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Title: Potential Collaborative Research topics with Koreaâ€™s Agency for Defense Development

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Potential Collaborative Research topics with Korea's Agency for Defense Development

The Engineering Institute:

A Collaborative Education and Research Program Between

Los Alamos National Laboratory and UCSD's Jacobs School of Engineering

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Abstract

- This presentation provides a high level summary of current research activities at the Los Alamos National Laboratory (LANL) – University of California Jacobs School of Engineering (UCSD) Engineering Institute that will be presented at Korea's Agency for Defense Development (ADD). These research activities are at the basic engineering science level with different level of maturity ranging from initial concepts to field proof-of-concept demonstrations. We believe that all of these activities are appropriate for collaborative research activities with ADD subject to approval by each institution. All the activities summarized herein have the common theme that they are multi-disciplinary in nature and typically involved the integration of high-fidelity predictive modeling, advanced sensing technologies and new development in information technology. These activities include:
- Wireless Sensor Systems
- Swarming Robot sensor systems
- Advanced signal processing (compressed sensing) and pattern recognition
- Model Verification & Validation
- Optimal/robust sensor system design
- Haptic systems for large-scale data processing
- Cyber-physical security for robots
- Multi-source energy harvesting
- Reliability-based approaches to damage prognosis
- SHMTools software development
- Cyber-physical systems advanced study institute

Possible Collaborative Research Activities

- Wireless Sensor Systems
- Swarming Robot sensor systems
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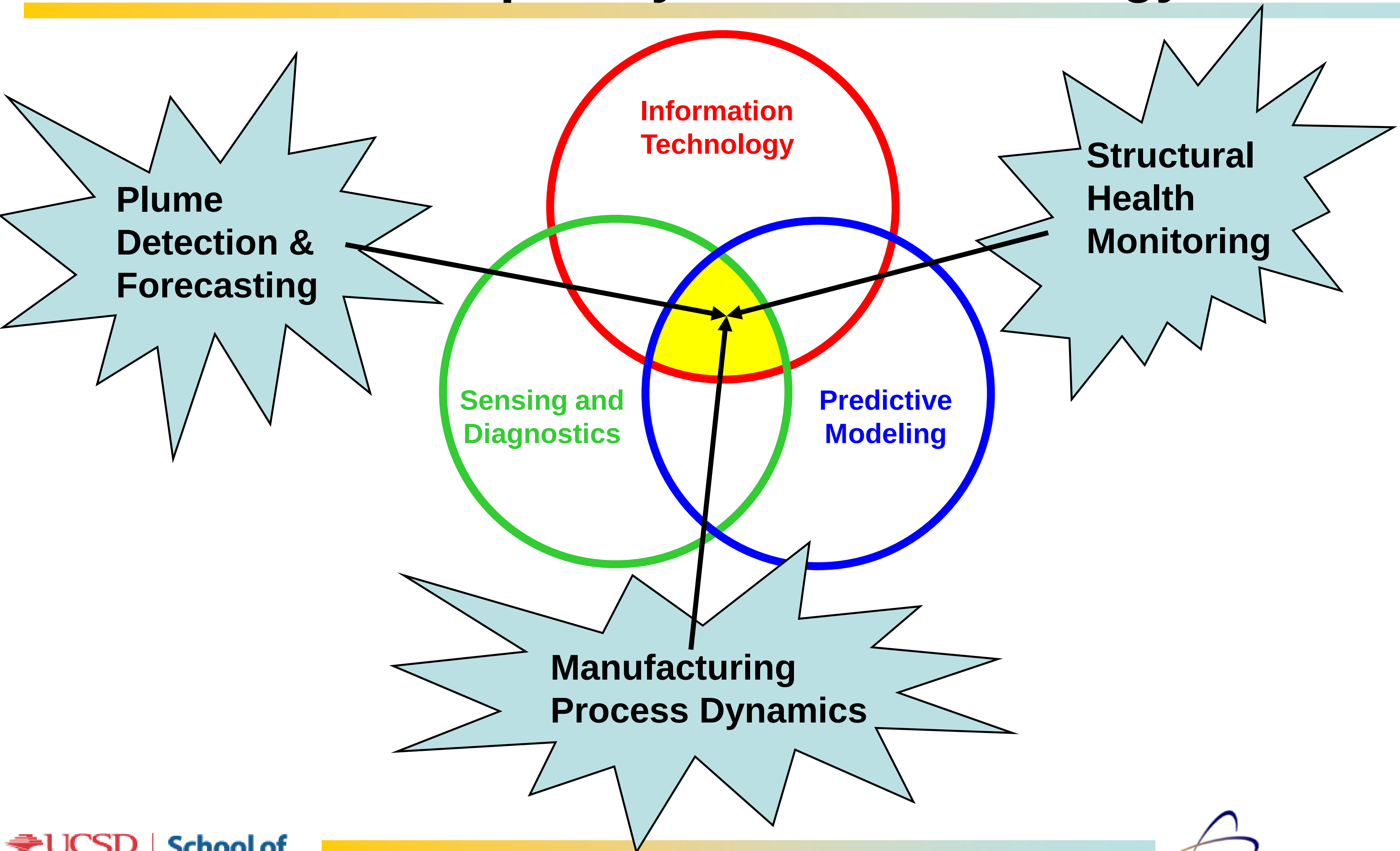
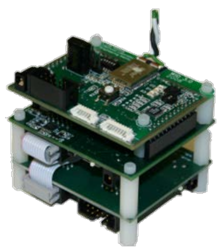
The Engineering Institute's Multidisciplinary Research Strategy



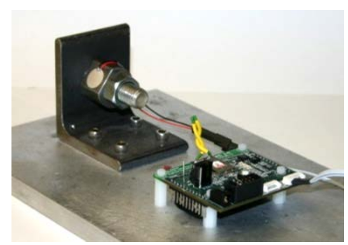
Wireless Sensor Nodes for System State Awareness

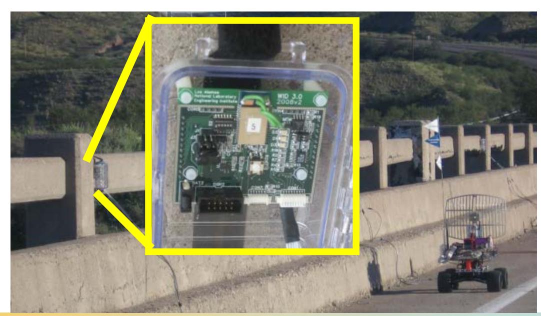
- Development of an ultra-compact, low power wireless sensor nodes for structural sensing and system state awareness.
  - can be coupled with energy harvesting techniques and a suite of signal processing tools for structural sensing and monitoring.
  - can be used for other situational awareness activities such as intruder detection and monitoring in hazardous environments.

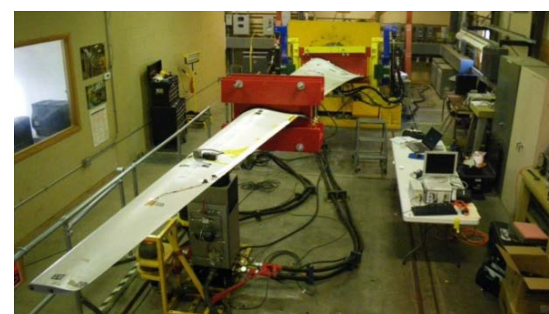
Energy Efficient Sensor Nodes



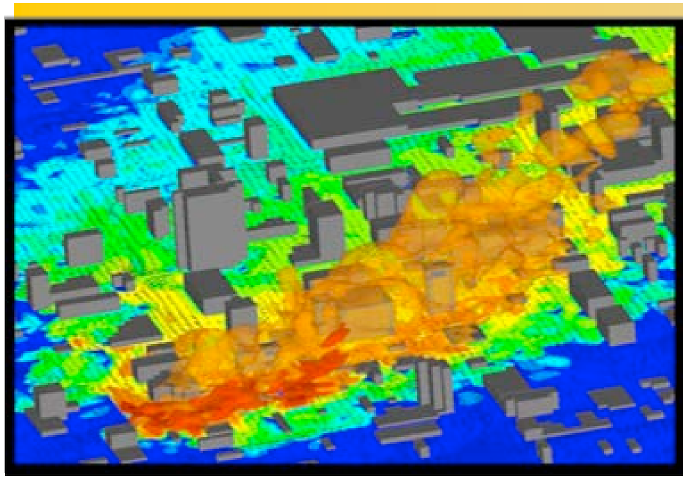
Field Demonstration

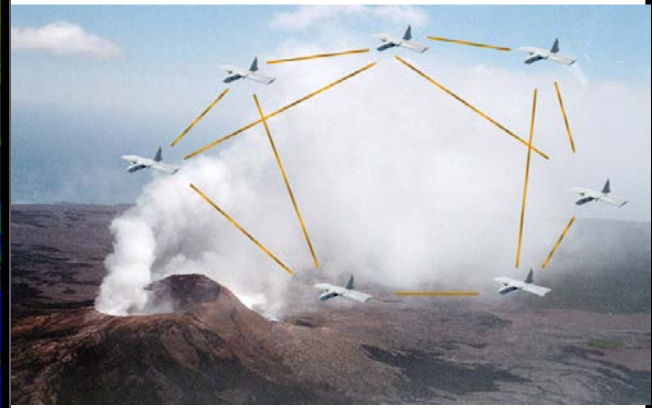






Detection, Estimation & Forecasting of Urban Plumes





Environmental flows are **convection dominated**.
Mixing is a strong function of **background stratification**.
Must estimate **winds**, **stratification**, & **concentration**.
Two related problems:

1. Data Assimilation (EnVE)

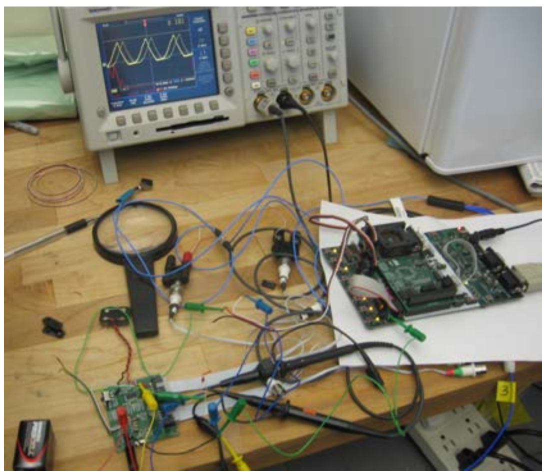
- Estimate state in model based on measurements.
- Quantify uncertainty in estimate / forecast.

2. Adaptive Observation (EnVO)

- UAVs with GPS, chem/bio/nuclear sensors, radios.
- Controlled mobility of sensor network: **couple UAV trajectory optimization with data assimilation algorithm to minimize the forecast uncertainty**.
- **Demonstrated the ability to communicate mobile sensor data to high performance computer!**

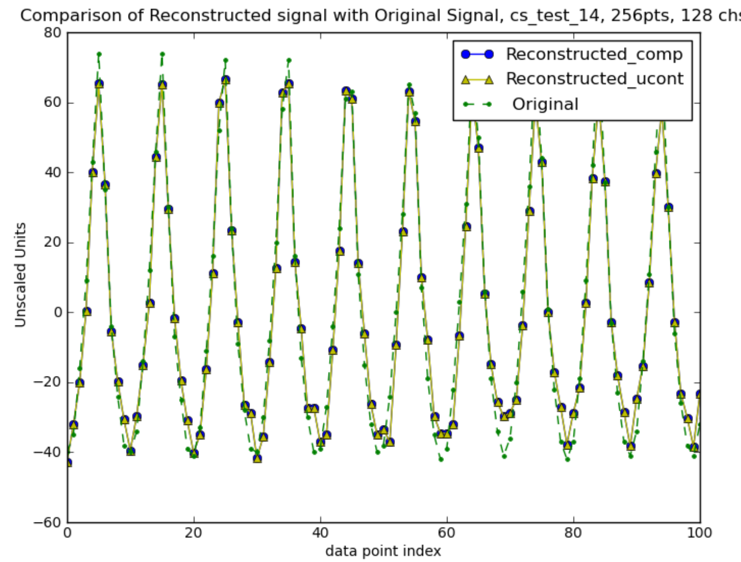
Embedded Compressed Sensing

- Proof of concept study developing low-power embedded sensor nodes implementing compressed sensing.
- Implemented a digital version of the “smashed filter.” (a “matched filter” in the compressed domain).



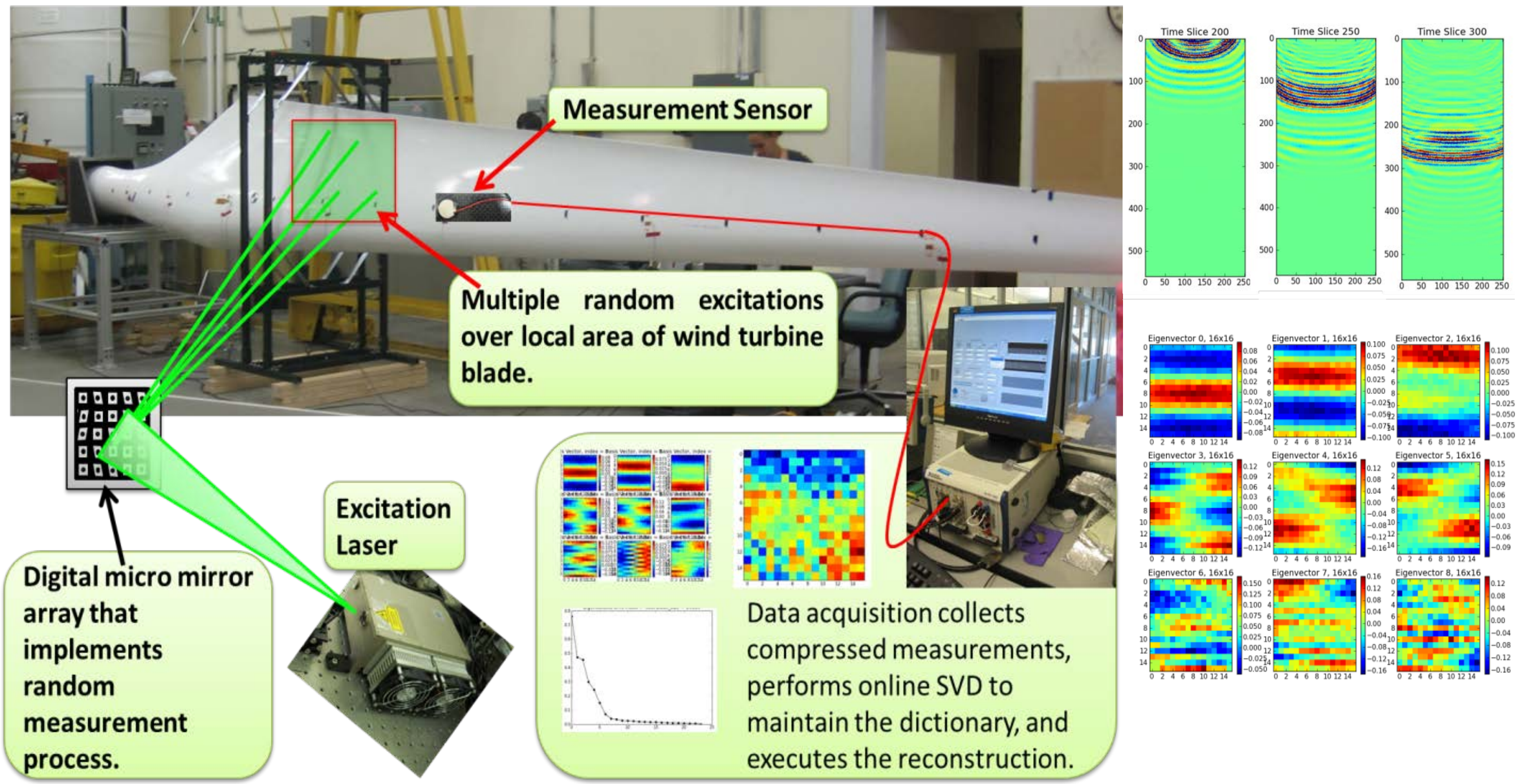
Prototype compressed sensing hardware

Test structure



Signals reconstructed using L1 norm minimization on compressed coefficients.

Applied Compressed Sensing, Structural Health Monitoring, and Non Destructive Evaluation Research with our EI-K partners.



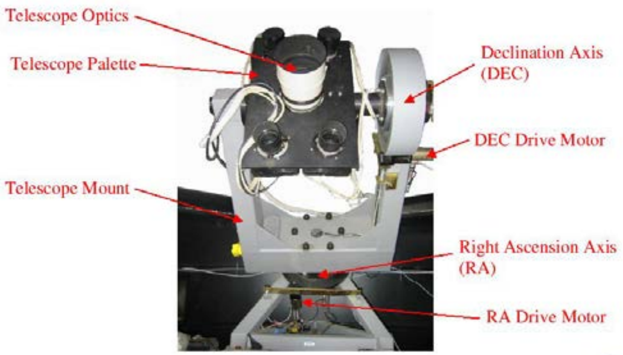
UCSD Jacobs | School of Engineering

Engineering Institute Korea
Los Alamos National Laboratory
Chonbuk National University
ETS. 2011

Los Alamos National Laboratory

Real-time Condition Assessment of RAPTOR Telescope Systems

Project Goal: Develop an embedded, autonomous monitoring system that provides RAPTOR operators with real-time telescope mechanical condition data facilitating improved maintenance schedules and system reliability.



Data Collection / Analysis

⇩

Statistical Pattern Recognition

⇩

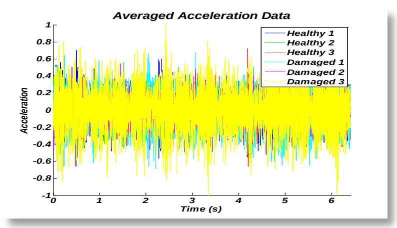
Damage Model Validation

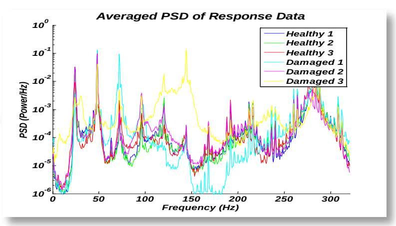
SHMTools

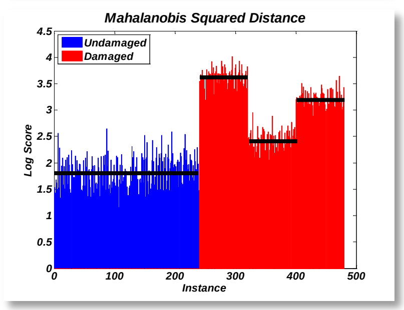
+

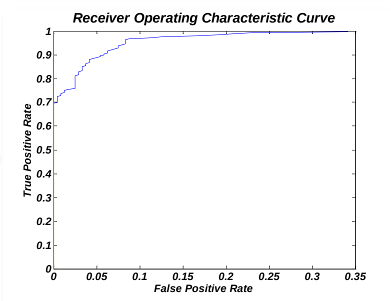
mFUSE

Function Sequencer for MATLAB





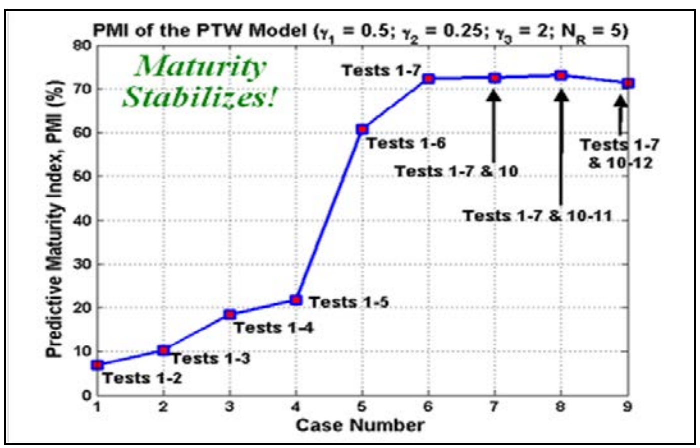




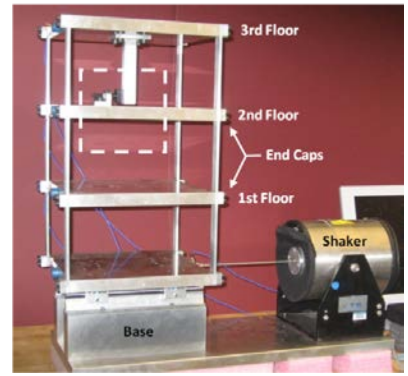
Verification & Validation Research for Advanced Modeling and Simulation

<u>Project Goal:</u> To develop a metric that describes the capacity of a code to make predictions in design space regions where experimental data do not exist.

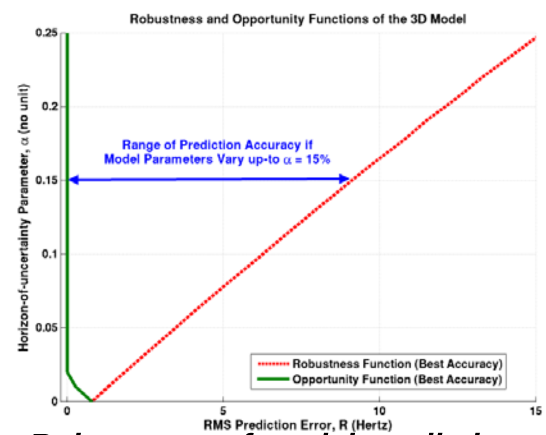
- PMI is a metric that evaluates predictive capability as model calibration proceeds." PMI is a function of:
  - coverage of design space by experimental data;
  - number of calibration parameters in model;
  - discrepancy between experimental and numerical data.



- This figure shows how PMI quantifies that additional experimental tests do *not* provide more information,



The three-story frame structure (left) and 3D finite element model (right).



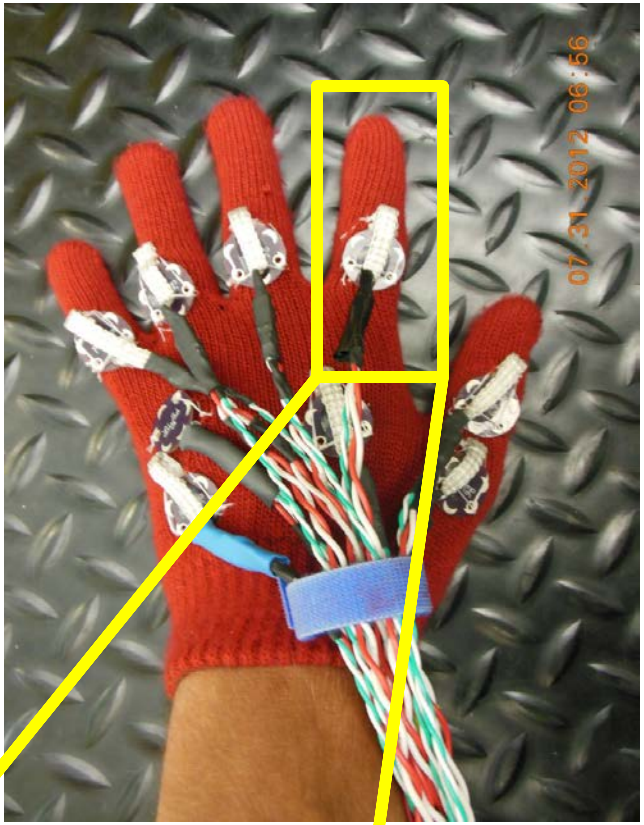
Robustness of model predictions.

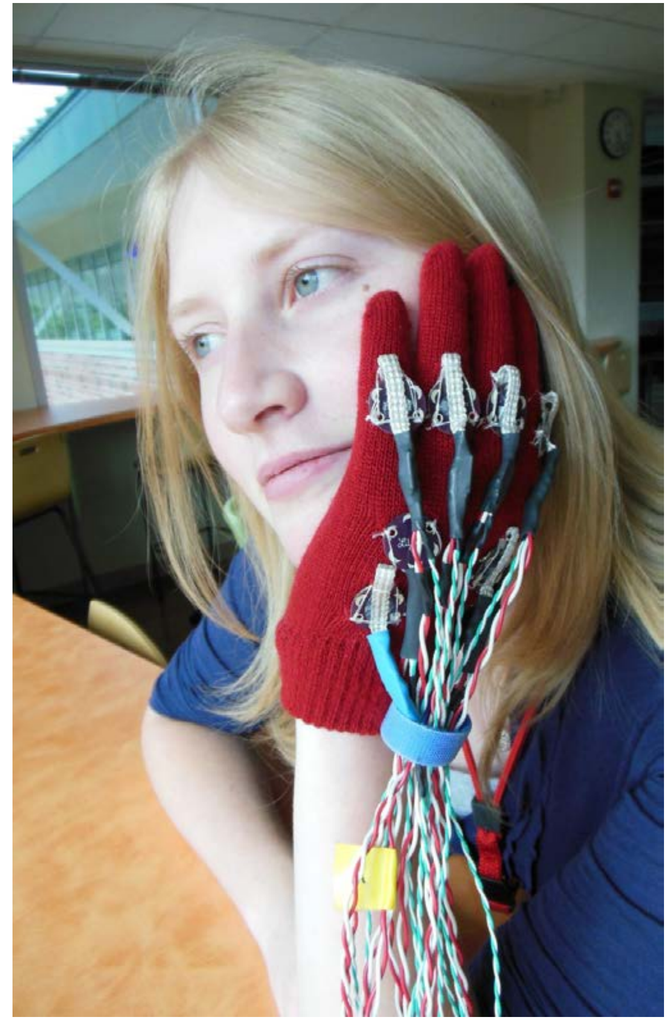
Bayesian Risk Formulation For Optimal Sensor System Designs

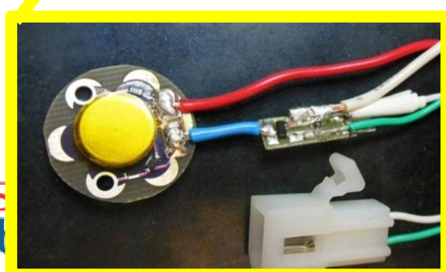
- What are the **relevant damage states, *θ*,** and their **probability** of occurring P(θ)?
  - "Undamaged" / "Damaged", Continuous states: extent, location
- What are the **system costs** associated with the SHM design?
  - Hardware cost, Maintenance cost, Operation cost
- What **actions, *d*,** does the SHM/DP system dictate in response to observing a damage state?
  - Continue/reduce/stop operation; Inspect component or entire structure; do nothing
- What are the **costs** of taking each of those response actions?
  - Cost of inspection vs missing damage, detecting damage in the wrong location

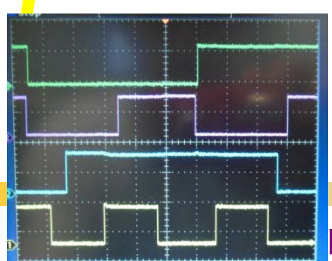
$$\mathrm{E}\left(L\right)=\sum_{\theta,d}\mathrm{L}_{\mathrm{d}}\left(d,\theta\right)\mathrm{P}\left(d\,\middle|\,\theta,e\right)\mathrm{P}\left(\theta\right)+\mathrm{L}_{\mathrm{e}}\left(e\right)$$

Vibro-Tactile Haptic Device Overview









Cyber-physical security challenges posed by humans to unattended mobile sensor node

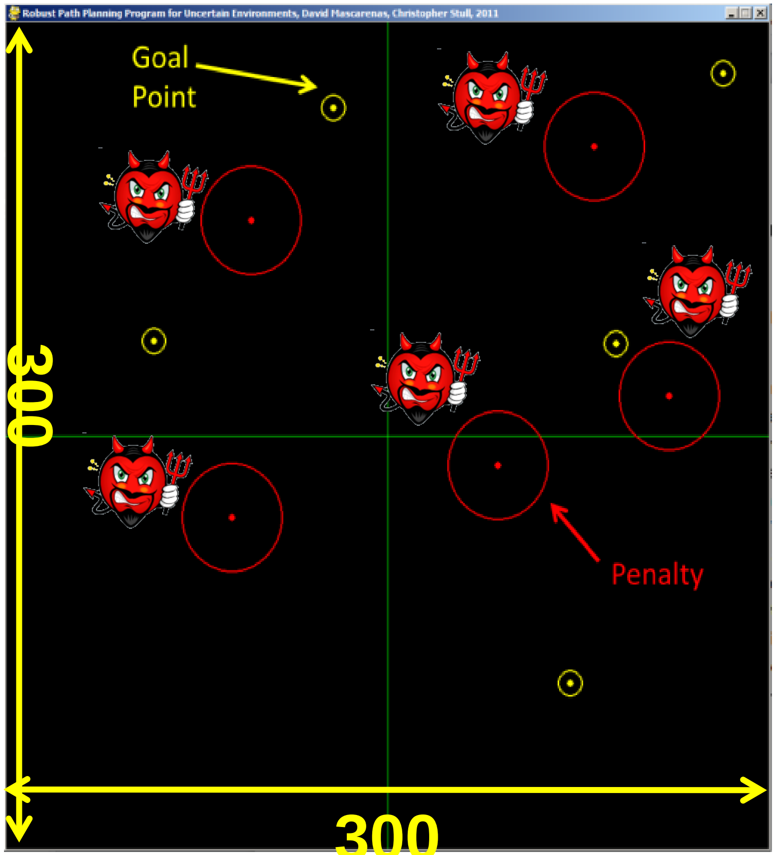
I've got it !!!
- Theft
- Vandalism
- Data tampering
- Contamination of hardware/software

If I vary my paths and change my routines I will be harder to exploit. How should I do this intelligently in the face of uncertainty?

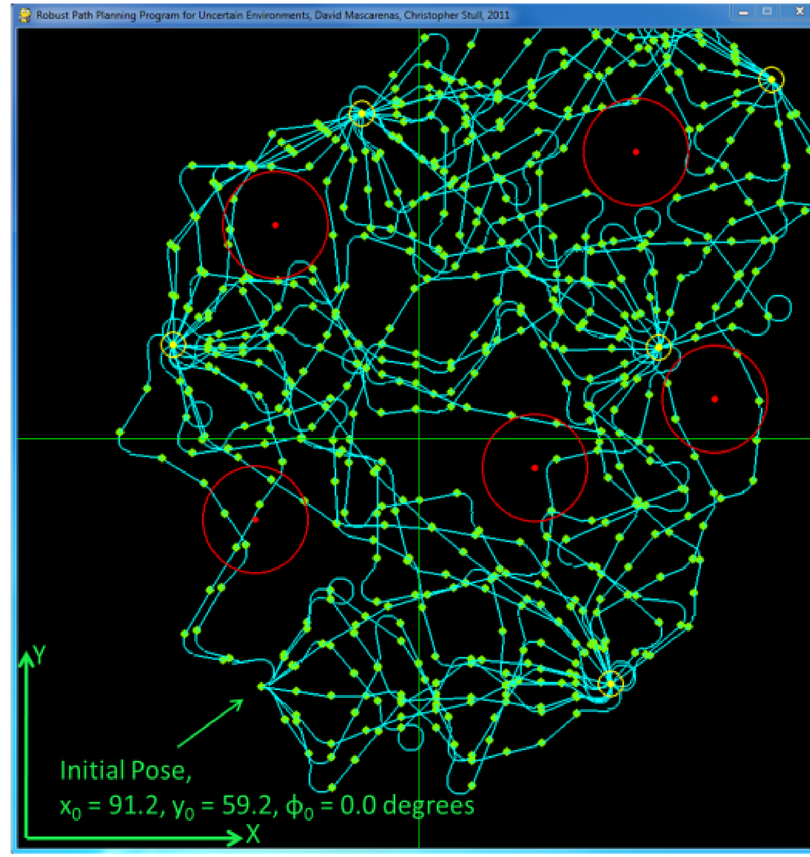
Inspired by Tim White, NEN-2

Take away message is that there are many, many ways complex cyber-physical systems can be exploited. By developing techniques to vary paths and change routines in an intelligent manner we hope to mitigate penalizers in a general sense.

: Well, I have an observation/estimate of the environment state and where I think penalties might be but there is a lot of uncertainty. I will use my random path generator to generate 10 random paths and I will see what I get.

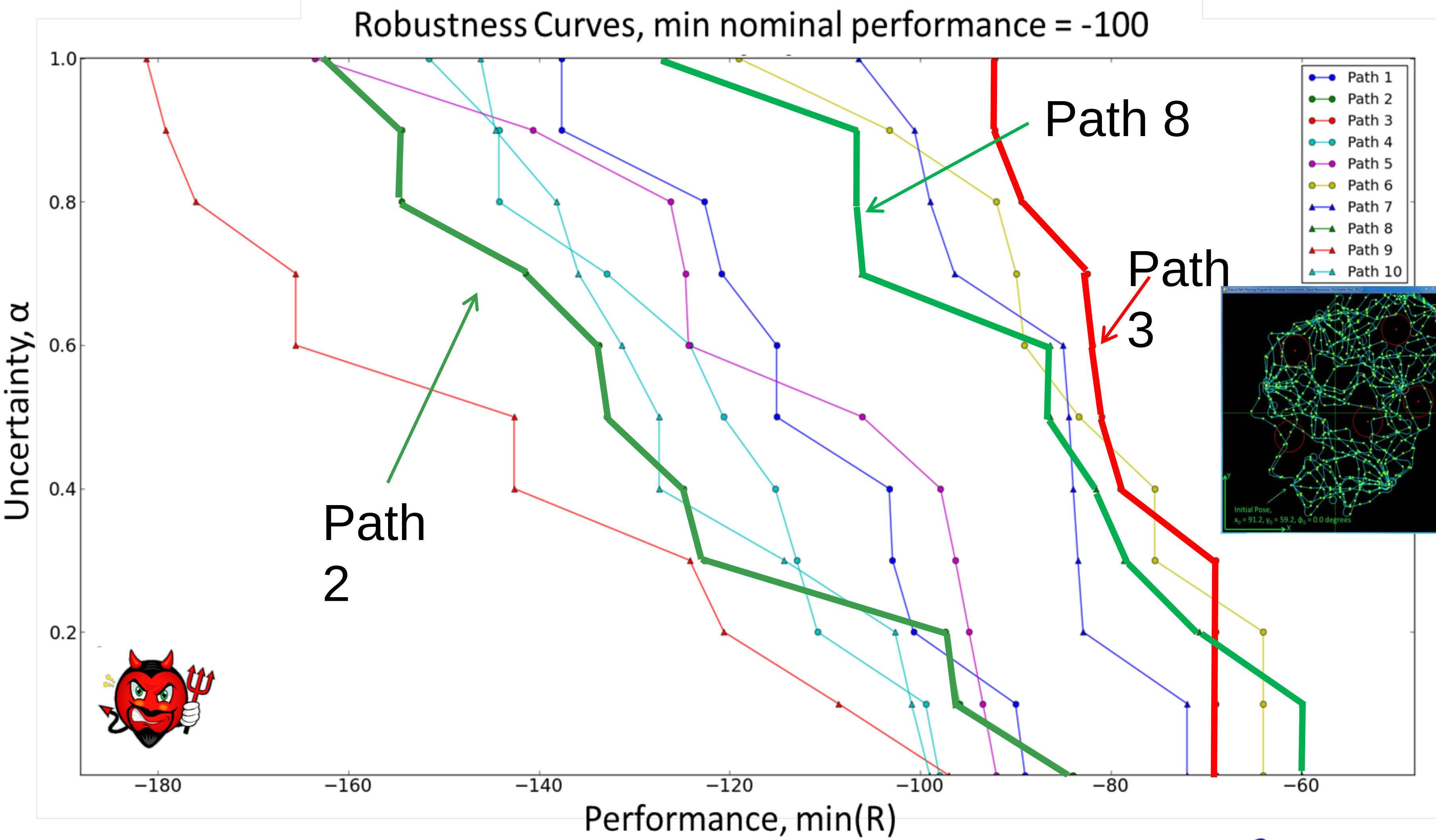


Typical elements in an environment that need to be address by the path planner. Adding regions of reward is a trivial extension. Obstacles in the environment can be dealt with as well.



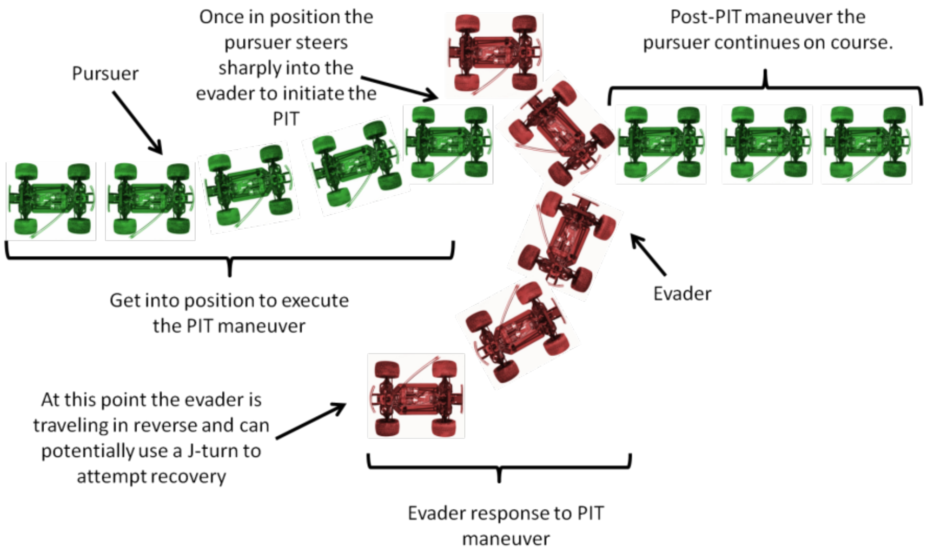
10 randomly generated paths. The paths satisfy a minimum nominal performance constraint.

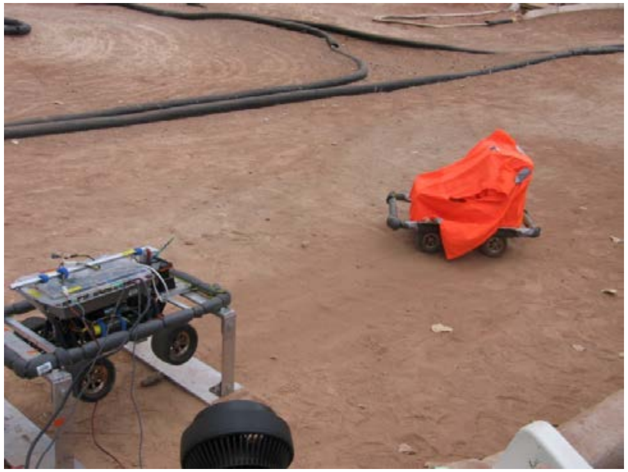
: **Ok, I have some admissible random paths and I went ahead and did some info-gap decision theory analysis. So which path should I choose**?

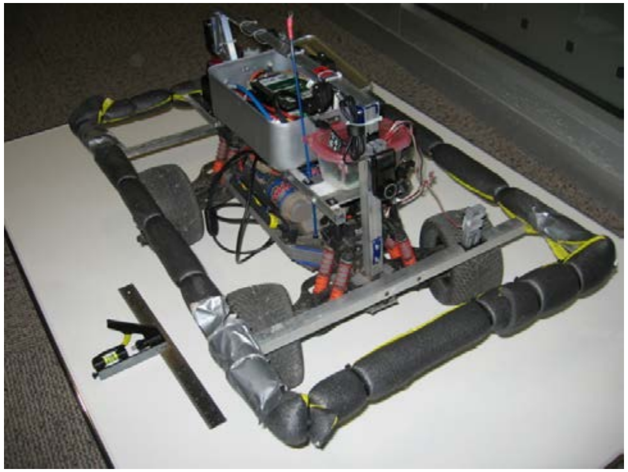


Mobile Sensor Node Research

- Wireless sensor network capable of self-preservation, Anti-theft
- Wide-area CO2 monitoring
- Wireless energy delivery







Crowdsourcing Cyber-Physical Security: The DEFCON 20 Cyber-Physical Security Honeypot Challenge

Robot Operating System (ROS)

From the ROS Community Metrics Report[1]

- Downloaded 290,000 times
- Cited in 125 papers
- From 2010 to 2011, the ROS community has **doubled** in size and the number of ROS packages has increased from 1643 to 3128!

One of the questions surrounding ROS for commercial and government use relates to how secure it is.

DEFCON

Set up a robotic ROS honeypot at a major computer security conference and challenge conference attendees to identify and exploit **cyber-physical** security weaknesses.

Jarrod McClean, Harvard, Computational Chemistry/DOE High Performance Computing Fellow/T-1/CNLS

Christopher Stull, LANL, AET-6

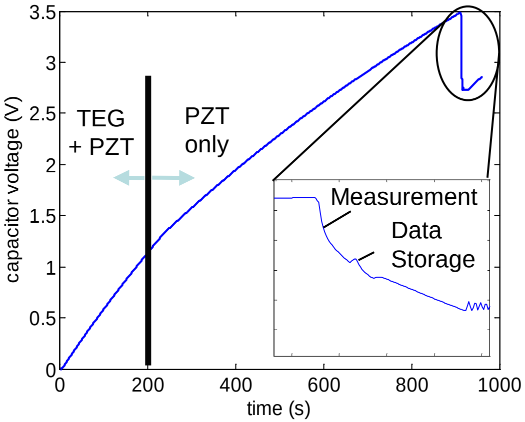
David Mascareñas, LANL Engineering Institute/AET-1

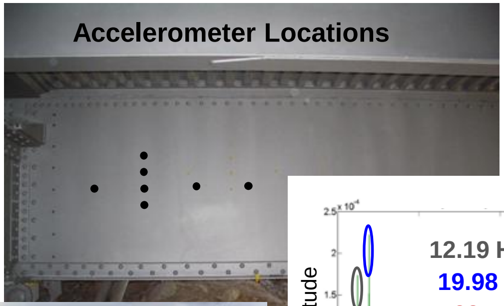
Additional guidance and support was provided by Charles Farrar, Keith Lindsay, Harald Dogliani, Richard Taylor, Ed Schaller, and Steve Girrens

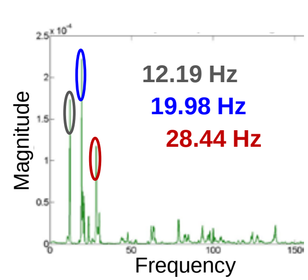
Multi-Source Energy Harvesting

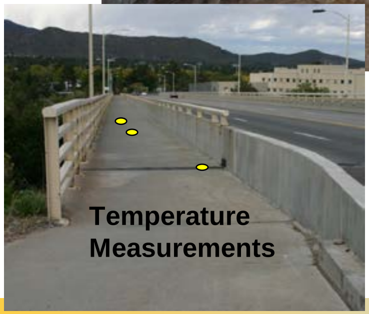
- **Unique Contributions: integrated design approach that couples harvester design with sensor node development; hybrid multi-source approach combines EH with traditional storage and transmission techniques; hybrid power sources for implantable medical devices**
- **Mission relevance: National, Global, Energy security**

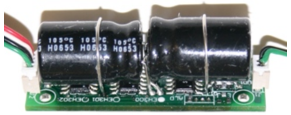


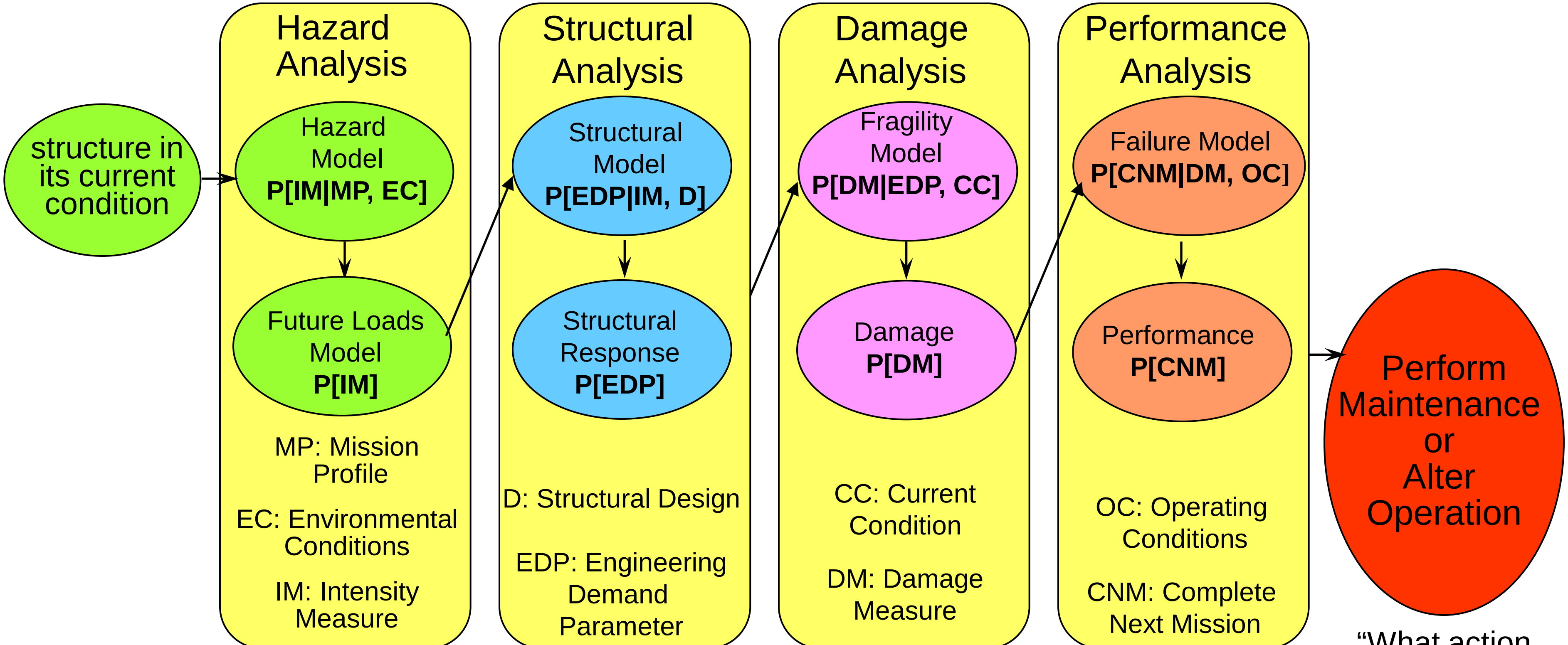








Reliability-Based Approaches to Damage Prognosis



"How likely is a loading event of intensity IM, in the aircraft's next X years of service"

"What structural demands (stress, cycles deformation, etc..) will this system experience?"

"What physical damage is this structure likely to experience?"

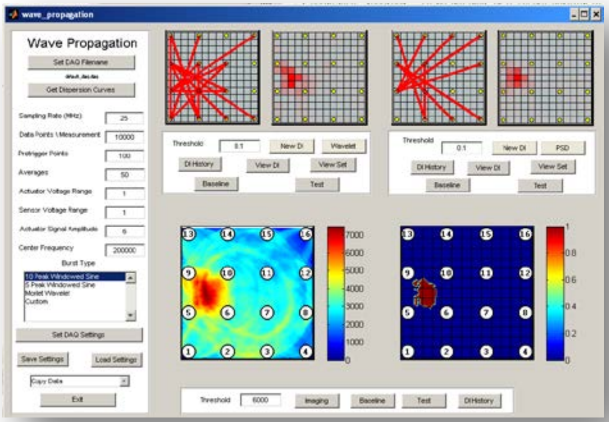
"How does damage impact structural performance?"

"What action must be taken to continue operation of the structure and meet performance objectives?"

SHMTools Software

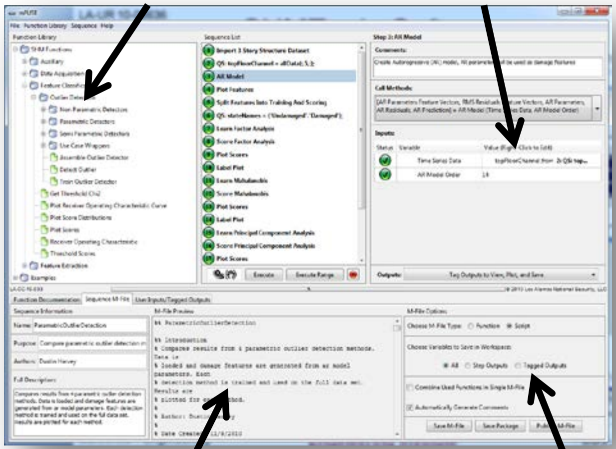
A flexible framework for feature extraction and pattern classification

- Standardized
  - Naming
  - Documentation
  - Function arguments
  - Experimental data
  - Usage examples
- Easy to Use
  - Modular
  - Extensive Documentation
  - Example Usage
- Expandable
  - Open Source
  - Flexible Structure
- Hardware Embeddable
  - Efficient
  - Compilable as C Code
- Research-Oriented
  - Freely available
  - Open source
  - Useful to the SHM community
  - Serves as reference material
  - Cites research literature
  - **500+ downloads since Sept. 2010!**



Extensive Function Library

User Input Controls



Script Preview

Process Export

Download from http://institutes.lanl.gov/ei

UCSD Jacobs School of Engineering

Engineering Institute

Los Alamos NATIONAL LABORATORY

EI Advanced Studies Institute Concept

- Invite innovative graduate student and postdoctoral researchers from around the country
- ~3 week duration
- Arrange into small teams of 2-4 researchers
- Develop a lecture series to catch bring researchers up to speed on <u>multidisciplinary</u> problems of interest to the laboratory.
- Research high-risk, forward thinking concepts.
- In some cases try to develop prototype, proof-of-concept demonstrations or models.