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Title:	A Full-scale Fatigue Test of 9-m CX-100 Wind Turbine Blades
Author(s):	Gyuhae Park Kevin M. Farinholt Stuart G. Taylor Charles R. Farrar
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A Full-scale Fatigue Test of 9-m CX-100 Wind Turbine Blades

G. Park, K. M. Farinholt, S. G. Taylor, C. R. Farrar
Los Alamos National Laboratory, USA

The 8th International Workshop on Structural Health Monitoring - Stanford University - 2011

Abstract

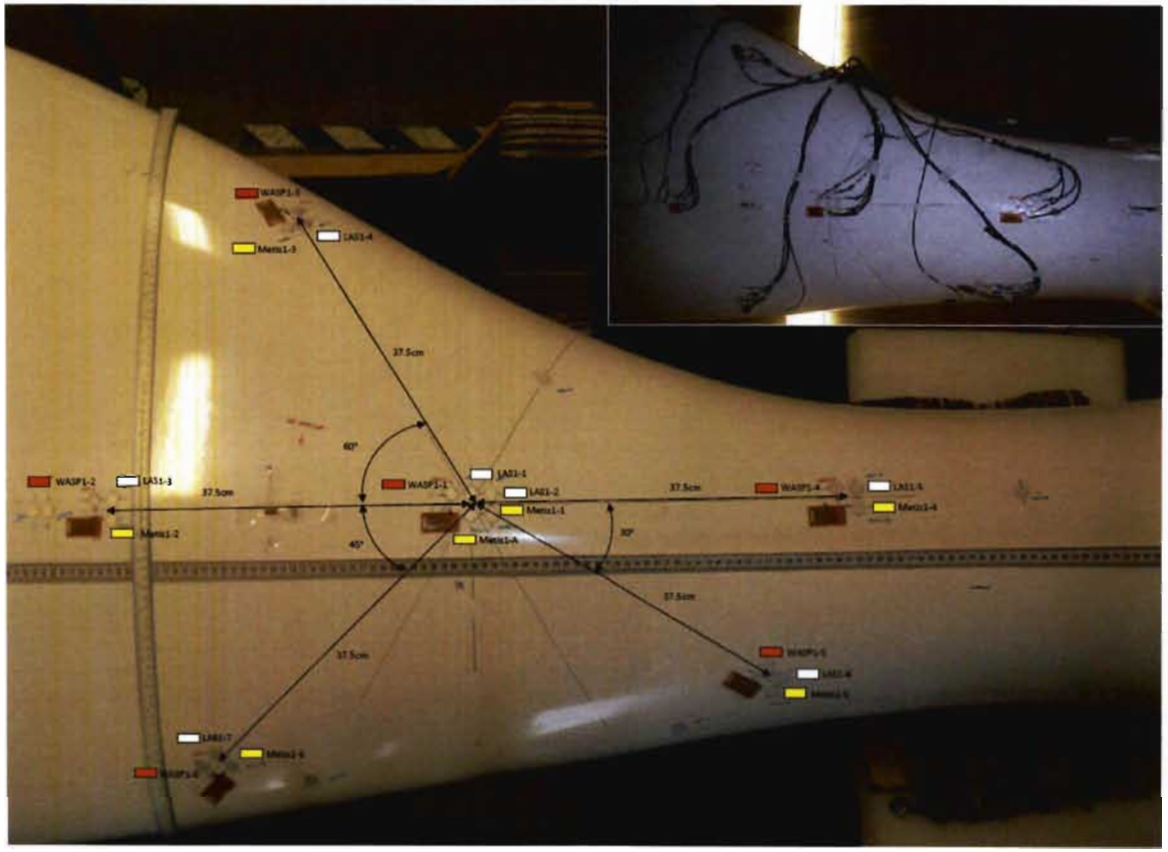
- This presentation presents the SHM result of a 9m CX-100 wind turbine blade under full-scale fatigue loads. The test was performed at the National Renewable Energy Laboratory. The 9-meter blade was instrumented with piezoelectric transducers, accelerometers, acoustic emission sensors, and foil strain gauges on the surface of the blade. The blade underwent fatigue excitation at 1.8 Hz for defined intervals, and data from the sensors were collected between and during fatigue loading sessions. The data were measured at multi-scale, high frequency ranges for identifying fatigue damage initiation, and low-frequency ranges for assessing damage progression. High and Low frequency response functions, time series based methods, and Lamb wave date measured by piezoelectric transducers were utilized to analyze the condition of the turbine blade, along with other sensing systems (acoustic emission). A specially designed hardware developed by Los Alamos National Laboratory was also implemented for performance comparison. This paper summarizes considerations needed to design such SHM systems, experimental procedures and results, and additional issues that can be used as guidelines for future investigations.

Presentation Outline

- Fatigue Test Plan
- Fatigue Test Progression
- Blade Modal Testing
- Sensor Impedance Analysis
- Active Sensing Platform
- Active Sensing Data Analysis
- Fatigue Test Projection
- Future Work

Fatigue Test Plan – Sensor Placement

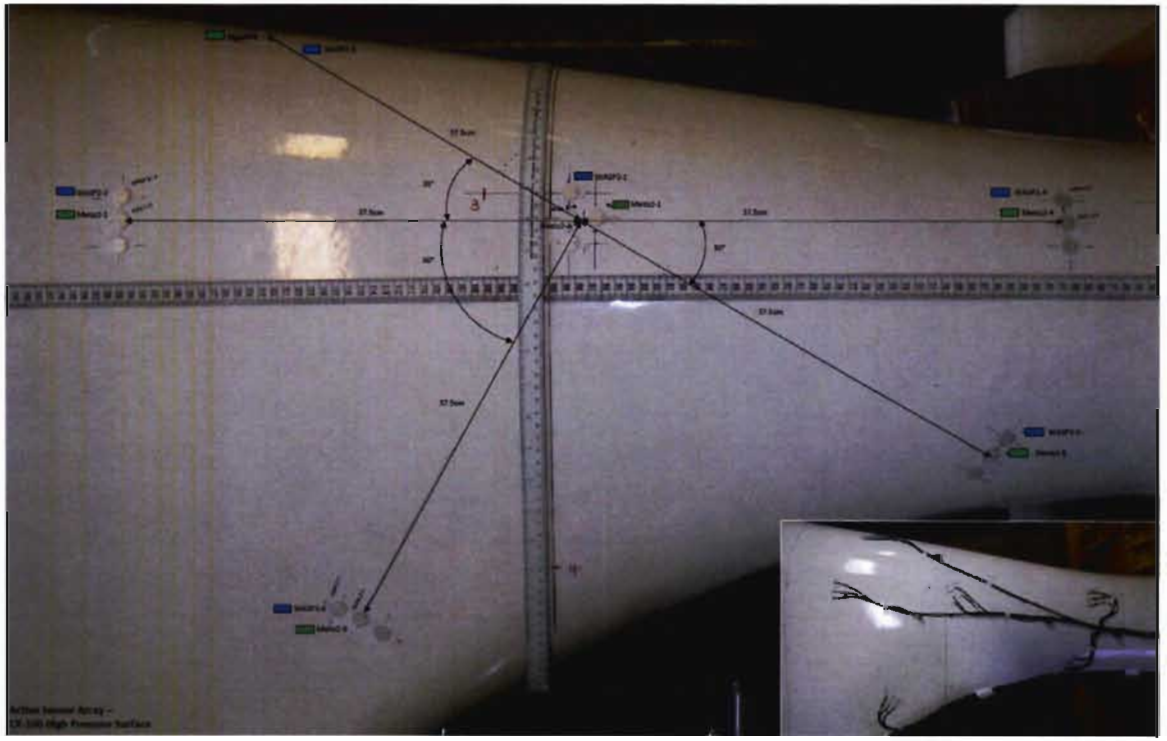
- Active arrays on Low-Pressure Surface
  - WASP
  - Metis
  - LASER
    - Inner
    - Outer



Active Sensor Array – Low pressure surface

Fatigue Test Plan – Sensor Placement

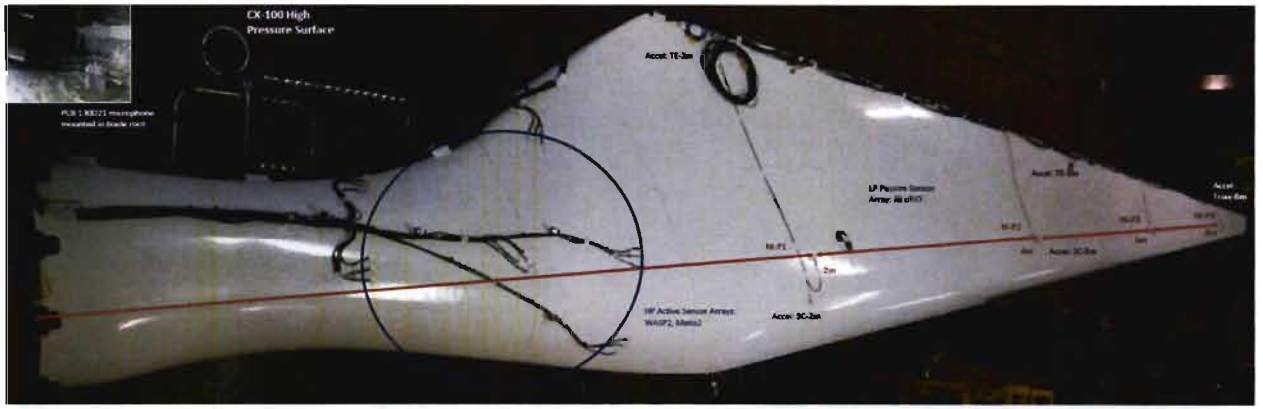
- Active Arrays on High-Pressure Surface
  - WASP
  - Metis

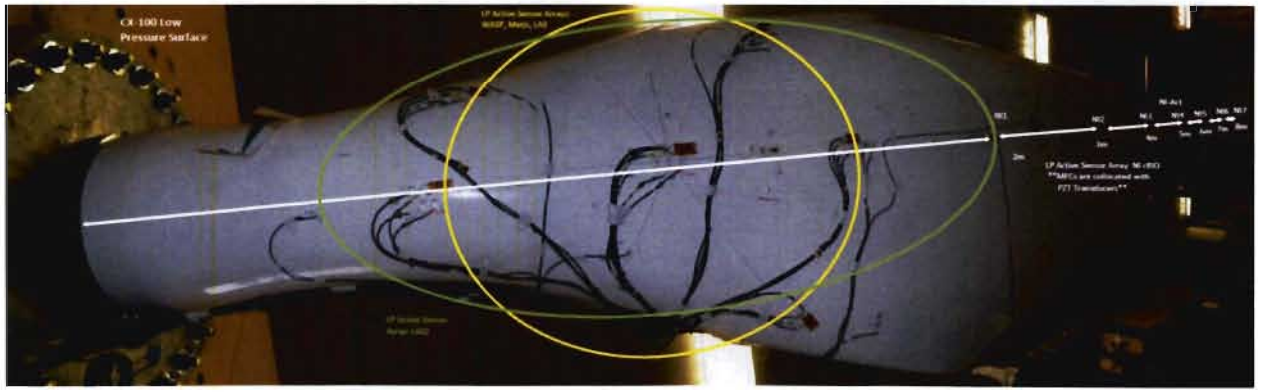


Active Sensor Array – Low pressure surface

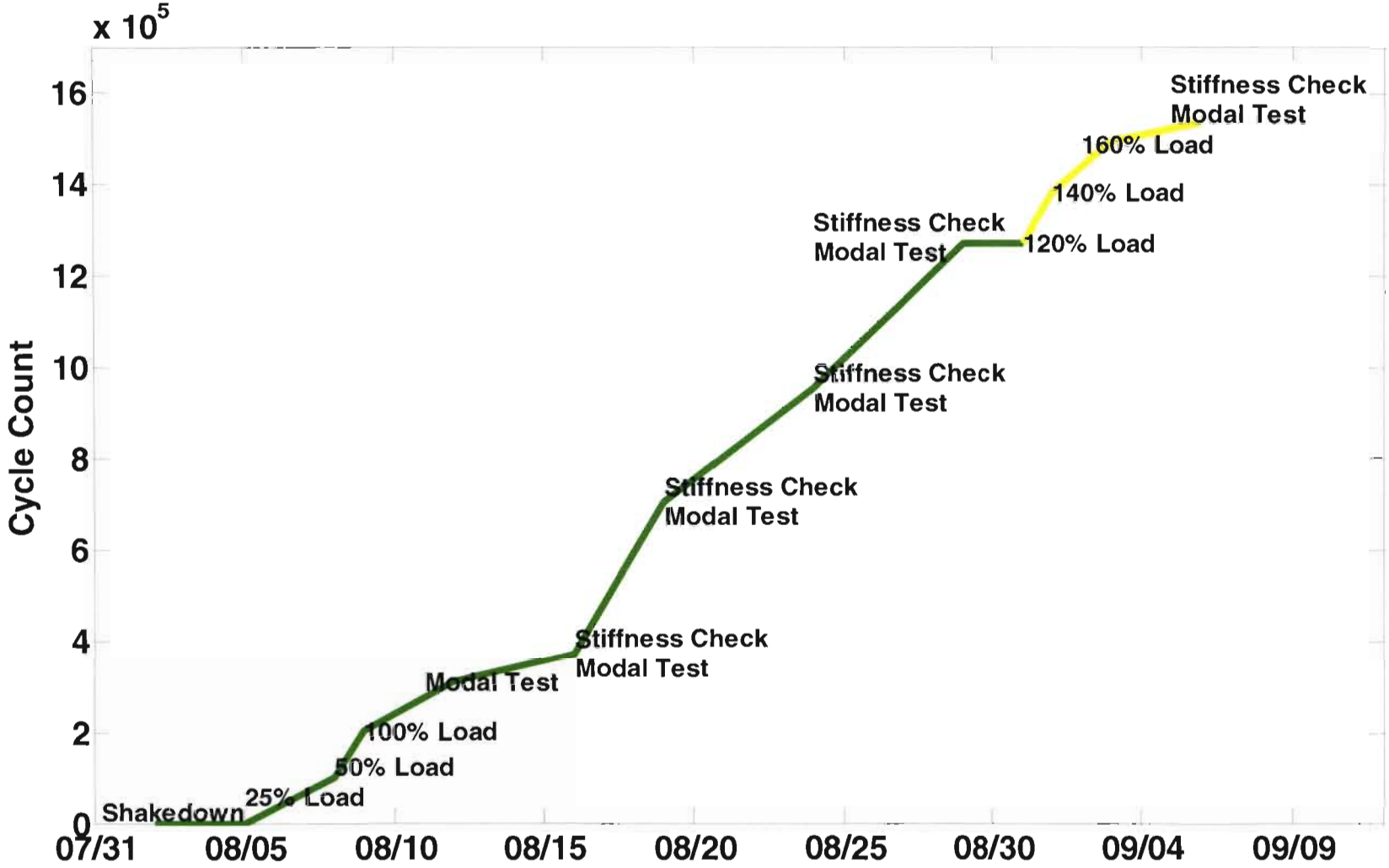
Fatigue Test Plan – Sensor Placement

- Active array along length of low-pressure surface
- Passive array along length of high-pressure surface





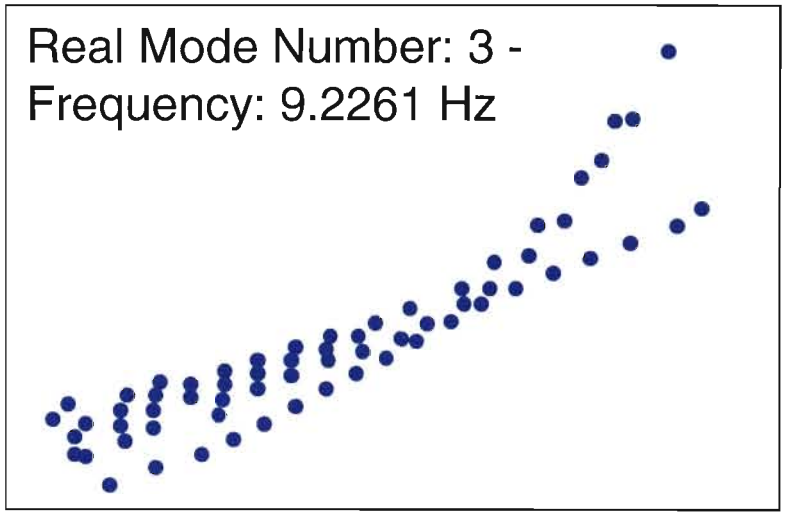
Fatigue Test Cycle Progression

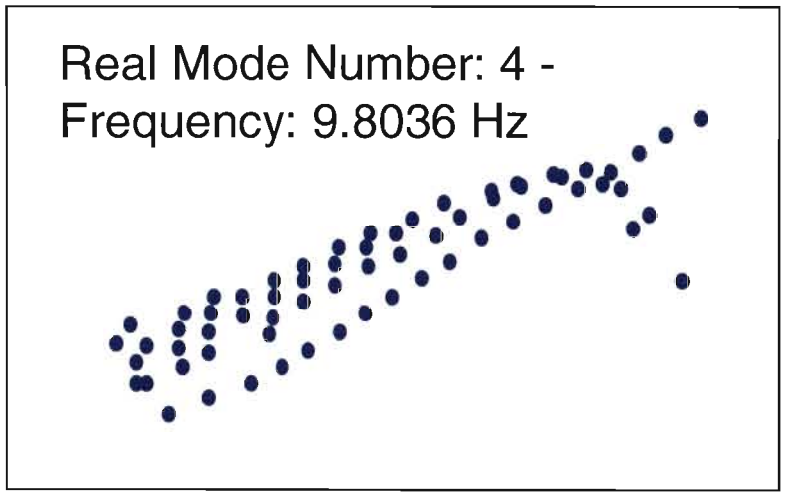


Modal Testing

Test Notes

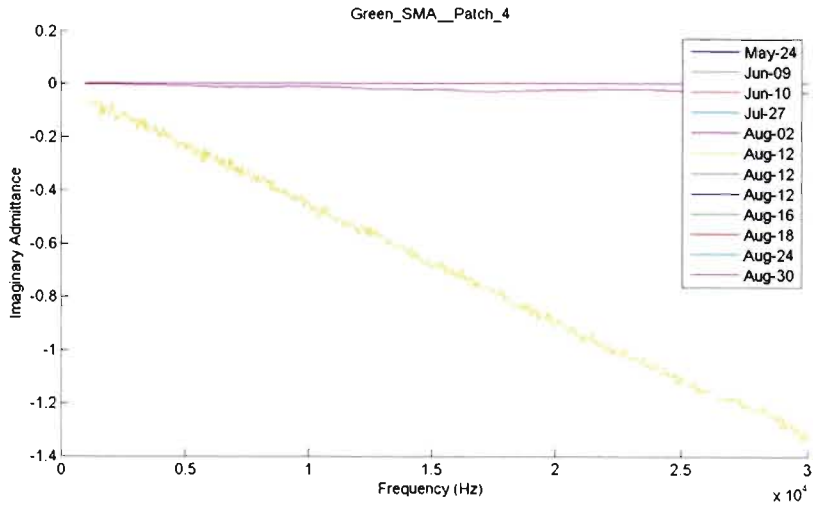
- 65 impact points
  - 47 Z-direction
  - 18 X-direction.
- 3 repeats/point
- 375 Hz Sampling
- 4096 pts (~11 s)
- Exponential Window

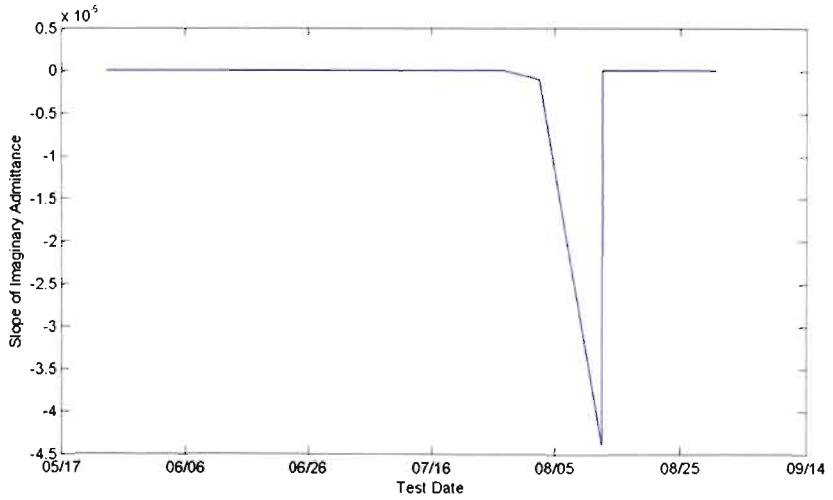




Impedance Analysis

- Impedance analysis revealed lost sensors and possible degraded performance
- One lost sensor was replaced with backup
- One channel with lost sensor replaced with excitation channel signal for time synchronization





Active Sensing Platform Overview

- Active/Passive sensing with 100 kHz bandwidth
- Multiple sensing modes
  - Active
  - Passive
  - Impedance
- Autonomous or web-driven data acquisition
- Higher (embedded) processing power

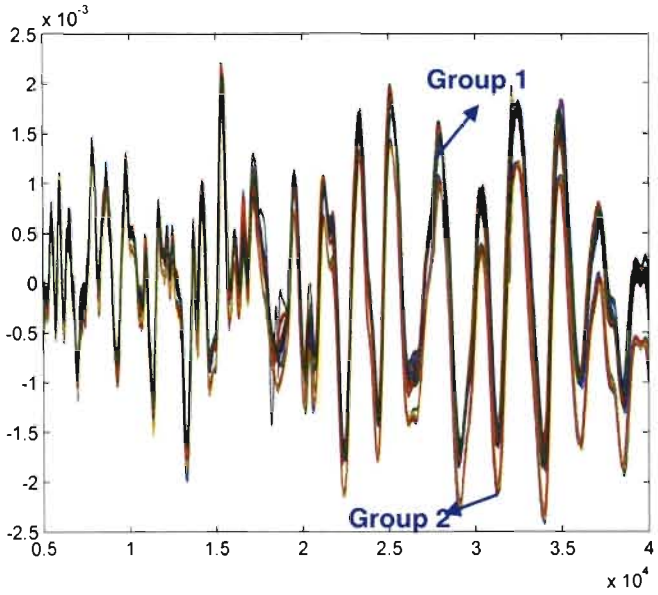
Active Sensing Platform Deployment

- Fatigue tests of CX-100 9-m blade
- Test 0 in 2010 (Sandia Lab; images shown)
- Test 1 (pristine blade) begins 8/5/2011
- Test 2 (damaged blade) begins Q3 2011
  - Verify Active Sensing Platform performance
  - Validate nonlinear composite beam model
- Flight deployment: Q2 2012
  - Deploy wireless active sensing platform
  - Validate nonlinear composite beam model

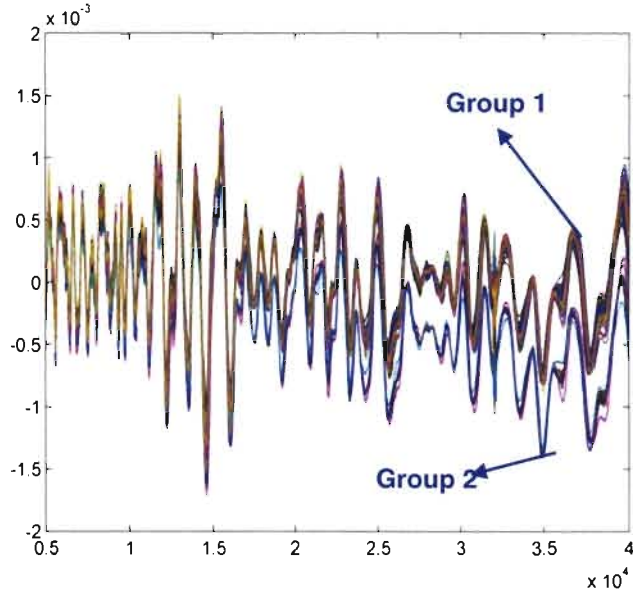
Photographs courtesy of Sandia National Laboratory

Active Sensing Signal Analysis

Inner Array



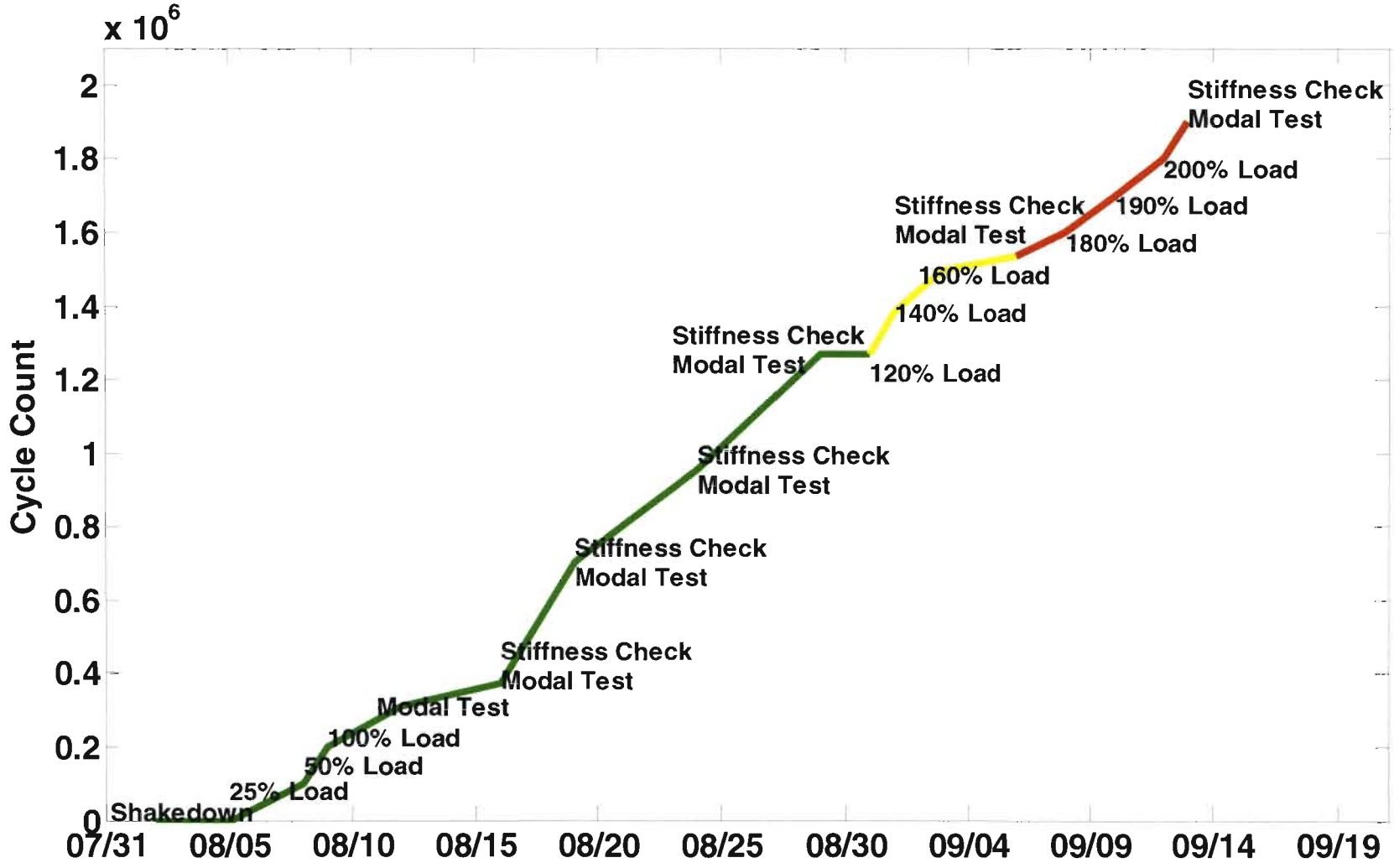
Outer Array



group 2 is comprised of 19 signals.
- Aug 02, 2011 14-43-05
- Aug 12, 2011 11-53-14 ~ Aug 16,2011 10-06-23

group 2 is comprised of 28 signals.
- Aug 02, 2011 14-44-02
- Aug 12, 2011 12-03-37 ~ Aug 16,2011 11-14-42

Fatigue Test Cycle Projection



Future Work

- As the load continues to be increased, we will begin to apply our damage detection algorithms in analyzing the data that are being collected.
- A second blade, which has been manufactured with intentional defects, will be mounted and tested early this fall.