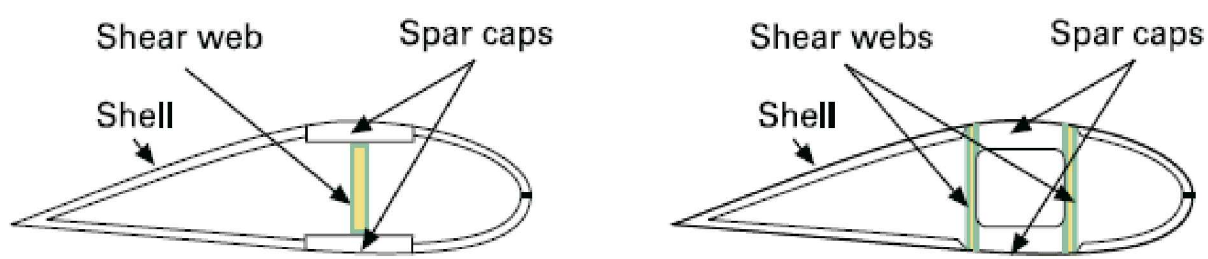
- Blind experiment: type, location and size of flaws are not know by inspector
- Statistically relevant flaw distribution – Probability of Detection (POD)
- Used to analytically determine the performance of NDI techniques – hits, misses, false-calls, flaw sizing, human factors, procedures

**Experimental Design Parameters**

- Representative design and manufacturing
- Various parts of blade such as spar cap, bonded joints, leading and trailing edge
- Statistically valid POD (number, size of flaws and inspection area)
- Random flaw location
- Maximum of two days to perform experiment
- Deployment




Specimens designs applicable to various blade construction




Spar Caps & Shear Web

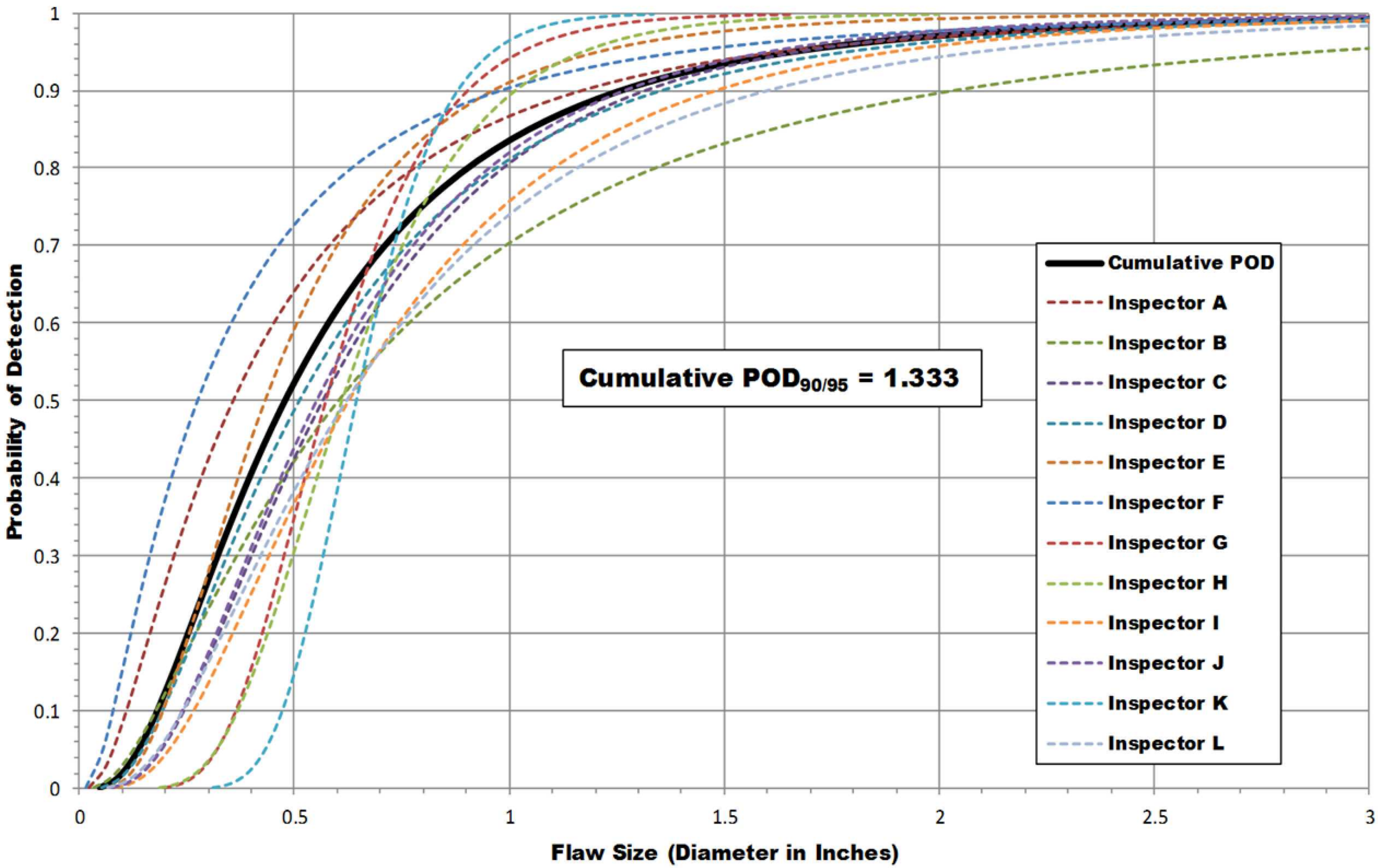
Box Beam

# Implementation of Wind POD Experiment

- 11 POD specimens with spar cap and shear web geometry
- Thickness ranges from 8 Plies (0.45” thick laminate, 0.85” thick with adhesive bond line) to 32 Plies (1.80” thick laminate, 2.20” thick with adhesive bond line)
- All panels painted with wind turbine blade paint (match inspection surface)

# Wind Blade Flaw Detection Experiment – Individual Inspector and Cumulative POD Comparison

## All Panels - Spar Cap with Shear Web and Box Spar Construction Types



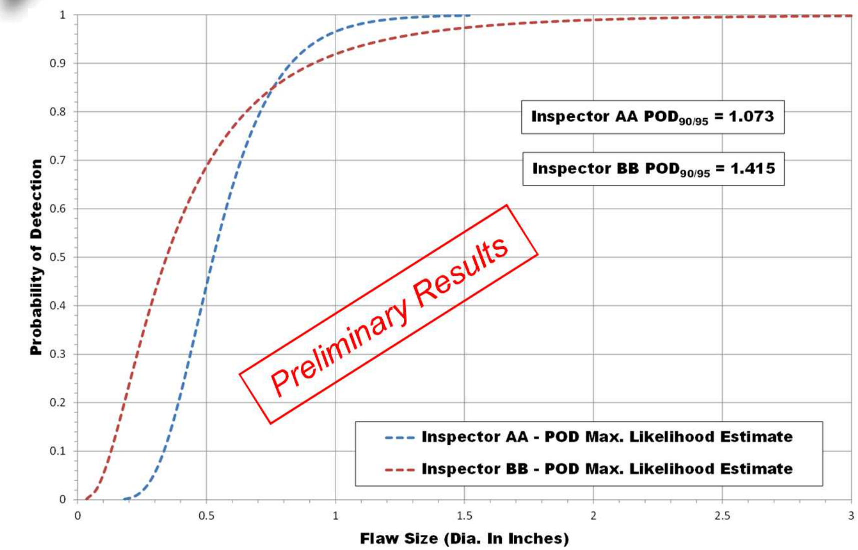

**Conventional Single Element Pulse-Echo Ultrasonic Inspection Method**

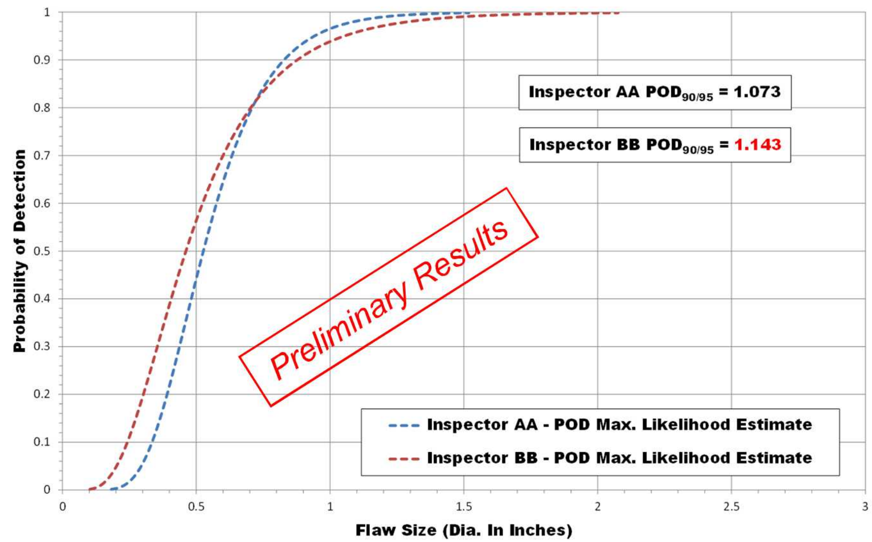
NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade Flaw Detection Experiment – Optimizing Results with Proper Analysis

## Results from Single-Element UT Scanner System

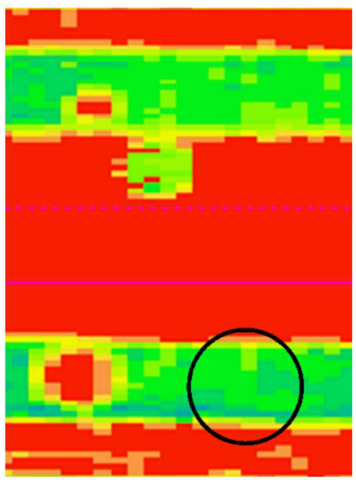


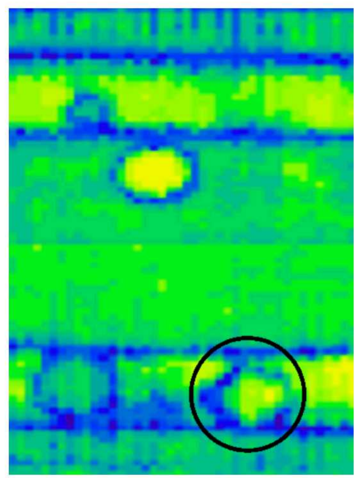




Non-optimal use of gate settings can allow damage to go undetected

Inspector BB – 2” Flaw “Miss” is changed to a “Hit” (additional data gates used to detect deeper flaws)

Initial Results - flaw under bondline is not imaged





Second Analysis – data reviewed using additional gate settings; damage detected

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade Flaw Detection Experiment – Various NDI Performance Attributes Evaluated

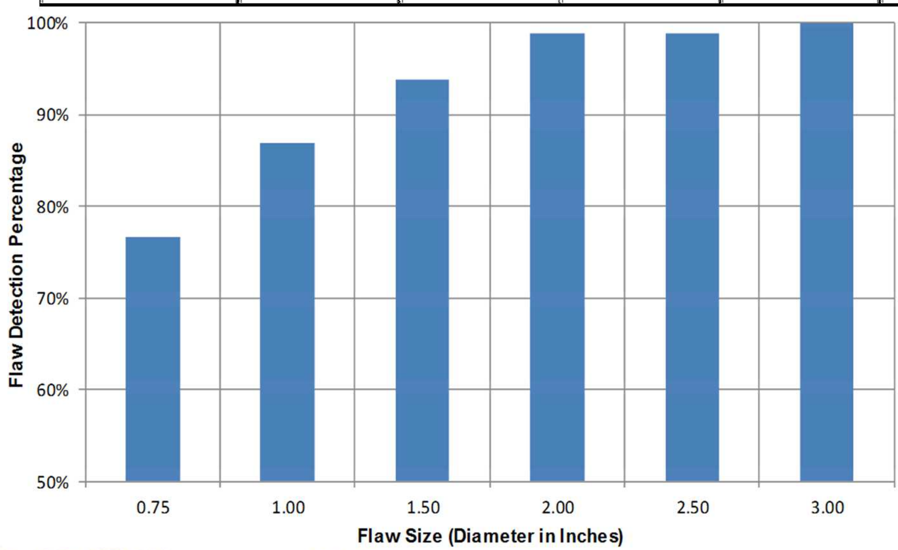
| Overall Flaw Detection Percentage & Accuracy in Determining Flaw Size<br>All Panels - 12 Inspectors - All Flaws (CT & CG) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Accuracy in Sizing the Flaws That Were Detected (1546 Total Flaws Detected) | | | | | | Flaw Detection Percentage (1704 Total Flaws) | |
| Flaw Size | 5 (100%) | 4 (76%-99%) | 3 (51%-75%) | 2 (25%-50%) | 1 (< 25%) | Flaw Size | Percent Detected |
| 0.75 | 42% | 18% | 16% | 10% | 15% | 0.75 | 74% |
| 1.00 | 35% | 32% | 19% | 9% | 6% | 1.00 | 83% |
| 1.50 | 24% | 40% | 19% | 10% | 7% | 1.50 | 93% |
| 2.00 | 22% | 47% | 16% | 10% | 4% | 2.00 | 97% |
| 2.50 | 20% | 46% | 22% | 9% | 4% | 2.50 | 99% |
| 3.00 | 16% | 52% | 13% | 8% | 12% | 3.00 | 99% |
| Overall Sizing Performance | 26% | 40% | 18% | 10% | 7% | Overall Flaw Detection | 91% |

**Spar Cap with Shear Web and Box Spar Construction Types**

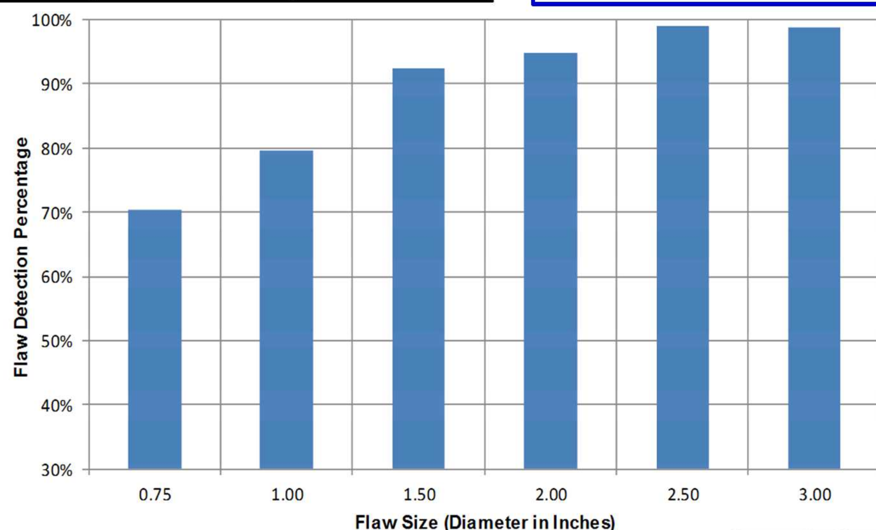
$POD_{90/95} = 1.334$

**Spar Cap with Shear Web Construction Types**

$POD_{90/95} = 1.208$




**All Panels - Constant Thickness Flaws**




**All Panels - Complex Geometry Flaws**

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade Flaw Detection Experiment – Improvements Produced by Use of Advanced NDI

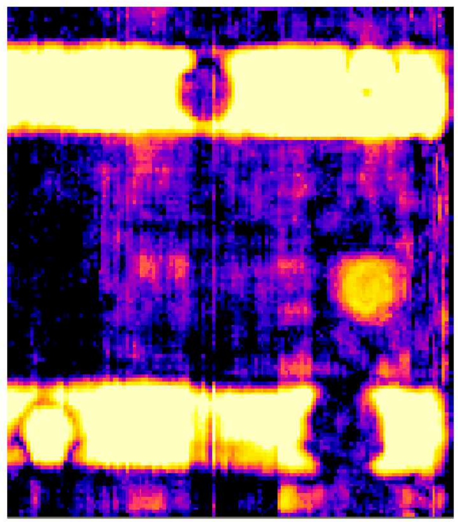
**All Panels, All Flaw Types – Conventional NDI**

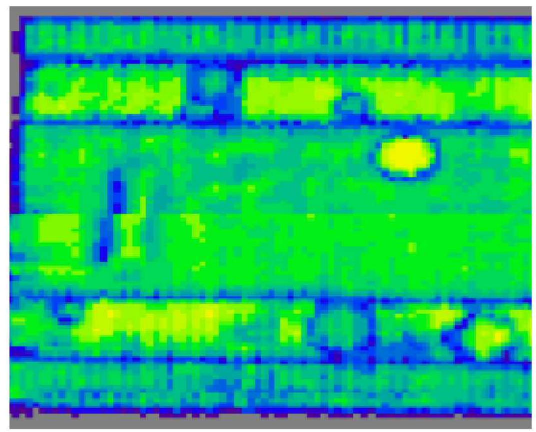
**POD $_{90/95}$ = 1.333**

**All Panels, All Flaw Types – Advanced NDI (sample)**

**POD $_{90/95}$ = 1.105**

**C-scan images produced by single-element ultrasonic scanner systems – easier to interpret data**

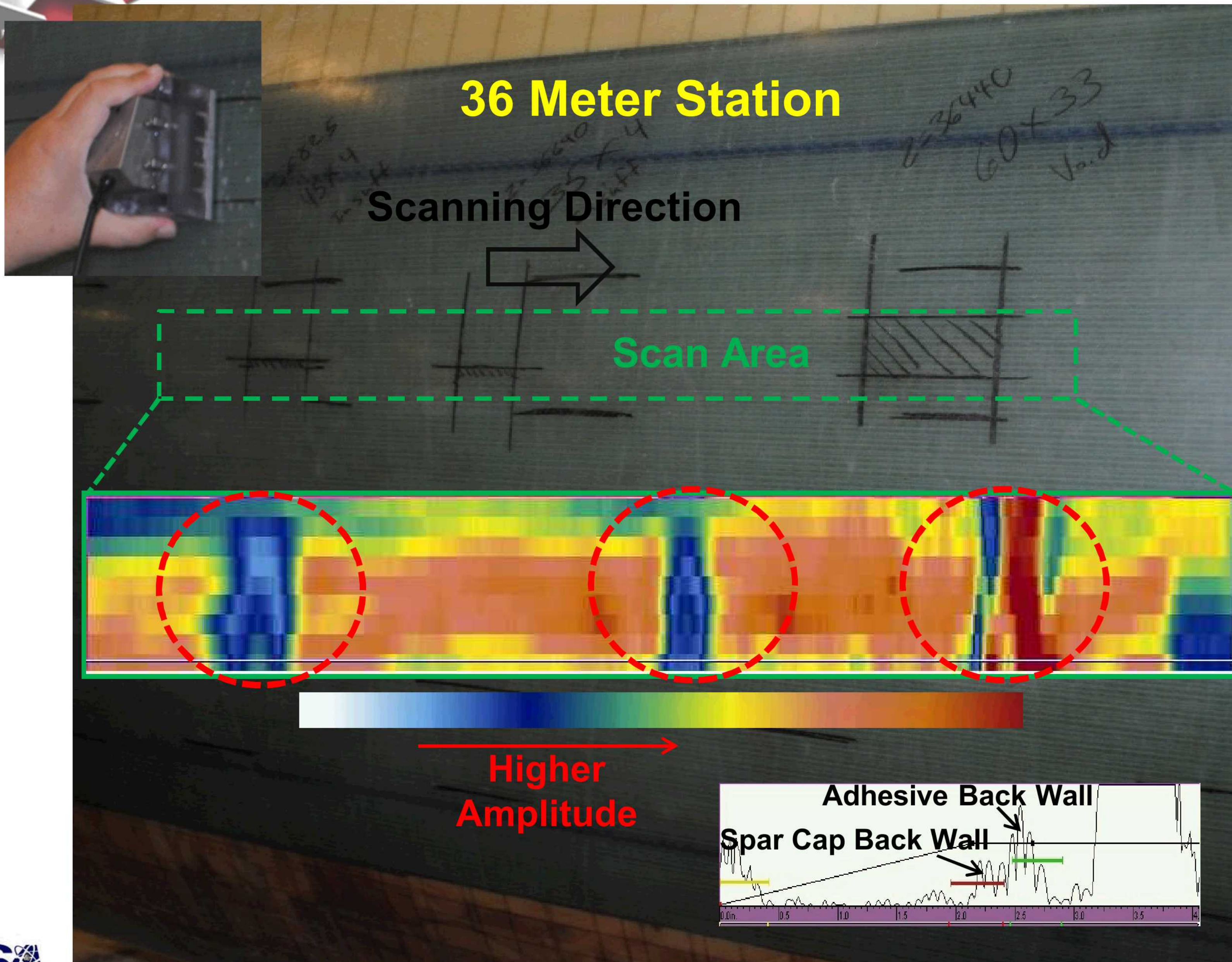




National Nuclear Security Administration

Sandia National Laboratories

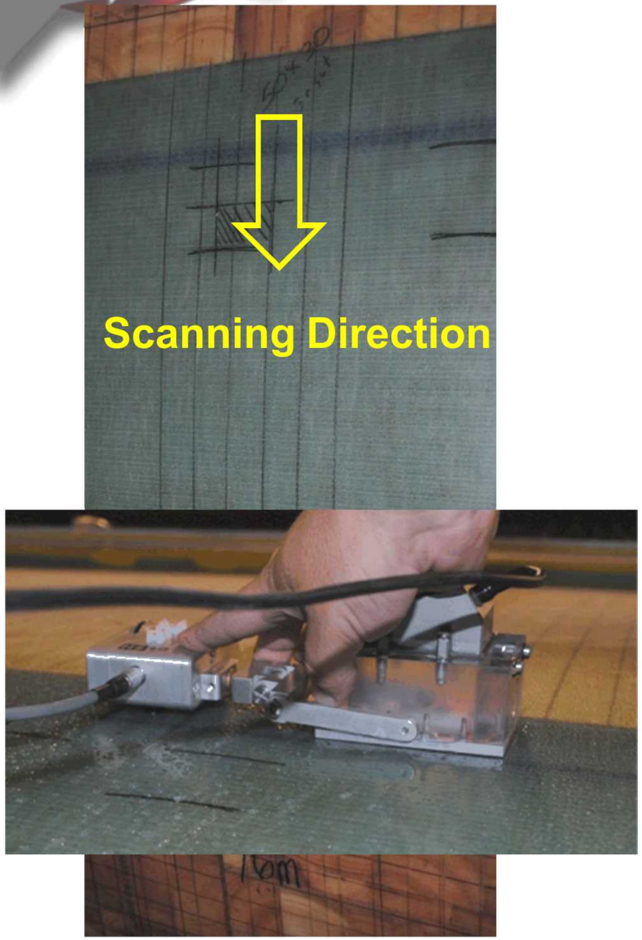
# On-Blade Testing in Manufacturing Facility



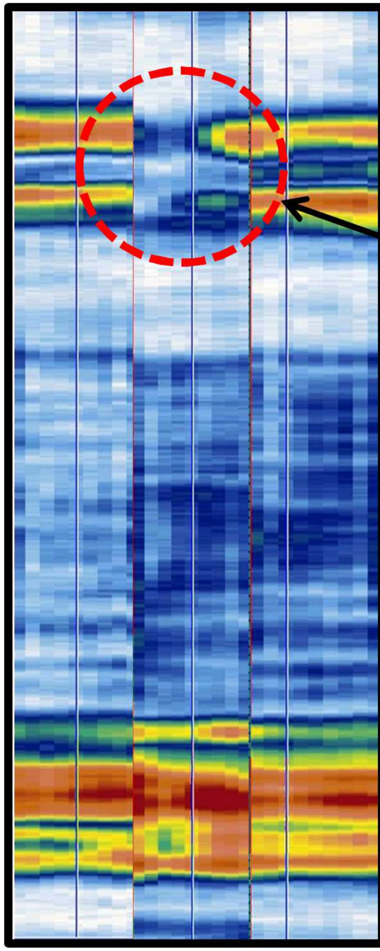

NNSA National Nuclear Security Administration

Sandia National Laboratories

# On-Blade Phased Array UT Inspections

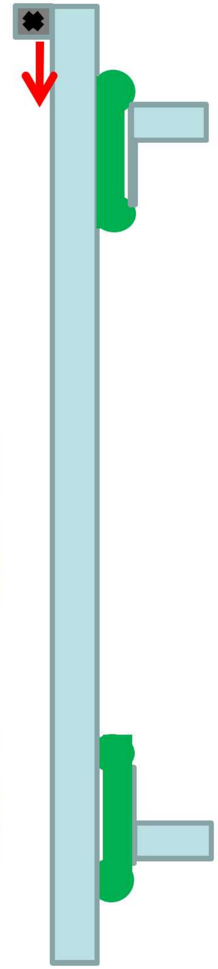



16 Meter Station on Fiberglass Spar Cap Blade



Adhesive Void Between Spar Cap and Shear Web

Vertical Strip C-Scan Image Showing Adhesive Void in Upper Bond Line



Spar Cap Cross Section Schematic Showing the Spar Cap, Adhesive Bond Line and Shear Webs

**Sealed water box and 1.5L16 Phased Array probe was used to detect missing adhesive in bond lines**

NNSA National Nuclear Security Administration

Sandia National Laboratories

# In-Service Inspection of Blades Including Wind Blade Repairs

- **Deployment** - Determine how advanced NDI methods can be gracefully integrated into wind farm operations.
- **Inspection of Repairs**:
  - As wind blades become larger and more expensive, there is a corresponding desire to install more extensive and invasive repairs.
  - Criticality of these repairs will require the use of through-thickness depth inspection methods to ensure the quality of the repair.
  - Accurate repair assessments can open up new opportunities for spar cap and root repairs.
  - Give engineers added confidence that the blade can be recertified for use, which would lead to significant cost savings.
- **Implementation** - deployment may involve the use of wind service companies to provide skilled inspectors with proven equipment and procedures

Goal: conduct inspections before minor damage grows to blade failure; improve blade reliability & minimize down time

Damage from Shipping, Installation


Impact Damage

Severe Growth of Fiber Fracture

Skin Laminate Fracture

Erosion and Impact Damage

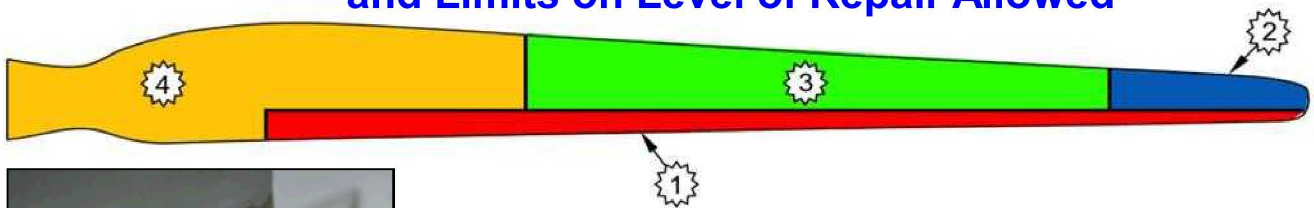
Trailing Edge Disbond and Fracture Damage

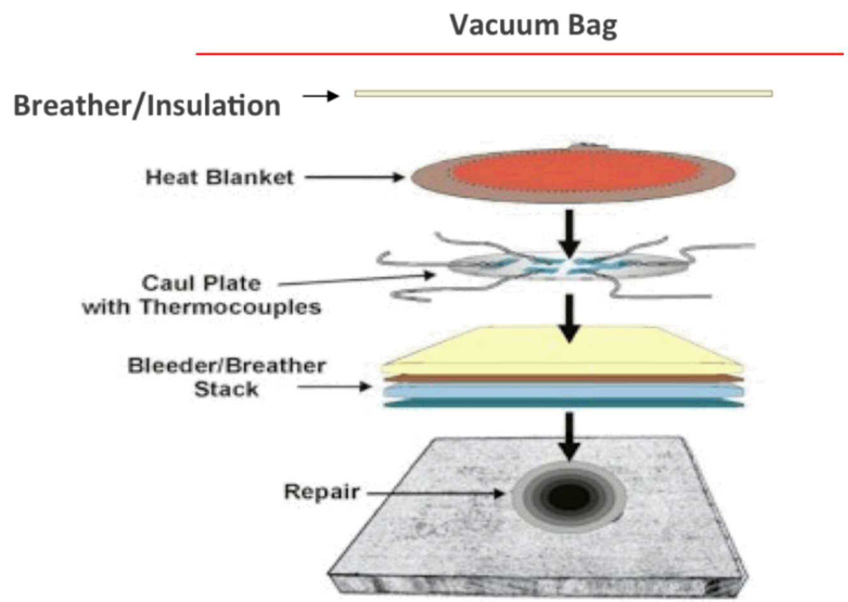
National Nuclear Security Administration

Sandia National Laboratories

# In-Service Inspection of Wind Blade Repairs

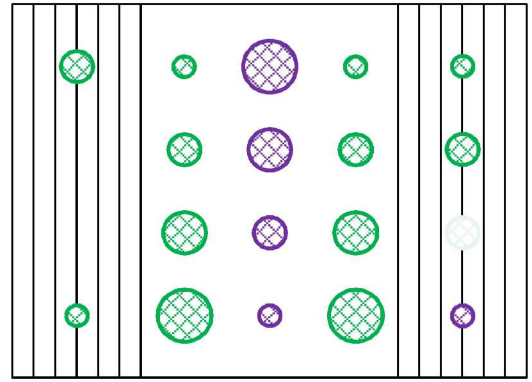
**Repair Zones on Wind Blades that Identify Criticality and Limits on Level of Repair Allowed**

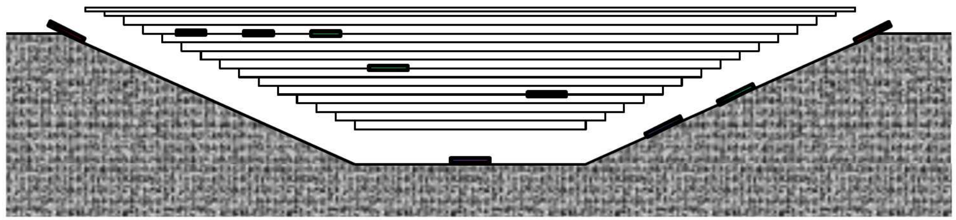


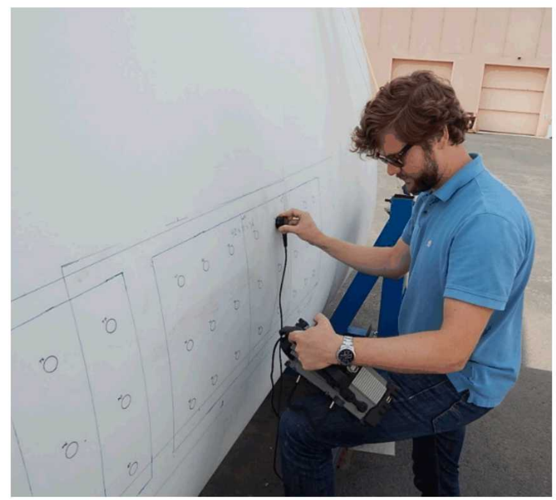




# In-Service Inspection of Wind Blade Repairs

**Installation of "Damaged" Repair on Large Scale NDI Test Specimen at Sandia**







NNSA National Nuclear Security Administration

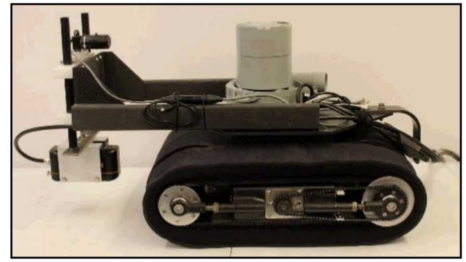
Sandia National Laboratories

# Inspecting for Lightning Damage in Carbon Blades

- Lightning is the largest operating-environment cause of blade failure.
- Activities - diagnosing the amount of damage to blade structures and its effect on the structure.
- Testing will include NDI on lightning strike specimens to determine damage response using both conventional and advanced NDI methods.

Lightning Strike Damage

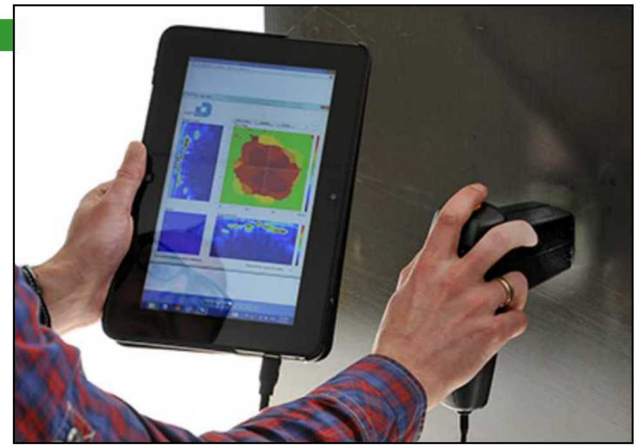
# Wind Blade In-Service Inspection – Robot-Deployed NDI System



- Automated, remotely-controlled with wireless data transfer to ground station
- Includes Phased Array Ultrasonics for full-penetration damage detection
- Combined with high-fidelity visual inspection using deployed camera
- Real-time health assessment – allows for immediate repairs during a single maintenance stop and rapid return-to-service
- Benefits are escalated for off-shore applications
- Avoid more extensive repairs and even catastrophic blade failures (replacement)

dolphitech

ICM
INTERNATIONAL CLIMBING MACHINES



Robot with On-Board NDI System and Camera(s) for Real-Time Assessments

NNSA
National Nuclear Security Administration

Sandia National Laboratories

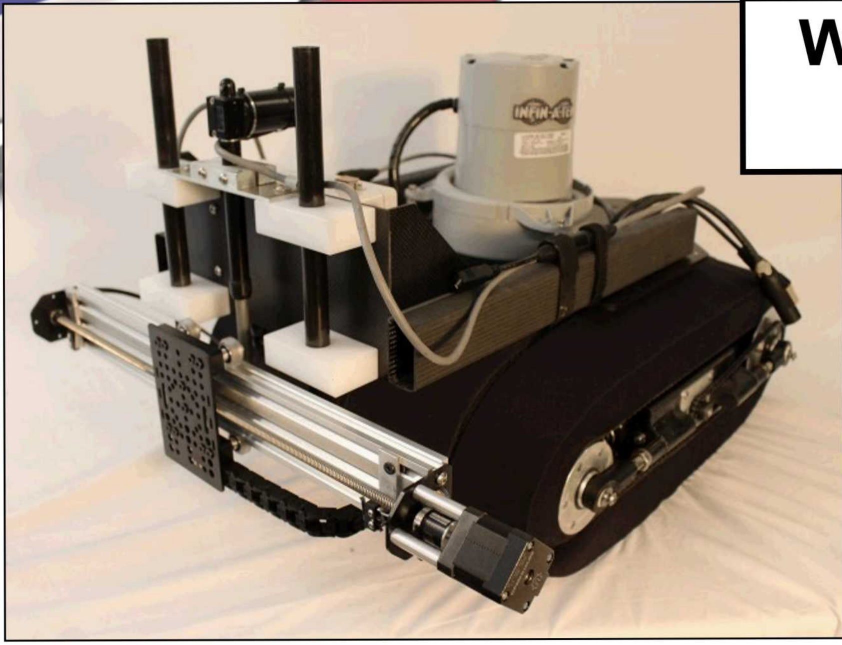
# Wind Blade In-Service Inspection – Robot-Deployed NDI System

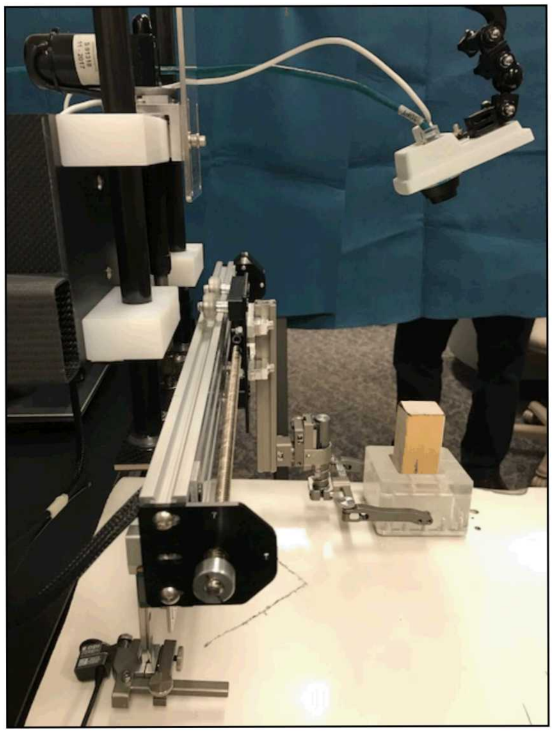
dolphitech

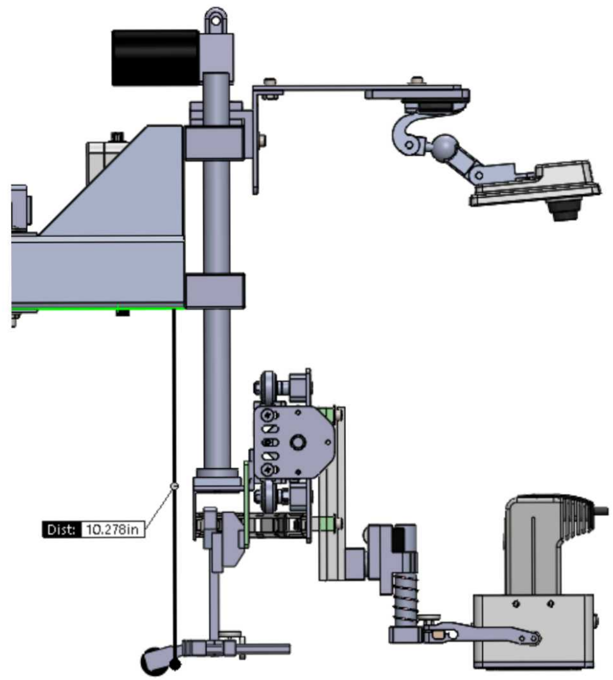
ICM INTERNATIONAL CLIMBING MACHINES

- **Goal**: produce a turnkey, automated, remotely-operated inspection system capable of detecting blade damage at all depths (full-penetration) that can rapidly inspect large regions on land-based and offshore wind blades.
- **Benefits**: System will provide cost-effective, routine, surface and subsurface inspections that previously had not been performed and thus, allow blades to reach their design life; accommodate more invasive repairs (post-repair inspection) which will avoid large replacement costs.
- **Background**: U.S. DoE *Wind Vision* roadmap identifies continuing declines in wind power costs and improved reliability will improve market competition with other electricity sources; increased availability (lower production costs) can be achieved by reducing unplanned maintenance through broader deployment of condition monitoring systems.
- **Motivation**: To minimize the risks of costly downtime and repair periods and ensure successful functioning of a wind farm, it is necessary to conduct in-service inspections. As the length of blades increase and operational environments produce high stress levels in the blades, it has become increasingly important to detect the onset of damage or the propagation of fabrication defects during blade operation. Detailed NDI is also necessary to firmly establish if repairs are needed and to assess the quality of the repair (post-repair inspections). Small defects can propagate to levels of concern during blade use while fatigue loading, bird/hail impact, lightning strike, erosion and other in-service conditions can lead to new damage in the blades.

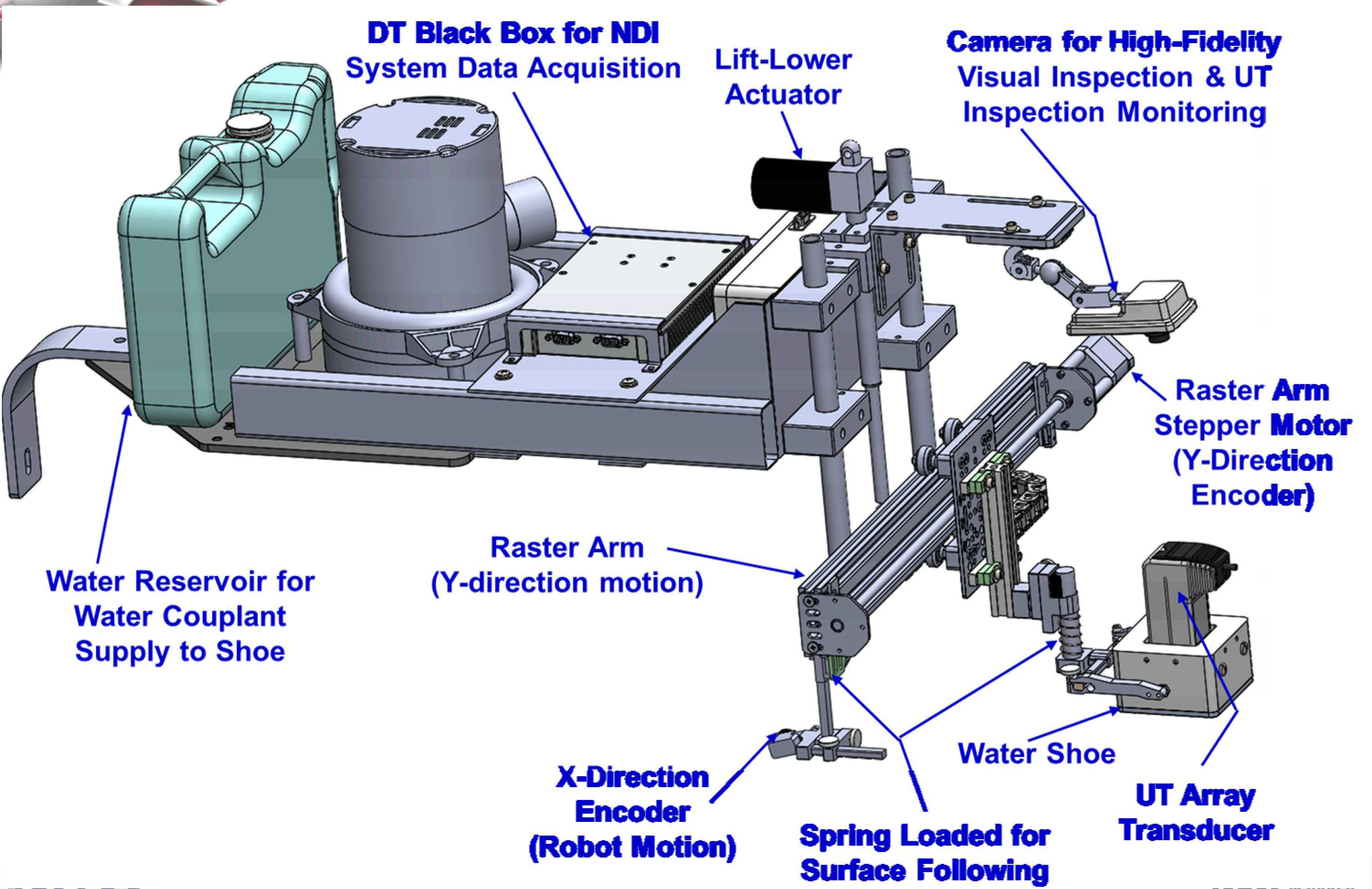
# Wind Blade In-Service Inspection – Robot-Deployed NDI System



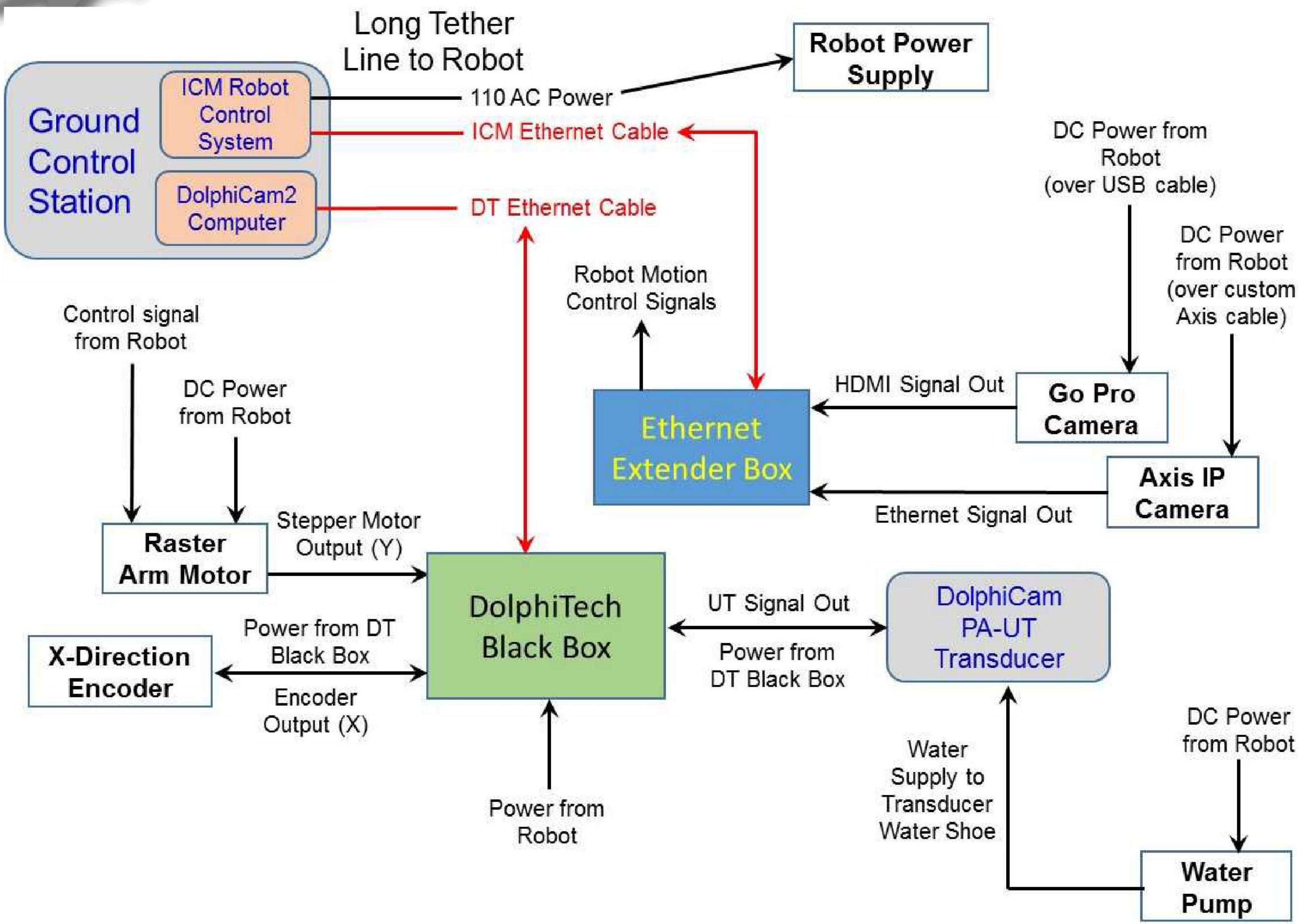




# Component Integration on Robot Superstructure



# Robot-Deployed NDI System – Schematic of Power, Controls and Data Transfer

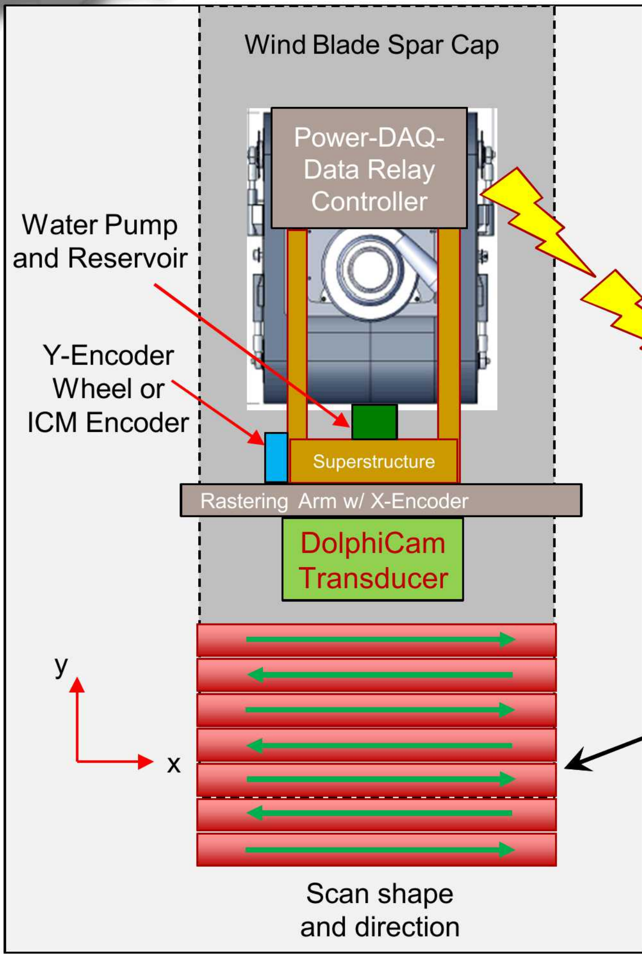


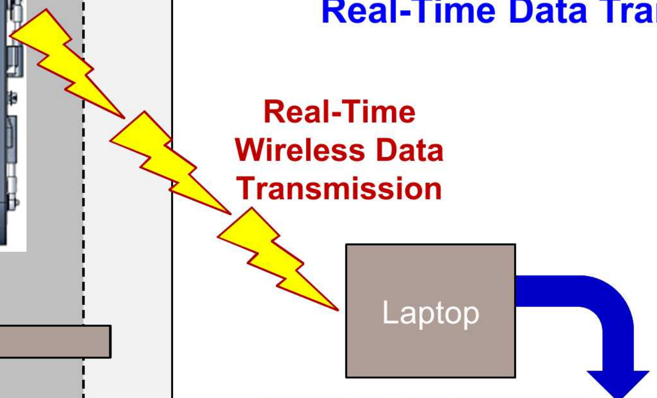

Sandia National Laboratories

# Wind Blade In-Service Inspection – Robot-Deployed NDI System

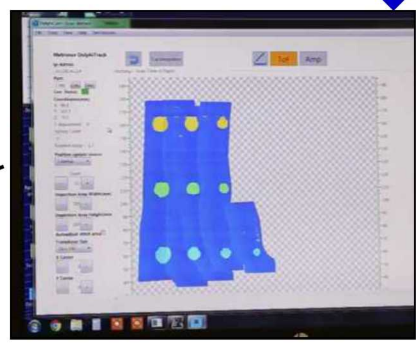
dolphitech

ICM INTERNATIONAL CLIMBING MACHINES

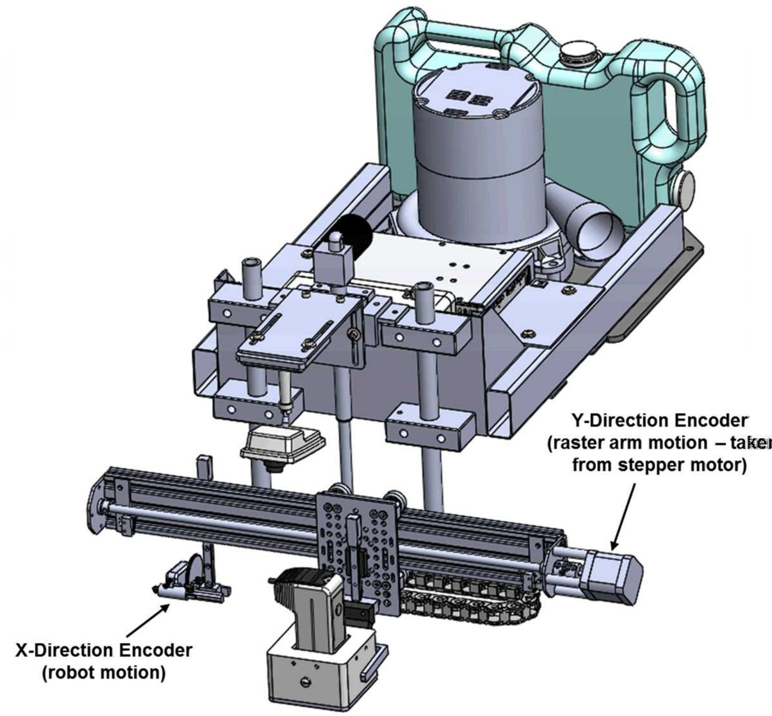



**Low-Frequency Dolphi-Cam UT Imaging System with DAQ Box for Power and Real-Time Data Transfer**



**Inspection Image**




**Robot increments in small X step and then rastering arm on robot moves DolphiCam head in the Y-direction. Repeat this process to produce a 2-D C-scan.**

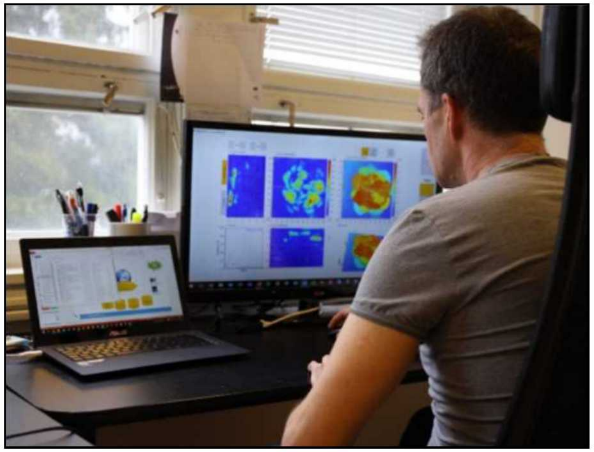
NNSA National Nuclear Security Administration

Sandia National Laboratories

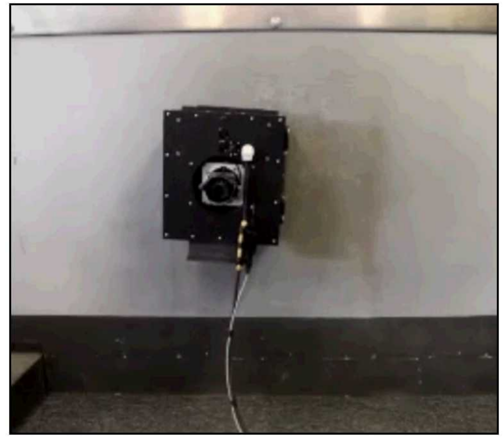
# Wind Blade In-Service Inspection – Robot-Deployed NDI System

dolphitech

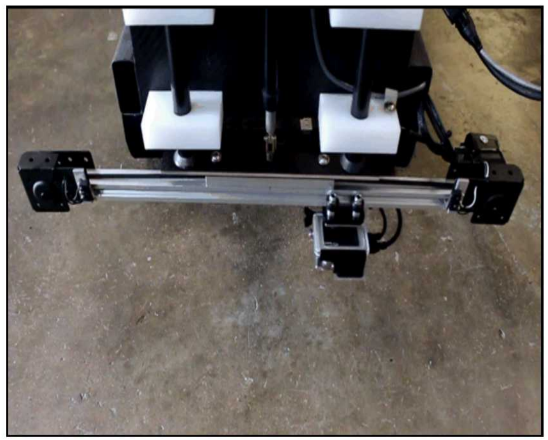
ICM INTERNATIONAL CLIMBING MACHINES



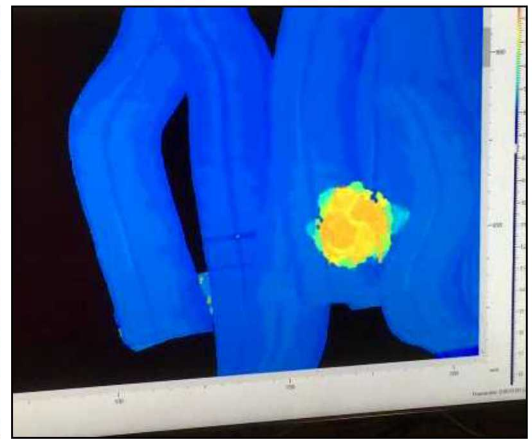
Ground Workstation – Data Acquisition & Analysis Plus Control of Robot



Robot Crawling on Vertical Surface



Raster Scan of Area



C-Scan Inspection Image

NNSA National Nuclear Security Administration

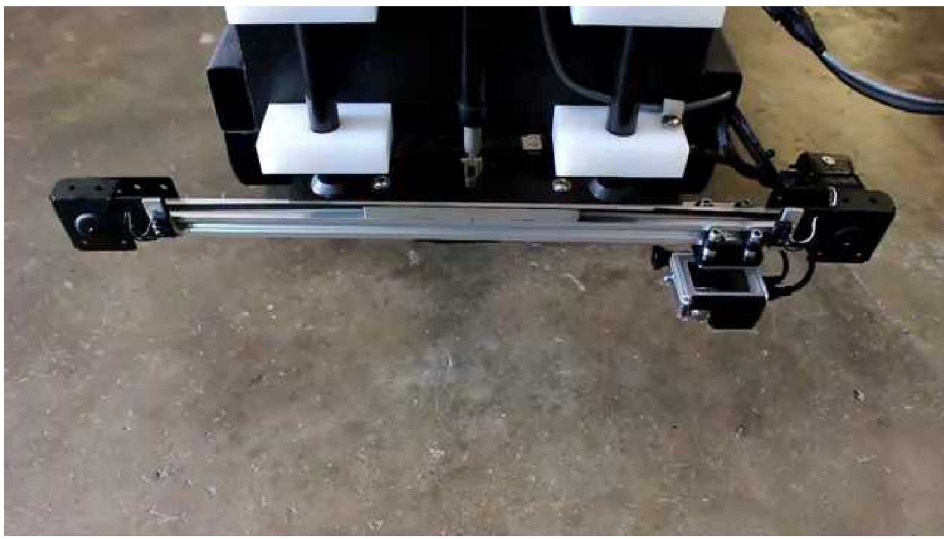
ON-GROUND ← → ON-BLADE

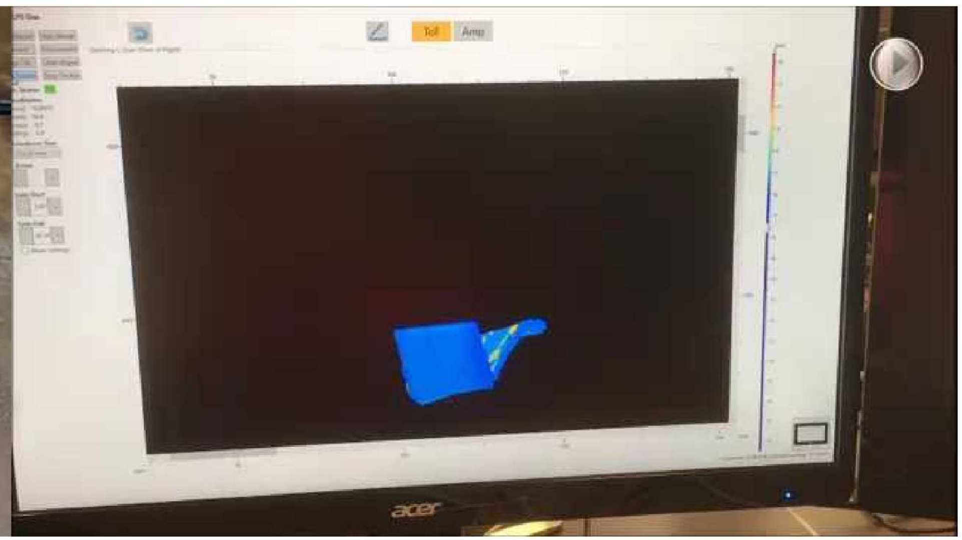
Sandia National Laboratories

# Wind Blade In-Service Inspection – Robot-Deployed NDI System

**Robot Crawling on Vertical Surface**

**Raster Scan of Area to Produce C-Scan Inspection Image**





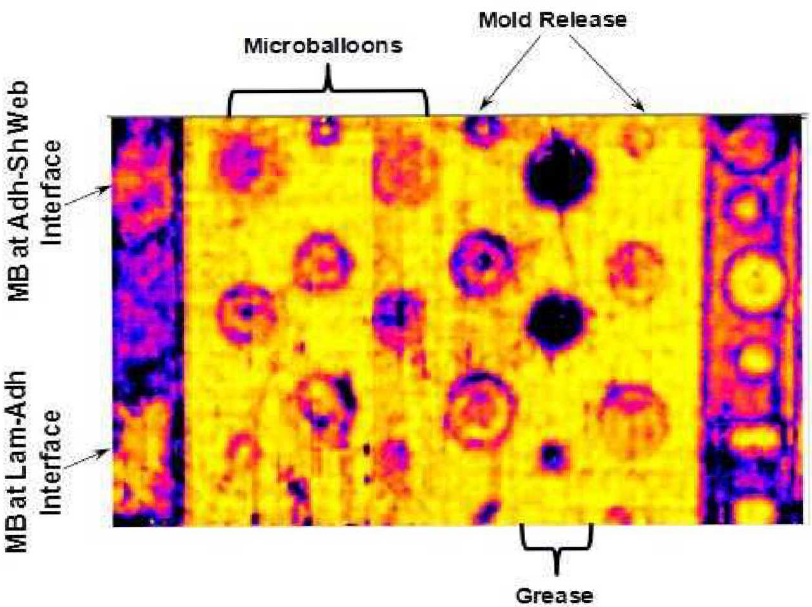

dolphitech

ICM
INTERNATIONAL CLIMBING MACHINES

NNSA
National Nuclear Security Administration

Sandia National Laboratories

# Robot-Deployed NDI System – Initial System Validation Testing




NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade In-Service Inspection – Drone-Deployed NDI System


National Nuclear Security Administration

Thermal Wave Imaging

SKYSPECS

Sandia National Laboratories

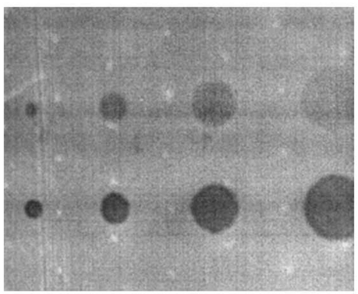
# Wind Blade In-Service Inspection – Drone-Deployed NDI System

SKYSPECS

## Thermography Inspection of Subsurface Flaws


Flir IR Camera

(320 X 256 pixels)

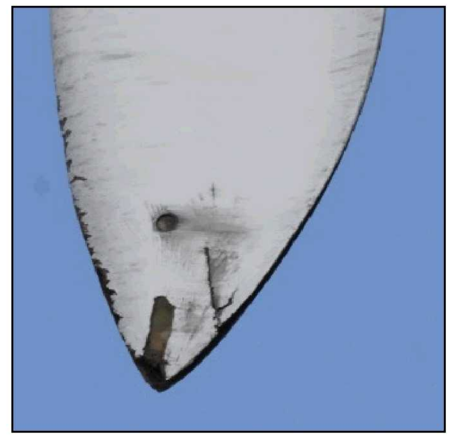


LiDAR and GPS Sensors & Computer for Automated Drone Controls

LiPo Batteries

## Visual Inspection of Surface Flaws

Digital Camera



NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade In-Service Inspection – Drone-Deployed NDI System

SKYSPECS

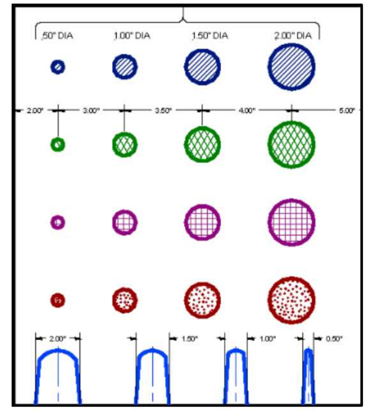
Thermal Wave Imaging

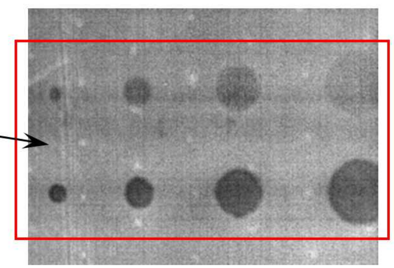
## Solar Radiation Thermography

**Heating: Blades Facing Sun**

**Cooling: Blades Facing Away from Sun**

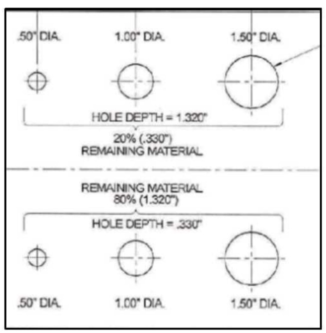
## Foam Core with Fiberglass Skin



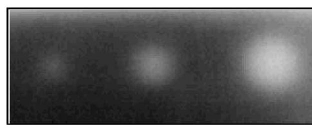


Heating Duration: 60s

## Thick Fiberglass Spar Cap




.330" Deep Flaws Clearly Visible



.660" Deep Flaws Barely Visible

Heating Duration: 120s

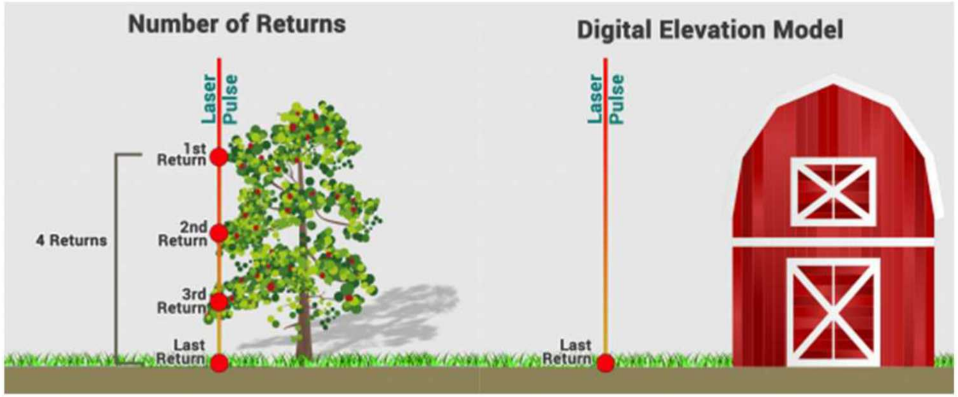
**IR Images of Engineered Damage**

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade In-Service Inspection – Drone-Deployed LiDAR Sensors

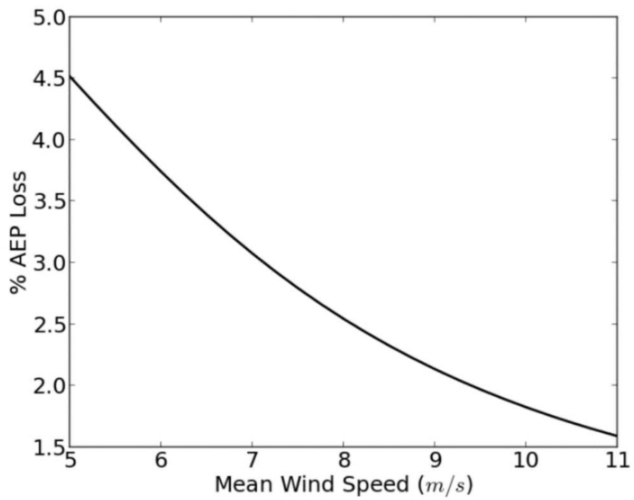
Leddar M16 LiDAR Sensor



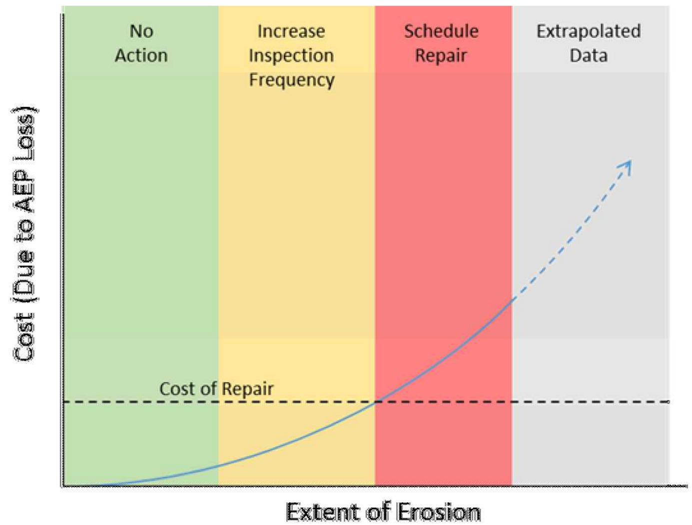

Example of Multiple and Single LiDAR Returns
(http://gisgeography.com/lidar-light-detection-and-ranging)

**Using LiDAR sensors to measure leading edge erosion, predict AEP loss, and provide guidance on performing erosion repairs**

Erosion Example



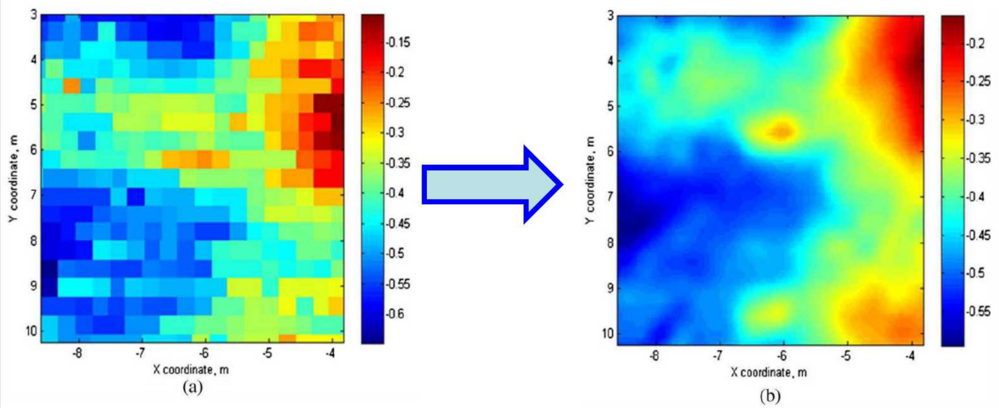

Decrease in Annual Energy Production vs. Mean Wind Speed
(Maniaci, D., "Leading Edge Erosion: Measurement and Modeling Campaigns," Sandia Report, SAND2016-8898, August 2016.)



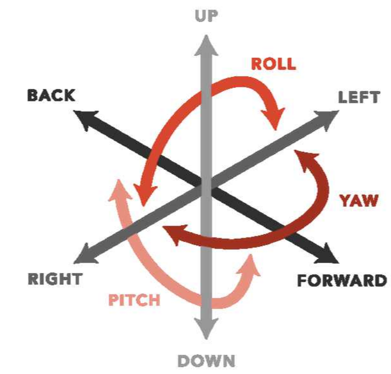

Notional Example of LiDAR-Based Decision Making

# Wind Blade In-Service Inspection –
# Drone-Deployed LiDAR and IR Camera Integration

**Use NASA's SuperResolution Algorithm to Process Data**



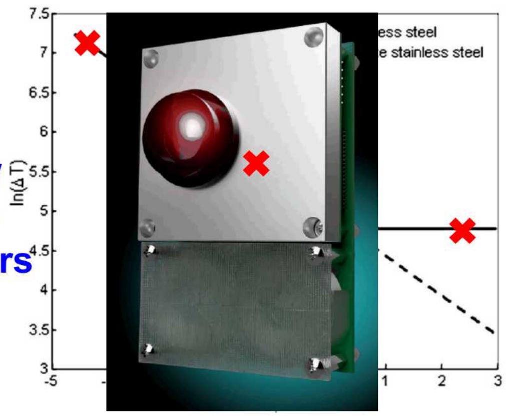

**Increase LiDAR Resolution**



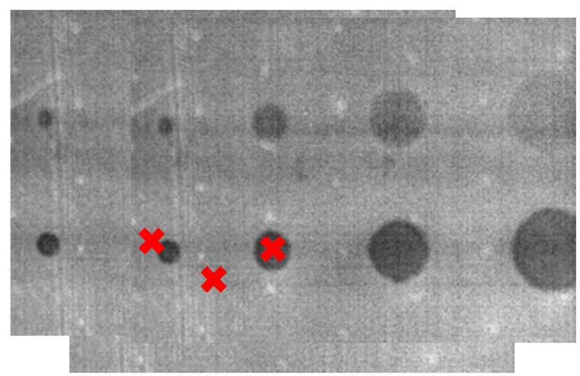

**Measure Relative Changes in 6 DOF state vector**

**Enables the drone to track relative position and orientation changes in order to measure IR data at an area of interest over time**

**Enables the use of low weight, low resolution solid-state LiDAR sensors**




**Temperature vs. Time history is needed to use Thermal Wave Imaging's TSR algorithm**



ETV

Thermal Wave Imaging

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade In-Service Inspection – Automated Damage Classification

- The goal is to produce an automated Damage Assessment and Maintenance Plan with actionable recommendations for Owner/Operators

## Establish Damage Severity Levels


LE erosion has penetrated into the blade structure exposing the underlying laminate of the leading edge.


LE erosion has removed the protective gelcoat and begun to penetrate into the bond and had exposed the underlying laminate of the leading edge.


LE erosion has removed the protective gelcoat and begun to minimally penetrate into the bond.


LE erosion has begun and appears to be superficially limited to the outer protective gelcoat.


The leading edge shows beginning signs of LE erosion and is limited to the outermost, superficial layers of protective gelcoat.

**Use Image Augmentation Techniques to Increase the Size of the Training Set**

**Train and Validate Damage Classification Neural Network**

**Next Phase**: Add NDI methods to develop a more advanced damage classification system

**Challenge**: Acquiring enough images of damage to create a strong training set

NNSA National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade Flaw Detection Needs –
# Role of Inspection in Production and Operation

- **Need for accurate NDI** becomes more important as the cost per blade, and lost revenue from downtime, grows
- **Many Inspection Challenges** - very thick and attentive spar cap structures, porous bond lines, varying core material & different manuf./in-service defects
- **NDI Practices Vary Widely** – differing levels of rigor & methods used
- **In-Service Inspection Needs** - damage from transportation, installation, stress, erosion, impact, lightning strike, and fluid ingress
- **In-Service Inspection Considerations** - NDI fidelity beyond what can be provided by visual methods is required; time, cost, & sensitivity needs (minimize production, maintenance and operation costs)
- **Sandia Labs NDI Evolution** – WBFDE quantitatively assessed performance of NDI to allow for optimum deployment of more sophisticated inspection methods; there are sensitive & rapid NDI options available
- Results can produce **improvements** in both **quality assurance measures during blade production** and **damage detection during operation** in the field - improve sensitivity, accuracy, repeatability & speed of inspection coverage
- Detection of fabrication defects helps enhance plant reliability while improved inspection of operating blades can result in efficient blade maintenance - **increase blade life; facilitate repairs before critical damage levels are reached and minimize turbine downtime**

# Wind Blade Inspection Program – Path Forward

**Next set of NDI tasks seek to help wind blades reach their design life and efficiently provide the necessary life management tools to maximize wind farm operations.**

## Automated Blade NDI In-Service

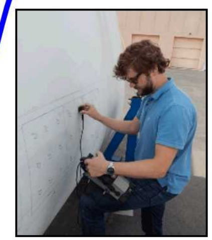
Drone System

Robot System

## Blade Production QA

## FY19 Activities

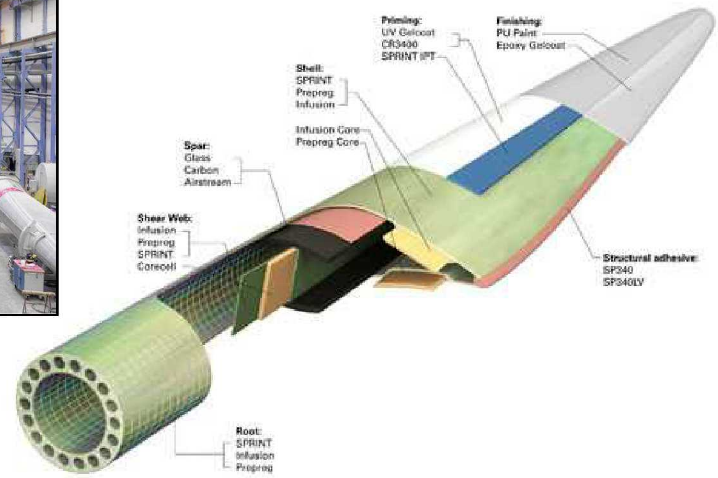
## Blade Repair Inspection

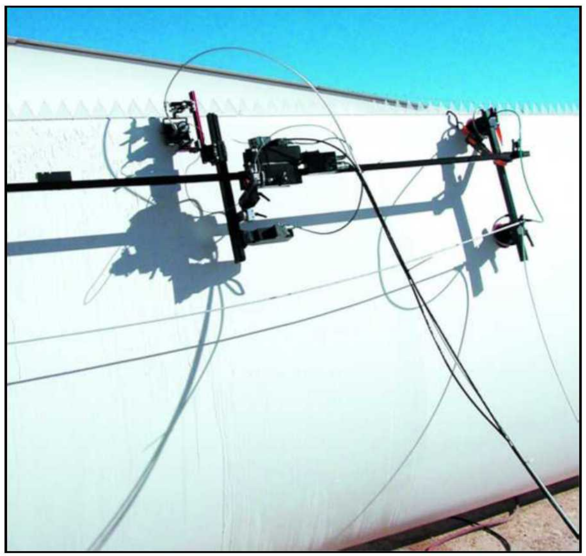


## Blade Health Assessment Validation Center


NNSA National Nuclear Security Administration

Sandia National Laboratories



**Dennis Roach, Ray Ely**
**Sandia National Labs**
**(505)844-6078**
**dproach@sandia.gov**
**grely@sandia.gov**

National Nuclear Security Administration

Sandia National Laboratories

# Wind Blade In-Service Inspection – Drone-Deployed NDI System

- Through Sandia's New Mexico Small Business Assistance (NMSBA) program, we partnered with Emerging Technology Ventures to develop a plan for integrating NDI sensors with aerodynamics modeling and machine learning
- The goal is to produce an automated Damage Assessment and Maintenance Plan with actionable recommendations for Owner/Operators