

# Department of AEROSPACE AND MECHANICAL ENGINEERING at the University of Notre Dame



Fall 2011 Newsletter

University of Notre Dame

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### Dear Alumni and Friends of the AME Department

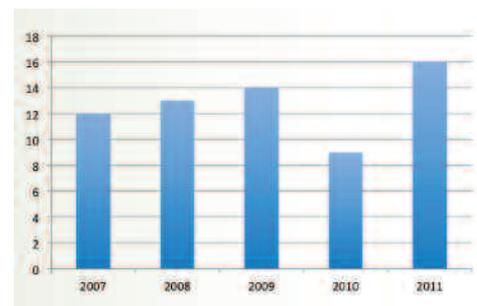
This has been an eventful year for the AME department. We continue to be strong in terms of student enrollment at all levels and have added new faculty members. In addition, the new facilities in the Stinson-Remick Hall of Engineering and the White Field Research Laboratory are now fully up and running. While this newsletter contains a sample of our activities this year, here are some numbers that will provide a more comprehensive overview of the state of the department. During the 2010-11 academic year, the department

- Granted 109 undergraduate degrees, with about two-thirds in mechanical engineering and the rest in aerospace engineering.
- Granted 19 master's degrees. The number of both bachelor's and master's degrees is comparable to the departmental average over the last five years.
- Granted 15 doctoral degrees. The average number of degrees over the last five years has been around 13 per year.
- Received research awards totaling well over \$6 million. This is similar to the average over the last few years.

The department currently has 28 full-time tenured and tenure-track faculty members. While we have two more joining us over the next year, we do expect a few retirements, so our size is likely to remain about the same. However, we continue to add research faculty to help with the growing research volume.

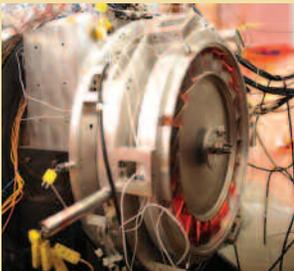
We have, however, also experienced setbacks. The most serious of those was the tragic passing of Professor John (Jack) Renaud in spring 2011 after a short illness. John, who was serving as the department chair, is fondly remembered by his colleagues for his vision as a leader, accomplishments as a faculty member, and qualities as a person.

Gretar Tryggvason, Interim Department Chair



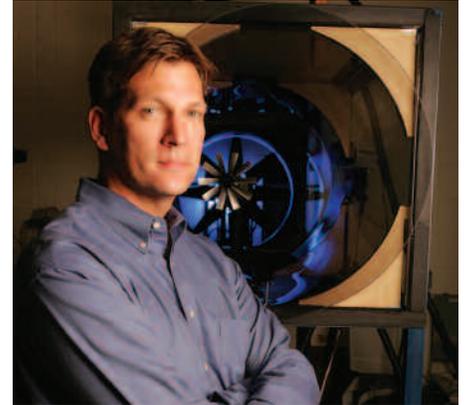
Doctoral Degrees Granted

# RESEARCH



## Fundamental Research: Turbomachinery and Acoustics

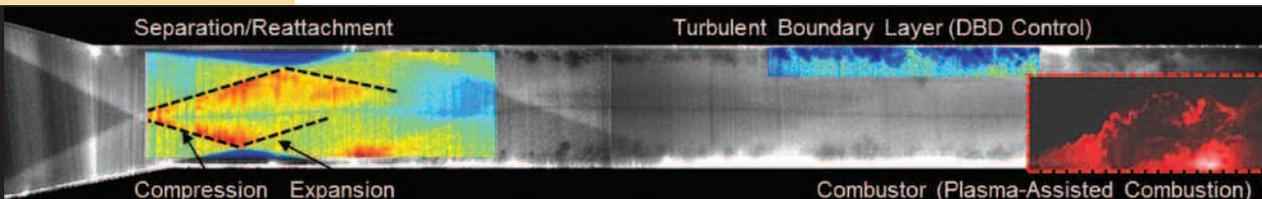
The modern jet engine is a technological marvel. Every day, thousands of aircrafts carry hundreds of thousands of passengers millions of miles from one point to another without incident. A jet engine produces tremendous amount of power in a very confined space and the high gas speed and high temperature puts enormous load on the engine and requires very detailed control of the flow. "I don't think the general public realizes how different modern jet engines are from what they were just a decade ago," says Associate Professor **Scott Morris**. "The manufactures are under enormous pressure to reduce fuel consumption and make engines quieter, while maintaining safety and reduce cost. They have made much progress but need to do much more." Helping the industry continue to increase efficient and reduce the noise is what Morris does.



Morris, who joined the University in 2002, directs experimental research on turbomachinery and aeroacoustics in both the Hessert Laboratory and the White Field Building. He and Research Assistant Professor Joshua Cameron have developed a laboratory consisting of a number of facilities, including a transonic axial compressor and a high-speed research turbine. Both facilities are single-stage rotating experiments that allow for advanced diagnostics and flow control under conditions that are similar to full-scale engines. His group also makes extensive use of the Anechoic Wind Tunnel in the Hessert lab. The research has attracted the attention of a number of turbine engine manufactures and funding agencies. Current support includes contracts from industry, as well as the United States Air Force and Navy. "We really have a very unique setup," says Morris. "The ability to examine flow geometries at full scale allows us to explore aspects that are not accessible to small-scale studies." Interest in his work is keeping the laboratory busy and growing. His group currently consists of two research faculty, two research engineers, two technicians, and 15 graduate students.

The results of Morris' work are already helping turbomachinery designers in a number of ways. For example, in a recent collaborative project with the Air Force Research Laboratory, a new design methodology for the aerodynamics of turbines was studied. The results show that it may be possible to maintain or increase the efficiency of engines while greatly reducing their weight and fuel burn. In another project sponsored by General Electric Aviation, the compressor section of gas-turbine engines was studied in order to optimize how to control stall or back-flow in the engine. The theoretical and experimental results from this work are providing new insight into the design of next-generation, ultra-efficient engines.

"Scott takes a very fundamental approach to problems that are of immense practical importance," says Gretar Tryggvason, interim department chair. "His work really demonstrates the impact that fundamental research can have on problems that people care about."



# MORE RESEARCH!

## Examining the Aging Heart

Assistant Professor **Philippe Sucosky's** project, "Mechanisms of Hemodynamic Shear Stress in Calcific Aortic Valve Disease," was recently funded by the American Heart Association. Specifically, Sucosky and his graduate students intend to examine the effects of normal and abnormal blood fluid forces on the biology of aortic valve leaflets and to determine the molecules involved in the response of valve leaflets to abnormal blood fluid forces. Sucosky, who directs the Multi-Scale Cardiovascular Bioengineering Laboratory (MSCBL) has examined several aspects of Cardiovascular diseases both experimentally and computationally. "Calcific aortic valve disease, where calcium accumulates on the aortic valve leaflets, is the most common valvular heart disease and can ultimately lead to heart failure," Sucosky says, "and the results of this research will enable the exploration of new drug-based treatments by providing new insights into the mechanisms of calcific aortic valve disease and the role played by blood flow and its associated forces in disease initiation." In addition to working on fixing aging hearts, Sucosky is working with the Healthworks Kids Museum to develop interactive displays to help children develop healthy lifestyle. As he puts it: "Being able to fix a heart problem is great, preventing the problem is even better!"

## Taking Ideas into the Real World

Professor **Timothy Ovaert** recently learned that his utility patent application entitled "Flooring Apparatus for Reducing Impact Energy During a Fall" was granted by the U.S. Patent and Trademark Office. The flooring underlayment, trade named SorbaShock™, is based on a columnar structure design that provides a substantially rigid, stable surface for walking yet buckles to dissipate energy during an impact event such as a fall. Installation applications include bathrooms, bedrooms, hallways, and anywhere passive fall protection is desired. SorbaShock has been licensed from Notre Dame and has already been installed in numerous locations throughout the United States and Canada, including a new 12,000-sq.-ft. senior care facility in Bowling Green, Ohio. The product was also recently featured and installed in the "Idea House" at the AAHSA 2011 LeadingAge Annual Meeting and IAHSA Global Aging Conference at the Washington, D.C. Convention Center. Additional information can be found at [sorbashock.com](http://sorbashock.com).

## Grappling with Errors and Uncertainty

The AME faculty joined several of their colleagues from across campus to host a Workshop on Verification and Validation (V&V) in Computational Science on October 17-19, 2011. With approximately 70 attendees from across the nation, the workshop brought together a diverse group of computational scientists working in fields in which reliability of predictive computational models is important. "Computations are increasingly used as the basis for some very serious decision making," says Professor **Joseph Powers**, the lead organizer, "and establishing the correctness of the computational models and quantifying the uncertainty is the next grand challenge for computational science. The workshop helped us assess the state-of-the-art and identify where we go next."

## PH.D. DEGREES AWARDED 2010-11

**Jacob Cress**, Optical Aberrations Caused by Coherent Structures in Subsonic, Compressible, Turbulent Boundary Layer.

**Baoyang Deng**, Bifurcations and Symmetries of Optimal Solutions for Distributed Robotic Systems

**Justin Deuerling**, Effects of Ultrastructural Organization on the Mechanical Properties and Anisotropy of Human Cortical Bone

**Alejandro Cuéllar**, A Heat Conduction Study at Non-Continuum Scales

**Kyle Jones**, Percolation Mechanisms in Orthopedic Implants

**Oleg Kim**, The In-flight Breakup of Drops Subjected to Electric and Ionic Fields of DC Corona Discharge

**Alexey Kozlov**, Plasma Actuators for Bluff Body Flow Control

**Dayu Lv**, Construction, Analysis, and Validation of a Mathematical Model of Human Metabolism

**Gilberto Rodriguez**, A Computer Aided Multiscale Material; Design Optimization Framework for Composite Materials Tailoring

**Benjamin Mertz**, Refinement, Validation, and Implementation of Lumped Circuit Element Model for Single Dielectric Barrier Discharge Plasma Actuators

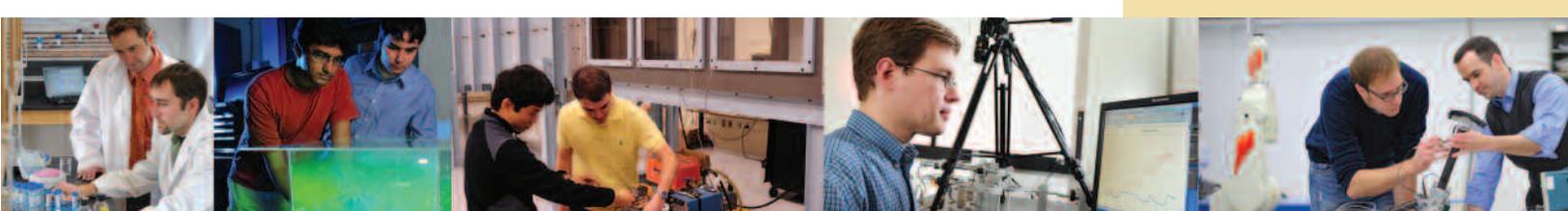
**Chandan Mozumdar**, Topometry Optimazation of Sheet Metal Structures for Crashworthiness Design Using Hybrid Cellular Automata

**Alice Nightingale**, Characterization and Adaptive-optic Correction of a Regularized Weakly-compressible Shear Layer

**Charles Penninger**, An Investigation in the Cellular Mechanism of Bone Remodeling using a Hybrid Cellular Automaton Approach

**David M. Schatzman**, A Study of Unsteady Turbulent Boundary Layer Separation under Conditions to Helicopter Rotor Dynamics

**Alexander Vorobiev**, An Experimental Investigation of Lift and Roll Control Using Plasma Actuator



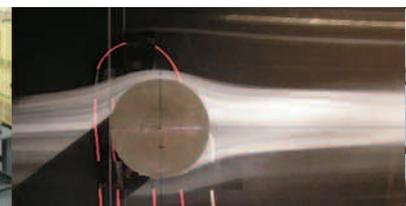
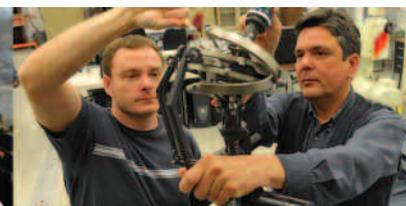
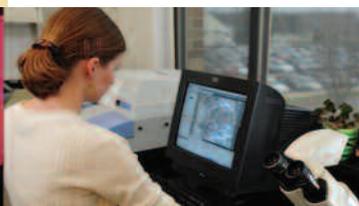
# RECENT FACULTY ADDITIONS



**Arezoo Ardekani** joined the Notre Dame faculty in January 2011, and holds the John Cardinal O'Hara, C.S.C. Assistant Professorship of Aerospace and Mechanical Engineering. She received a Ph.D. in mechanical and aerospace engineering from University of California at Irvine in 2009. Prior to joining the University, she served as a Shapiro Postdoctoral Fellow at Massachusetts Institute of Technology. Ardekani heads the Complex Fluids and Multiphase Flows Laboratory in the Fitzpatrick Hall of Engineering, where she and her students focus on understanding fundamental properties of multiphase flows of Newtonian and non-Newtonian fluids that are relevant to complex fluids, biofluids, and micro/nanofluids used in biomimetic applications, biomedical devices, alternative energy, and environmental remediation. She recently received a grant from the National Science Foundation to study settling and swimming in stratified fluids, with particular focus on how density interfaces in aquatic environments can modify swimming, as well as collective motion of small organisms. Her work is mostly computational and theoretical but is sometimes supported by small-scale experiments. "When you consider the messy environment that microorganisms live in, sometimes you simply must go beyond assuming a spherical cow," says Ardekani, "and to bring reality into your theory; input from the laboratory is essential!"

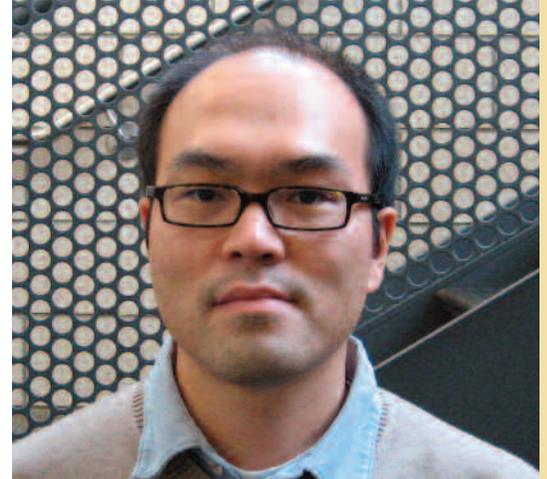


**David B. Go's** connections to Notre Dame go back a long time. Growing up in South Bend, he attended the University and received a B.S. in mechanical engineering. After working for General Electric Aviation and obtaining his M.S. in aerospace engineering from the University of Cincinnati, he moved downstate and conducted research at Purdue University, completing his Ph.D. in 2008. Shortly thereafter he returned to Notre Dame as an assistant professor of aerospace and mechanical engineering. Arriving at the University he established the Small Scale Transport Research Laboratory in the Fitzpatrick Hall of Engineering. He and his students focus on small-scale (millimeters to nanometers) transport, including plasma dynamics, heat transfer, and fluid dynamics. Currently, Go is developing miniature and "micro" plasmas for electronics cooling and energy conversion applications, as well as new ionization technologies to improve biological and chemical analysis, such as the proteins in cancer cells. "The really challenging and important problems today all involve phenomena that are inherently multiphysics, multiscale, and multidisciplinary," he says. "There is a lot to learn, and it often requires working with collaborators that have a background very different than your own, but I find that tremendously exciting and rewarding." In 2010, Go received the Air Force Young Investigator Award to study the unique plasma physics that occur at scales approaching one micrometer.

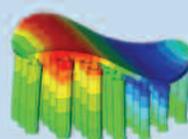


# OUR FUTURE LEADERS!

After **Hyungrok Do** completed his Ph.D. at Stanford University in June 2009, he continued to serve there as a postdoctoral fellow. He joined the University as an assistant professor of aerospace and mechanical engineering in fall 2011. Both his dissertation research and postdoctoral work were completed in the Thermal and Fluid Science Division of the Department of Mechanical Engineering at Stanford. His research interests center around energy conversion and propulsion, with a particular emphasis on plasma science (the use of plasma to control combustion) and supersonic combustion. In his dissertation Do examined flame stabilization in scramjet engines. His postdoctoral work has been devoted to the study of the abrupt loss of thrust occurring due to heat release during certain flight conditions. In addition to making fundamental contributions to our understanding of these phenomena, he has introduced a novel flame-holding approach for supersonic combustors, based on a two-stage injection of discharged plasma. Holding the flame steady in high-speed combustors is a challenging problem, and his concept is a significant departure from conventional ideas, which are mostly based on passive approaches such as wall cavities. According to Do, “we already know that we can control flow using plasma. Controlling reacting flows reactions is, I believe, the next frontier.” He is currently setting up his research lab in the Hessert facility.



**Fabio Semperlotti** joined the Notre Dame faculty as an assistant professor of aerospace and mechanical engineering this fall, following a yearlong stint as a research fellow at the University of Michigan in Ann Arbor. He received his Ph.D. from the Pennsylvania State University in 2009. Semperlotti’s research, which is both theoretical and experimental, is in the general area of structural dynamics with a focus on the health monitoring of structures, smart structures and structure dynamics, and control. In his dissertation he worked on developing new approaches to detect defects (such as cracks and loose fasteners) as part of a larger effort that was funded by the Army and involved several industrial partners from the rotorcraft industry. In addition to developing new theoretical approaches based on nonlinear responses of structures to excitations and the detection of the direction and amplitude of elastic waves, he tested and validated his theories experimentally. The accurate monitoring of the emergence of damages in structure is important in a wide range of situations, including both infrastructure and vehicles, but for helicopters the urgency is paramount. “Preventive maintenance is a major cost for a large number of aerospace systems,” says Semperlotti, “if we can conduct maintenance based on need, rather than a fixed schedule, we are talking about not only significant savings but also much improved safety.” Semperlotti directs the Structural Health Monitoring and Dynamics Laboratory in the Fitzpatrick Hall of Engineering.



# FACULTY NEWS

## BRACH SERVES ON NHTSA PANEL

Push-button key fobs, air bags, cruise control, and other electronics make the modern car equivalent to a supercomputer on wheels. All of these systems are designed to guard against problems, but approximately 15,000 complaints related to unintended acceleration (UA) have raised concerns about complex electronic design, including the effect of electromagnetic interference on a vehicle and its safety.

An expert in the field of accident reconstruction, **Raymond M. Brach**, professor emeritus in the Department of Aerospace and Mechanical Engineering, recently served on a panel of experts appointed by the National Research Council on behalf of the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) to explore electronic vehicle controls and UA.

The panel was charged with investigating the design and manufacture of electronic systems and safeguards used by automotive manufacturers; examining the electromagnetic compatibility of the devices in vehicles; reviewing the design and testing standards for the devices; and looking for other possible sources of UA, such as human error, mechanical failure, or mechanical interference with accelerator mechanisms. Their work builds on the National Aeronautics and Space Administration's findings, which were published in February 2011.

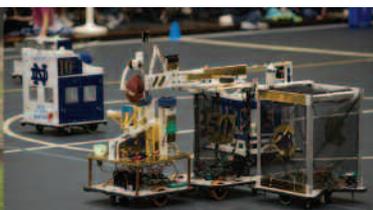
Professor **Stephen M. Batill** has received the Notre Dame 2011 Faculty Award, recognizing his distinguished record of teaching and his influence on countless students in more than two dozen different courses, as well as his mentorship of both undergraduate and graduate students. As a consummate Notre Dame man and Triple Domer, Batill has also served the University in many capacities, including as associate dean, department chair, director of international study programs, and faculty fellow of the Kroc Institute for International Peace Studies. A Fulbright Foundation scholar, he has contributed significantly to research advancements and educational initiatives in his field. He has also served his country with honor in the United States Air Force, as a faculty member at the U.S. Air Force Academy, and as a development engineer at Wright Patterson Air Force Base.



**Thomas C. Corke**, the Clark Equipment Professor of Aerospace and Mechanical Engineering and director of the Center for Flow Physics and Control, received the 2010 American Institute of Aeronautics and Astronautics (AIAA) Aerodynamics Award, "For his strong commitment to academic and research achievement, consistent record of superior technical accomplishment, and numerous experimental and computational contributions to aerodynamics." Corke is a fellow of the AIAA, the American Physical Society, and the American Society of Mechanical Engineers.

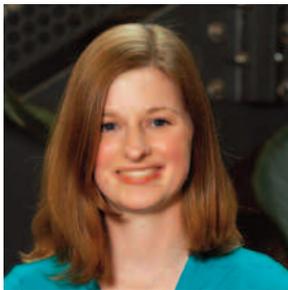
Assistant Professor **David B. Go** was selected by the Air Force Office of Scientific Research as one of 43 engineers and scientists who will participate in the 2011 Young Investigator Program. The program, which is only open to engineers and scientists at U.S. research institutions who have received a doctoral degree within the last five years, recognizes those who "show exceptional ability and promise for conducting basic research." Go will use the award to investigate the scaling of plasmas to dimensions approaching one micrometer. He aims to develop the foundational theory for the unique physics at these scales leading to the development of new microplasma devices for applications such as environmental monitoring.

Professor **Samuel Paolucci** was elected a fellow of the American Physical Society in 2010. His citation reads: "For major theoretical contributions to the theory of hydrodynamic stability of natural convection flows, development of novel adaptive computational methods based on wavelets and fundamental contributions to the theory of low-dimensional manifolds as applied to complex kinetics for chemically reacting flows." In addition to this most recent honor, he is a fellow of the American Society of Mechanical Engineers.



# FROM OUR ALUMNI

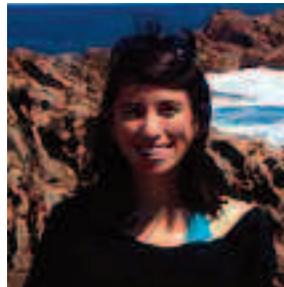
**M. Brett McMickell** (Ph.D., '04) received the 2011 American Institute of Aeronautics and Astronautics (AIAA) Lawrence Sperry Award, which is presented annually for notable contribution made by a young person to the advancement of aeronautics and astronautics. His citation reads: "For proven leadership in the area of small satellite technology with focus on the advancement of momentum and structural control systems." McMickell received the award in conjunction with 49th AIAA Aerospace Sciences Meeting, January 4-7, 2011, at the Orlando World Center Marriott in Orlando, Fla. He writes that, "It was at the University of Notre Dame that I was really introduced to Aerospace and developed the skills that have lead to my success. Thank you for providing a strong foundation for my career."



**Holly Weiss** (B.S., '07), an AME graduate student working with Assistant Professor Diane Wagner, was one of 34 honorees selected to receive a Whitaker International Fellowship for the 2010-11 academic year across 15 countries. Each grant recipient spends one to two years performing research at a host institution, where each has the opportunity to integrate into a different culture, work in a new research environment, and attend international conferences. During her tenure as a Whitaker Fellow, Weiss continued her research in bone tissue engineering at the Katholieke Universiteit Leuven in Belgium,

where she worked in the Laboratory for Skeletal Development and Joint Disorders. Weiss worked on recapitulating the events of initial bone formation and applying those events to engineer a tissue intermediate for bone repair. While in Belgium she developed and implemented an assay for initiating endochondral ossification and successfully induced de novo bone formation in a mouse model. She has since returned to Notre Dame to complete her Ph.D. in bioengineering.

**Kelsey Kennedy** (B.S., '10) was awarded a Scholarship for International Research Fees (SIRF), which covers tuition plus stipend and will allow her to complete a master's of engineering science with a major in biomedical engineering in the Optical and Biomedical Engineering Laboratory at the University of Western Australia. She was already in Australia as part of a research internship and getting the fellowship "means two more years in Perth," she writes. "I'm extremely excited to take on this new degree. One of the things they looked at closely for this scholarship was past research experience, so I am very grateful for the chance I had to work on research during my senior year at Notre Dame." Kennedy will be developing new high resolution imaging techniques for breast cancer surgical guidance and will work with surgeons in local hospitals to implement these techniques in a clinical setting.



## DEPARTMENTAL AWARDS, AME CLASS OF 2011

**Aero Propulsion Award**  
Minh Tam Nguyen

**Patrick J. Deviny  
Scholarship Award**  
Brendan John Kiefer

**Vincent P. Goddard Award for  
Aerospace Design**  
Jonathan Richard Holland

**Pi Tau Sigma Honor Award**  
Steven Richard Brus

**Rev. Thomas A. Steiner Award**  
Nicholas Charles Geraci  
Michelle Lynn Roemer

**Rockwell Automation  
Design Award**  
David J. Rudy  
Michelle Lynn Roemer

**Sigma Gamma Tau  
Honor Award**  
Jonathan Richard Holland

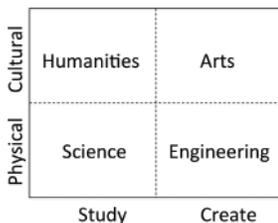
**Zahm Prize for  
Aeronautical Engineering**  
Nicholas Charles Geraci

**Zahm Prize for Mechanical  
Engineering**  
Matthew Timothy Kiener



## Musings on an Engineering Education

Engineering is often viewed as a narrow discipline, the refuge of the nerds where they can crank numbers far removed from other human beings. Nothing could, of course, be farther from the truth. Engineering is inherently a human-centric discipline that is responsible for our current standard of living and requires communications and collaborations to a degree often not found in other professions. We often do a poor job of explaining the nature of engineering. Thus, in the minds of the public, engineers are often lumped with scientists. A "rocket scientist" is, after all, usually an aerospace engineer! However, as important as science is, engineering and the sciences are different. As von Karman famously said, "scientists discover what is; engineers create what has not been." Let me elaborate on this statement by projecting the various fields taught in a university onto a plane defined by whether we study or create on one axis and whether we are dealing with the cultural or physical aspects of the human environment (see graph below). There certainly are other ways of looking at university curriculum, but this allows us to identify the humanities as studying our cultural world, the arts as creating it, and the sciences as a discipline where we study the physical world. In engineering we create the human centric parts of the physical world. Of course, what we build must conform to the laws of physics, so science is an important part of what an engineer must know. During the 20th century, the most significant obstacles facing an engineer were the limitations of physics. In the 21st century it is not inconceivable that human factors may become the major roadblocks and the engineer may have to



master new fields to continue to build an environment that can meet societal needs. In the United States, all engineering students must complete a "general" education component. This part of the curriculum may become increasingly important for engineering education. The AME curriculum at the University of Notre Dame includes many innovative components, such as early exposure to engineering — focusing on systems thinking — emphasis on the design and creation of artifacts, and significant opportunities for a global experience in the regular curriculum. As engineering education evolves to meet the demands of the new century, our curriculum will have to change, and we are likely to find that the Notre Dame's long tradition of a broad education in the humanities and the arts will provide us with unparalleled additional resources to develop competencies in the other two quadrants of the graph.



**Gretar Tryggvason joined the department in fall 2010 as the Viola D. Hank Professor of Aerospace and Mechanical Engineering. He currently serves as the interim department chair**