

# Implementation of Decentralized Damage Localization in Wireless Sensor Networks

Fei Sun

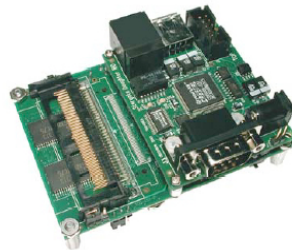
Master Project

Advisor: Dr. Chenyang Lu

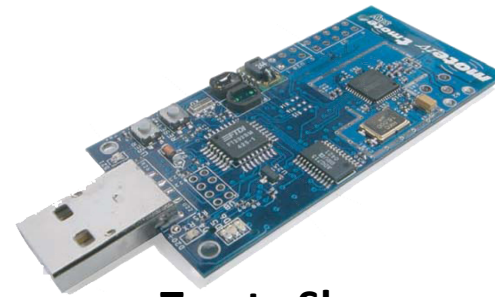
# Wireless Sensor Network



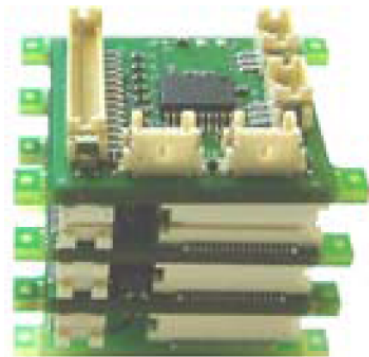
**Mica2 & Mica2dot**



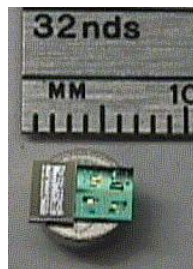
**Stargate**



**Tmote Sky**



**NMRC 25mm cube**



**Smart Dust**



**Intel iMote**

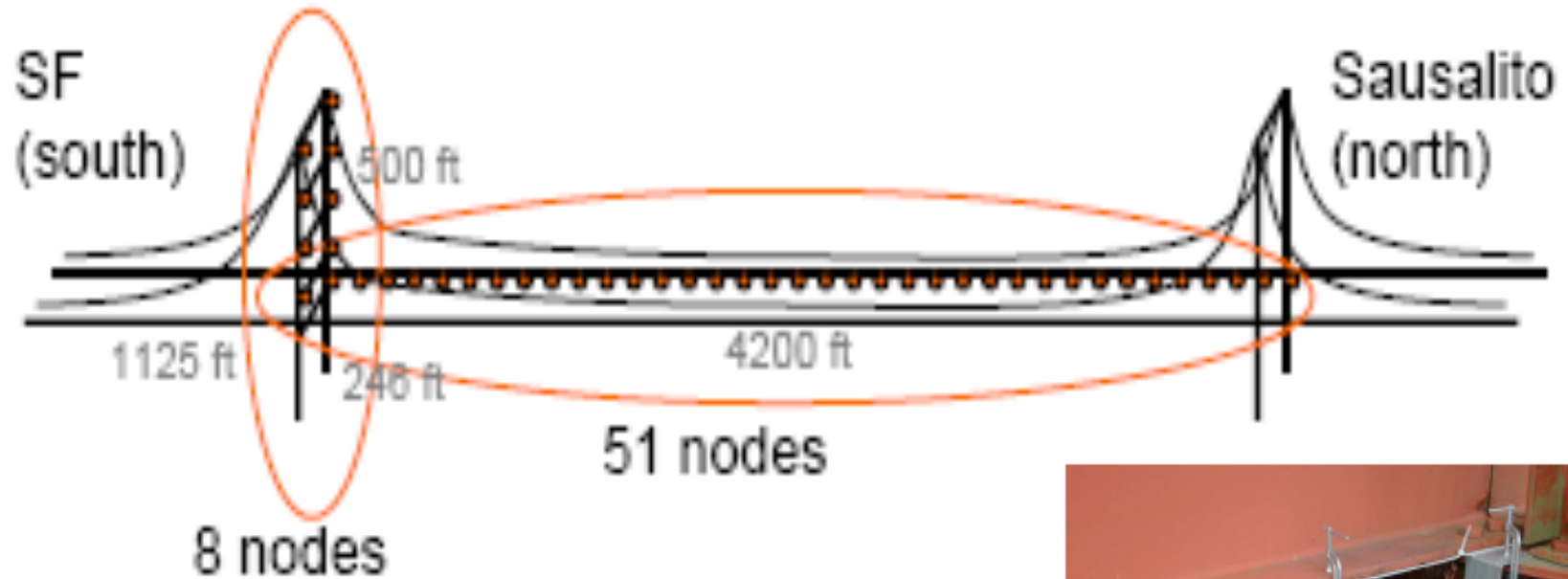
# Structural Health Monitoring

- A Civil Engineering technique used to determine the condition of structures
  - e. g. buildings, bridges
- Detect and localize damage using vibration sensors

# Motivation and Challenges

- Wired sensor deployment is expensive
- Wireless deployments can be:
  - Cost efficient
  - Higher density
  - More flexible

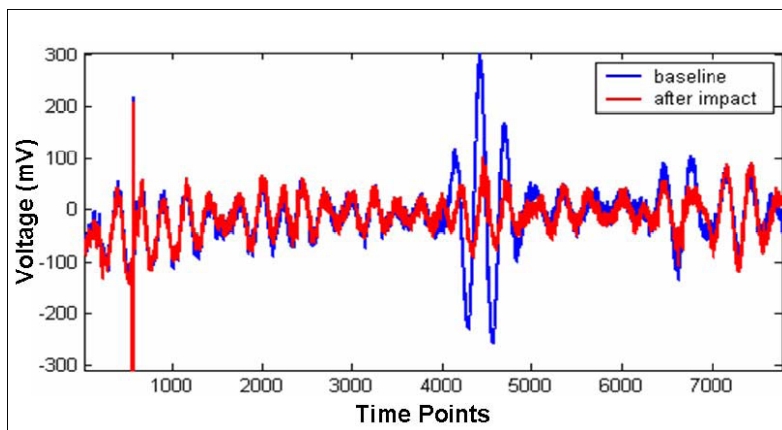
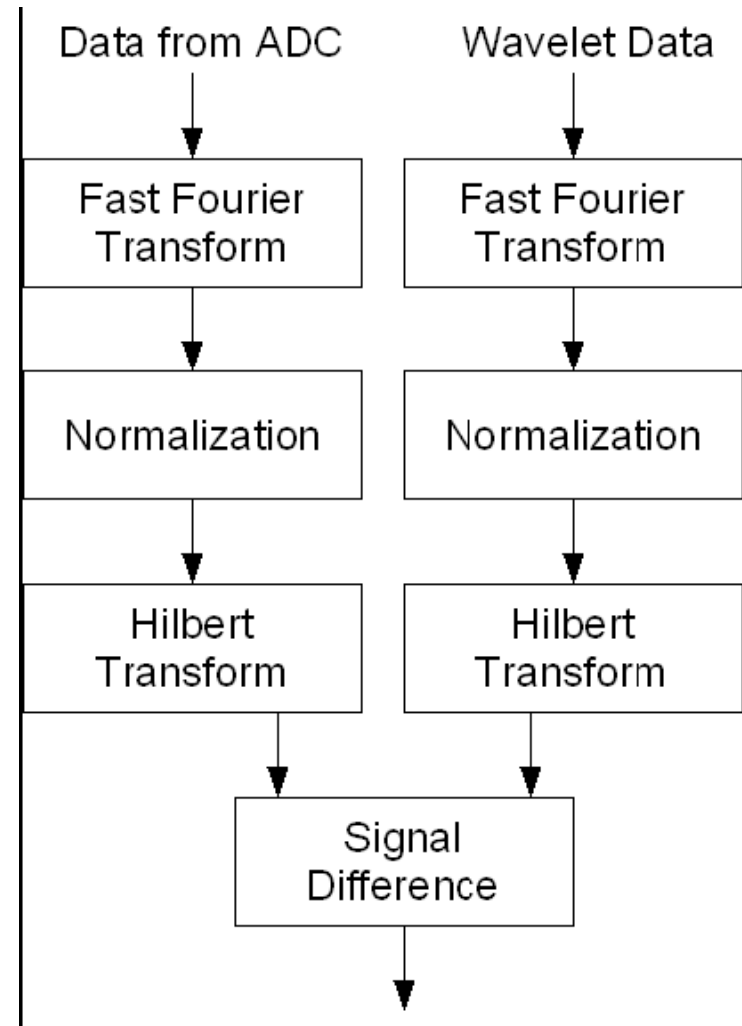
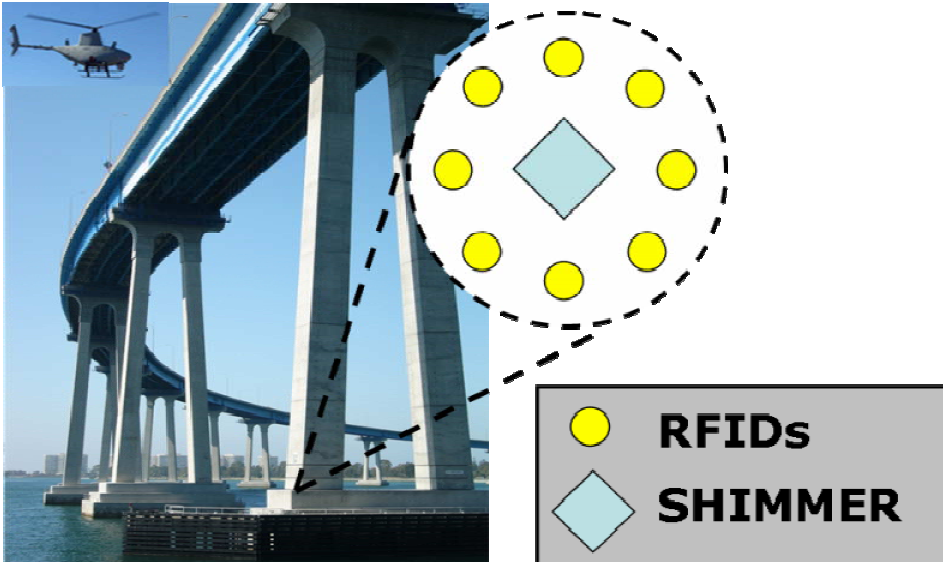
# Related Work - Golden Gate Bridge



GGB project by UC Berkley






# Related Work - SHIMMER

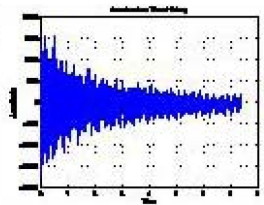


SHIMMER project by the Los Alamos National Lab

# Problem Description

- Damage **localization** in addition to detection
- Limited Resource on WSN node
  - Limited memory 
  - Limited transmission bandwidth 
  - Limited power supply
- Unreliable wireless connectivity 

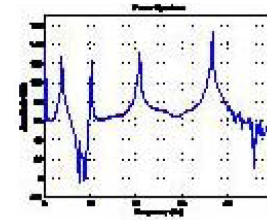
# DLAC Algorithm



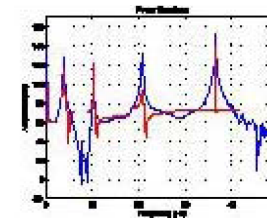
Acceleration Data

FFT

Power Spectrum



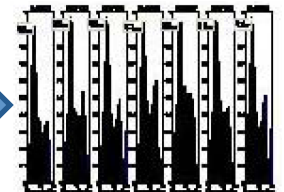
Curve Fitting



Healthy Model

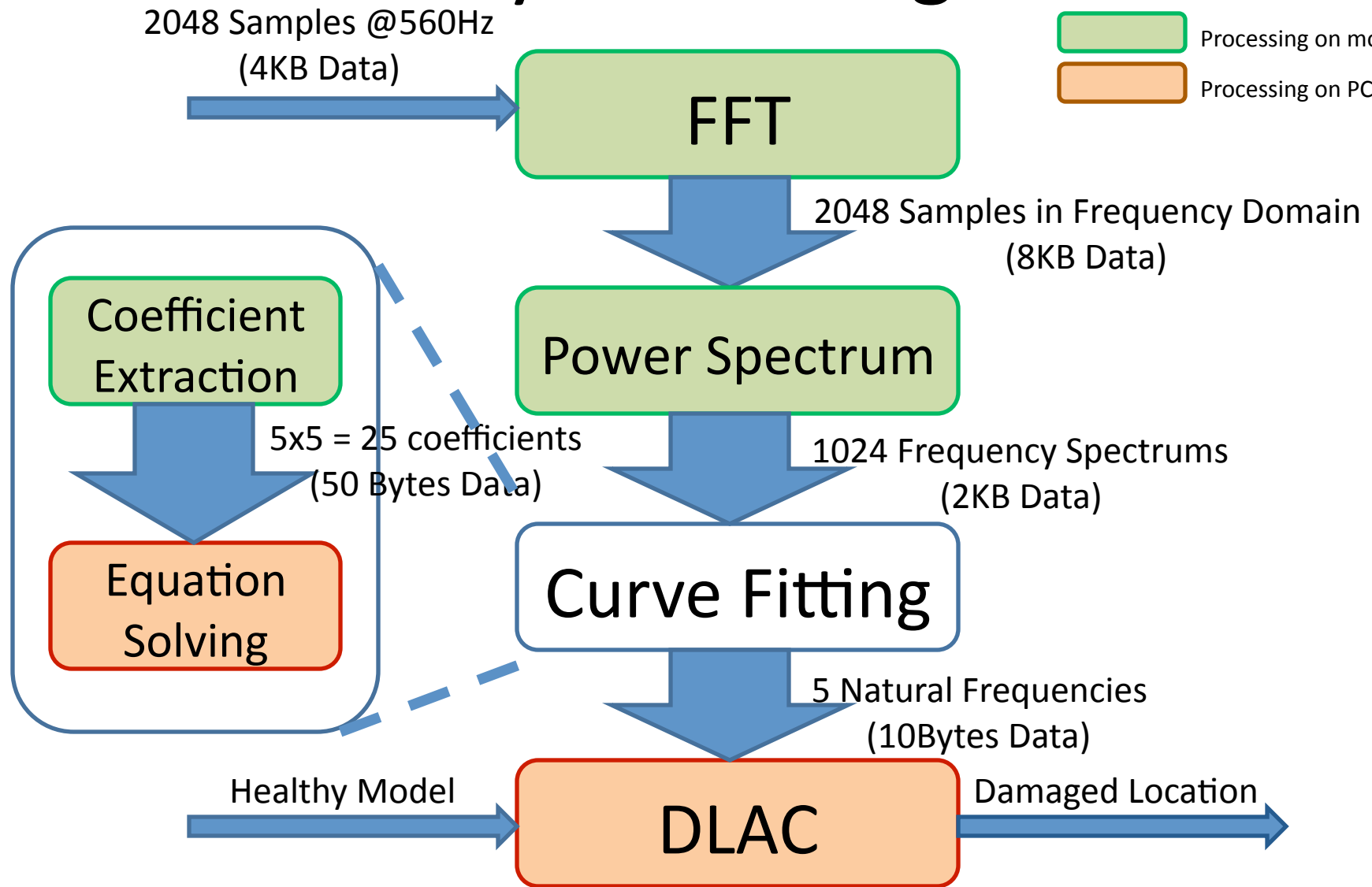
DLAC

Damage Location





# System Design



# Implementation

- Hardware
  - Intel Mote 2
    - 32-bit 416 MHz CPU
    - 32MB RAM
  - Intel ITS400 Sensor Board
    - LIS3L02DQ 3-Axis Accelerometer
- Software
  - TinyOS
  - NesC



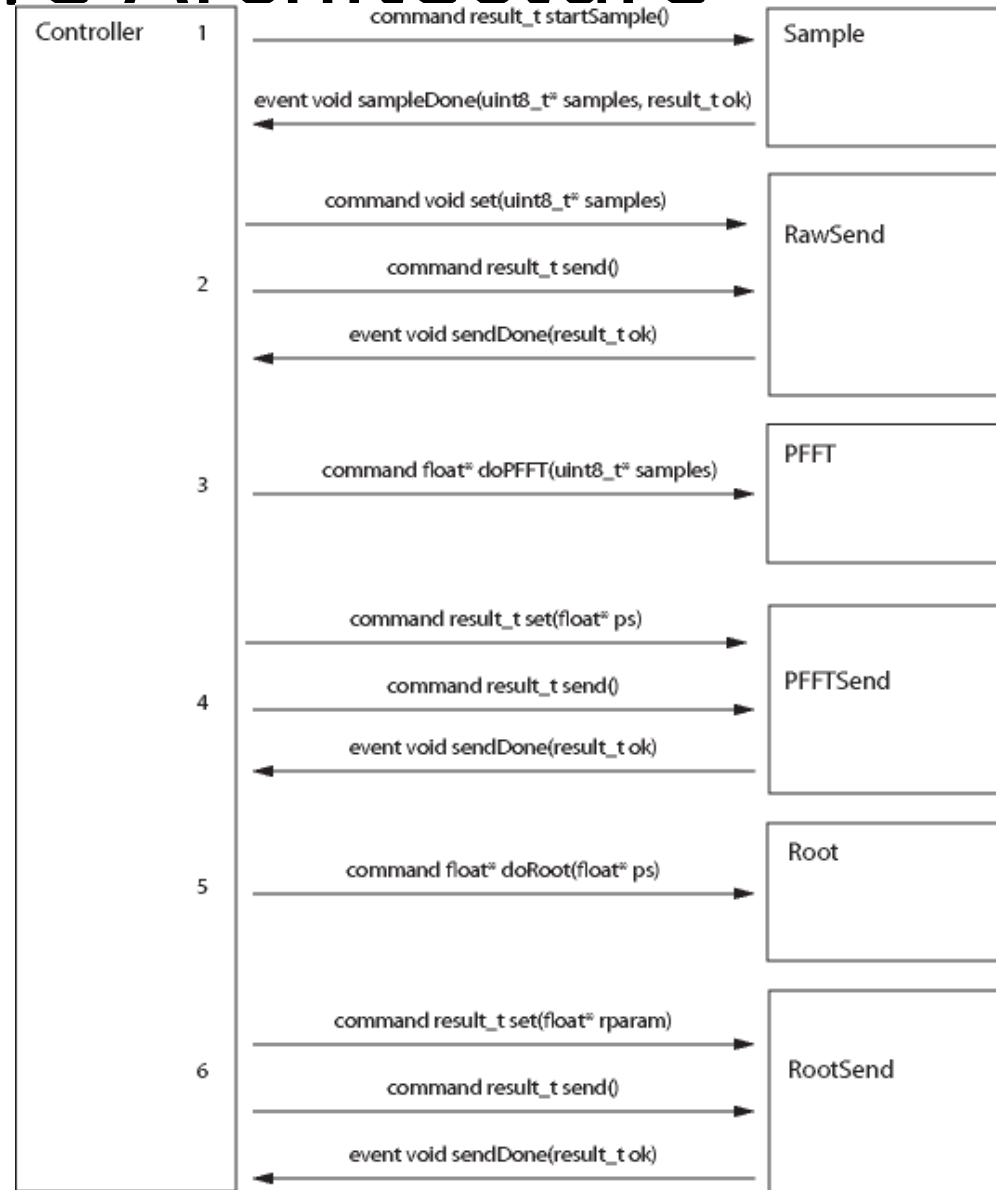
IMote2



ITS400 Sensor Board

# Software Architecture

- Reliable data transmission done through ARQ
- Average on the power spectrums to reduce noise
- Often times, the sensor board driver crashes and never returns a sampleDone event
  - Time out timer used to detect and bypass such scenario



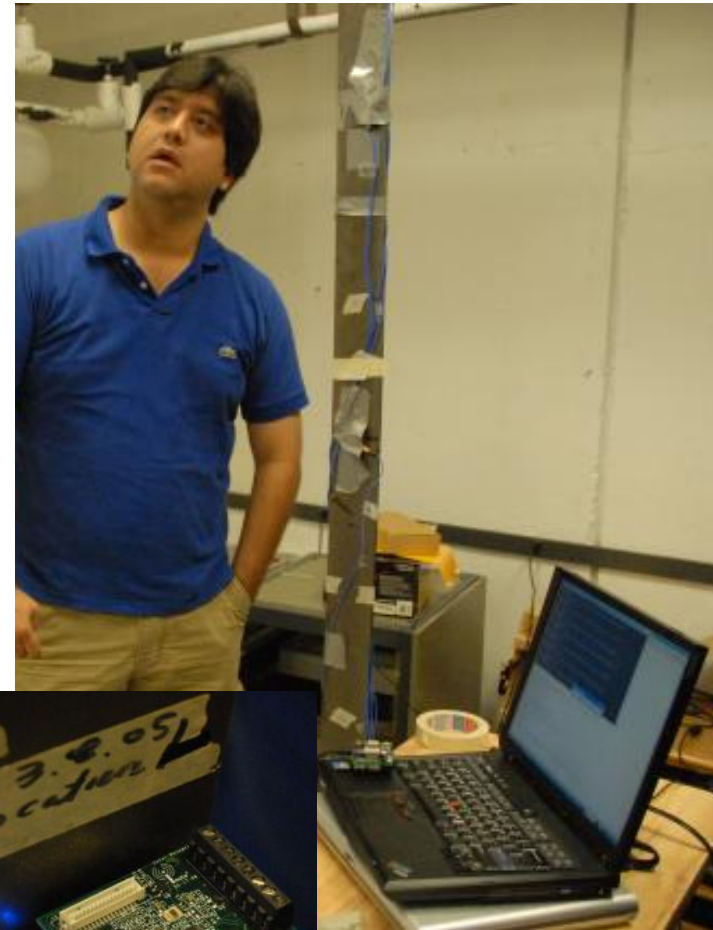
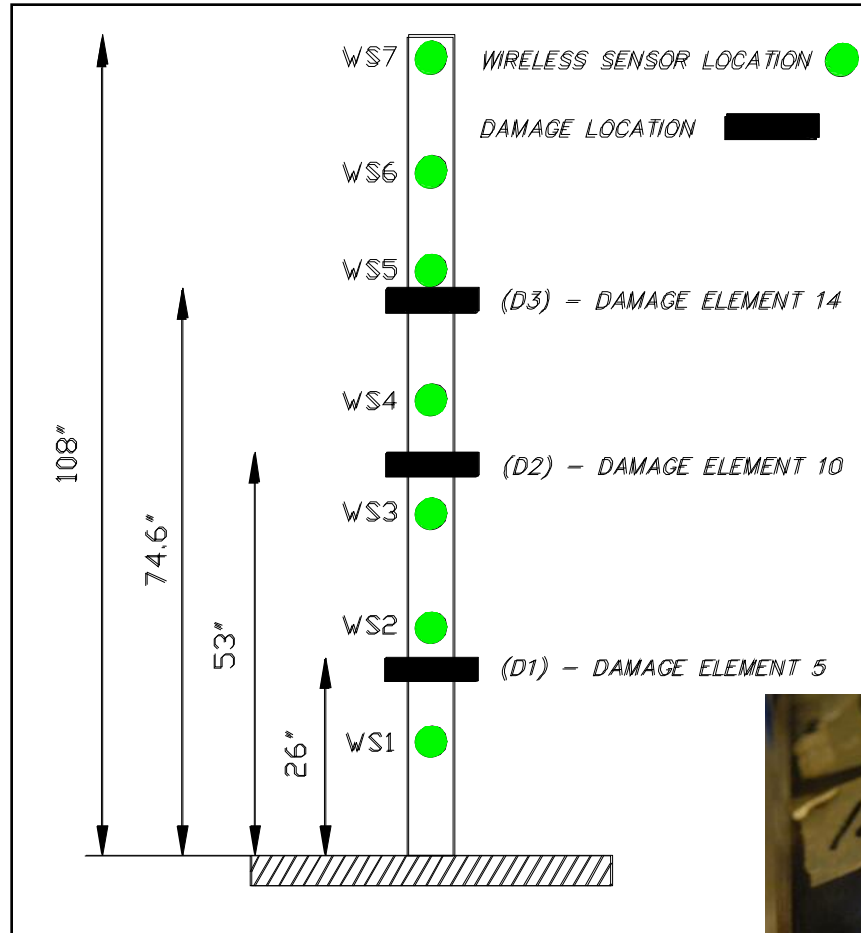
# User Control Interface

The screenshot shows a software window titled "Wireless Sample 2" with a blue title bar and standard Windows window controls. The main content area displays a table with two columns: "MotelID" and "SampleFreq". Below the table, there are two buttons: "Start DLAC !!!" and "Save Results".

MotelID	SampleFreq	Set Init Values	Get Result	Get Raw Data	Get PS Data
41	274.98	Set Init Values	Get Result	Get Raw Data	Get PS Data
35	276.57	Set Init Values	Get Result	Get Raw Data	Get PS Data
49	276.03	Set Init Values	Get Result	Get Raw Data	Get PS Data
48	283.48	Set Init Values	Get Result	Get Raw Data	Get PS Data
27	277.81	Set Init Values	Get Result	Get Raw Data	Get PS Data
45	272.2	Set Init Values	Get Result	Get Raw Data	Get PS Data
42	274.87	Set Init Values	Get Result	Get Raw Data	Get PS Data

Start DLAC !!!      Save Results

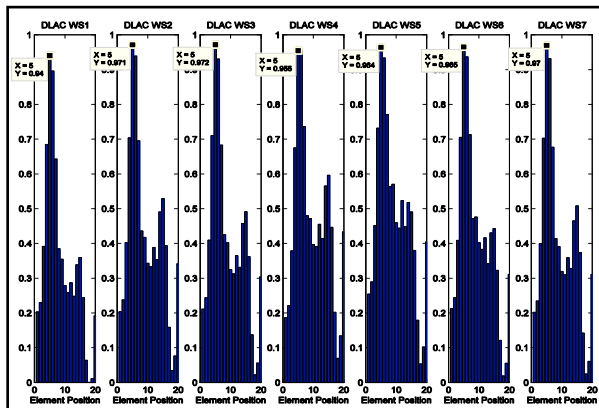
# The Beam Test



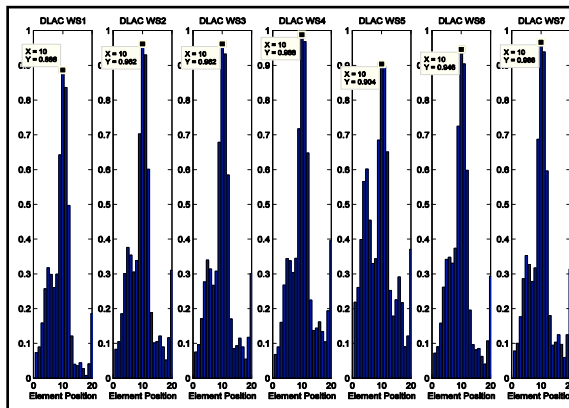
The beam structure in the Earthquake Lab

# Beam Results

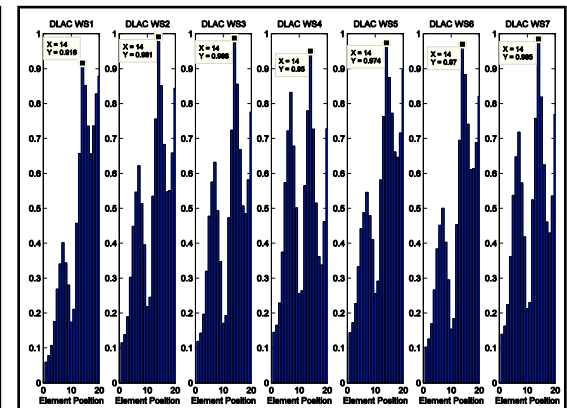
- Successful damage detection and localization for **all** damage scenarios
  - With correlation measurements  $>90\%$  at the damaged positions



Damage Location #5

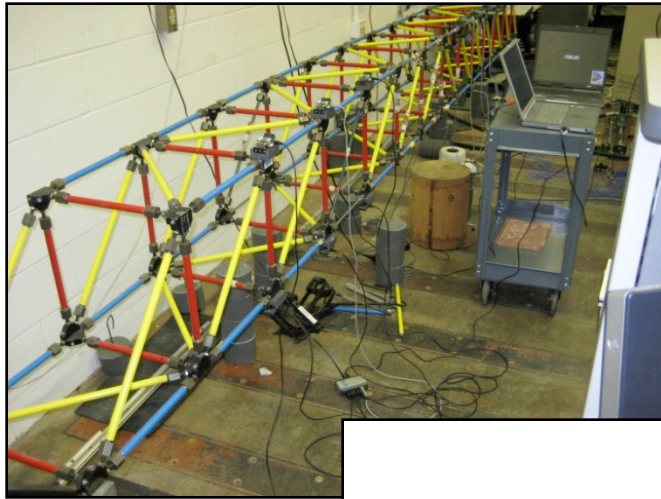


Damage Location #10

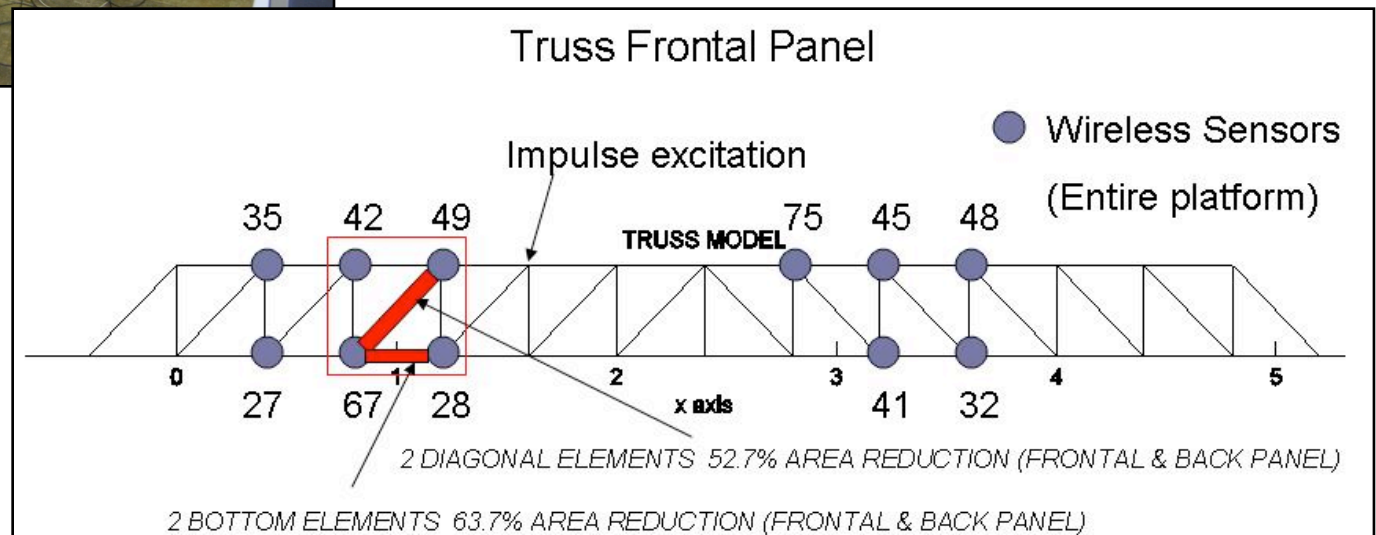


Damage Location #14

# The Truss Test

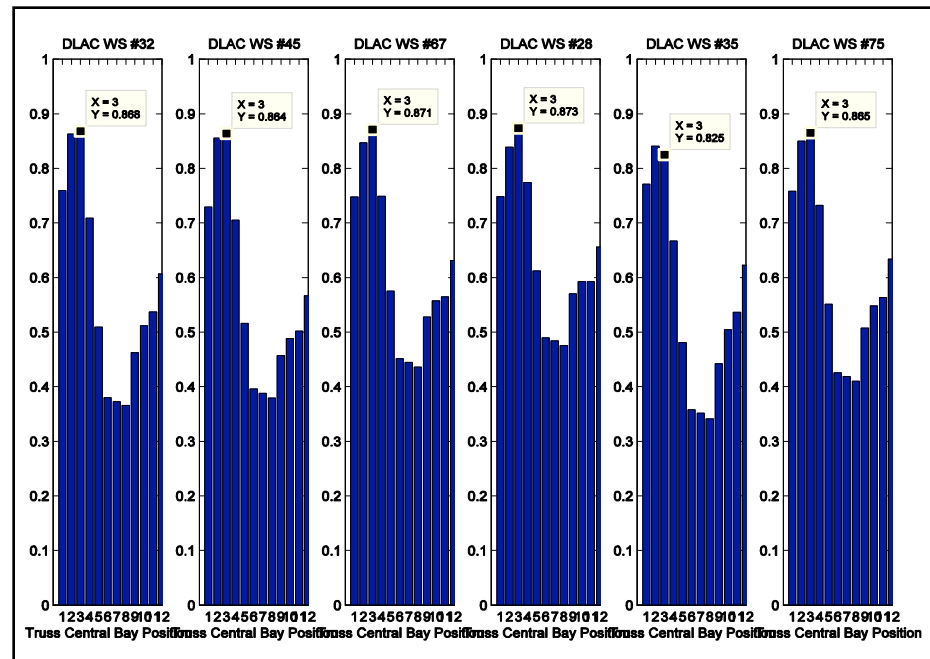


The truss structure at UIUC



# Truss Results

- Successful damage detection and localization for **all** damage scenarios
  - With correlation measurements  $>85\%$  at the damaged positions



Damage Location #3



# Conclusion

- Design and Implementation of a SHM damage detection and localization technique on WSNs
  - correlation-based and decentralized
- Successful damage localization for two sets of experiments
- Future Work:
  - Debug sensor failure
  - Power Management

# Appreciation

- Dr. Chenyang Lu
- Dr. Shirley Dyke
- Nestor Castaneda
- WUSTL WSN Group
- WUSTL Earthquake Lab
- Dr. Tomonori Nagayama