Structural Health Monitoring Using Statistical Pattern Recognition

Presented by

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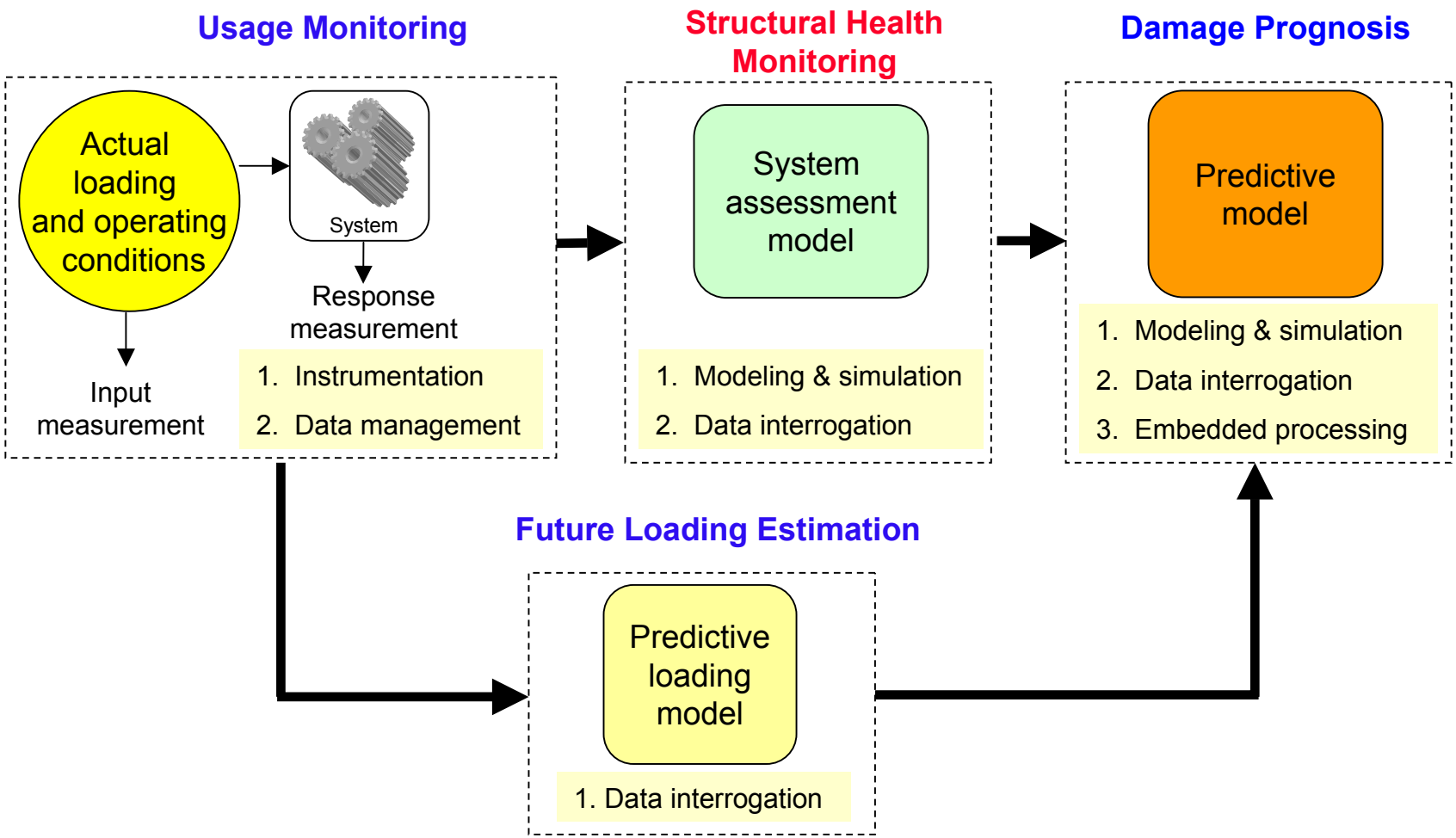
Overview of the Course

- Summarize the rapidly evolving field of structural health monitoring.
  - Summarize the historical developments of this technology.
  - Provide overview of current methods.
  - Show “real world” application of this technology.
  - Identify the limitations of the current technology.
  - Present cutting edge statistical tools for diagnosis.
  - Discuss current and future research directions.

- Course Theme: Structural Health Monitoring is a problem in statistical pattern recognition.

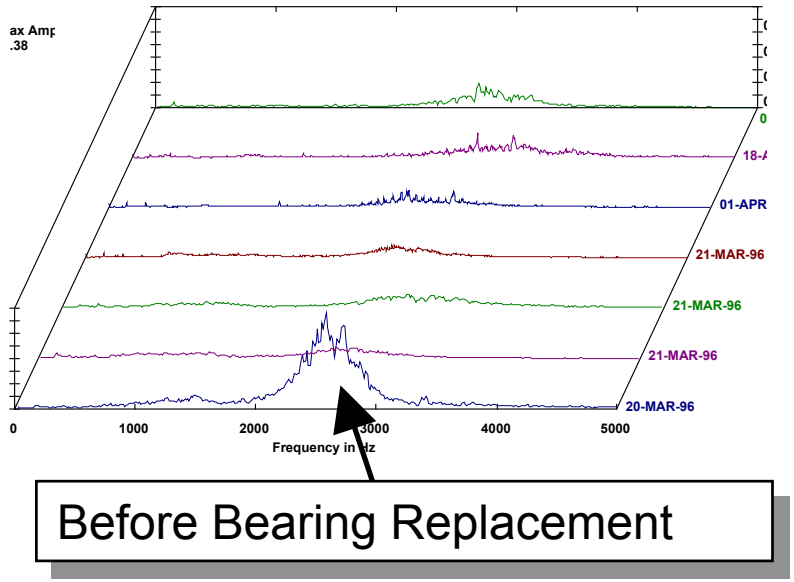
Where Does Structural Health Monitoring Fit In "The Big Picture"



Process of Structural Health Monitoring

- Vibration-based damage detection is part of the more general process of “Structural Health Monitoring”
- The Structural Health Monitoring process includes:
    1. Operational evaluation of the structure
    2. Data acquisition and cleansing
    3. Feature extraction and information condensation
    4. Statistical model development

Rotating Machinery Application



Spectral response of machine vibrations before (bottom trace) and after bearing replacement

Engineers at Intel's Fab-11 plant measure vibrations on a vacuum blower motor

Early Work on Offshore Structures

- Offshore Industry spent millions of dollars during the 70's and 80's in an effort to launch practical damage detection and health monitoring of offshore platforms
- Numerous examples in the literature of numerical modeling efforts as well as scale-model and full-scale experiments
- Many practical problems were encountered:
  - Machine noise
  - Non-uniform inputs
  - Hostile environment for instrumentation
  - Marine growth
  - Changes in foundation with time

- Modal frequencies can be insensitive to many of the damage types the offshore industry is interested in

Overview of Aerospace Applications

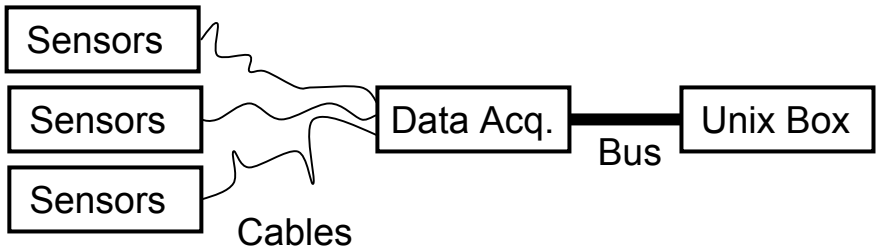
- Aging aircraft
- Rotorcraft
- Reusable launch vehicles:
  - Space shuttle
  - X-33
  - DC-XA
- International space station & related truss test beds
- MIR space station

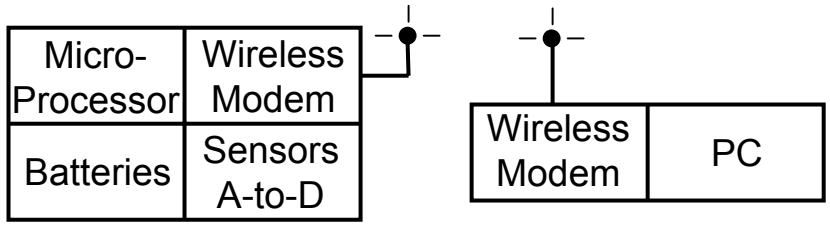
Damage to 1988 Aloha Airlines flight motivated the development of an FAA Aging Aircraft Center at Sandia National Laboratory

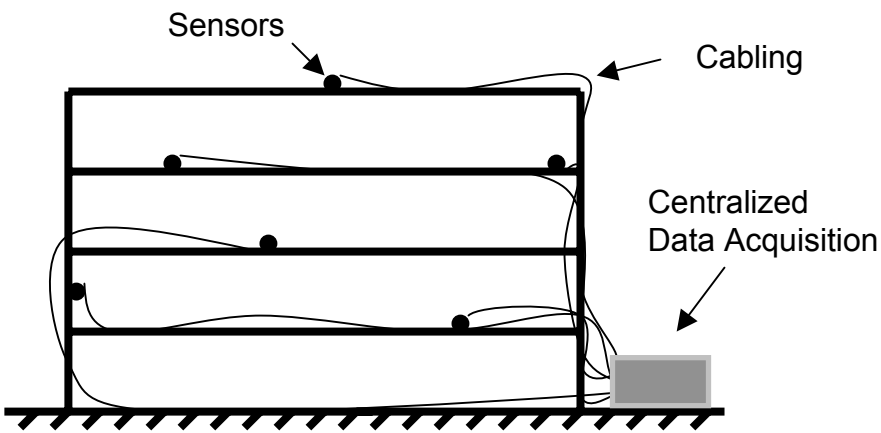
1. Operational Evaluation

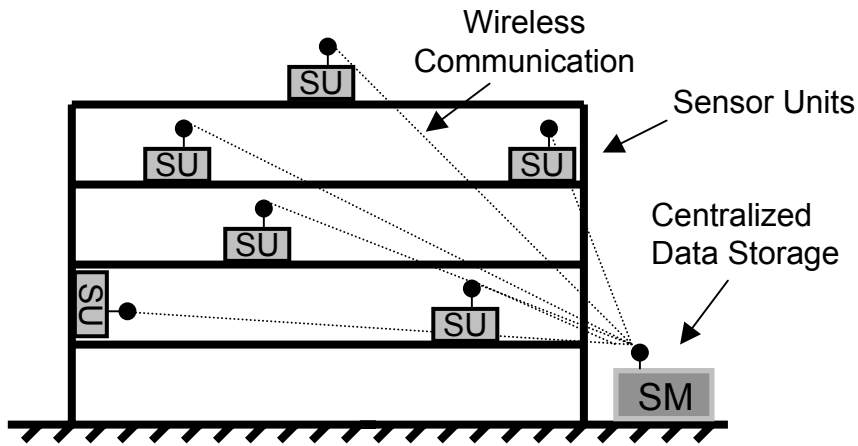
- Operational evaluation begins to answer questions regarding implementation issues for a structural health monitoring system.
  - Provide economic and/or life-safety justifications for performing the monitoring.
  - Define system-specific damage including types of damage and expected locations.
  - Define the operational and environmental conditions under which the system functions.
  - Define the limitations on data acquisition in the operational environment.
- Operational evaluation will require input from many different sources (designers, operators, maintenance people, financial analysts, regulatory officials)

2. Data Acquisition: Conventional Monitoring vs. WiMMS





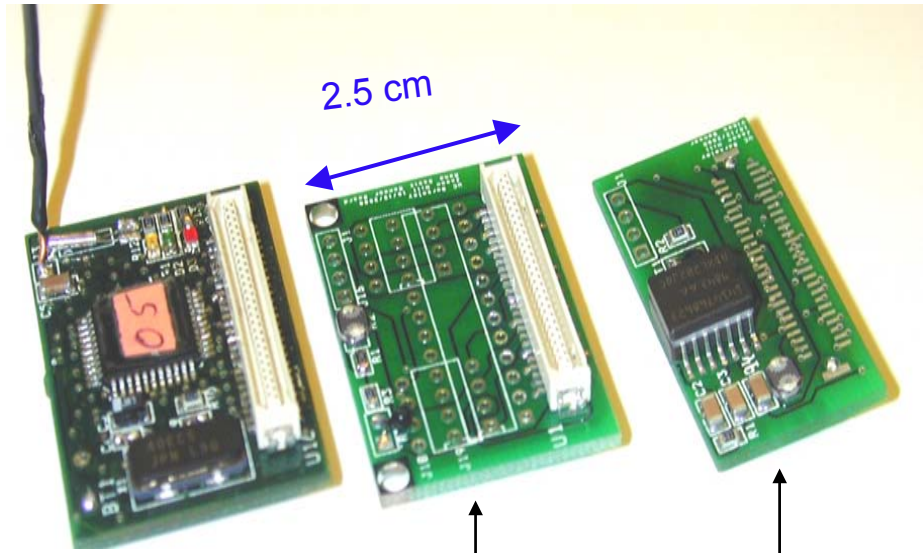




From Straser, 1998

2. Data Acquisition: Commercial Wireless Monitoring Systems

- Developed at UC Berkeley EE Dept.
- Marketed through Crossbow, San Jose
- See www.xbow.com



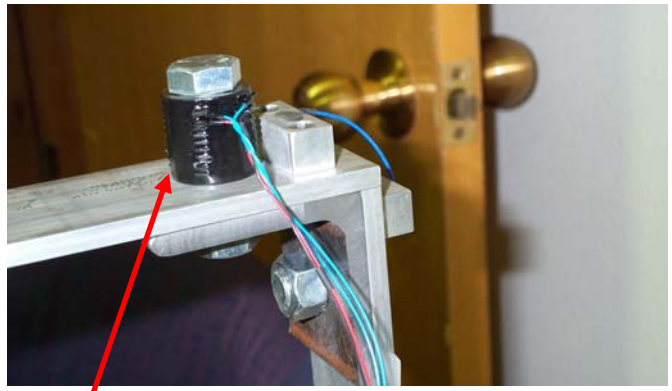
Local processor and transmitter

Photo Detector and thermal sensor

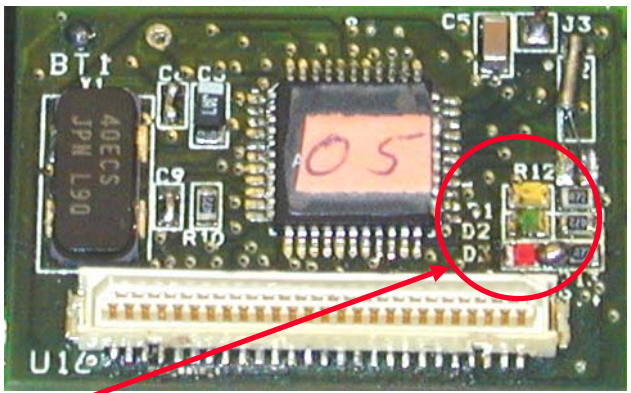
Analog Devices two axis accelerometer

2. Data Acquisition: Demonstration of the Mote System

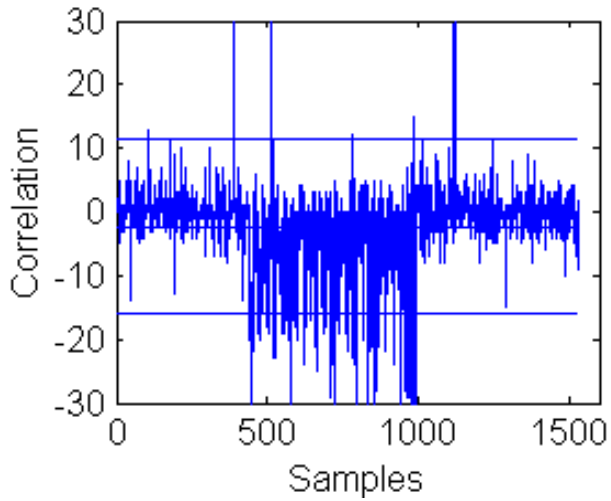
A portal test structure



The preload in the bolt is varied by a PZT actuator



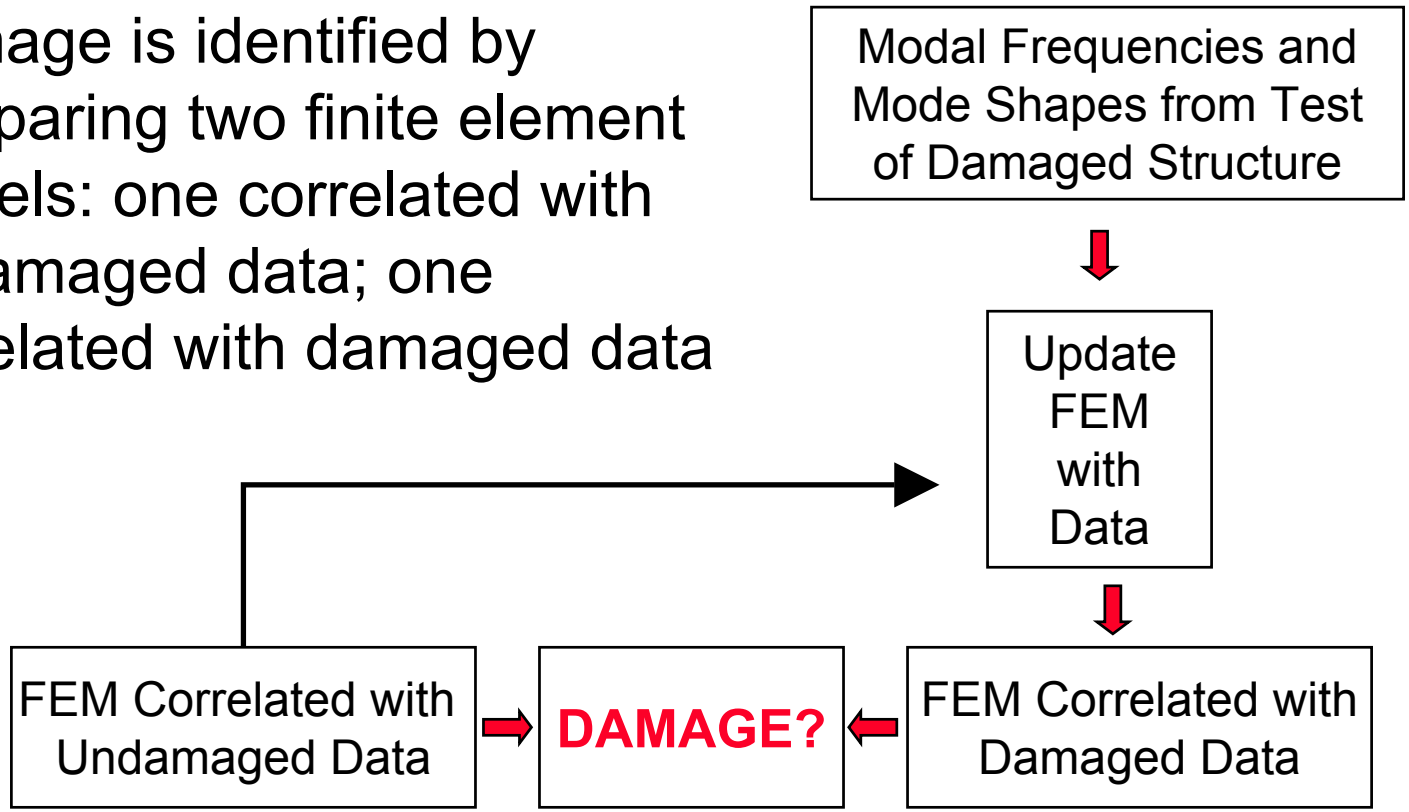
The loosening of the bolt is detected and reported by the LDE lights in the sensor



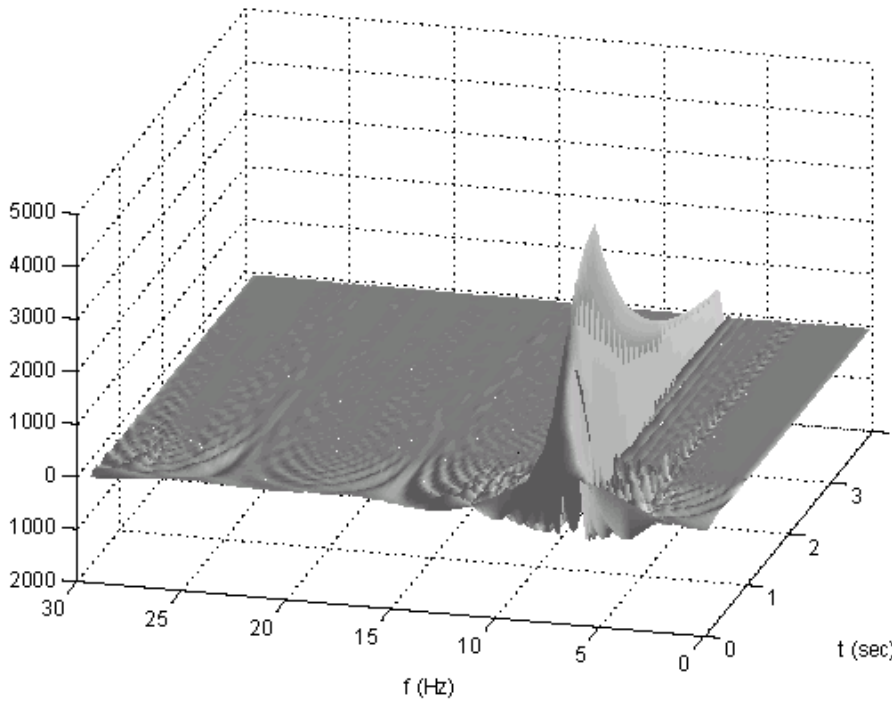
Correlation reading between two sensors

3. Feature Extraction: Flowchart of Model Update-Based Damage Identification

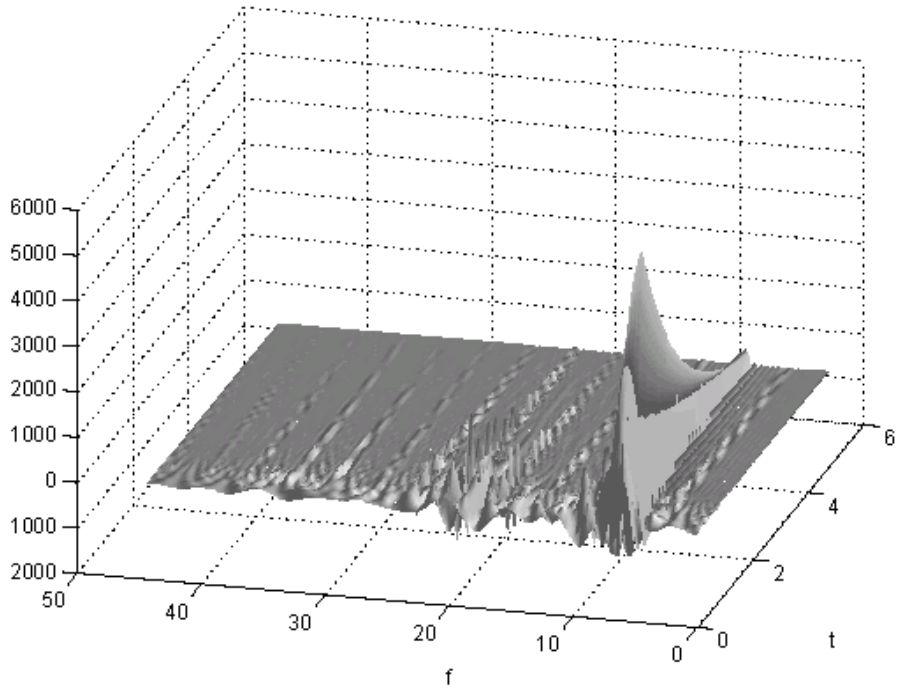
Damage is identified by comparing two finite element models: one correlated with undamaged data; one correlated with damaged data



3. Feature Extraction: Uncracked vs. Cracked Beam Response: Wigner-Ville Transform

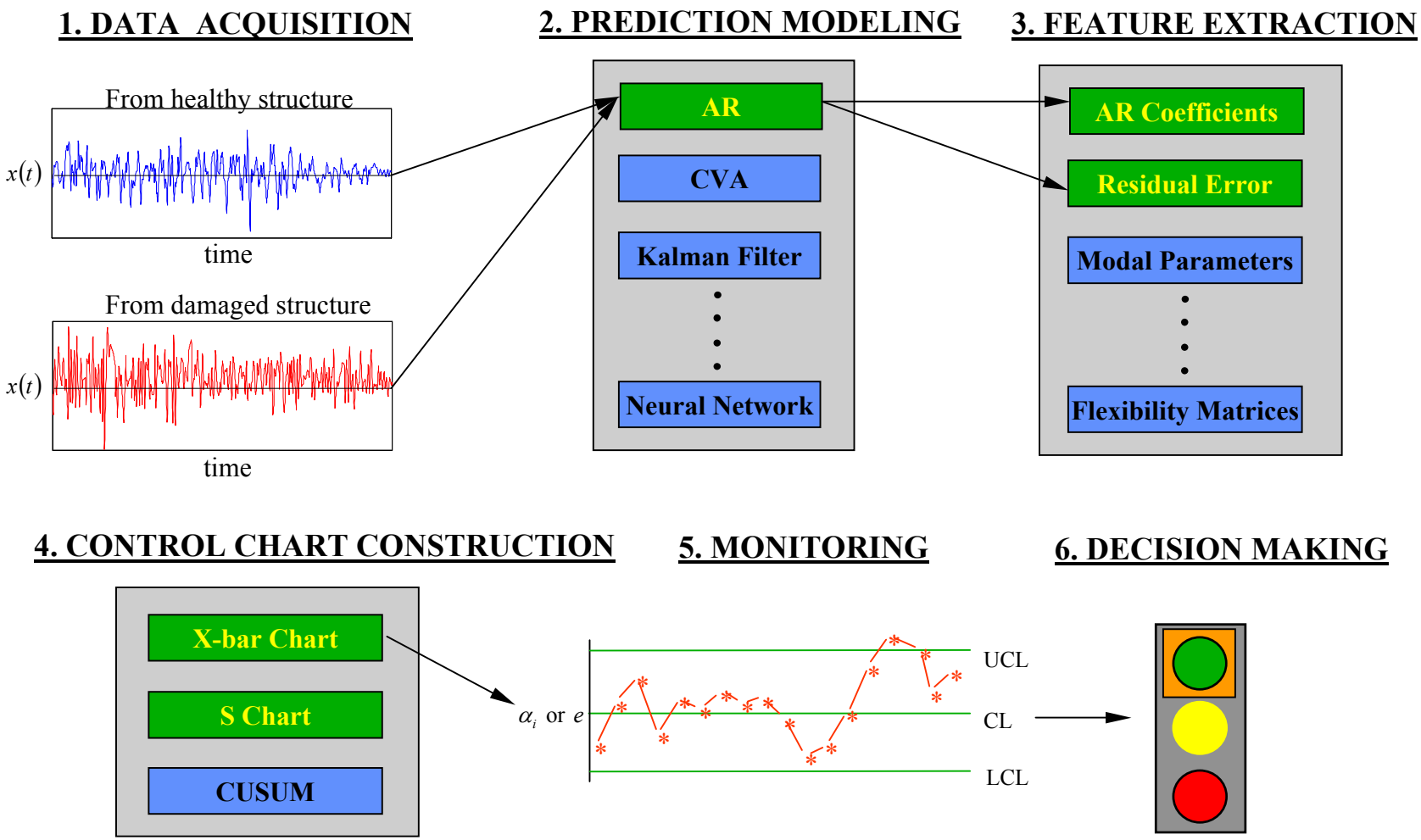


Uncracked



Cracked

4. Statistical Modeling: Outline of the Statistical Process



How to Get Started in Structural Health Monitoring

- We will be happy to help you get your program going:
  - Consult for you on various aspects of your project:
    - Program and resource planning
    - Experiment design
    - Feature selection and identification
    - Statistical methods
  - Conduct an in-house short course tailored to your application
- Please contact us for any further information:
  - Email Hoon or Chuck directly:
    - sohn@la-dynamics.com
    - farrar@la-dynamics.com
  - http://www.la-dynamics.com
  - (435) 603-0375