SAND2010-0655C

2009 NREL Wind Turbine Condition Monitoring Workshop

NDT, CM and SHM of Wind Turbine Blades at the National Labs

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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.

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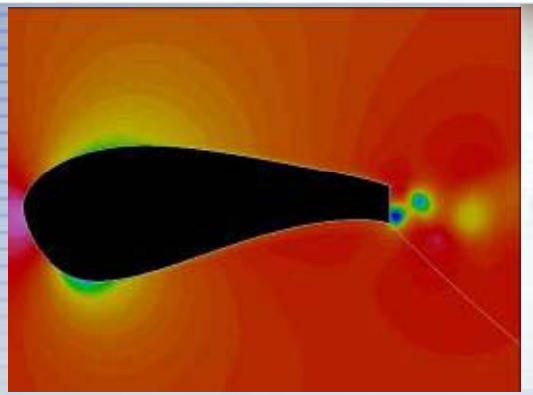
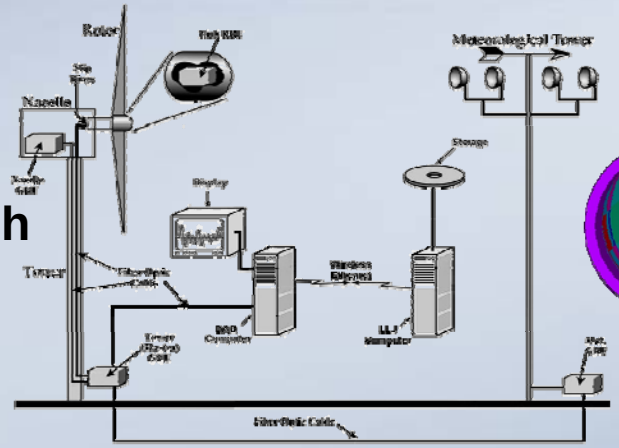
Presentation Overview

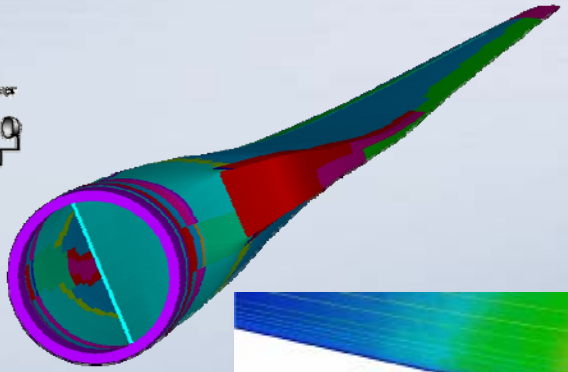
- Wind Turbine Blade R&D
- Challenges
- NDT, CM and SHM Examples

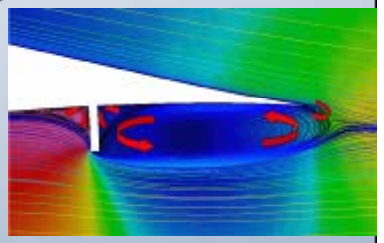
Sandia Wind and Water Power Technology

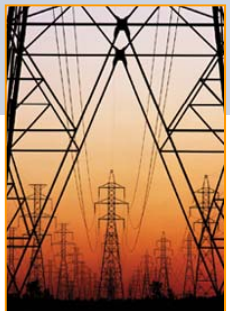
- **Blade Technology**
  - Materials and Manufacturing
  - Structural, Aerodynamic, and Full System Modeling
  - Sensors and Structural Health Monitoring
  - Advanced Blade Concepts
  - Lab - Field Testing and Data Acquisition
- **System Reliability**
  - Industry data collection
  - Improve reliability of the existing technology and future designs
- **System Integration & Outreach**
- **Water Power**

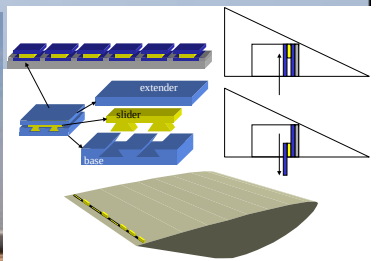






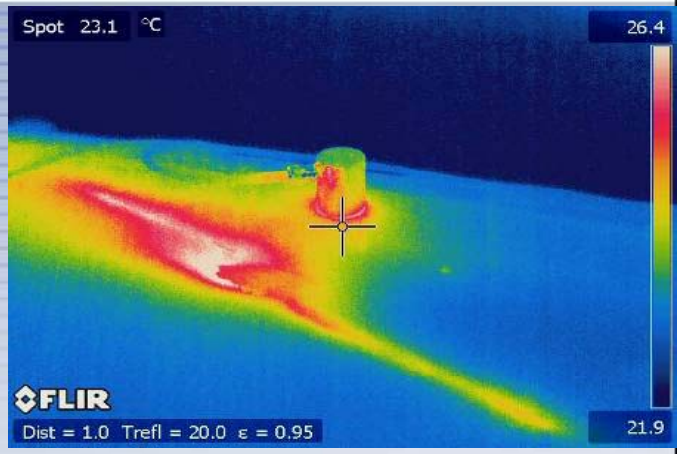


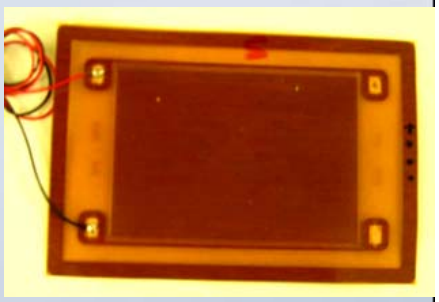




Sensor-Related Tasks at Sandia Labs

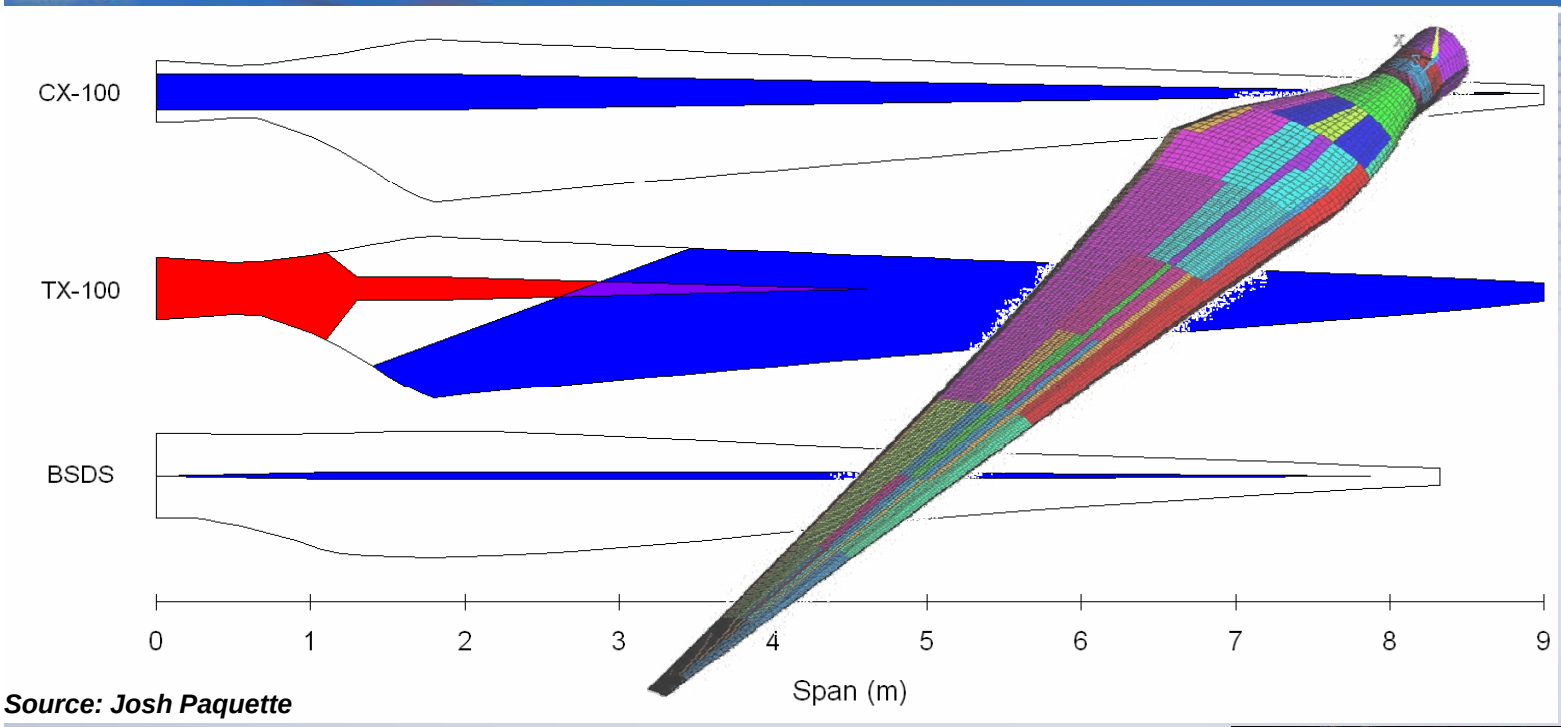
- **Laboratory and field Testing (Lead: Josh Paquette)**
  - Blade model validation
  - Blade performance and diagnostics
- **Blade Manufacturing (lead: Daniel Laird)**
- **Reliability (Lead: Paul Veers)**
- **Next-generation of wind turbine blades**
  - Sensor Blade Projects (Lead: Mark Rumsey)
    - Evaluate applicable sensing technologies
    - Address sensor-in-blade issues (Manufacturability, Reliability, Cost)
    - Determine sensor requirements for active aero blade
  - Active-aero Project (Lead: Dale Berg)
    - Develop/modify structural and aero models
    - Model and validate sensor/actuation performance
    - Research fast active devices to augment active pitch control
    - Build and test subscale structures
    - Build and test a SMART rotor





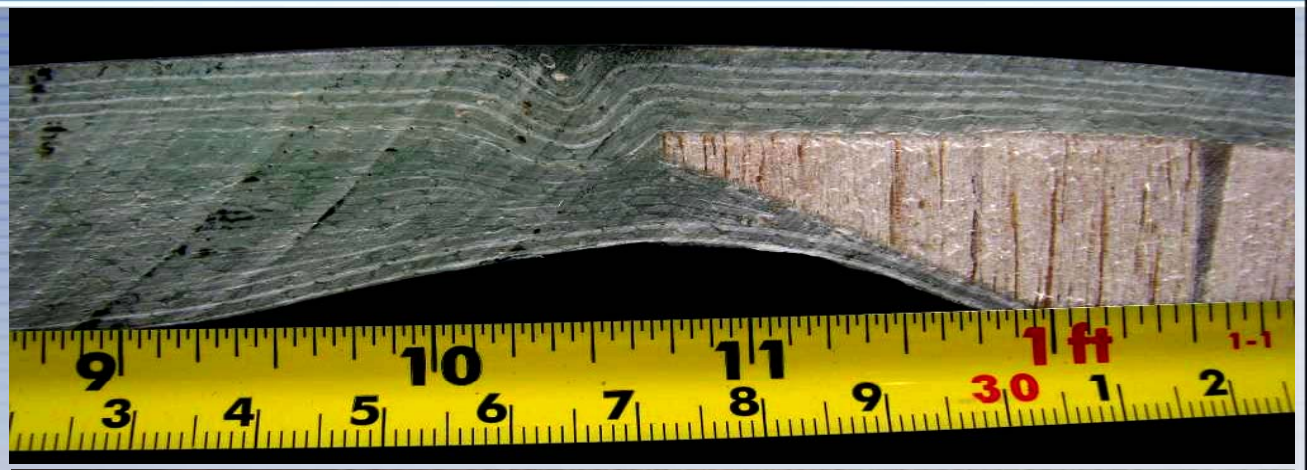
Sandia Blade Research Projects

Blade Geometry and Major Laminate Regions



Source: Josh Paquette

Challenges – Defects … cosmetic or not?

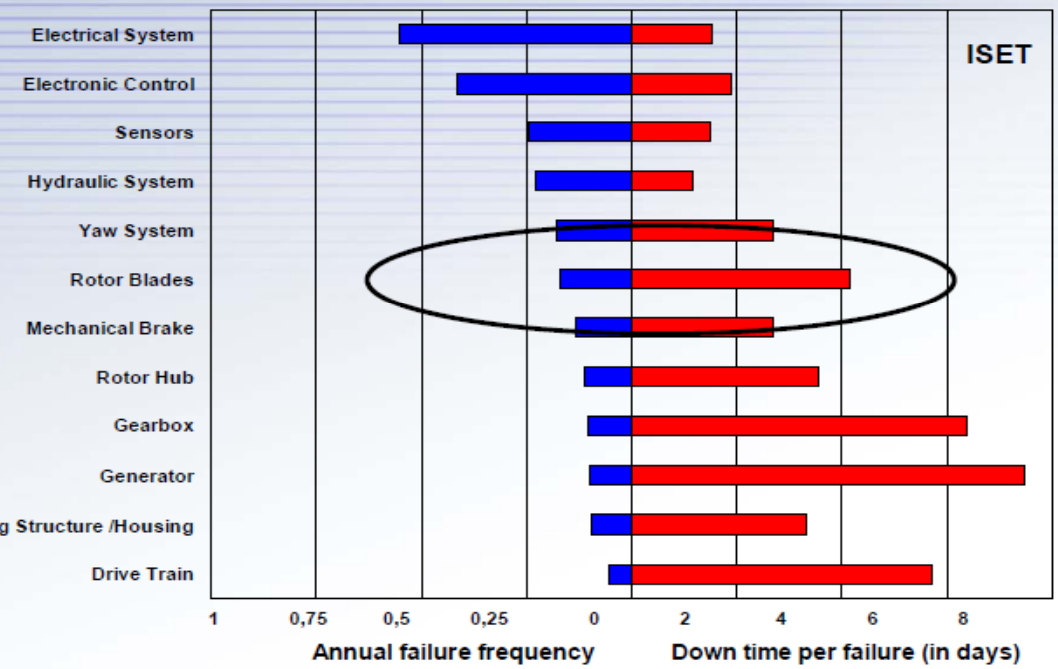


Challenges – Wind Turbine Reliability

"80% of the blades that require repair have never been flown."
Gary Kanaby, Knight & Carver Wind Blade Division.

Blade Reliability

- Blades are being delivered to the site in a condition that often requires additional treatment of quality issues before they can be installed
- Rare installations need to have all the blades replaced after the discovery of a batch problem
- Blade failure can cause extensive down time and lead to expensive repairs.
- *Blade reliability issues need early attention because of the lost production and cost of significant failures*



Historical European Experience (Paul Kühn, ISET)

Blades are in the middle – medium failure rate, relatively high cost.
US environments may be more aggressive.

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Source: Veers and Hill, 2008 Blade Workshop (http://www.sandia.gov/wind)

Challenges – The Monitoring

Monitor What?

- loads, wind dynamics, turbine dynamics, strains, temperature gradients, …

Monitor Where? (location, location, location)

- manufacturing defects, joints, bond lines, cracks, dry-spots, voids, discovered defects, impacts, design stress concentrations, …

Monitor with What? (sensing technology)

- piezo-based sensor/actuators, metal-foil strain gages, optical strain gages (FBGs), acoustic emission sensors, accelerometry, IR thermography, …

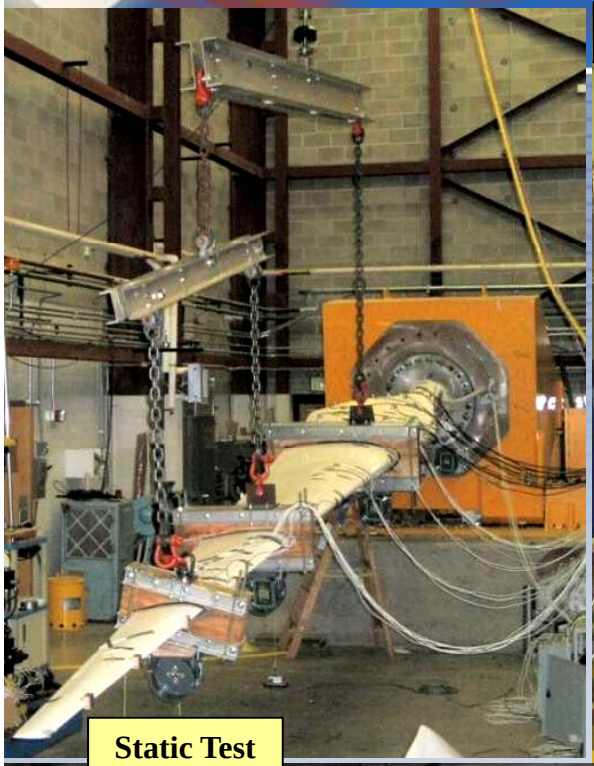
Monitor When? (and how often)

- condition-based versus schedule-based

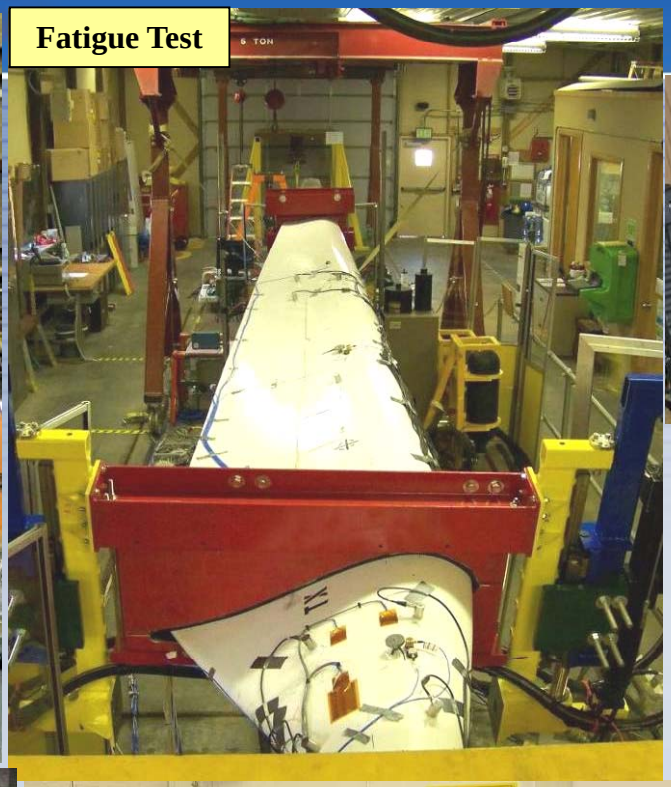
Monitor How? (technique)

- integration method, redundancy, interrogation, NDT, CM, SHM, PHM, …

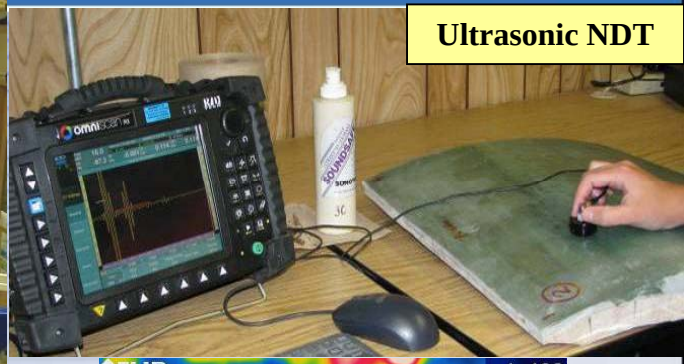
Blade and Substructure Testing



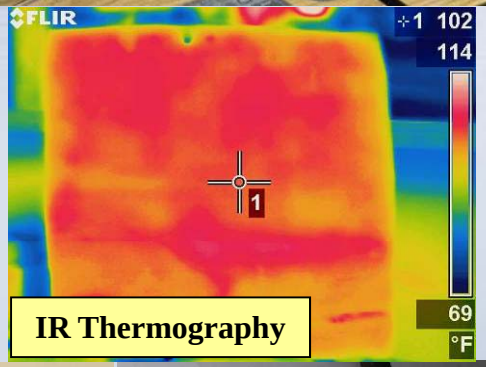
Static Test



Fatigue Test



Ultrasonic NDT



IR Thermography

Radiography

Flash Thermography

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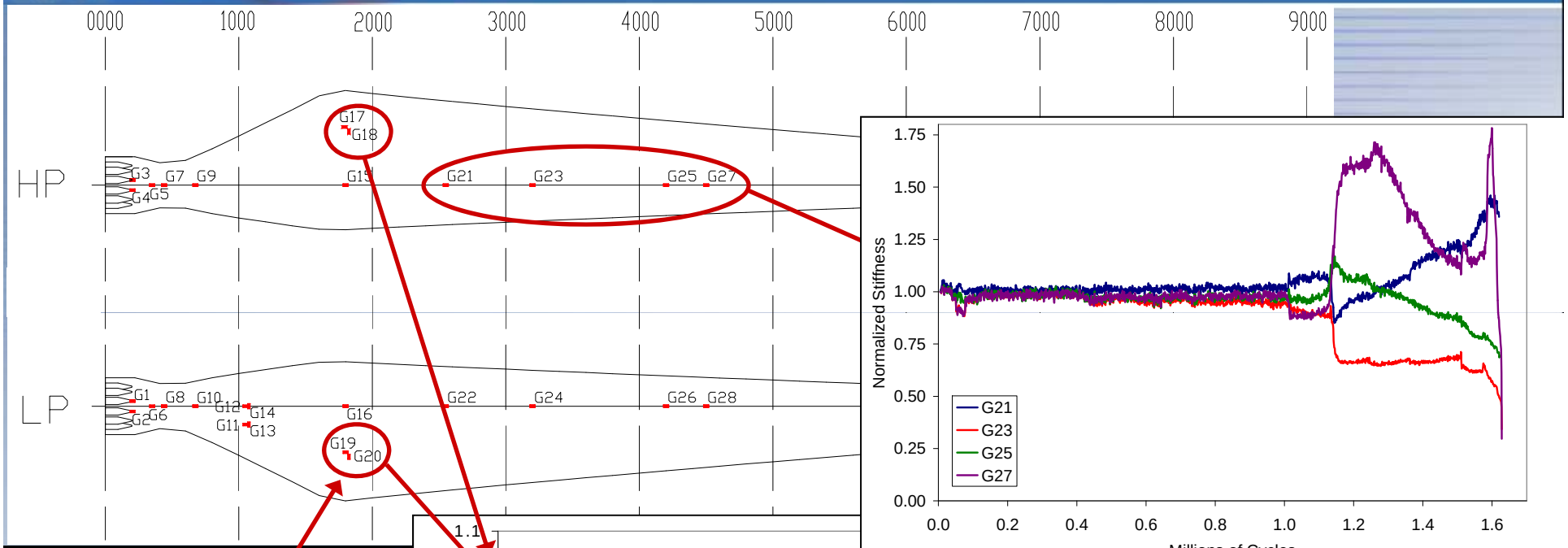
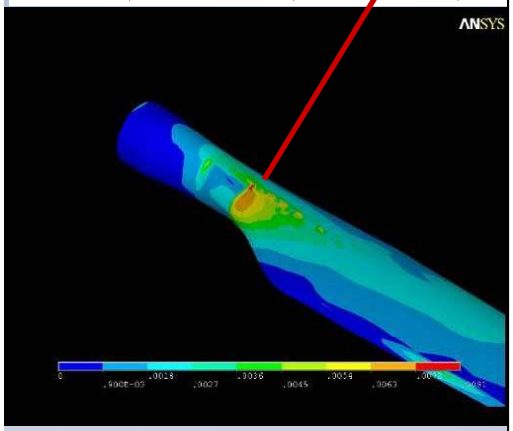
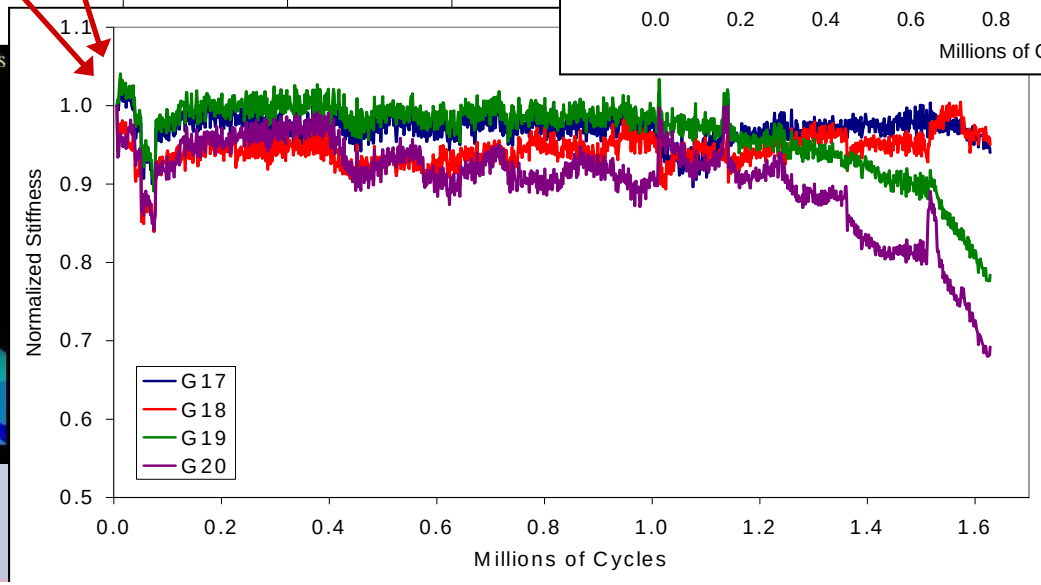
Metal-Foil Strain Gaging Setup and Response

during a Fatigue Test of Sandia CX-100 Blade







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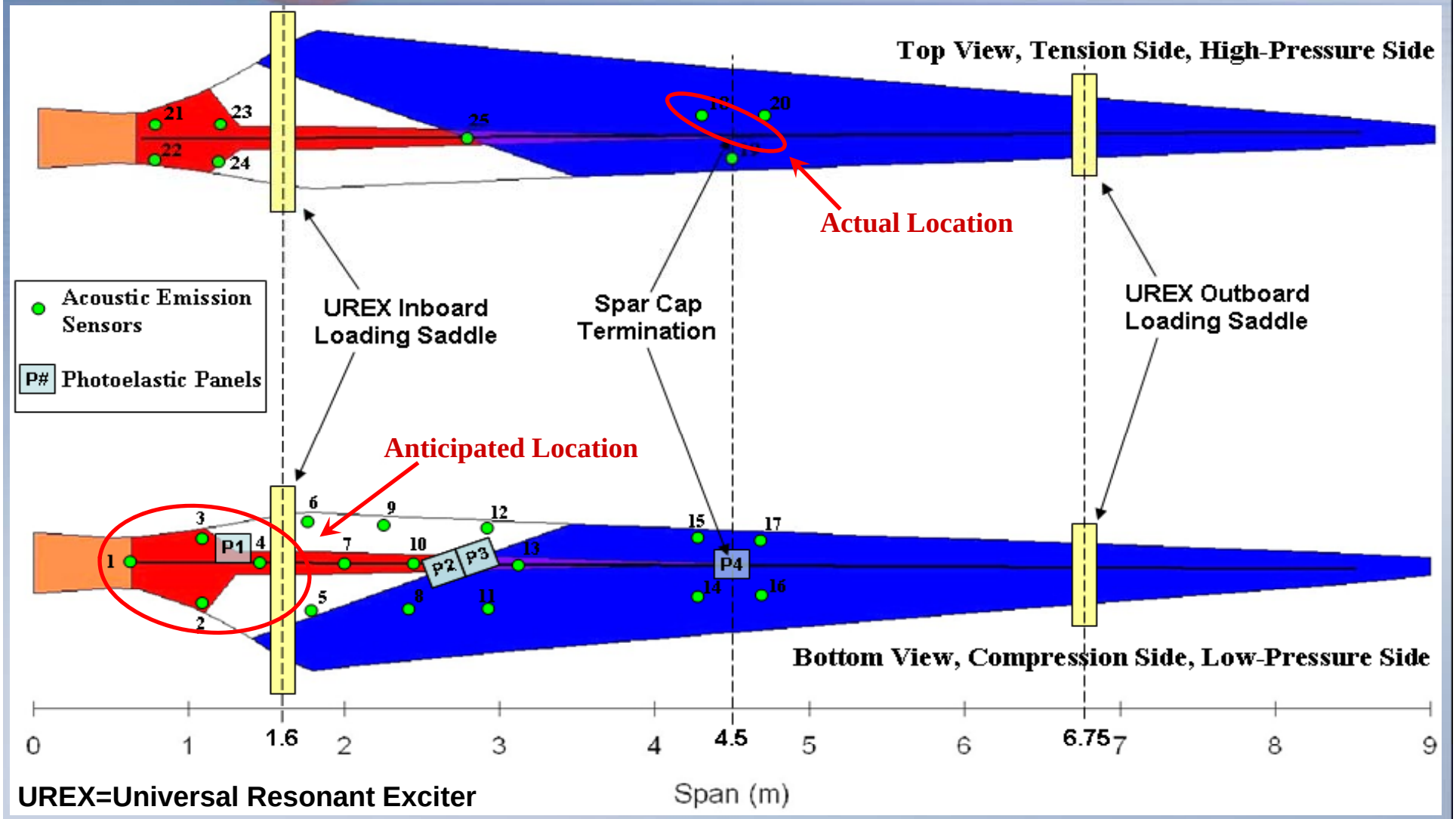
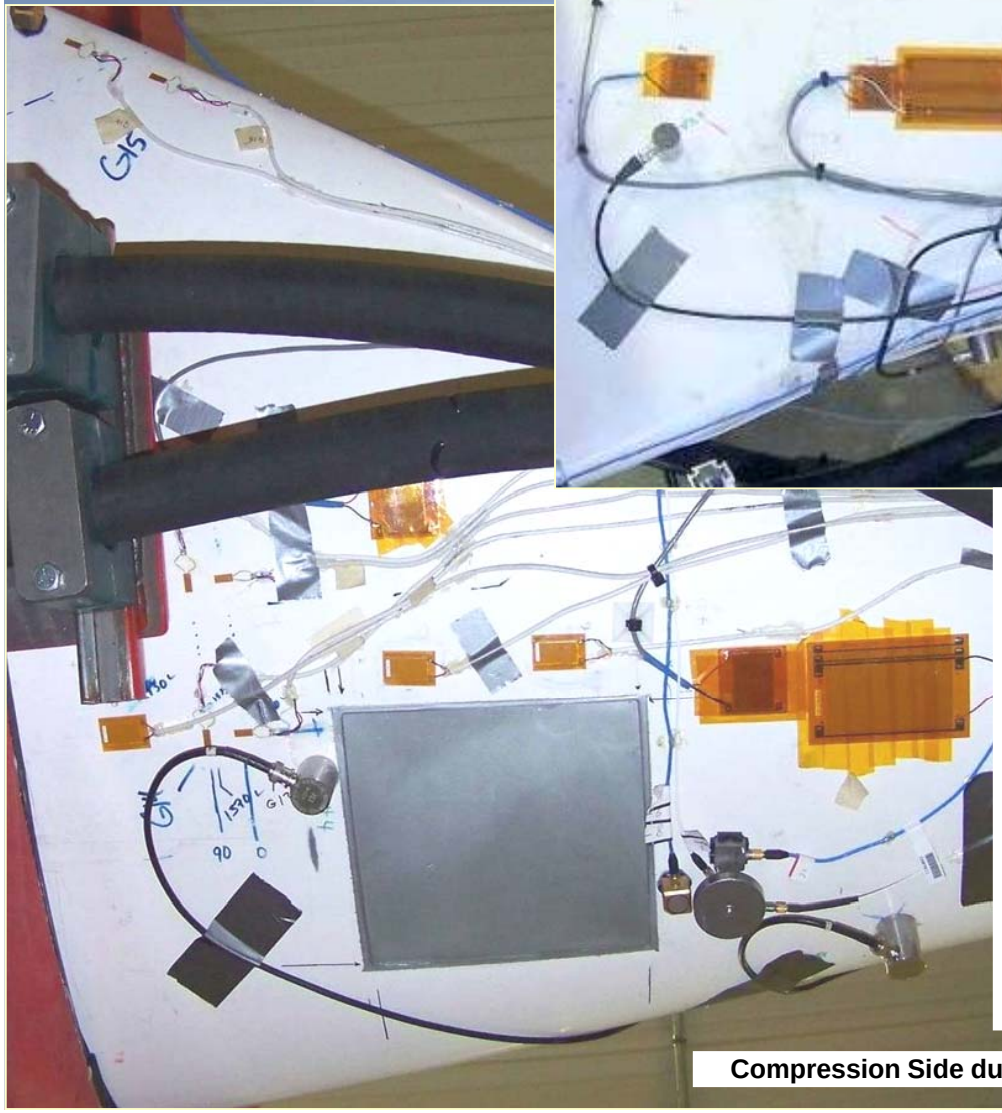
Fatigue Test Setup for TX-100 Blade



UREX=Universal Resonant Exciter

Lab Test Setup of TX-100 Blade

Tension Side during Blade Test



Compression Side during Blade Test

List of devices shown in the photos:

- Macro Fiber Composite (MFC) piezoelectric sensors/actuators
- acoustic emission NDI sensors
- metal foil strain gages
- photoelastic panel
- single axis accelerometer
- two multi-axis accelerometers
- force actuator
- force transducer

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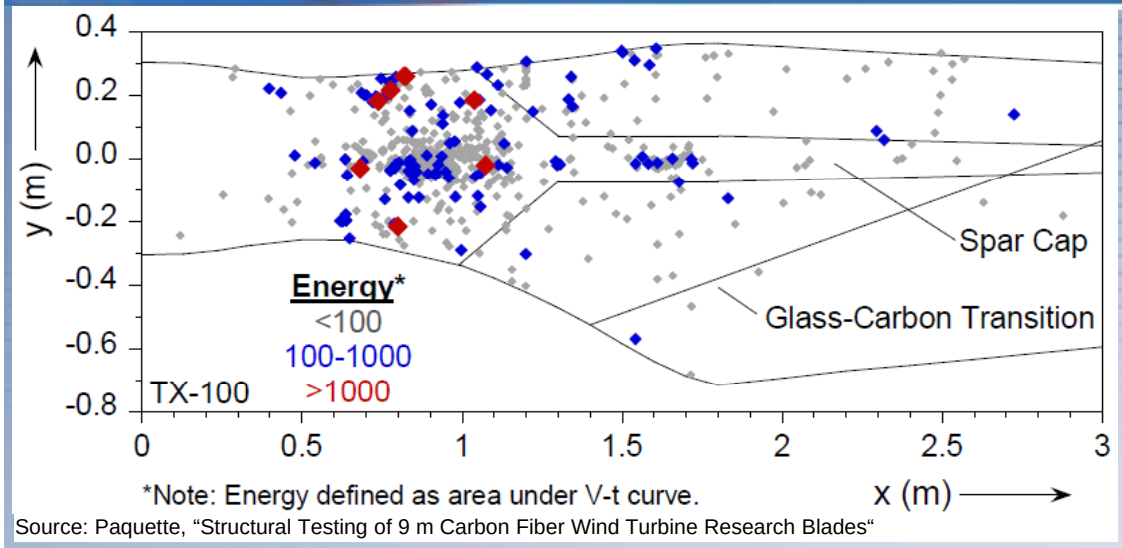
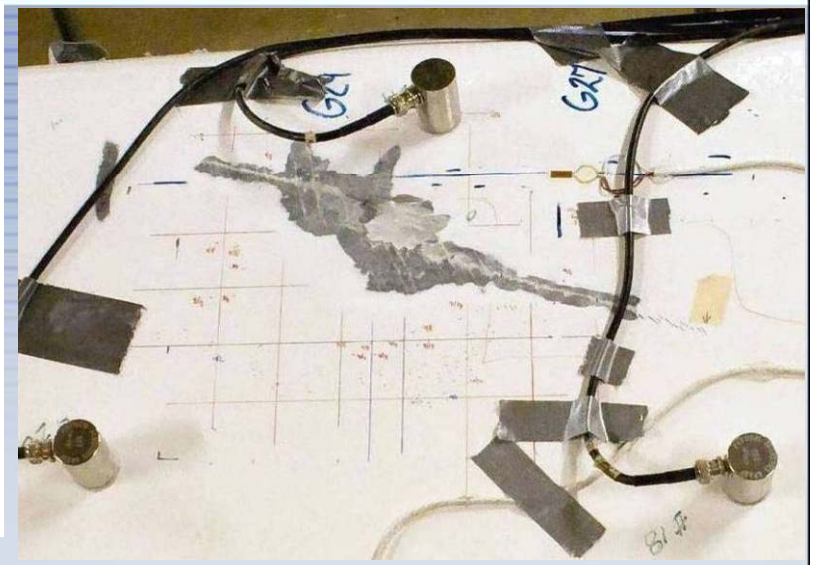
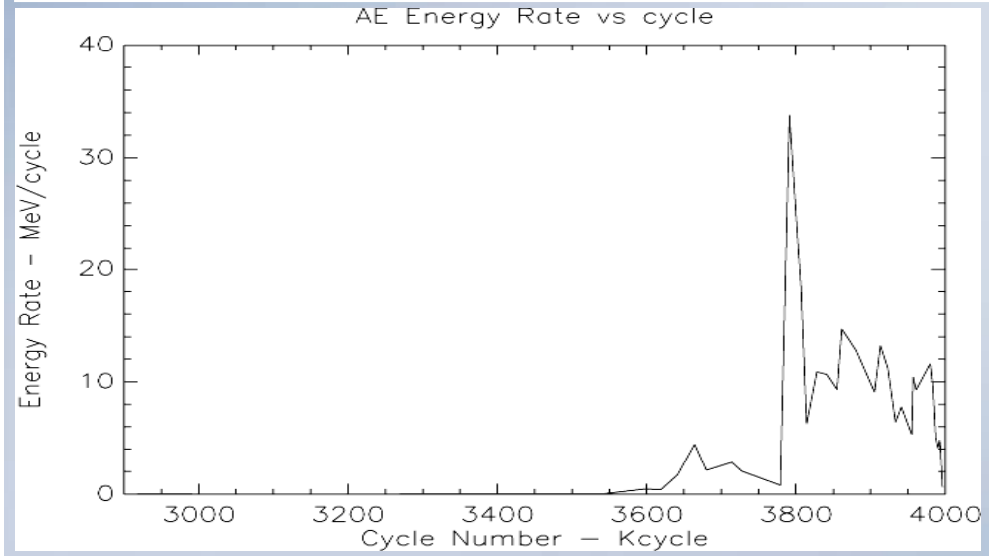
Response from Acoustic Emission NDT

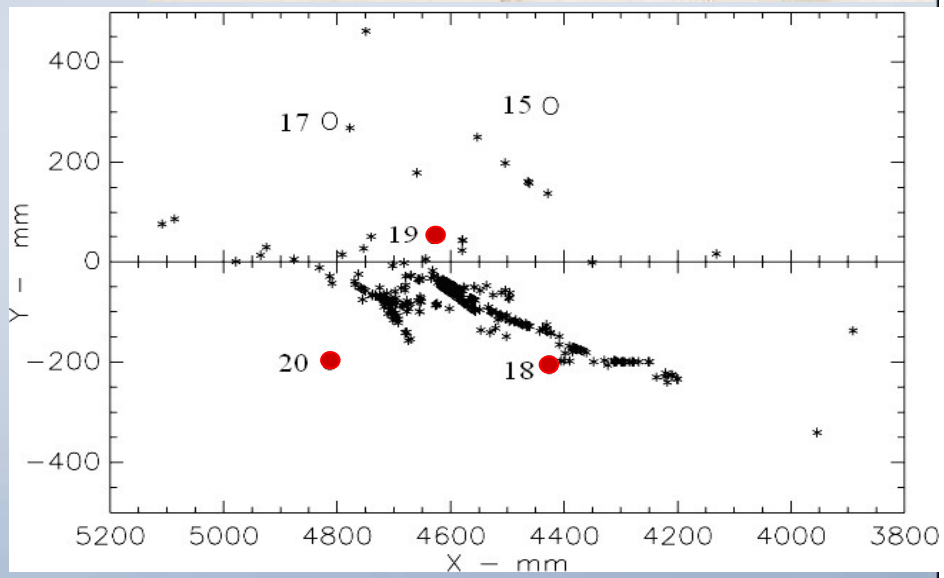
during a Fatigue Test of Sandia TX-100 Blade



Source: Paquette, "Structural Testing of 9 m Carbon Fiber Wind Turbine Research Blades"







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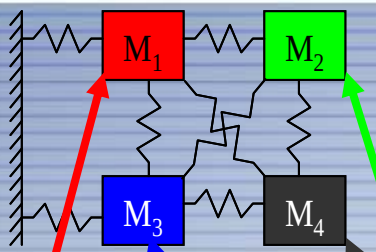
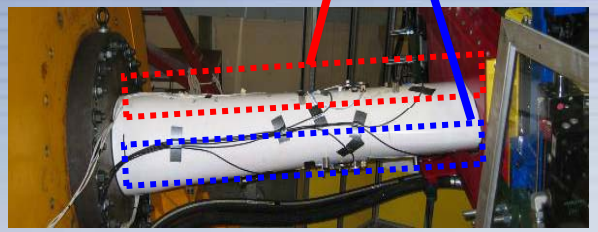
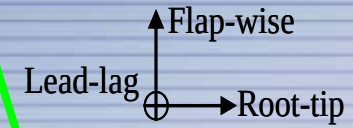
SHM on a Sandia Labs TX-100 Blade

Active Damage Detection – Method of Virtual Force

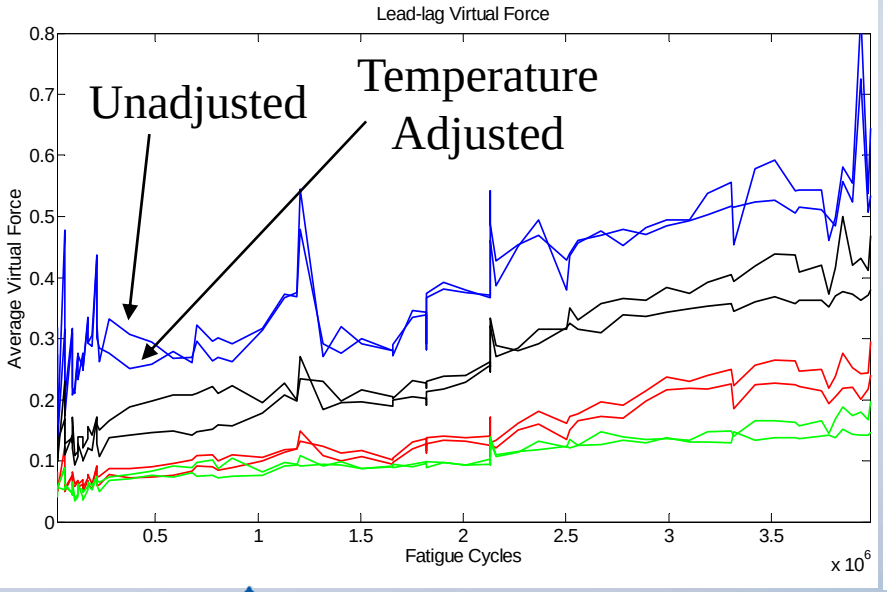
Active in-plane Virtual Forces sensitive to damage.

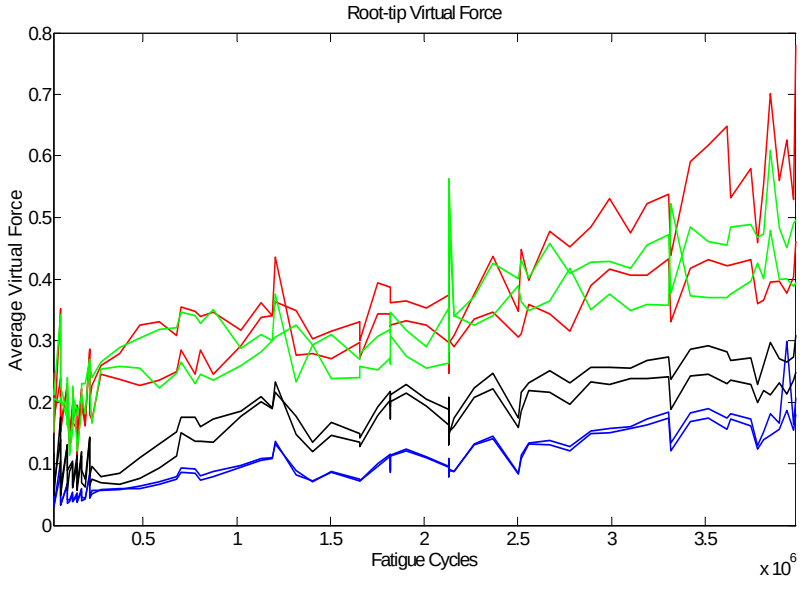






SHM performed by Jon White and Doug Adams





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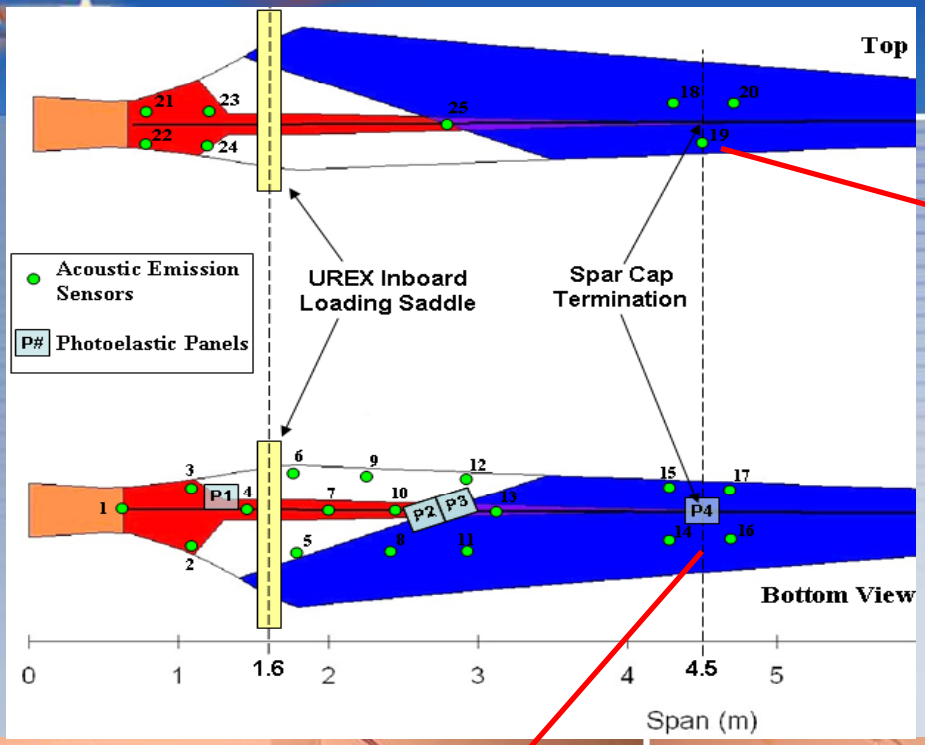
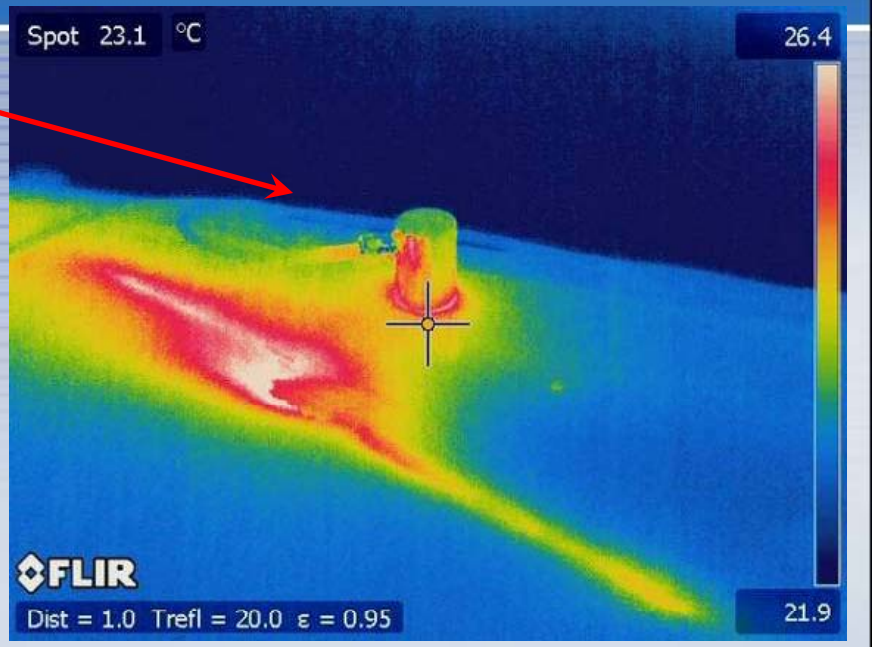
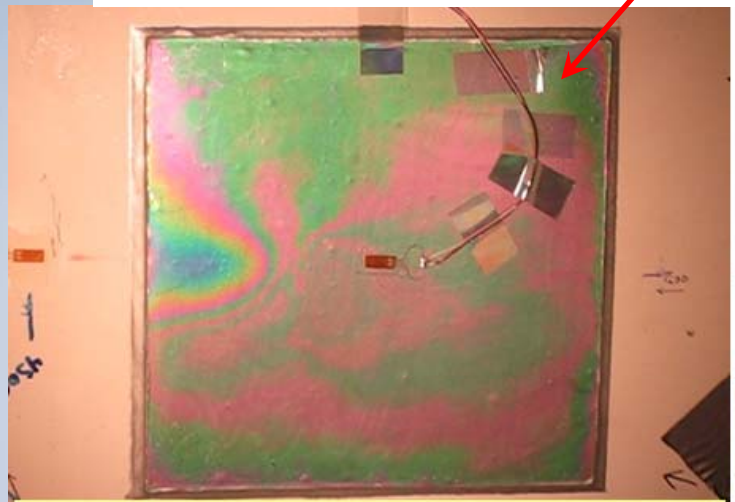
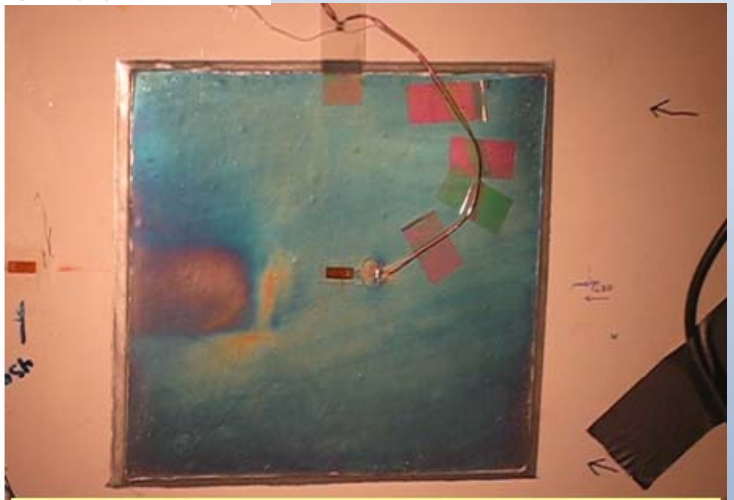
Photoelastic and Infrared Thermography







Shot at maximum load: maximum compression load on lower surface, maximum tensile load on upper surface.



Shot at minimum load: minimum compression load on lower surface, minimum tensile load on upper surface.

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Sandia Lab Sensor Blade Project

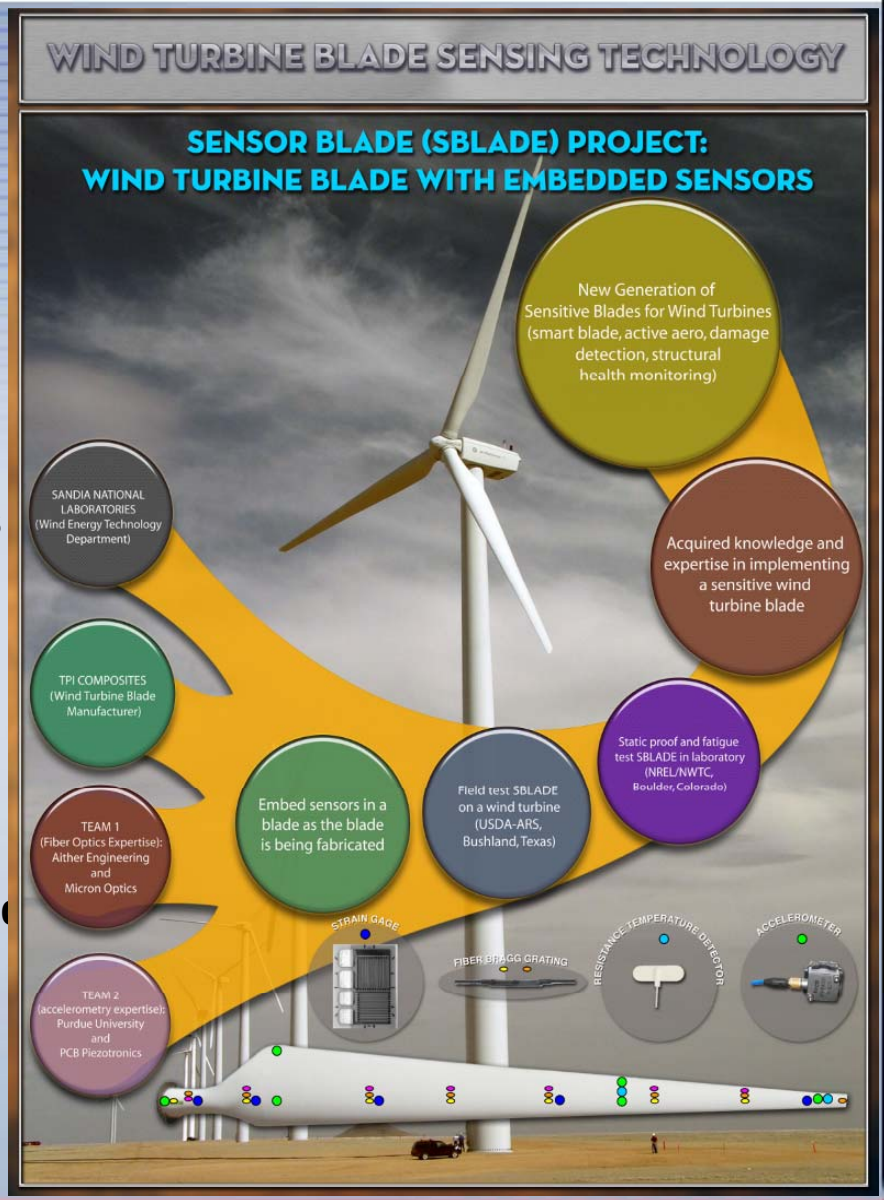
Goal: **Increase the viability of wind energy by implementing sensing technologies in blades to enable advance wind turbine control and monitoring strategies**

Challenges:

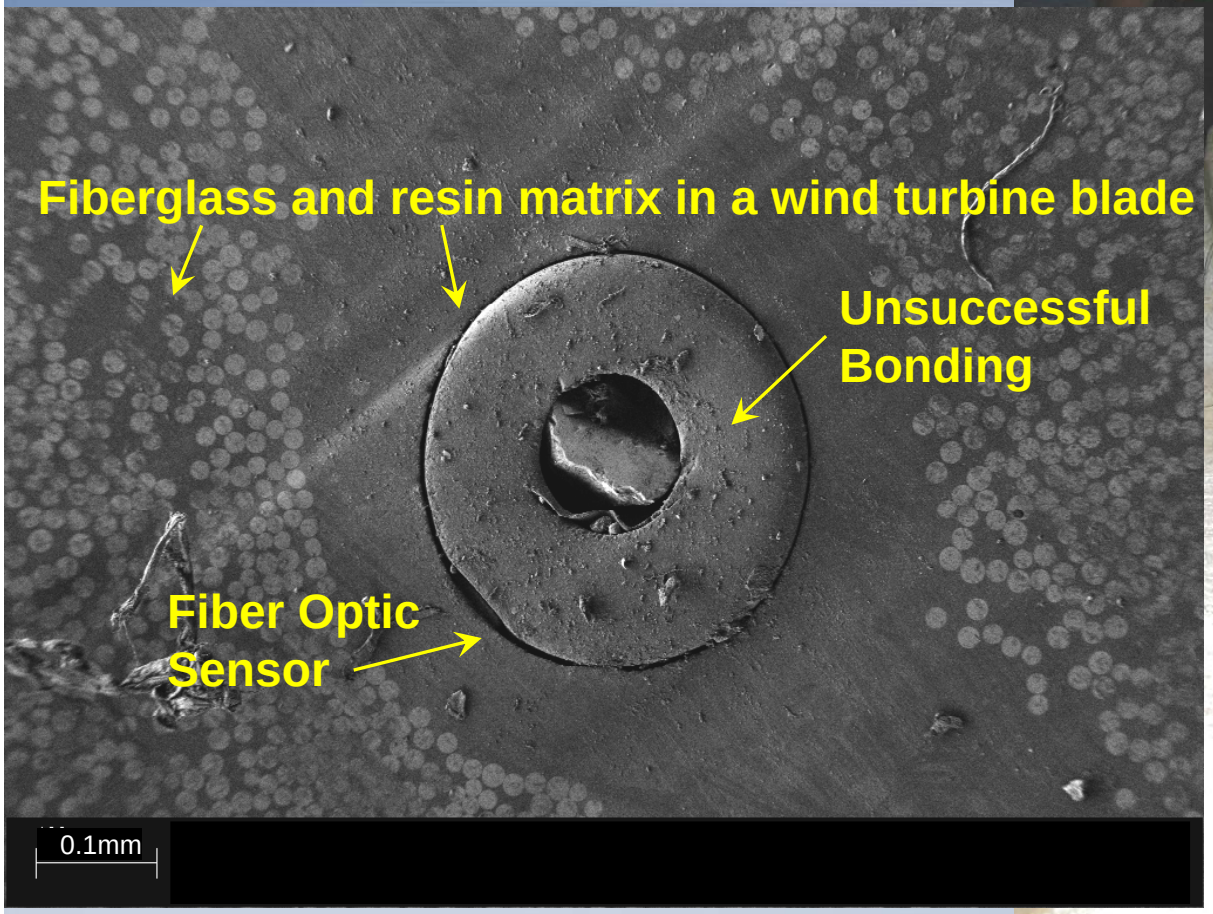
- Implementing applicable sensing technologies in blades
- Maintaining or improving system reliability

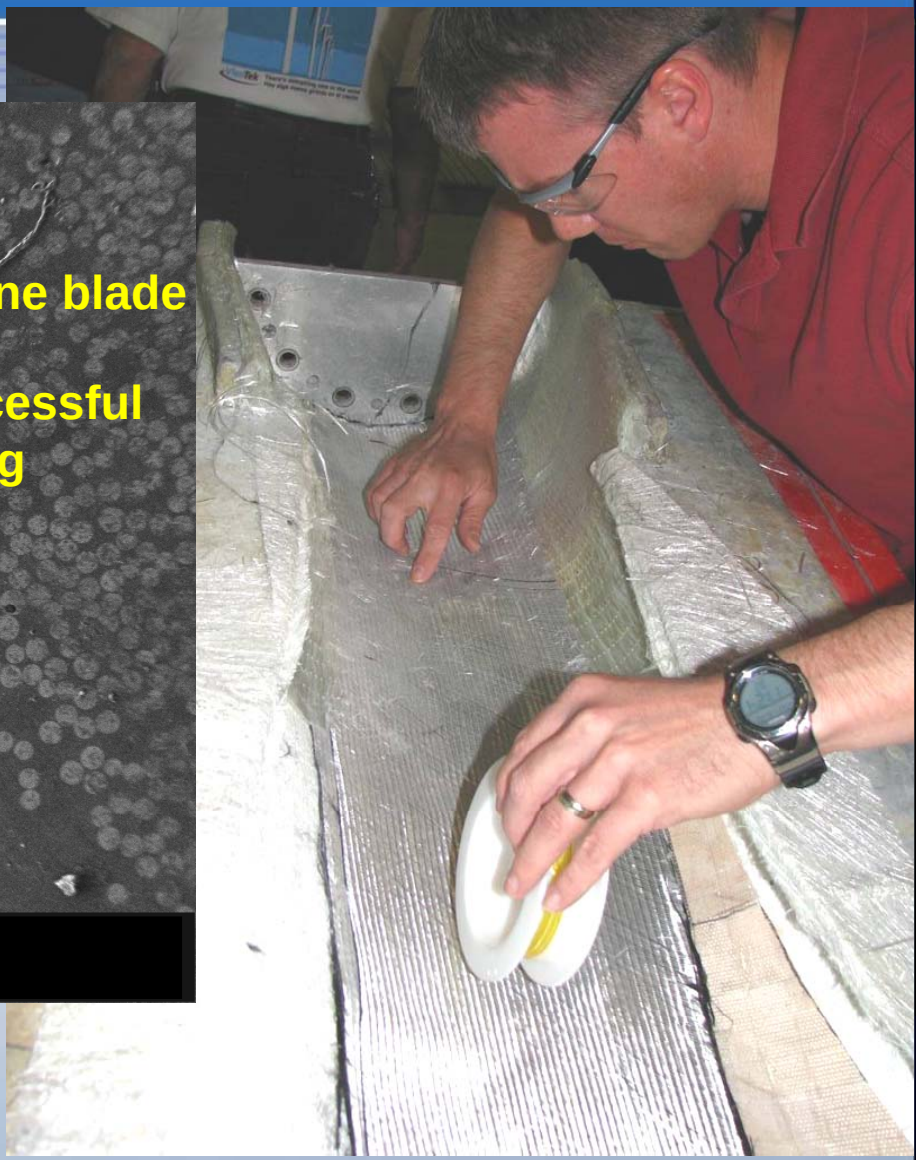
Opportunities:

- New markets for sensing systems suppliers
- Increased wind turbine capability, reliability and availability
- Decrease the cost of energy from the wind



Sensor Integration Issues





tpi DELIVERING COMPOSITE SOLUTIONS

AITHER ENGINEERING, INC.

MONTANA STATE UNIVERSITY

Sandia National Laboratories

SHM at Los Alamos National Laboratories

"Structural Damage Identification in Wind Turbine Blades using Piezoelectric Active-Sensing"

Abraham Light-Marquez, Alexandra Sobin

Gyuhae Park ● Kevin Farinholt

Los Alamos
Dynamics Summer School

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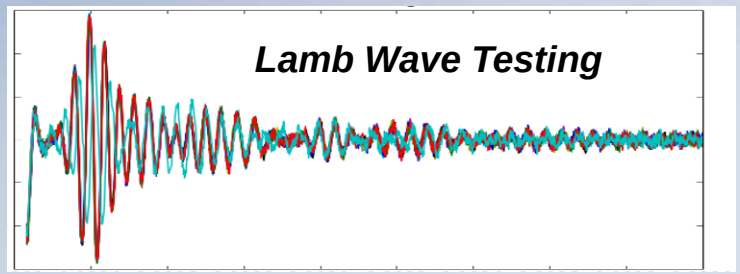

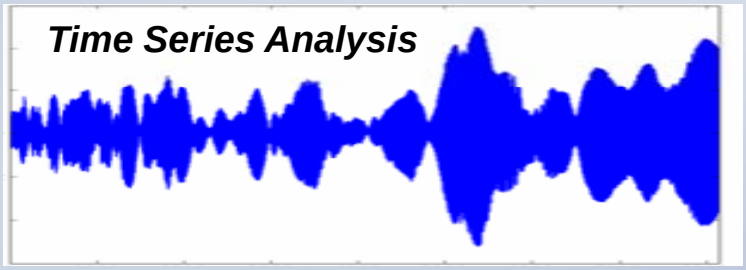

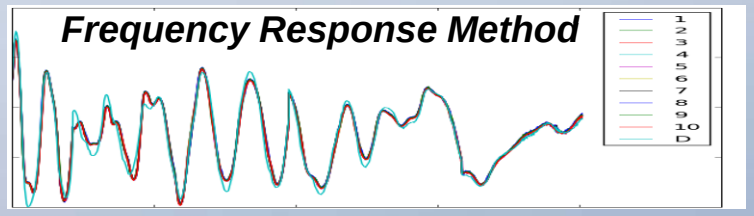

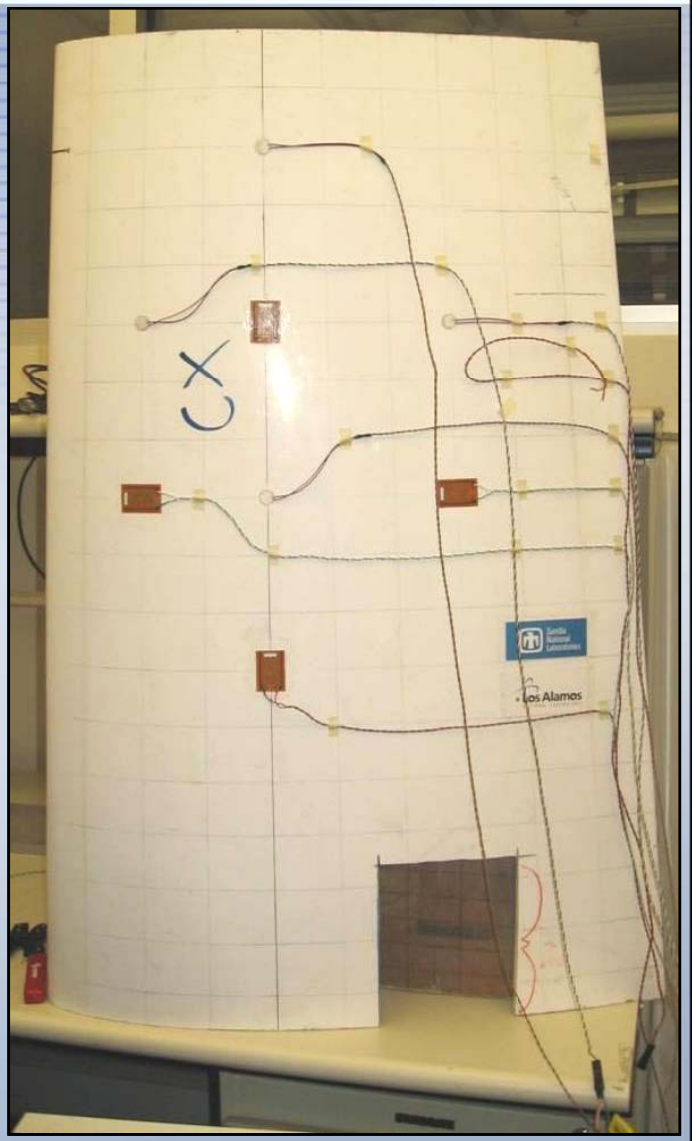

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Thank You!

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