## EI Annual Workshops

EI hosts an annual workshop with focus on the broad areas of predictive modeling, advanced sensing and information technology. The reports from these workshops are available on our website. We also work with other LANL organizations to co-host workshops. For more information, please contact Chuck Farrar at farrar@lanl.gov, 663-5330.

## Events

**Please contact Chuck Farrar (farrar@lanl.gov, 663-5335) for more information.**

- **Spring 2012 UCSD courses (Instructor)**
  - **Structural Health monitoring Principles (SE 265, Charles Farrar), M/W 8:30-9:50 am**
  - **Experimental Mechanics and NDE (SE 252, Francesco Lanza di Scalea), M 5:00-7:30 pm**
  - **Digital Signal Processing I (SE251A, William Hodgkiss), Tu/Th 9:00-10:20 am**
  - **Nonlinear Mechanical Vibrations (SE205, Mike Todd), Tu/Th 9:00-10:20 am**
  - **Advanced Reinforced and Prestressed Concrete Design (SE211, Pui-Shum Shing & Jose Restrepo), Tu/Th 1:30-2:50 pm**

**Engineering Institute News Letter January 2012**

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# Engineering Institute

## this issue



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## The Engineering Institute

The Engineering Institute (EI) is a collaboration between LANL and the University of California at San Diego (UCSD) Jacobs School of Engineering whose mission is to develop a comprehensive approach for 1) conducting mission-driven, multidisciplinary engineering research and 2) recruiting, revitalization and retention of the current and future staff necessary to support LANL's national security missions.

The components of the Engineering Institute are 1) the Los Alamos Dynamic Summer School 2) a joint LANL/UCSD degree program, 3) joint LANL/UCSD research projects, 4) annual workshops, and 5) industry short courses.

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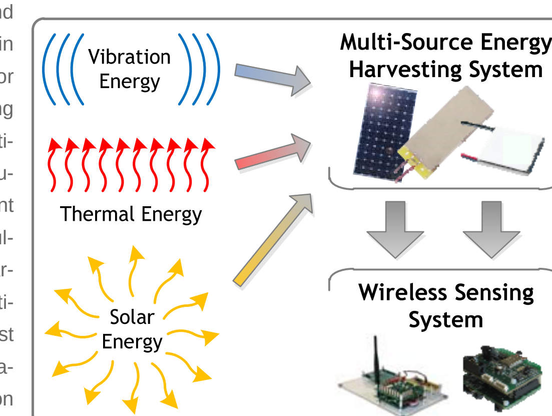
## Multi-Source Energy Harvesting for Remote Power Application

Energy harvesting technology is critical in the development of self-powered, autonomous electronic devices. In remote locations, power from an electrical grid is often unavailable. While batteries present a potential energy source for remote electronics, their periodic replacement increases costs and requires ease of access to the device. Harvesting energy from the local environment (such as vibration, thermal, and solar energy) allows electronic devices to become self-powered and alleviates the issues associated with battery operation. Conventional (single source) energy harvesting systems, however, are highly susceptible to fluctuations in available ambient energy which can cause a device to go "offline" if adequate ambient energy is unavailable.

A team composed of EI and AET-1 researchers (Kevin Farinholt, Steve Anton, and Trevor Avant) has been investigating ways to create robust, multi-source energy harvesting solutions in which several ambient energy sources are utilized simultaneously in a single energy harvesting system. Such a multi-source system is robust against varying environmental and operational conditions as the operation is not tied to a single ambient source. The research approach for this project is divided into three principle tasks: a) the identification, modeling, and characterization of novel transducer materials that convert energy between mechanical, thermal, and electrical domains, b) the development of efficient power management circuitry that collects and conditions energy from several disparate sources while providing regulated power output, and c) the fabrication of a robust multi-source energy harvesting system that will be demonstrated in the laboratory, and ultimately deployed in field demonstrations to power a small wireless sensor network. Successful development of a multi-source energy harvesting system will provide robust energy solutions that can be adapted by the end user to provide sustainable power for long-term deployment of embedded sensing hardware.




Initial research has focused on exploring novel transducer materials for energy harvesting applications including ferroelectret foams, also known as piezoelectrets, and dielectric elastomers. Piezoelectrets are a specific class of electrets (dielectric materials exhibiting quasi-permanent electric charge and/or dipole polarization) composed of cellular space-charge polymer foam (typically polypropylene) with internal bipolar charges at the voids. The charged voids form macroscopic dipoles, which mimic the behavior of conventional piezoelectric materials. Basic material modeling of piezoelectrets has been studied and experimental tests are underway to characterize the mechanical response (through tensile testing) and electromechanical response (through vibration energy harvesting experiments) of the material. Advantages of piezoelectrets for energy harvesting include their low density, compliant nature allowing attachment to curved surfaces, and large piezoelectric constant, d33, compared to other polymer based piezoelectric materials. Preliminary investigations into the use of dielectric elastomers for energy harvesting purposes have also begun. Dielectric elastomers, which are conventionally used in actuation, are essentially compliant capacitors composed of an elastomer film sandwiched between two compliant electrodes. An advantage of dielectric elastomer energy harvesters is their ability to withstand large amounts of strain on the order of 100%, however, disadvantages include the requirement that the material be pre-charged prior to operation.

Investigation into power management circuitry for multi-source energy harvesting is also underway. Different energy harvesting techniques typically output unique energy signatures, for example, piezoelectric devices give high voltage, low current output, where thermoelectric harvesters give comparatively low voltage and high current output. Switching circuitry is currently being developed to address this issue where each energy source is isolated from the main energy storage medium via secondary storage elements. Using comparators and switches, energy from each source charges its respective secondary capacitor and once a voltage threshold is met, the secondary capacitor drains into the primary storage capacitor. This method presents an initial design, however, additional topologies will be investigated and compared to improve overall efficiency.

## UCSD Course Sequences

***Signal Processing***
Digital Signal Processing
Array Processing
Detection Theory
Parameter Estimation
Stochastic Processes
Sensor Networks
Random Processes

***Embedded Systems***
Introduction to Embedded Systems
Software for Embedded Systems
Validation and Testing of Embedded Systems
Design Automation and Prototyping for Embedded Systems

***Parallel Computing***
Large Scale Computing
Parallel Computation

***Controls***
Linear Systems Theory
Nonlinear Control Systems
Approx Identification and Control
Applied Structural Control

***NDE/SHM***
Experimental Mechanics and NDE
Structural Health Monitoring

***Structural Dynamics***
Structural Dynamics
Advanced Structural Dynamics
Nonlinear Mechanical Vibration
Random Vibrations
Wave Propagation in Elastic Media
Wave Propagation in Continuous Structural Elements

***Applied Mechanics***
Theory of Elasticity
Theory of Plasticity/ Viscoelasticity
Structural Stability
Solid Mechanics for Structural and Aerospace Engineering
Mechanics of Laminated Composite Structures

***Computational Mechanics***
Numerical Methods
Finite Element Analysis I & II
Computational Fluid Dynamics
Model Verification and Validation

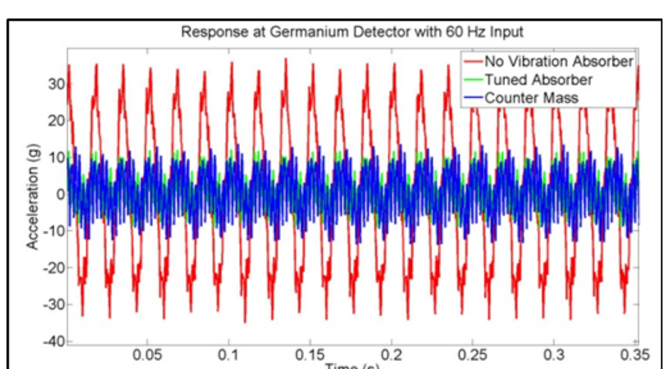
If you are interested in having any of these classes or a class sequences offered at LANL, please contact Kathie Womack (Womack@lanl.gov, 663-5206)

## Active Vibration Control for Mechanically-Cooled Germanium Detectors

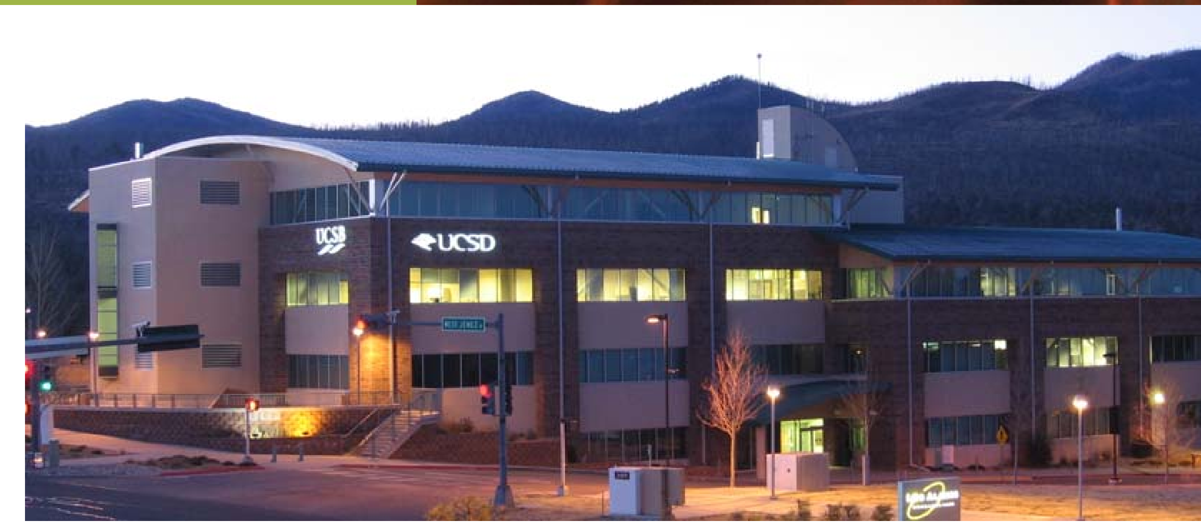
Developing tools to perform nuclear spectroscopy using unattended sensor nodes would greatly enhance LANL's ability to address nuclear material identification and detection challenges in the non-proliferation and treaty verification domains. High purity germanium crystals are the gold-standard detector used for performing high-resolution nuclear spectroscopy. In order to function properly, these crystals must be brought down to liquid nitrogen temperatures. In practice, the required temperature is typically achieved using liquid nitrogen dewars. The shortcoming with this strategy is that the dewars must be refilled roughly every week. This requirement is not practical for applications that require collecting nuclear spectroscopy data in remote/inaccessible areas. An alternative is is to use a piston-driven cryocooler to achieve liquid nitrogen temperatures. Piston-driven cryocoolers, can operate unattended, but the microphonic noise induced by the vibrations produced by these coolers causes the resolution of the spectroscopic measurements to severely degrade, making identification of nuclear materials significantly more difficult.

EI researchers, led by David Mascarenas, are currently developing a control system capable of adapting to its host environment in order to substantially reduce the effects of the piston-driven cryocooler vibrations on the resolution of spectroscopy measurements. The successful completion of this project will enable the next generation of unattended, long-endurance, high-resolution nuclear spectroscopy sensor nodes for non-proliferation and treaty verification applications .

The research for developing a vibration-cancellation system capable of adapting to its host environment takes a two pillar approach. The first pillar is to build an Least Mean Squares (LMS) adaptive control system using embedded computing technology. The approach will be to first further reduce the vibration present, and to increase the order of the system to cancel the next highest peak in the frequency domain until a suitable level of performance is obtained. The second approach will be to look at ways to develop passive mechanical structures to redirect/dissipate vibration energy so it does not affect the germanium crystal.



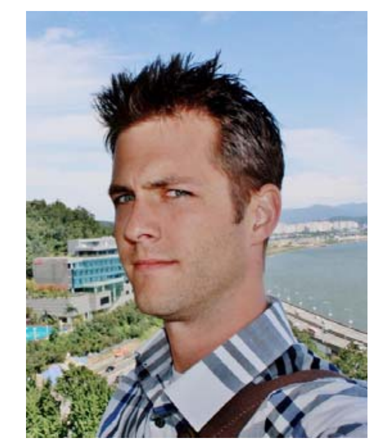

Developing new tools to support non-proliferation and treaty verification activities are vital to ensure the lab is capable of addressing newly emerging threats. The vibration cancellation prototype developed during this project will be the foundation of follow-up work to commercialize this technology and make it more widely available to the global security community.




## A new director-funded postdoc at EI—Eric Flynn

Eric Flynn recently joined the institute as a director-funded postdoctoral fellow. Eric received his Ph.D. in Structural Engineering from UCSD in 2010 and his M.S and B.S in Engineering from Caltech and Harvey Mudd College.

Eric's dissertation involved the application of a Bayesian experimental design framework to the optimal design of SHM systems and damage detection algorithms, with particular attention to ultrasonic guided waves technology. While in UCSD, he has been an integral part of the Engineering Institute's research in SHM. He led the effort of developing an integrated SHM software solution, referred to as "SHMTools", which has been downloaded more than 600 times since its release in April 2010. In addition, he led the field demonstration of "mobile host based wireless sensing networks" in the Alamosa Canyon Bridge, NM, 2008, which received considerable attentions from the SHM community. For his postdoctoral research at LANL, Eric plans to expand the application of his Bayesian optimization work to a broad set of LANL research areas including high performance computing, space situational awareness, and linear accelerator research. Eric is an alumni of the 2005 Los Alamos Dynamic Summer School.



## Conference Presentation of Summer School Students

This February, students from 12th Los Alamos Dynamic Summer School presented their research at the IMAC-XXX, A Conference & Exposition on Structural Dynamics, held in Jacksonville, FL. The papers presented include,

- "Model Calibration and Validation for Material Damping Using Finite Element Analyses," by R.A. Menefee, J.M. Rinker, P.H. Shin, P. Schembri, A. Siranosian
- "Experimental Assessment of NLBeam for Modeling Large Deformation Structural Dynamics," by S. Dalton, L. Monahan, I. Stevenson, D.J. Luscher, K.M. Farinholt, G. Park
- "Dynamic Characterization of Whisper 500 Turbine Blade," by C. Nonis, S. Garrett, S. G. Taylor, K.M. Farinholt, G. Park
- "Structural Health Monitoring of a Wind Turbine Blade under Fatigue Loads," by S.J. Dyas, J. Scheidler, S.G. Taylor, K.M. Farinholt, G. Park
- "Characterization of Bio-Inspired Synthetic Hair Cell Sensors," by E.A. Jampole, N.A. Spurgeon, T.D. Avant, K.M. Farinholt
- "Embedded Vibration Cancellation of a Piston-Driven Cryocooler for Nuclear Spectroscopy Applications," by W. Johnson, R. Long, M. Nelson, D. Mascareñas

## Advisory Board for EI

The EI has formed an internal advisory board to help guide its educational and research activities. The purpose of this Board is to maximize the positive impact the EI's recruiting, training and retention activities have on LANL engineers and maximize the number of line organizations impacted by these activities.

The roles and responsibilities of the EI Advisory Board include

- Represent their respective line organization's needs in terms of recruiting, training and retention to the EI staff.
- Guide the collaborative research projects and educational activities of the EI
- Help to define other EI activities such as workshops and development of proposal writing teams
- Bridge a gap between line organization and EI for summer internships, for post-doctoral research appointments, or for staff hiring.

The following members will serve on this advisory board for a two-year period,

Frank Addessio (T-3)
Don Hush (ISR-2)
Doug Kautz (WCM-2)
Thomas Mason (W-6)
Evelyn Mullen (IAT-DO)
R. Alan Patterson (MST-DO)
Ray Guffee (AET-1)
Daniel Rees (AOT-RFE)
Angela Mielke (ISR-3)