

# LA-UR-22-25877

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**Title:** A Structural engineering Graduate Degree Program with specialization in structural health monitoring & non-destructive evaluation

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**Intended for:** Advertise graduate degree program to perspective students

**Issued:** 2022-06-24



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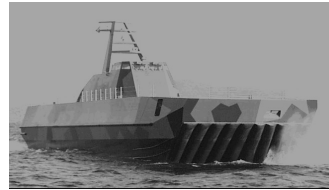
Jacobs School of Engineering, University of California, San Diego

# A STRUCTURAL ENGINEERING GRADUATE DEGREE PROGRAM WITH SPECIALIZATION IN STRUCTURAL HEALTH MONITORING & NON-DESTRUCTIVE EVALUATION

**PROF. MICHAEL D. TODD**  
**ADJUNCT PROF. CHARLES R. FARRAR**

**Structural Health Monitoring (SHM)** encompasses the integration of a broad range of technologies from sensing/actuating, data interrogation, and statistical modeling to enable system-level or component-level health assessment and predictive modeling.

## Structure



- defined failure or functionality loss
- operational evaluation
- technology integration
- deployment challenges

## Sensing/Instrumentation



- novel transducers
- architecture optimization
- power management
- data archiving/telemetry
- modality multiplexing

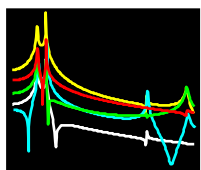
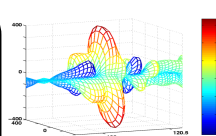
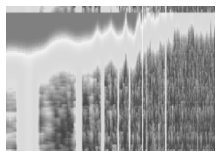
- advanced FEA
- failure mode modeling
- correlation/updating

## Modeling/Simulation



- feature extraction
- algorithm development
- data mining
- information technology
- data compression and management
- hardware implementation

## Data Interrogation/Management

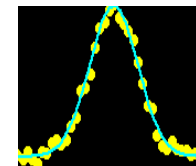
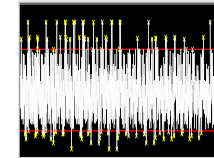


## Diagnostic State of Structure



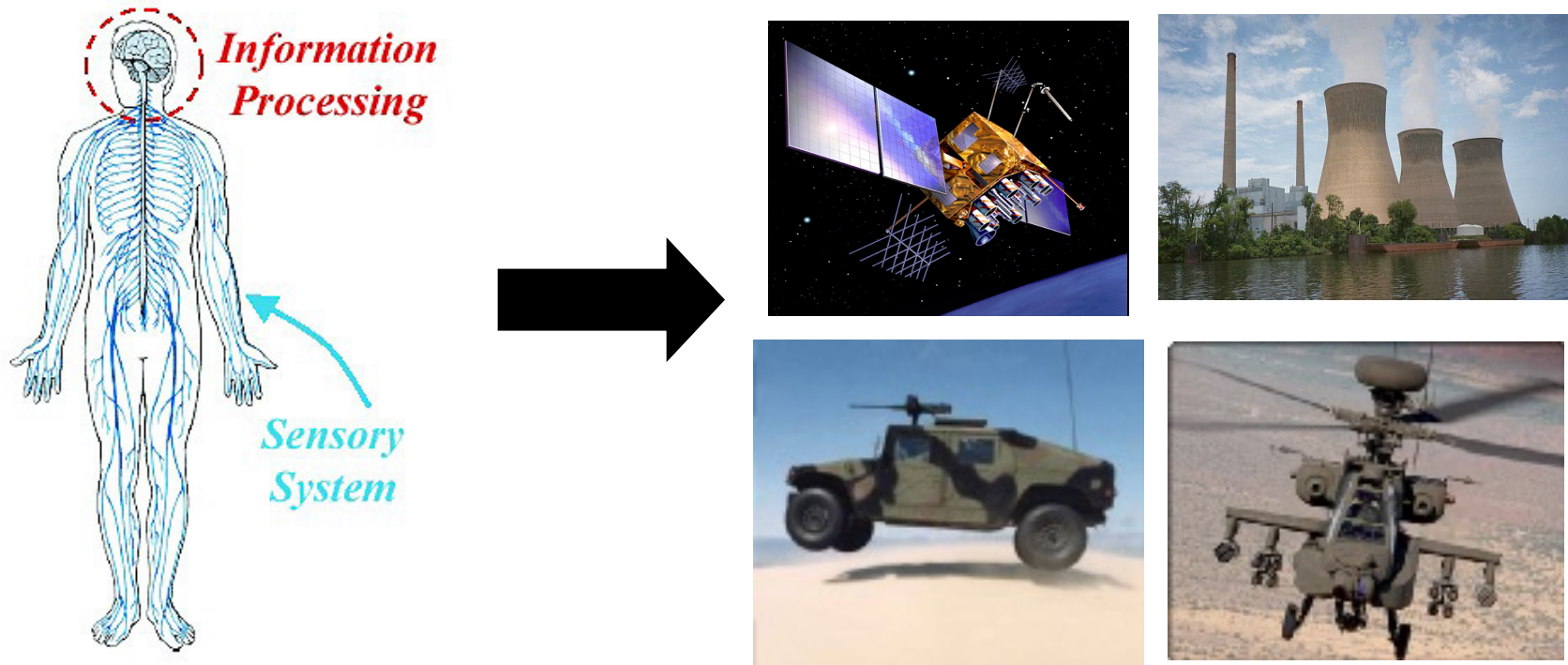
- integration of all components to make an INFORMED decision about the current asset state and make a PREDICTION about the future asset state
- What should I do about this hull damage?

## Decision Sciences



- statistical modeling
- uncertainty propagation and quantification
- economic constraints
- other considerations

Doing SHM is like being a “doctor for structures” ....



We devise and deploy sensing and information processing strategies so that structures become “smart” and help inform us when their performance is degrading, need maintenance, or will soon fail.

- MS/PhD in SHM/NDE (only one in the USA!) equips you with interdisciplinary knowledge:
  - Sensing technologies
  - Data interrogation
  - Modeling and analysis
- Intersection and integration of these fundamental to supporting SHM/NDE
  - Encompasses structural, civil, mechanical, aerospace, and marine engineering
  - Supports “design-to-retirement” life cycle management of systems

Requirement	Thesis option	Comprehensive option
<b>Core courses:</b>	SE 263 – NDE (4) SE 265 – SHM Principles (4)	SE 263 – NDE (4) SE 265 – SHM Principles (4)
<b>Capstone experience:</b>	No requirement	SE 296 – Independent Study (4)
<b>Thesis research:</b>	SE 299 – Graduate Research (8)	No requirement
<b>Sensing Technology focus area</b>	One course (4)	One course (4)
<b>Data Interrogation focus area</b>	Two courses (8)	Two courses (8)
<b>Modeling &amp; Analysis focus area</b>	Two courses (8)	Two courses (8)
<b>Technical elective:</b>	No requirement	One course (4)
<b>Total Units:</b>	<b>36</b>	<b>36</b>

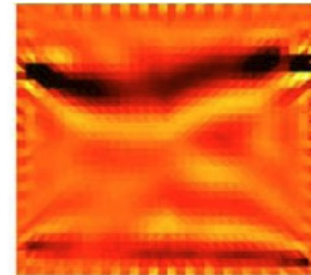
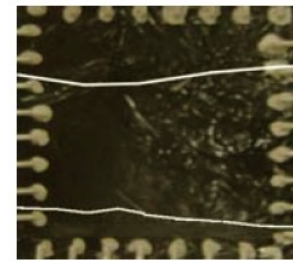
## Examples of the Interdisciplinarity in Focus Area and Elective Courses in the SHM/NDE Program

1. Sensing Technologies	2. Data Interrogation	3. Modeling & Analysis
SE 252 – Experimental Mechanics and NDE	SE 207 - Diagnostic Imaging	SE 207 – Fracture Mechanics and Failure Mechanisms
SE 264 – Sensors and Data Acquisition	SE 267A – Signal Processing and Spectral Analysis	SE 207 - Validation and Verification of Models
SE 266 – Smart and Multifunctional Materials	SE 267B – System Identification*	SE 202 – Structural Stability
SE 268 – Structural Testing and Model Correlation	ECE 251A/B – Digital Signal Processing I/II	SE 203 – Structural Dynamics
CSE 237A – Introduction to Embedded Computing	ECE 253 – Fundamentals of Digital Image Processing	SE 205 – Nonlinear Mechanical Vibrations
ECE 257B – Principles of Wireless Networks	ECE 254 – Detection Theory	SE 206 – Random Vibrations
	SE 268 – Structural Testing and Model Correlation	SE 224 – Structural Reliability and Risk Analysis
	CSE 254 – Statistical Learning	SE 276A – Finite Elements in Solid Mechanics I
	CSE 255 – Data Mining and Predictive Analysis	SE 262 – Aerospace Structures Repair
	MAE 283A – Parametric Identification: Theory and Methods	SE 254 – FRPs in Civil Structures

## Some of the Key Courses in the SHM/NDE Degree Program...

### SE 263: Nondestructive Evaluation and Design

- Learn and use some of the fundamental techniques devised to inspect structures non-destructively, such as liquid penetrant, elastic wave propagation, ultrasonic testing, impact-echo, acoustic emission testing, infrared thermography

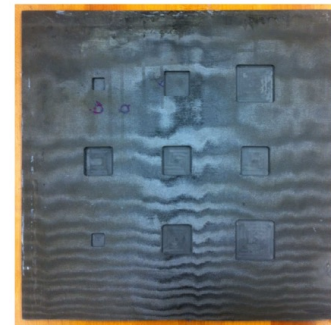
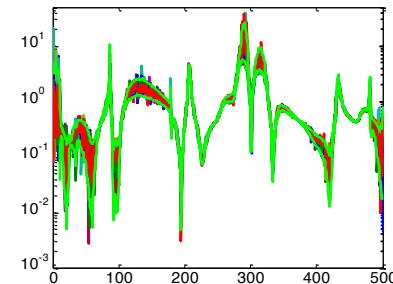


### SE 264: Sensors and Data Acquisition for Structural Engineering

- Study the operating principles for what kinds of data are collected for SHM and how it is acquired and processed for extracting useful information

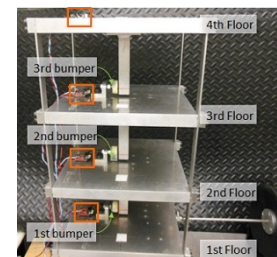
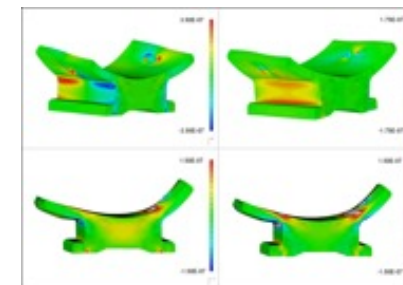
### SE 267: Signal Processing and Spectral Analysis for Structural Engineering

- Discover many of the fundamental signal processing methods for extracting useful information from data acquired in-situ from a structure



### SE 268: Structural System Testing/Model Correlation

- Integrate the process of modeling a structure, designing and executing a vibration test, and updating the model to reflect the test (co-taught with industry partners)



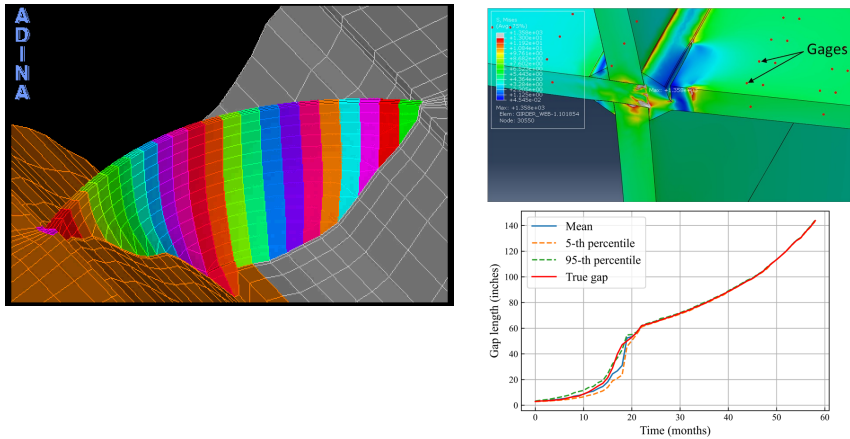
### SE 265: Structural Health Monitoring Principles: Capstone

- Study the entire SHM paradigm of data acquisition, information extraction, and risk-informed decision-making in the context of small-group consultancies

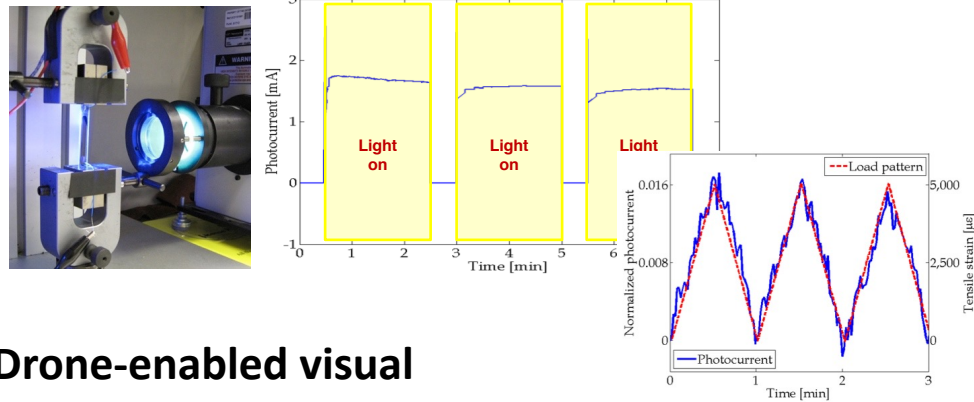


## The SHM/NDE Research Portfolio in the Department is Diverse...

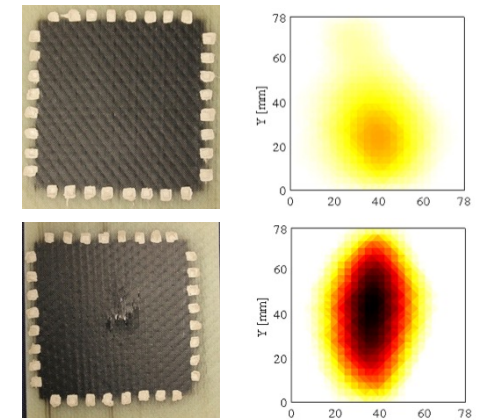
"Digital Twin" modeling of our inland waterway navigational infrastructure



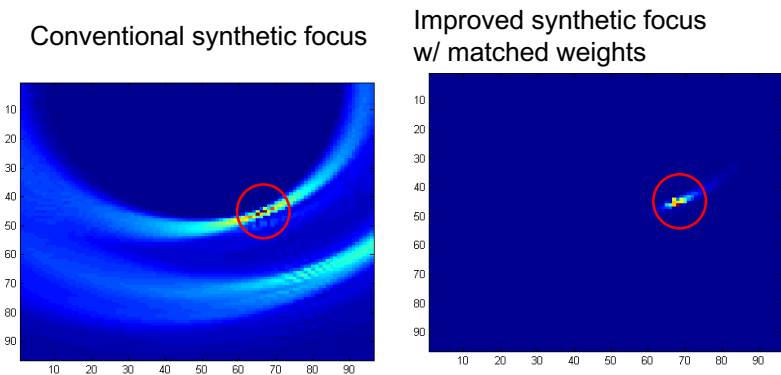
Exploiting carbon nanotube properties for advanced sensing strategies



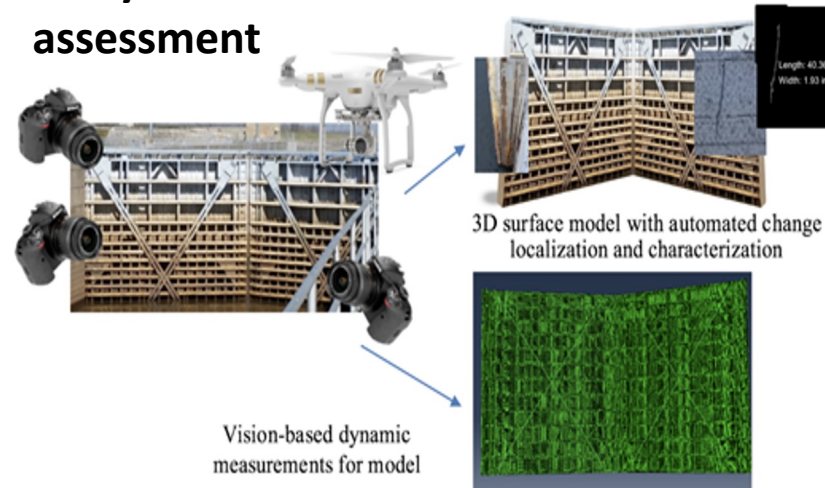
Spatial damage sensing with electrical impedance tomography



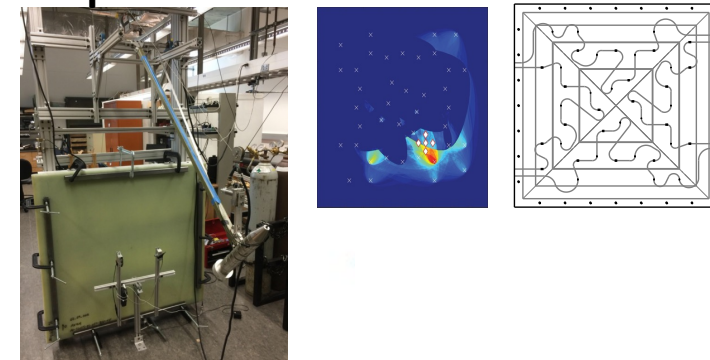
Advanced ultrasonic imaging techniques



Drone-enabled visual analytics for structural assessment



Embedded optical fibers for impact detection



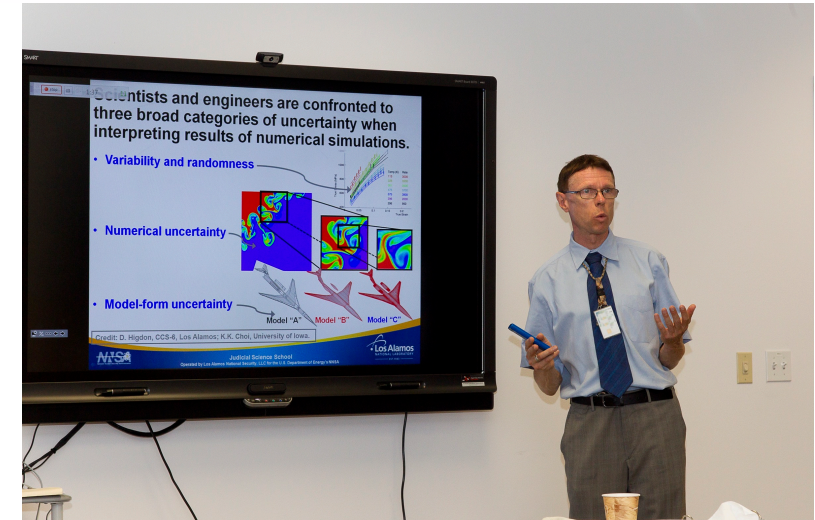
## The Broad "Systems" Type of Education in the SHM/NDE Creates Career Opportunities in Many Sectors...

- **Aerospace** (e.g., Northrop Grumman, Collins Aerospace, Boeing)
- **Automotive** (e.g., GM, Ford, supply chain companies)
- **Civil** (e.g., design firms, retrofitting firms, Caltrans)
- **Engineering services firms** (e.g., ATA-Engineering, Quartus, HBK, FDH), and **focused small businesses** (e.g., Metis Design, Micron Optics, Acellent Technology, Structural Focus, Elintrix Inc.)
- **US government** (Dept. of Defense and Dept. of Energy laboratories, e.g., Los Alamos National Lab, Naval Research Laboratory, USACE Engineering R&D Center)
- **Academia**

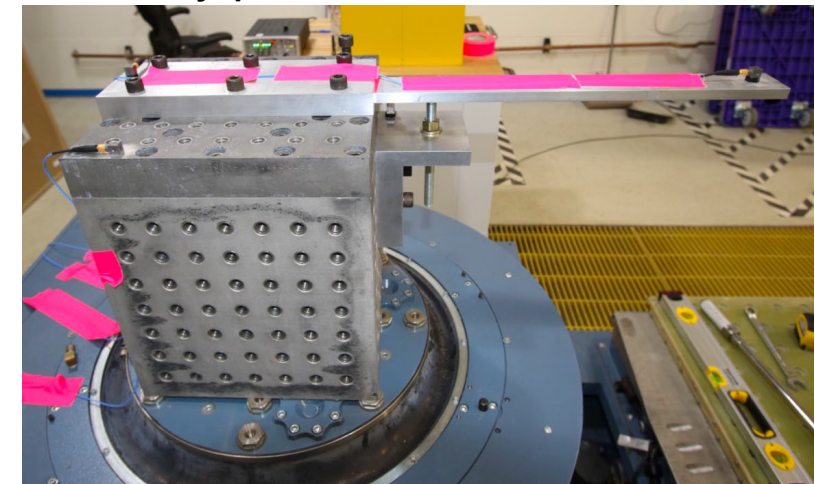


## Distance Learning at Los Alamos National Laboratory

- Los Alamos is experiencing an unprecedented growth in weapons engineering. Majority of new hires are at the BS level.
- New hires may wait 6-18 months to obtain a security clearance – **what do they do while waiting for the clearance?**
- Solution: offer them the opportunity to obtain a MS degree on site at LANL during this period.
  - **They are paid full salary!**
  - **LANL covers all education costs (books, tuition, software)**
- For MEs the UCSD SHM/NDE program is ideal because of the flexibility in courses that can be used to meet the degree requirements.
- LANL engineers use job-related projects to meet capstone course requirements.
- This distance-learning degree program was first offered in 2017 and to date approx. 40 engineers have obtained their MS degrees.



LANL Engineer giving model validation & uncertainty quantification lecture



Capstone project vibration test developed by LANL Engineer pursuing MS degree

## Primary SHM/NDE Faculty in the Structural Engineering Department



Mike Todd



Francesco  
Lanza di Scalea



Ken Loh



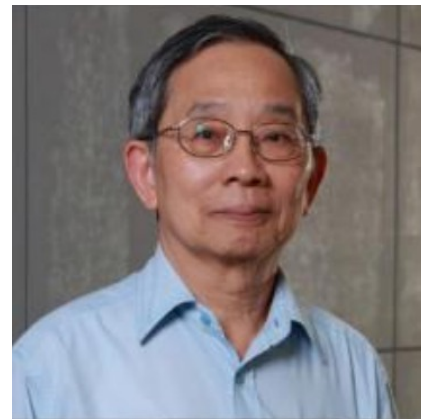
Joel Conte



Falko Kuester



Chuck Farrar (Adjunct)  
Los Alamos National  
Laboratory



Chin-Hsiung Loh  
(Adjunct)