

## 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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## Estimation and Forecasting of Contaminant Plumes

The estimation and forecasting of multi-scale uncertain flow systems is one of the most visible, scientifically challenging and societally relevant computational grand challenge problems of our generation. A collaborative UCSD/LANL team at the Engineering Institute has focused on key aspects of this interdisciplinary problem. The specific application driving this investigation is the forecasting of the movement of contaminant plumes released, either accidentally or maliciously, in both urban and battlefield environments for coordinating emergency response and troop movements, respectively. Related applications include, short-term weather forecasting, long-term ocean current forecasting (for El Nino and climate prediction), and magnetohydrodynamic plasma forecasting (for sunspot cycles and solar flare trajectories).

The team specifically focuses on observations derived from a dozen small unmanned aerial vehicles (UAVs) flying in and around the plume, gathering data about the extent and concentration of the plume, the magnitude, direction, and variability of the winds driving its evolution, and the stratification of the atmosphere which limits or drives its vertical mixing.

Each of the UAVs is equipped with GPS and sophisticated avionics and sensors, and is assumed to be in intermittent radio contact with a powerful supercomputer back home which both synchronizes the computational model of the plume with the measured data and coordinates the future trajectories flown by the sensor-equipped UAVs. Prof. Thomas Bewley (UCSD) in collaboration with Prof. Daniel Tartakovsky (UCSD) and Dr. Frank Alexander (LANL), is working together with UCSD students Joseph Cessna, Christopher Colburn, and David Zhang to rethink the fundamentals of this UAV-based plume forecasting problem from the ground up. In addition to improved simulation tools for atmospheric flow systems (a problem already receiving substantial research attention), there must be a concomitant emphasis on improved data assimilation and adaptive obser-

vation algorithms to address this problem properly; these algorithms thus form the focus of the team's research.

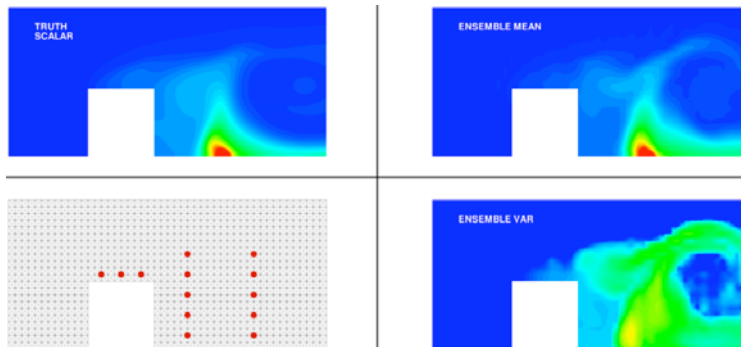
Data assimilation refers to the synchronization of the supercomputer simulation with existing flow conditions in real time. There are two existing viable methods for accomplishing this: Ensemble Kalman methods, which march sequentially in time and, subject to linear/Gaussian assumptions, well summarize the principle direction of uncertainty, space/time variational methods, which well handle nonlinear/nonGaussian systems by revisiting past measurements in light of new data but, on their own, do not well summarize uncertainty. The UCSD/LANL team has proposed, developed, and implemented the first consistent, tight hybrid of these two methods, dubbed Ensemble Variational Estimation

(EnVE), and is currently evaluating this method using synthetic data.

Adaptive observation refers to targeting the sensor motion. This problem is subtle; one gains inadequate information to forecast the plume movement simply by sending sensors towards local maxima in the plume concentration profile, or by orbiting portions of the plume at various isocontours. Rather, it is highly

preferred to tailor the upcoming sensor motions to provide measurements which target and minimize the forecast uncertainty. Building squarely on the theoretical framework of EnVE, the UCSD/LANL team has developed a new, elegant algorithm for achieving exactly this, dubbed Ensemble Variational Observation (EnVO).

As the EnVE and EnVO algorithms are being further developed and refined, other members of the interdisciplinary team are assembling a fleet of UAVs and developing the concomitant sensing and communication hardware and software in order, ultimately, to perform a full-scale flight test in which a large-scale atmospheric plume is sampled, estimated, and forecasted in real time, thereby demonstrating the valuable new technological capability which is facilitated by this exciting line of research.



Truth (top-left) and ensemble estimate (top-right) of an unsteady 2D flow past a 2D bluff body with scalar release in the wake, as simulated using the EnVE data assimilation algorithm applied to the Stanford unstructured-grid turbulence code. Also plotted is the sparse, fixed sensor array (bottom-left) used to synchronize the truth and the estimate and the ensemble variance, a quantification of the estimate uncertainty (bottom-right)

## UCSD Course Sequences

### **Signal Processing**

Digital 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 SE 272  
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  
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)



## A laser focusing and optimization problem for the next Mars Rover

Walter Barkley (AET-2) has recently received his MS degree from UCSD through the institute

My colleague told me about the live classes being taught via video-conference at the Engineering Institute in 2004 so I enrolled in the Fall to enhance my credentials and to sharpen my mind. With a Bachelor's of Science in Mechanical Engineering and a Professional Engineering license, I began the pursuit of a Master's in Mechanical Engineering.

The staff at the Engineering Institute was exceptional in their assistance to this endeavor. Chuck Farrar established the relationship with UCSD and built the program. Kathie Womack and Lindy Nagata worked from both sides tirelessly in bringing the courses to the Institute and helping students. Matt Bement, a TSM of EI and an expert in Controls Engineering, served as my local advisor. Bill Hodgkiss, an Electrical Engineering professor at UCSD, was instrumental in my success. Miroslav Krstic, a professor in Mechanical Engineering at UCSD, was my advisor and mentor. Tom Bewley, a professor in Mechanical Engineering at

UCSD, provide inspiration in linear controls. My course work included three quarters of Digital Signal Processing, four quarters of linear and non-linear Controls Engineering and two quarters of Structural Engineering (9 total courses, 36 units). UCSD allows up to 24 units of graduate course work through UC extension which, at the time, was only \$300 per quarter. My thesis was a laser focusing and optimization problem for the next Mars Rover, originally scheduled to launch in the Fall of 2009 but now delayed until 2011.

Overall, my experience with the Engineering Institute and UCSD was outstanding. The challenges were in the work scheduling to attend the classes, the time management to complete the course work, and in the support and understanding required by my family. A special thanks to my wife, Allison Majure, for her support and encouragement. Also, thank you to Mike Borden at LANSCE and Raj Vaiyda at AET-2, my group leaders, for supporting this achievement and to Toby Vigil for funding the tuition, books, and occasional trips to UCSD.

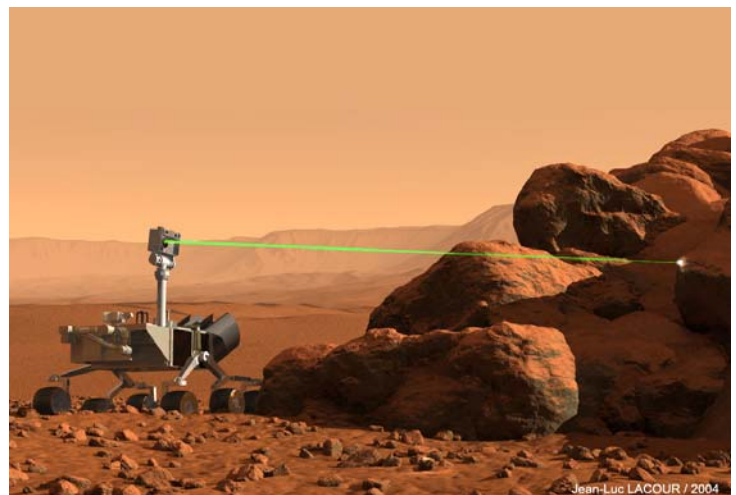
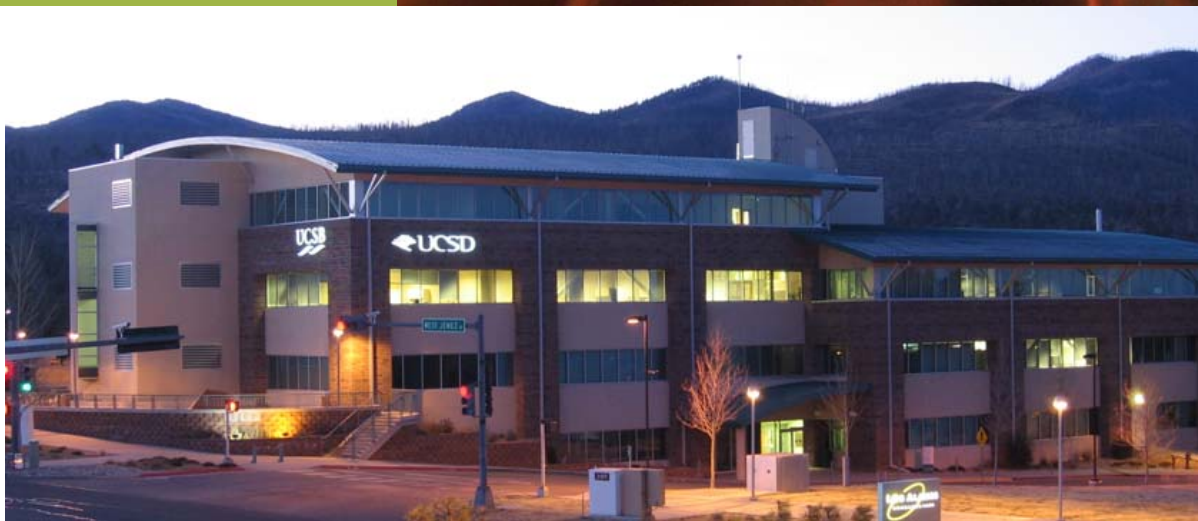


Image courtesy of NASA JPL.



## 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 Addressio (T-3)  
 Don Hush (CCS-3)  
 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)

## Students' Highlights

Eric Flynn, a UCSD graduate student shown in the right, won a 'Best Student Paper' Award at the ASME 2008 Conference on Smart Materials, Adaptive Structures, and Intelligent Systems, held in Ellicott City, Maryland, October 2008. The paper, entitled "Optimal Sensor Placement for Active Sensing," describes a new approach for determining the optimal layout for arranging sensors on a structure in order to make appropriate measurements. The work is sponsored as part of the EI research projects. Eric is a gradu-

ate of 2005 Los Alamos dynamic summer school (LADSS) and is currently advised by Prof. Michael Todd in the Department of Structural Engineering.



Molly Nelis, one of 2008 LADSS students, won the 3rd Place in Material sciences & Engineering at the 2008 DOE Science & Energy Research Challenge Poster Competition. This prestigious national competition, which took place at ORNL in November, was open to all undergraduate students who conducted DOE related science research during this academic year. The poster, entitled "Use of a Collocated Sensor/ Actuator for Vibration Suppression and Structural Health Monitoring," was her research work conducted as part of 2008 LADSS and mentored by Gyuhae Park (INST-OFF)

## 10th Los Alamos Dynamic Summer School (June-August 2009)

The solicitation for the 10th edition of the Los Alamos Dynamics Summer School (LADSS) has recently sent out, and the EI is currently accepting student applications. In short, the goal of the LADSS is to get US citizens to attend graduate school. Students will participate in weekly tutorials and guest lectures from distinguished personnel on various aspects of engineering dynamics, and be placed into 3 person teams to do a research activity in 9 weeks that can be presented in an internal conference. The more information you can find at <http://institute.lanl.gov/ei/dynamics-summer-school>.

We are also currently seeking research projects for LADSS. If you feel you have an interesting research topic that can be completed in a 9 week time frame, please contact Gyuhae Park <[gpark@lanl.gov](mailto:gpark@lanl.gov)> or Matt Bement <[bement@lanl.gov](mailto:bement@lanl.gov)> for further discussion. The research projects in the previous years are listed in the following link (<http://institute.lanl.gov/ei/dynamics-summer-school/projects/>). The EI staffs will assist the projects by co-mentoring the research team for the duration of the school. The quality of the LADSS students are excellent and the outcome of their research work usually exceeds the expectation.





## EI Annual Workshops

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

## Events

Please contact Chuck Farrar ([farrar@lanl.gov](mailto:farrar@lanl.gov), 663-5335) for more information.

- **Winter 2009 UCSD courses (Instructor)**
  - ◆ Applied Structural Control (Matt Bement), Tu/Th 1:30-2:50 pm
  - ◆ Introduction to Embedded Computing (Tajana Rosing), Tu/Th 4:30-5:50 pm
  - ◆ Digital Signal Processing I (William Hodgkiss), Tu/Th 9:00-10:20 am
  - ◆ Advanced Structural Dynamics (Michael Todd), Tu/Th 10:30-11:50 am
- **EI staff will attend the following conferences**
  - ◆ 4th Annual Energy Harvesting Workshop, January 18-19 2009, Blacksburg, VA
  - ◆ IMAC-XXVII Conference & Exposition on Structural Dynamics, February 9-12 2009, Orlando, FL
  - ◆ SPIE Smart Structures and Materials & Nondestructive Evaluation and Health Monitoring, March 8-12 2009, San Diego, CA

Engineering Institute News Letter December 2008



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