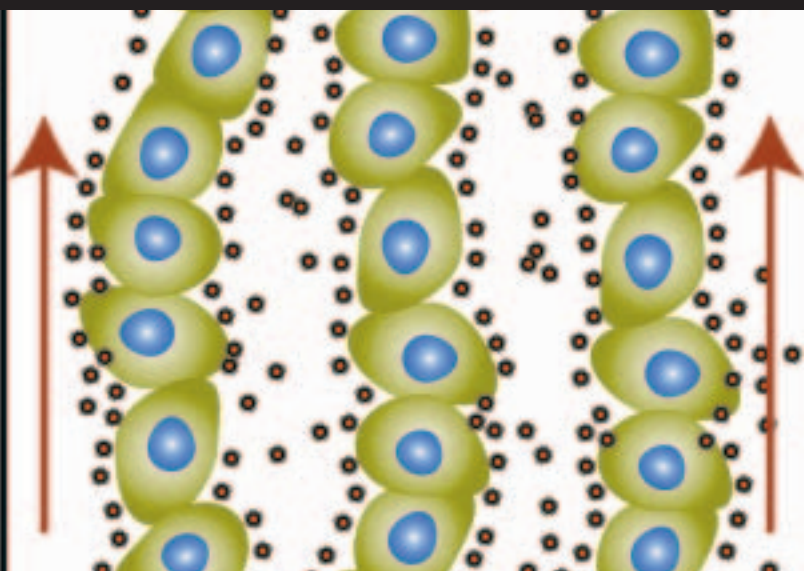
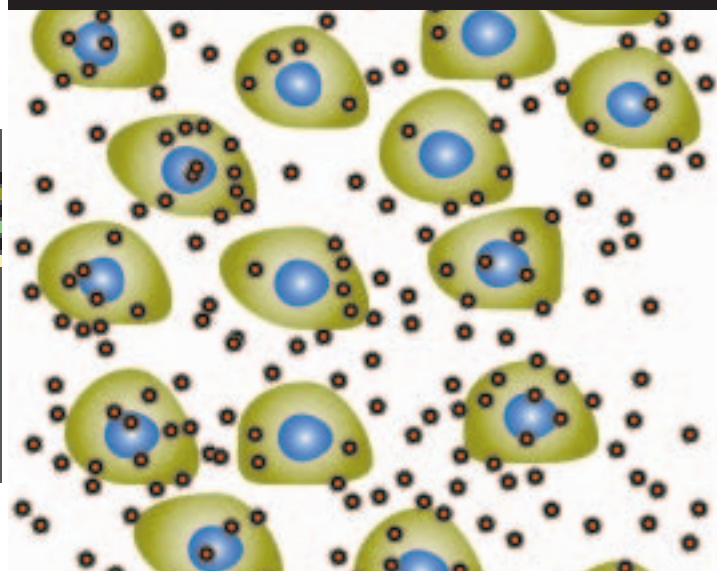


DUKE Mechanical Engineering + Materials Science



Magnetic Nano-'Shepherds' Organize Cells

The power of magnetism may address a major problem facing bioengineers as they try to create new tissue – getting human cells to not only form structures, but to stimulate the growth of blood vessels to nourish that growth.



LETTER FROM THE CHAIR

As I write this, I am nearing the end of my first year as Chair of Duke MEMS. In taking stock of the past few months, it occurs to me that while some of you may know me, most of my time at Duke has been spent in another department, so a few brief words of introduction may be appropriate.

I joined Duke as an assistant professor of civil and environmental engineering in 1992, after earning BS, MS and PhD degrees in mechanical engineering from Oregon State University and Stanford University. My research area is computational solid and structural mechanics, and I have been a secondary faculty member in MEMS for most of my Duke career. Between 2003 and 2008, I was the Senior Associate Dean for Education in Pratt, with oversight responsibilities for undergraduate and graduate education.

When Tom Katsouleas joined Duke as Dean last summer, and Rob Clark departed Duke to become Dean at the University of Rochester, the opportunity presented itself to join MEMS as Chair, and this chance appealed to me for many reasons. The faculty and students in this department are top-notch, and the position presented me with the opportunity as well to "return to my roots" as a mechanical engineer.

In short, economic challenges notwithstanding, it has been a truly astounding year of progress for the department. Our undergraduate population continues to swell, with over 60 students graduating this spring with degrees in mechanical engineering.

Our students continue to excel, as they always have, in their independent study and research with our faculty, and are responding enthusiastically to our recent curriculum revisions which emphasize and reinforce a hands-on approach to mechanical design. As an example of our students' accomplishment, this year the Duke Motorsports team earned their best-ever finish in the SAE formula car competition in Michigan this spring.

Our graduate program remains healthy and continues to grow, with several PhD students giving podium presentations and winning paper awards at national meetings this year. What's more, the department is well along with the design of new masters' offerings that will emphasize energy, materials, and aerospace engineering as concentration areas.

And the level of faculty accomplishment this year has been exceptional, ranging from Earl Dowell's winning of the Guggenheim Medal; to the granting of yet another honorary doctorate to Adrian Bejan (by the University of Rome I, his 16th such distinction); to

the naming of Stefano Curtarolo a Presidential Early Career Award for Scientists and Engineers (PECASE) winner (joining Silvia Ferrari as Duke MEMS winners of this high distinction); to the winning of an NSF CAREER award by our newest faculty member, Chuan-Hua Chen. Astoundingly, Chuan-Hua's success brings the total number of Duke MEMS faculty who won CAREER awards to seven!

I am pleased to report that our faculty search this year yielded a truly exceptional new colleague, Dr. Xuanhe Zhao, who has agreed to join our ranks in the summer of 2010 after completing a postdoctoral year at Harvard. Xuanhe's scholarship is in the mechanics of soft, active materials, and has application in the development of mechanical actuation devices, in a wide variety of biomedical applications, and in battery technologies. His education combines degrees in electrical engineering, materials science, and mechanics. His scholarship represents the interdisciplinary approach so needed in our modern technological society, and so emphasized in Duke's philosophy to education and research.

So what can you expect to see next from Duke MEMS? Without a doubt, our field plays a central role in many areas of national importance. The area of energy and the environment, so vital to both national interests and the very health of the planet, is certainly an area in which Duke MEMS is and will continue to be a key player. Professors Joe Knight, Hadley Cocks and Adrian Bejan have been true visionaries, together with other faculty in Pratt and in Trinity College, in developing and nurturing our new undergraduate Energy and the Environment Certificate.

Our vision in Pratt continues to be to attack the truly "big problems" of our day. Whether those are concerned with energy generation, distribution, and consumption; or global health; or security; or safe transportation; or several other alternatives, there can be no doubt of the importance of both mechanical engineering and materials science. The enthusiasm, talent and dedication of our faculty and students will serve us well in this time of need. I hope that you enjoy reading about the recent accomplishments of our students and faculty in these pages, and that you will not hesitate to drop by the department office in Hudson Hall and say hello the next time you are on campus.

Tod A. Laursen
Professor and Chair



Cover feature

A multidisciplinary team of investigators from Duke University, Case Western Reserve University and the University of Massachusetts, Amherst created an environment where magnetic particles suspended within a specialized solution act like molecular sheep dogs. In response to external magnetic fields, the shepherds nudge free-floating human cells to form chains that could potentially be integrated into approaches for creating human tissues and organs.

The cells not only naturally adhere to each other upon contact, the researchers said, but the aligned cellular configurations may promote or accelerate the creation and growth of tiny blood vessels.

“We have developed an exciting way of using magnetism to manipulate human cells floating freely in a solution containing magnetic nanoparticles” said Randall Erb, fourth-year graduate student in the laboratory of Benjamin Yellen, assistant professor of Mechanical Engineering and Materials Science, at Duke University’s Pratt School of Engineering. “This new cell assembly process holds much promise for tissue engineering research and offers a novel way to organize cells in an inexpensive, easily accessible way.”

Melissa Krebs, third-year biomedical engineering graduate student at Case Western and Erb’s sister, co-authored a paper appearing online in advance of the May publication of *Nanoletters*, a journal published by the American Chemical Society.

“The cells have receptors on their surfaces that have an affinity for other cells,” Krebs said. “They become sticky and attach to each other. When endothelial cells get together in a linear fashion, as they did in our experiments, it may help them to organize into tiny tubules.”

The iron-containing nanoparticles used by the researchers are suspended within a liquid known as a ferrofluid. One of the unique properties of these ferrofluids is that they become highly magnetized in the presence of external magnetism,

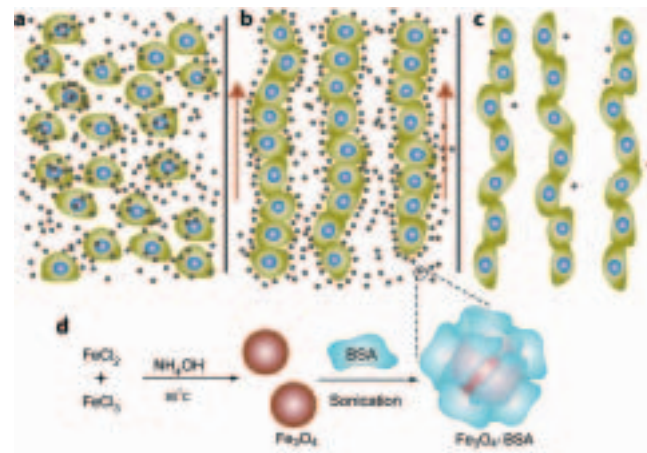
which allows researchers to readily manipulate the chain formation by altering the strength of the magnetic field.

At the end of the process, the nanoparticles are simply washed away, leaving a linear chain of cells. That the cells remain alive, healthy and relatively unaltered without any harmful effects from the process is one of the major advances of the new approach over other strategies using magnetism.

“Others have tried using magnetic particles either within or on the surface of the cells,” Erb said. “However, the iron in the nanoparticles can be toxic to cells. Also, the process of removing the nanoparticles afterward can be harmful to

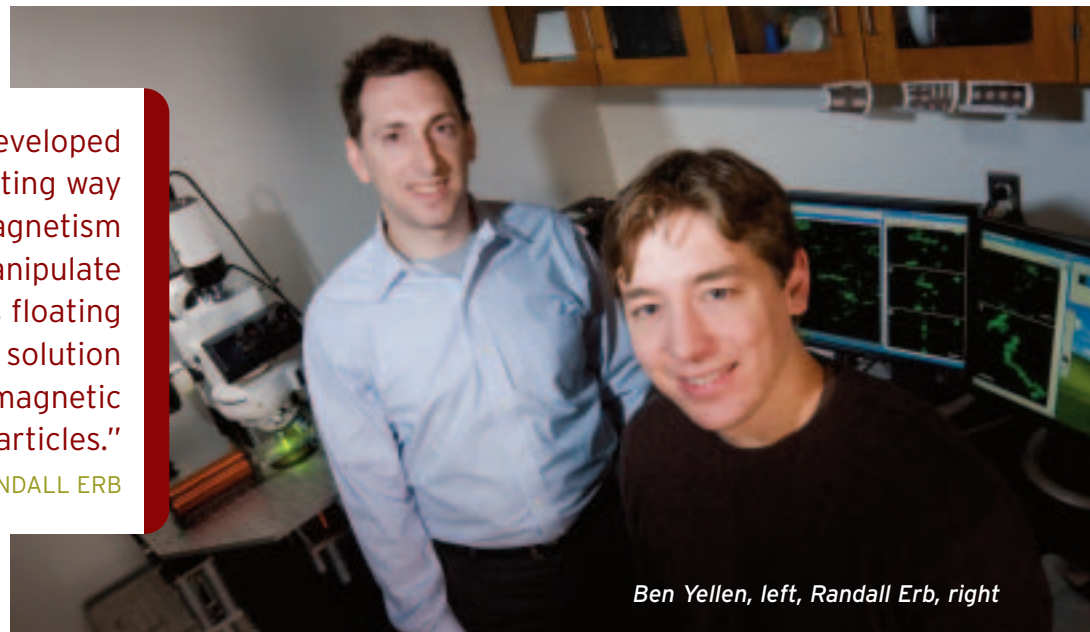
mately want to engineer will have to be three-dimensional.”

For their experiments, the researchers used human umbilical vein endothelial cells. Other types of cells have also been used, and it appears to the researchers that



“We have developed an exciting way of using magnetism to manipulate human cells floating freely in a solution containing magnetic nanoparticles.”

- RANDALL ERB



Ben Yellen, left, Randall Erb, right

the cell and its function.”

The key ingredient for these studies was the synthesis of non-toxic ferrofluids by colleagues Bappaditya Samanta and Vincent Rotello at the University of Massachusetts, who developed a method for coating the magnetic nanoparticles with bovine serum albumin (BSA), a protein derived from cow blood. BSA is a stable protein used in many experiments because it is biochemically inert. In these experiments, the BSA shielded the cells from the toxic iron.

“The other main benefit of our approach is that we are creating three-dimensional cell chains without any sophisticated techniques or equipment,” Krebs said. “Any type of tissue we’d uli-

this new approach can work with any type of cell.

“While still in the early stages, we have shown that we can form oriented cellular structures,” said Eben Alsberg, assistant professor of Biomedical Engineering and Orthopedic Surgery at Case Western and senior author of the paper. “The next step is to see if the spatial arrangement of these cells in three dimensions will promote vascular formation. A major hurdle in tissue engineering has been vascularization, and we hope that this technology may help to address the problem.”

The research was supported by the National Institutes of Health, the National Science Foundation and Case Western.

Faculty Highlights

ACOUSTICS & VIBRATIONS



Brian Mann, assistant professor, is a specialist in nonlinear dynamics and vibrations. He is particularly interested in problems where analytical, numerical and experimental techniques are applied. Mann recently published one of the first investigations of using nonlinear behavior

DID YOU KNOW?
Mann enjoys designing and building furniture with traditional hand tools.

in vibration-based energy harvesting. The article titled “Energy harvesting from the nonlinear oscillations of magnetic levitation” was published in the

Journal of Sound and Vibration 319 (2008) 515-530. In this paper, Mann describes theoretical studies and experimental tests of a novel energy-harvesting device that uses magnetic restoring forces to levitate an oscillating center magnet. Through this work, Mann hopes to document how nonlinear phenomenon can be exploited to improve the effectiveness of energy harvesting devices. This work was supported through a National Science Foundation CAREER Award.



Linda Franzoni, associate dean for student programs and professor of the practice, specializes in acoustics, and structural dynamics and vibration. She was nominated by the Acoustical Society of America (ASA) to be their representative to the United States National Committee on Theoretical and Applied Mechanics. This committee serves as the focal point for U.S. engineering, scientific, and mathematical commu-

nities working in mechanics and functions as the national forum for defining major issues in mechanics research, technology, and education. Franzoni will represent the ASA for a four-year term running from November 1, 2009 through October 31, 2013.



Donald Bliss, associate professor, specializes in high frequency and architectural acoustics, aeroacoustics, structural acoustics, aerodynamics, and applied mathematics methods for local/global analysis and time delay. Bliss recently co-authored a paper with graduate student

DID YOU KNOW?
Bliss is the department's Director of Undergraduate Studies.

Krista Michalis titled “Prediction and Modification of Broadband Interior Noise in Enclosures Using Energy-Intensity BEM and Absorption Scaling,” published in the Proceedings of ASME NoiseCon 2008. The paper and associated talk

by Michalis won the student paper for the entire conference.

In addition, Bliss gave the April 2009 keynote talk at the NOVEM 2009 Noise and Vibration: Emerging Methods conference. He spoke on modeling broadband acoustic fields in enclosures with vibrating walls using absorption scaling.

AERODYNAMICS & FLUID DYNAMICS

Kenneth C. Hall, the Julian Abele Professor of Mechanical Engineering and Materials Science, specializes in unsteady aerodynamics, structural dynamics, and aeroelasticity of turbomachinery and aerospace vehicles. Much of his research focuses on design



DID YOU KNOW? *Hall, an avid pilot and distance runner who aims to log 1,000 miles this calendar year, completed his first marathon race at the Walt Disney World Marathon in January 2009 with a time of 4:11:45.*

optimization by applying the adjoint technique to traditional computational fluid dynamics (CFD) analyses of quantities such as aerodynamic efficiency, flutter stability or forced response. Traditional CFD analysis codes execute a series of instructions in the “forward” direction. Using the adjoint technique, information from this forward calculation is stored for

latter use — somewhat akin to leaving breadcrumbs laid along a path. The adjoint computer code, sometimes called the “reverse” code, literally starts at the end of the trail and works in reverse, using the bits of information left behind in the forward computation as it backtracks. Through the adjoint approach, Hall is able to extend the usefulness of CFD data, and account for any number of design variables simultaneously without increasing the cost of the computation. He and his colleagues are now using this programming approach to help designers come up with turbines that are more efficient and less likely to be affected by damaging vibrations. They currently work with the GUIde Consortium, a group of government, industry and academic researchers investigating new technologies to prevent aeromechanical problems in turbomachinery.

Hall recently published “Computationally fast harmonic balance methods for unsteady aerodynamic predictions of helicopter rotors,” in the *Journal of Computational Physics*, Vol. 227, No. 12, 2008.



DID YOU KNOW? *Dowell plays tennis and can do both East Coast and West Coast swing along with a little cha cha and rumba. He claims it's all in the footwork.*

Earl H. Howell, the William Holland Hall Professor of Engineering, is a specialist in aeroelasticity. Dowell's set is now complete. That is, he's received the last major aerospace engineering award not already on his crowded mantle. This spring, the dean emeritus of the Pratt School of Engineering and William Holland Hall professor of mechanical engineering and materials science, received the 2008 Daniel Guggenheim Medal Award. Dowell, who joined the Duke faculty in 1983 as dean of engineering and

served in that role for 16 years, received the award "for pioneering contributions to nonlinear aeroelasticity, structural dynamics and unsteady aerodynamics which had a significant influence on aeronautics and for contributions to education and public service in aerospace engineering." With this award, Dowell has amassed all the major honors in his field, including the Walter J. and Angelina H. Crichlow Trust Prize and the Spirit of St. Louis Medal. Dowell is best known for his research into aeroelasticity, a specialized field for which he literally wrote the book. His expertise lie in understanding how materials and shapes, particular those of aircraft wings and surfaces, respond to the aerodynamic forces they experience during flight, and then how to ameliorate and/or take advantage of these effects. He and his colleagues have, for example, been working for decades with the U.S. Air Force in the design and testing of their aircraft. Current work at Duke includes that on the F-22 now just coming into service and the F-35 which is in flight testing prior to being placed in service a few years from now.

Edward J. Shaughnessy, Jr., professor, applies analytical, experimental, and computational methods to a broad variety of fluid mechanics problems arising in mechanical, aerospace, and environmental engineering, and to problems in biology, medicine, and biotechnology. His current



DID YOU KNOW? *Shaughnessy enjoys all forms of salt water fishing.*

research focuses on the design and development of intelligent and autonomous firearms. Shaughnessy teaches fluid mechanics at both the undergraduate and graduate levels, using Fluid Mechanics by Shaughnessy,

Katz, and Schaffer (Oxford) to give the junior class a demanding and thoroughly modern exposure to the subject. He also serves as the faculty adviser to Duke's chapter of Pi Tau Sigma, the National Mechanical Engineering Honor Society.



DID YOU KNOW? *Protz's office is stocked with a collection of Afghan rugs, which he brought from there himself.*

Jon Protz, assistant professor, is leading a research group to develop a microfabricated turbine-driven power plant as part of a seedling effort for the Defense Advanced Research Projects Agency. The size of a sugar cube and powered by environmentally-friendly ethanol, these tiny engines are designed as a replacement for batteries and would let a typical laptop run for more than 24 hrs before it needed recharged. Protz has

also been working on the development of a microfabricated MEMS klystron, a type of high-tech vacuum tube, as an amplifier for terahertz radiation; and has just completed an effort to demonstrate abiotic genetic memory using DNA and other bio materials. He recently published "Performance of a High-Speed Microscale Turbocharger" in the ASME/IEEE *Journal of Microelectromechanical Systems* 2008.



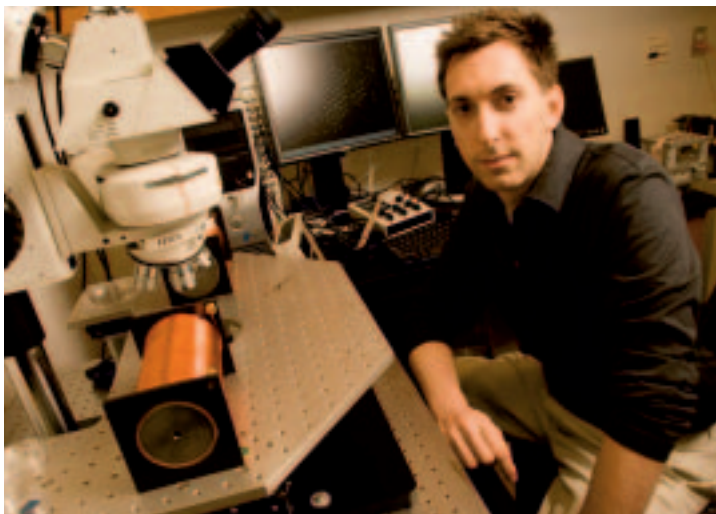
DID YOU KNOW? *Kielb is a cyclist and runner. He has survived the Marine Corps and Stockholm Marathons.*

\$2,400,000). He has authored or co-authored over sixty technical papers and has presented invited lectures worldwide. Kielb is a Fellow of the ASME and is a former chair of the Board of Directors of the International Gas Turbine Institute. He was a co-recipient of American Society of Mechanical Engineers 2001 Melville Award.

Robert E. Kielb, senior research scientist and associate department chair, specializes in turbomachinery aeroelasticity. He has over 35 years of experience including 8 years with the U. S. Air Force, 10 years with NASA Glenn Research Center, and 12 years with GE Aircraft Engines. He is also an affiliated professor at the Swedish Royal Institute of Technology and director of the GUIDe Consortium (6 companies and 6 universities,

Faculty Highlights

BIOMECHANICS & BIOMATERIALS



Benjamin B. Yellen, assistant professor, specializes in applications of electricity and magnetism to problems in medicine, energy, and the environment. His work is featured on the

DID YOU KNOW? *Yellen is an excellent chef, and cooks nearly every meal.*

cover of this newsletter. He was recently awarded a \$249,000 grant from the National Science

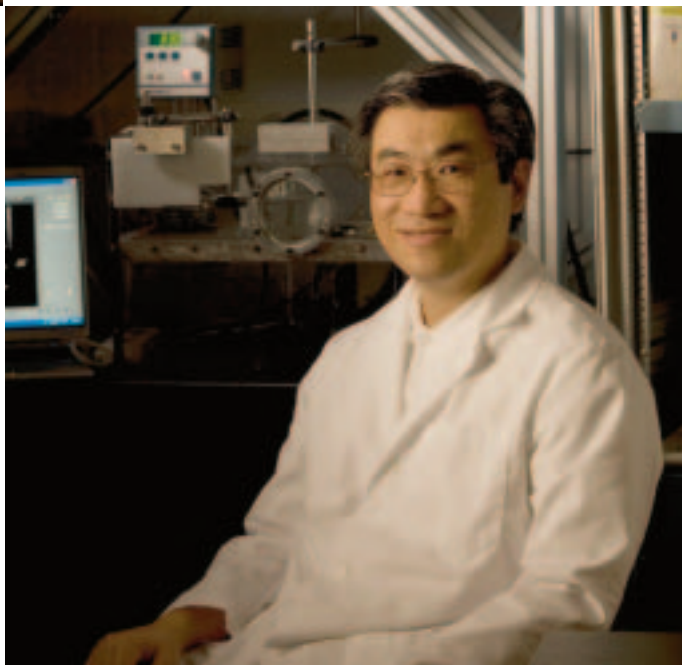
Foundation (with associate professor Stefan Zauscher) to engineer a pH switch at the solid/liquid interface. He is also working with computational mechanics specialist Lawrie Virgin (Duke) on a 3-year NSF funded project on traveling wave magnetophoresis.

Pei Zhong, associate professor, specializes in therapeutic ultrasound including high intensity focused ultrasound (HIFU) for cancer treatment, ultrasound-targeted gene delivery and activity, shock wave lithotripsy. Currently, Zhong is working to develop novel HIFU treatment strategy for prostate cancer and breast cancer therapy through fundings from the Duke Comprehensive

DID YOU KNOW? *Zhong is collaborating with Siemens to develop the next-generation shock wave lithotripter.*

Cancer Center Prostate Cancer Pre-SCORE (2-year grant of \$100,000) and the National Institutes of Health

(2-year grant of \$386,100). He recently co-authored the paper "The effect of high intensity focused ultrasound treatment on metastases in a murine melanoma model" published in the *Biochemical and Biophysical Research Communications*, 375: 645-650, 2008. He is also working to broaden the impact and use of high intensity focused ultrasound therapy in cancer treatment through support from the National Institutes of Health and the National Cancer Institute (2-year grant of \$386,100).



Piotr Marszalek, a specialist in single-molecule mechanics, was promoted to full professor in 2009. In a recent article in the journal *Small*, Marszalek presents results on nanoscale detection of ionizing radiation damage to DNA using atomic force

DID YOU KNOW? *Marszalek is an avid devotee of classical music.*

microscopy. This work is of particular interest because human cells can be significantly damaged by ionizing radiation, even at very low doses.

This work will help to expand the use of AFM techniques in nanoscale DNA damage research. Coauthors of the paper (*Small* 4, 288-298) include Ch. Ke, Y. Jiang, P.A. Mieczkowski, G.G. Muramoto, and J.P. Chute.

Marszalek is also continuing his investigations on the nanomechanics of spiral proteins through a \$1,100,000 grant from the National Institutes of Health. In 2007, he was the first to explain the physical forces that give DNA its famous double helix shape.





David Needham, professor, is a specialist in microsphere engineering and anti-cancer drug delivery. Needham's liposome technology, licensed to Celsion Corporation, was granted orphan drug designation in March 2009 for its proprietary heat-activated liposomal encapsulation of doxorubicin used to treat primary liver cancer. The Food and Drug Administration's Orphan Drug Act provides

DID YOU KNOW? *Needham is known as "Dr. Dart" on the Darty Old Men team in the Triangle Dart League of Chapel Hill, NC*

economic incentives to encourage biotechnology and pharmaceutical companies to develop drugs that demonstrate promise for the treatment of life-threatening or very serious conditions that are rare and affect 200,000 persons or less in the United States. Primary liver cancer is one of the most deadly

forms of cancer and ranks as the fifth most common solid tumor cancer. The incidence of primary liver cancer is approximately 20,000 cases per year in the United States and is rapidly growing worldwide at approximately 1,000,000 cases per year, due to the high prevalence of Hepatitis B and C in developing countries. Orphan drug designation entitles Celsion to seven years of market exclusivity following FDA approval, FDA assistance in clinical trial design, a reduction in FDA user fees, U.S. tax credits related to development expenses as well as the opportunity to apply for funding from the U.S. government to defray costs of clinical trial expenses.

Needham also serves as the senior academic partner on a National Institutes of Health Small Business Innovation Research program with Molecular Express, a company based in Los Angeles, Calif. The focus of the project is thermal targeting of antimicrobial drugs to sites of infection.

Laurens E. Howle, associate professor, has expanded his work to include pharmacokinetics and pharmacodynamics disciplines where modeling of transport in biological systems and modeling of risk and uncertainty are combined to understand drug clearance and metabolism in humans. He also continues to lead research on decompression sickness

DID YOU KNOW? *Howle was featured in Discover magazine, on Discovery Channel Daily Planet, in National Geographic, and MIT Technology Review for his research on a high-efficiency wind turbine design that mimics the shape of humpback whale flippers.*

through a \$758,331 grant from NAVSEA focused on the development of probabilistic models of decompression sickness. He

recently co-authored the paper "Effect of varying injection rates of a saline chaser on aerotic enhancement of CT angiography: phantom study" published in the *European Journal of Radiology*, 18(8): 1683-1689, 2008.





Adrian Bejan, the J.A. Jones Distinguished Professor, is an expert in thermodynamics, heat transfer, constructal theory, and the physics of self-organization and biological evolution. Current research includes new applications for vascularized smart materials, aircraft thermal management, fuel cells, resistance to fire attack, and optimization of design strategy for morphing flow systems. Bejan's book, *Design with Constructal Theory*, co-authored with S. Lorente, won honorable mention in the 2008 American

DID YOU KNOW? *Friends, colleagues and former graduate students fondly toasted Professor Bejan on his 60th birthday in the International Journal of Heat and Mass Transfer, Vol 51, 2008, pp. 5759-5761.*

348 references and 551 pages of text. Bejan's work was also recognized in a very personal way — he was awarded his 16th honorary doctorate degree from the University of Rome I, "La Sapienza."

Publishers Awards for Professional and Scholarly Excellence (The PROSE Awards). The text, published by Wiley, Hoboken, presents more than 322 illustrations,

Unifying the Animate and the Inanimate Designs of Nature

Living beings and inanimate phenomena may have more in common than previously thought. Duke University engineer Adrian Bejan and Penn State biologist James Marden believe they have now unified both the biological and geophysical principles of nature's design through the constructal theory, which can also be viewed as the 'physics of evolution.'

What they believe connects the two worlds is a theory that flow systems — from animal locomotion to the formation of river deltas — evolve in time to balance and minimize imperfections. Flows evolve to reduce friction or other forms of resistance, so that they flow more easily with time. This view has been termed the constructal law, which Bejan first stated 13 years ago.

"This is an exciting development for physicists, but it should also resonate with biologists," Bejan said. "The idea that organic evolution is analogous to the way form evolves in inanimate flow systems is a novel concept that has the potential to unite perspectives and

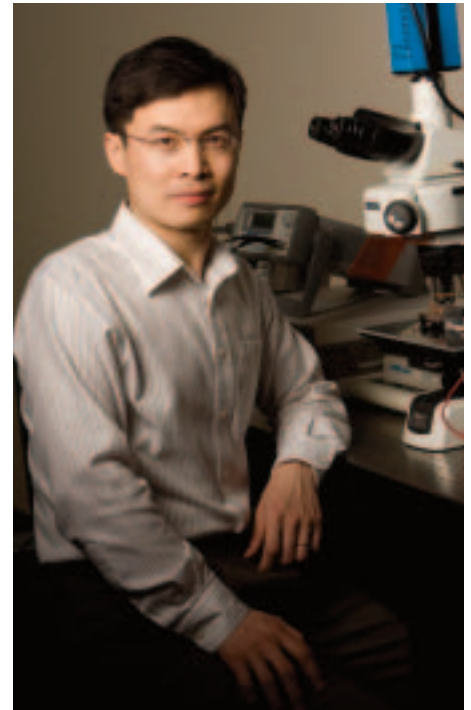
approaches across disparate disciplines. We suggest that the constructal law provides a powerful tool for examining and understanding variation in both the animate and inanimate compartments of nature."

The team's findings were published online in the journal *Physics of Life Reviews*. The research was supported by the U.S. Air Force Office of Scientific Research and the National Science Foundation.

"Our discovery that animal locomotion adheres to the constructal law tells us that — even though you couldn't predict exactly what animals would look like if you started evolution over on Earth, or it happened on another planet — with a given gravity and density of their tissues, the same basic patterns of their design would evolve again," Marden said.

In numerous papers over past decade, Bejan has demonstrated that the constructal law predicts the design of a wide range of flow systems seen in nature, from biology and geophysics to social dynamics and technology evolution.

The idea that organic evolution is analogous to the way form evolves in inanimate flow systems is a novel concept that has the potential to unite perspectives and approaches across disparate disciplines.



Chuan-Hua Chen, assistant professor, specializes in physiochemical hydrodynamics, microfluidics and nanofluidics, and heat transfer. Chen was awarded a National Science Foundation early CAREER award in 2009 for a proposal titled "Electrohydrodynamic Coulter

DID YOU KNOW? *Chen and his wife had their second daughter, in November 2009. Between fatherhood, working towards tenure and buying a new house this year, Chen admits he often falls asleep before his children do at night.*

Counting". Chen plans to develop the electrohydrodynamic jet as a tunable fluidic aperture in lieu of solid-state nanopores used for resistive-pulse sensing. The proposed system prevents the clogging problem in nanopore sensing while offering a tunable analysis range. The applications include detection of unlabeled biomolecules and deployment of single nanoparticles. He was also awarded an Oak Ridge Associated Universities Ralph E. Powe Junior Faculty Enhancement Award.

Chen served as guest editor for the journal *Lab on a Chip* in 2008-2009, co-editing a special issue on the fundamental principles and techniques in microfluidics. In addition, he was awarded two patents this year: a closed-loop electro-osmotic microchannel cooling system, and electroosmotic micropumps with planar features.



Josiah Knight, associate professor, specializes in energy and environmental engineering, with a focus on solar thermal and transportation energy; and tribology, concentrating on hydrodynamic

lubrication with thermal and cavitation effects. Knight co-authored a resource policy article with Duke Nicholas School professor Daniel Richter for the March 13 2009, issue of *Science* magazine focusing on the economic, social, and

DID YOU KNOW? *Knight is an assistant scoutmaster for his son's Boy Scouts of America troop in Orange County, NC.*

environmental benefits of sustainable wood energy.

Knight and his team argue that advanced wood

combustion, already in use in Europe, could be a tremendously successful approach to supplying heat, cooling and power to many regions of the U.S. Knight is co-director of the Gendell Center for Energy and the Environment at Duke, and is leading the development of Duke's Energy and the Environment undergraduate certificate program.



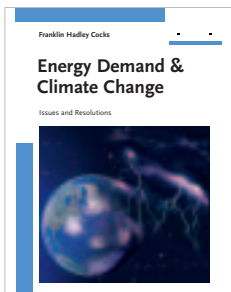
Franklin Hadley Cocks, professor, specializes in energy and environmental engineering. He recently published "Energy Demand and Climate

Change: Issues and Resolutions" by Wiley in June 2009. The text, aimed at a wide readership ranging

DID YOU KNOW? *Cocks founded the Master of Engineering Management program at Duke.*

from educated laypeople and students to practitioners in engineering and environmental science, provides the fundamentals necessary to understand today's energy and climate problems and provides possible answers based on current technology such as solar, water and geothermal power.

It also introduces the reader to new concepts that are already or may soon be realized, such as nuclear fusion or a hydrogen-based economy.

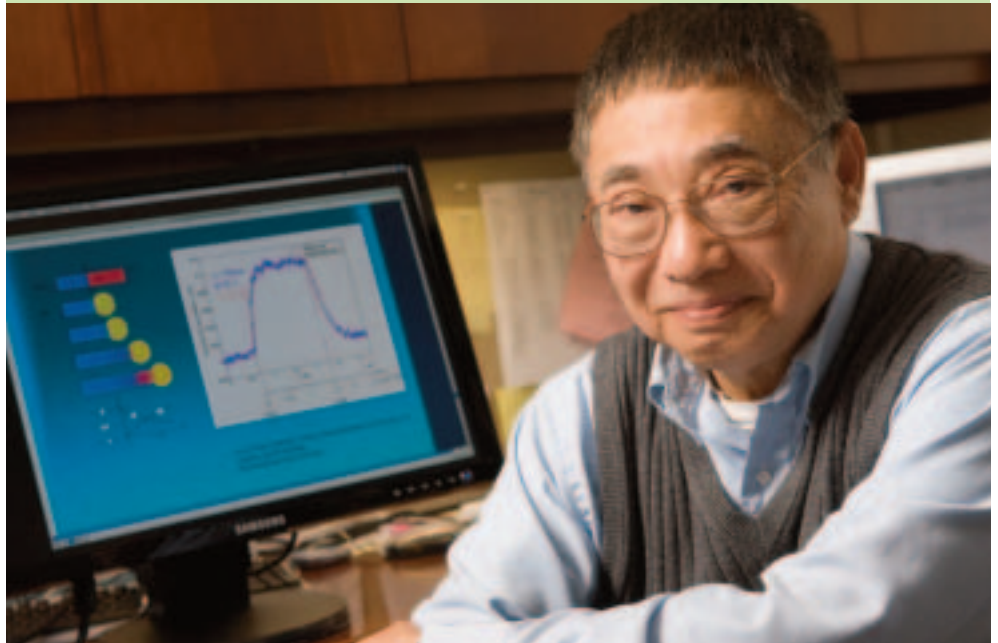


Stefano Curtarolo, a specialist in computational materials science, was promoted to associate professor with tenure in 2009. He was also awarded a Presidential Early Career Award for Scientists and Engineers (PECASE) and \$1 million in recognition of his discovery and characterization of novel combinations of elements on the recommendation of the Department of Defense Office of Naval Research (ONR).

ONR cited Curtarolo's research on physics and thermodynamics of superconducting materials, topological transitions of quasi-crystalline thin films, size-induced instabilities in nano-catalysts; and for mentoring minority graduate students. He also earned praise for an exceptional record of international talks, presentations and seminars. Curtarolo previously won both ONR and National Science Foundation Young Investigator awards in 2007.

DID YOU KNOW? *Curtarolo buys and restores classic Volkswagens as a hobby.*

As a theoretician, Curtarolo uses supercomputers to search for and test novel combinations of elements for specific purposes, or to better understand existing materials. He searches for such materials as novel titanium alloys for marine structures, new superconductors, ceramic materials for nuclear detection, and metallic nanoparticles for growing nanotubes and fuel cell alloys for energy conversion.



Teh Tan, professor, is conducting fundamental research in materials science and processes related to electronic materials. He and his colleagues have originated the study of the subject of intrinsic gettering which is now widely used to improve yield in integrated circuit fabrications using Czochralski silicon. He has also studies the basic aspects of the following topics in silicon: precipitation, kinetic process of defect evolution, impurity diffusion mechanisms and point defects. These studies have led to greater understanding of the structure and properties of defects in silicon. He recently published "Transition Region Width of Nanowire Hetero- and pn-junctions Grown Using Vapor-Liquid-Solid Processes," in the journal *Applied Physics A* 90, 591-596 (2008).



Tod Laursen, professor and department chair, specializes in computational mechanics. Laursen and co-author B. Yang recently published “A Contact Searching Algorithm Including Bounding Volume Trees Applied to Finite Sliding Mortar Formulations,” in *Computational Mechanics*, 41, 189-205, 2008. In this paper,

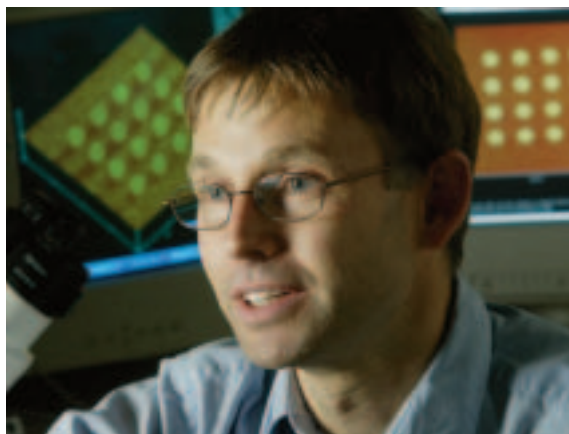
DID YOU KNOW? *Laursen, whose two teenage sons are both professional-level violinists, centers most family vacations around music festivals where his sons learn and perform.*

Laursen presents a new finite element approach to studying contact mechanics—the deformation of solids that touch each other at one or more points. He has developed a contact searching algorithm for use with large deformation mortar contact formulations. Laursen also serves as the editor in chief of the journal *Finite Elements in Analysis and Design*, published by Elsevier Science.

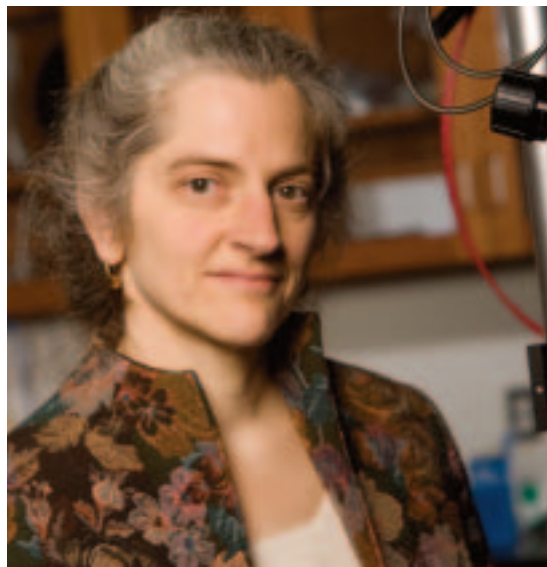
Stefan Zauscher, associate professor, specializes in exploring the intersection of surface and colloid science, polymer materials engineering and biointerface science. In 2008, he won the Young Investigator Award in Experimental Science at the International Conference on Computational and Experimental Engineering and Sciences (ICCES). Zauscher also recently published research titled “Fabrication of Micropatterned Stimulus-Responsive Polymer-Brush Anemone,” in the journal *Advanced Materials*, 2009, 21, 1-5. In the paper, Zauscher demonstrates how brush microstructures can potentially be used in microfluidic systems to capture, dock, and release microparticles in predefined locations, analogous to sea anemones capturing their prey. He also serves as the departments Director of Graduate Studies.

DID YOU KNOW? *Zauscher is an avid, non-competitive cyclist. He bike commutes to work every day, rain or shine, and on the weekend he typically logs 40-60 miles.*

Mechanical engineering associate professors Stefan Zauscher and Pei Zhong garnered a bronze metal from the Deputy Assistant Director of the Army for their paper titled “Biomechanical and Biochemical Cellular Response Due to Shock Waves.” The research paper ranked third overall for the entire Army Science Conference and also won the best paper award in the Force Protection /Survivability



session. They share honors with Duke collaborators: James Barthel, Samidha Konkar, Georgy Sankin, Eric Darling and Farshid Guilak.



Anne Lazarides, assistant professor, specializes in the exploration of structure/property relations in hybrid nanostructures, particularly plasmonics. Her aim is to develop nanostructured materials that assemble under biomolecule direction and can be used to provide optical signals in integrated nanosystems. She recently published “Reconfigurable Core-Satellite Nanoassemblies as Molecularly Driven Plasmonic Switches” in *Nano Letters* 8(7), 1803-1808 (2008) with coauthors David S. Sebba, Jack J. Mock, David R. Smith, and Thom H. LaBean.

Lawrence Virgin, professor, specializes in structural dynamics and mechanics. He was recently awarded \$530,814 for a three-year Air Force Office of Scientific Research project titled “Snap-through and Continuation” and \$374,514 from the National Science Foundation for a project titled “New challenges in non-smooth dynamical systems: experiments and analysis.” He is also the co-PI on a National Science Foundation grant for a project titled “Non-linear Dynamics of Traveling Wave Magnetophoresis for Applications in Colloidal Separation.” Virgin recently published two significant studies in the *Journal of Sound and Vibration*, 310 (2008). The first study is titled “Vibration isolation using buckled or pre-bent columns. Part 1: Two-dimensional motions of horizontal rigid bar.” The second is titled “Vibration isolation using buckled or pre-bent columns. Part 2: Three-dimensional motions of horizontal rigid plate.” He is also conducting research on structural dynamics and fatigue in rocket booster engines for NASA.



Marco Polo Swimming Pool Game Inspires Robot Detection

Duke's Silvia Ferrari led a team who used the simple pursuit-evasion game "Marco Polo" to solve a complex problem -- namely, how to create a system that allows robots to not only "sense" a moving target, but intercept it. Such systems have broad applications, ranging from security systems to track unwanted intruders like enemy ships or burglars, to systems that create radiation or environmental hazard maps, or even track endangered species.

The main challenge facing researchers is developing the artificial intelligence to control the robots and their sensors without direct human guidance.

"Games give us a good way of making these highly complex problems easier to visualize," said Ferrari. "Just as in Marco Polo, we needed to create a way that permits mobile robots to detect other moving objects and make predictions about where the targets might go," Ferrari said. "When done efficiently, the mobile sensor switches from pursuit mode to capture mode in the shortest amount of time."

Ferrari and colleague Rafael Fierro, associate professor of electrical engineering at the University of New Mexico, published the results from their latest experiments online in the *Journal on Control and Optimization*, a publication of the Society for Industrial and Applied Mathematics.

Ferrari's laboratory had already developed a similar type of algorithm, known as cell decomposition, in which space is broken down into a series of distinct cells. Past experiments allowed a robot to move through space without colliding with stationary obstacles.

"We are now developing algorithms that will more closely mimic the real world by giving intruders the ability to take evasive actions," Ferrari said. "The other main issue is to ensure that all the different mobile sensors can communicate with each other at all times and coordinate their activities based on that communication."

The research was supported by the National Science Foundation, Office of Naval Research and U.S. Army Research Office. Other members of the research team were Duke's Chenghui Cai and Kelli Baumgartner, and Oklahoma State University's James McClintock and Brent Perteet.

Silvia Ferrari, assistant professor, specializes in developing systems that attempt to mimic human thought processes for use in mechanical systems that must have the ability to react quickly in the face of changing circumstances. This includes not only as mine-sweeping applications, but such activities as security surveillance, airborne drone guidance and even criminal profiling.



DID YOU KNOW?

In her spare time, Ferrari enjoys painting, skiing, ice hockey, and windsurfing.

Game Provides 'Clue' to Remote Sensing

A newly developed mathematical model that figures out the best strategy to win the popular board game CLUE could some day help robot mine sweepers navigate strange surroundings to find hidden explosives.

In the case of CLUE, players move a pawn around the board and enter rooms seeking information about the killer and murder weapon before moving on to the next room seeking more information. In the same way,



sensors — like the pawn in CLUE — must take in information about the surroundings to help the robot maneuver around obstacles as it searches for its target.

"The key to success, both for the CLUE player and the robots, is to not only take in the new information it discovers, but to use this new information to help guide its next move." - Cai

Ferrari and collaborator Chenghui Cai published the results of their latest research online in the journal *IEEE Transactions on Systems, Man and Cybernetics*. Cai is now a post-doctoral fellow in computer and electrical engineering at Duke.

"The key to success, both for the CLUE player and the robots, is to not only take in the new information it discovers, but to use this new information to help guide its next move," Cai said. "This learning-adapting process continues until either the player has won the game, or the robot has found the mines."

Researchers in the field of artificial intelligence research refer to these kinds of situations as "treasure hunt" problems and have developed different mathematical approaches to

improve the odds of discovering this buried treasure. Games are often used to test or to help illustrate such complex problems.

Ferrari and Cai developed a mathematical way of representing the choices and acquisition of information that takes place in such activities, and tested it against experienced CLUE players, as well as players employing other types of game-playing algorithms. Both studies were supported by the National Science Foundation.



Devendra Garg, professor, specializes in robotics and automatic control, with an emphasis on multiple-sensor modeling, distributed agent networking and sensor fusion. He recently published a chapter in the Wiley Encyclopedia of Computer Science and Engineering (John

DID YOU KNOW?
The American Society of Mechanical Engineers has established a Life-Time Achievement Award for Intelligent Systems named after Devendra Garg.

Wiley & Sons, Hoboken, N.J., 2008) titled "Neural Controllers." He also served as an international advisory board member for several conferences including the 2008 IEEE International

Conference on Automation and Logistics in Qingdao, China, September 2008; the 3rd International Conference on Positioning Technology in Shizuoka, Japan, November 2008; and the 2008 International Conference on International Information and Automation for Sustainability in Sri Lanka, December 2008.

Education

SENIOR DESIGN HIGHLIGHTS:



The **'High Altitude Wind Turbine Team'** designed and built a wind turbine and generator assembly that could be elevated into the air using lighter-than-air components. The team included seniors Perry Haynsworth, Benjamin McConnell, Adam Nelson and Todd Stamp. The prototype was assembled using a 3D printer to produce a wind turbine designed in SolidWorks and then mounted onto a shaft connected to an aluminum frame. Generators were attached to each end of the turbine in order to transfer the rotation of the turbine into electrical power. The prototype was successfully tested in Duke's subsonic wind tunnel.



The **'Alternative Underwater Propulsion System Team'** designed an alternative method for underwater propulsion that would provide scientific organizations with a quieter way to research marine environments. Based on a concept design review, the team decided to apply biomimicry and build a vehicle modeled after fish-like motion. The team included Mark Riherd, Kathryn Dankovich, Alyssa Roessler and Anne Vanderschueren. The final prototype was thoroughly water-proofed and stabilized in order to successfully propel the vehicle forward. The robotic fish was used to gather experimental data on the performance of the device. The team performed engineering analysis on the prototype and optimized the product based on test data.



Engineering Solutions Hands-On

During the fall of 2008, students in Laurens Howle's ME141L course were given a challenge and their mission was to conceive of a solution, design it, and finally build it.

Dr. Rendon Nelson, a radiologist at Duke Hospital, brought a clinical problem to the class to solve. He had worked with Howle before on other projects and thought the class could help him solve a challenge he faced in the hospital.

In order to interpret an image and diagnose a patient, Nelson must obtain clear pictures of such soft tissues as the liver, spleen or pancreas. He often uses computed tomography (CT) technology to take these pictures. To get the clearest image possible, Nelson must give the patient an intravenous injection of a contrast agent. The agent needs to be given in one steady and continuous dose, and many patients need doses as large as 150 milliliters.

"Most nurses are not strong enough to push the plunger in a syringe that large," Nelson explained. "To compensate, the agent is often administered from a series of smaller syringes. While that makes it easier for the nurses, it can lead to less-than-optimal images because the doses rise and fall as each syringe is used. We needed a device that nurses could use to deliver a steady dose of the agent."

At the beginning of the semester,

Nelson came to the class and explained the problem and provided the technical specifications of what was needed. Within a month, each group presented a PowerPoint presentation of their ideas, and not long after that they had fashioned prototypes for Nelson to evaluate.

"Each person had a specific responsibility, ranging from ordering parts to constructing the device to finite element analysis." - STEINBERG

The course not only gave students firsthand experience in developing an idea from beginning to end, but also exposed them to other important aspects of product development, such as working with a client and incorporating their input, dealing with costs and ordering issues, and overcoming unforeseen roadblocks.

"We were under a tight deadline, so we had to delegate all the different aspects of the project," said Scott Steinberg, a senior biomedical engineering major. His team's prototype was selected as the class's best. Other students in the team were Ryan Ptera, Mark Riherd, Alexander Robinson, Todd Stamp, Scott Steinberg, Bryan Stem, Maryanne Uselton, Anne

Vanderschueren, Andrew Ward and Miles Whitten.

"Each person had a specific responsibility, ranging from ordering parts to constructing the device to finite element analysis," Steinberg said. "We also got the opportunity to use tools like the jigsaw, lathe and milling machine. That was the first hands-on experience I had since high school."

The final product made use of gears

turned by a large "steering" wheel. As the wheel is turned, the device easily pushed the plunger into the syringe, dispensing the contrast agent.

While the appearance of the prototype will likely change, the students are planning to patent the device in hopes that a medical instrument company will become interested in developing it into a product.

"All the teams did a great job," Howle said. "What I especially liked about it is that they used what they learned during the class to guide the development of the device they ended up building. I was also impressed how they were able to overcome the obstacles and setbacks that they all encountered."



Freshman in the Fast Lane

Raced Since Age of Seven



Paul Harraka is not your typical engineering student. Not only does he live in the fast lane, he wins. Racing in NASCAR's "minor league," Harraka earned the checkered flag 11 times out of 23 races in the Whelen All-American Series held between March and September at the All-American Speedway in Roseville, Calif. Last year, he was named that venue's Rookie of the Year.

Harraka plans to continue a NASCAR career during and after his four years of college, and he feels that his time at Duke as a double major - mechanical engineering and public policy - will make him a better driver and future businessman in the sport.

Also, he said, having a college degree should make him more versatile and marketable to racing teams. It would also make him unique in the sport — as it now stands, Ryan Newman is the only NASCAR racer who has graduated from college. For Harraka, getting an education is just as important as a

racing career. The New Jersey native graduated from Lake Norman High School in Mooresville, N.C., with a 4.38 GPA, in spite of his hectic traveling schedule.

Harraka began his racing career at the age of seven, competing in go-kart events across the country and Canada. By the time he was 15, he had won more than 150 such races, including 13 national championships and six world championships. He remains the youngest racer to have won a national championship.

Speedy Students

ME undergraduates **Kevin Autrey** (Pratt '09) and **Clark McGehee** (Pratt '10) competed in the Ironman Florida 2008. This athletic duo swam an amazing 2.4 miles, biked 112 miles, and then finished it off with a 26.2 mile run — all in 13 hours and 32 minutes.



Pratt Undergraduate Research Fellow
Mechanical Engineering
Ivan Wang

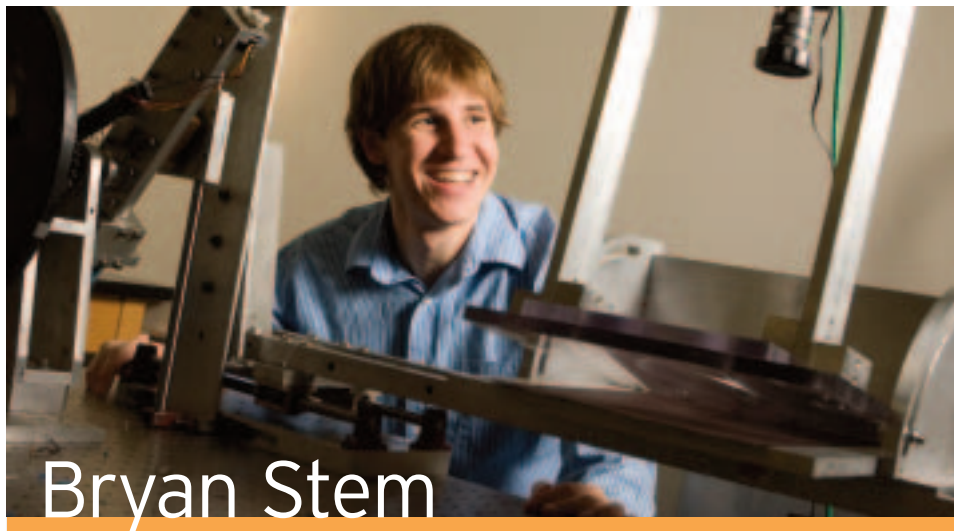
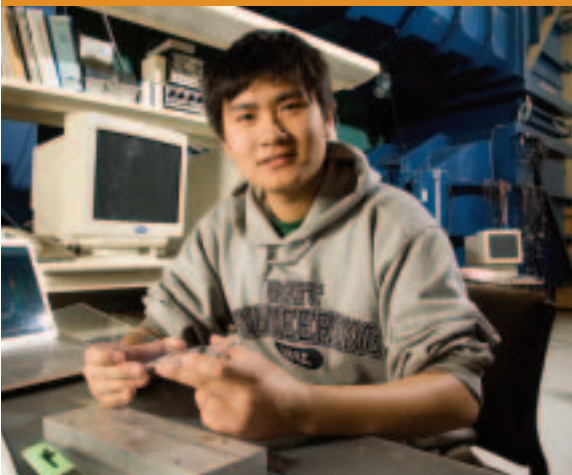
Double major: mechanical engineering, mathematics

Adviser: Dr. Earl Dowell, William Holland Hall Professor and Dean Emeritus

Project title: Evaluating the Aeroelastic Response of a Folding Wing Using Component Modal Analysis

Abstract: A folding wing is a wing configuration consisting of multiple segments, where the angle between any pair of adjacent segments can change during flight. This project analyzes a simplified model of a folding wing consisting of two rectangular wing segments joined together at a certain angle with a torsional spring using component modal analysis. This method allows us to initially treat the two halves of the wing as separate parts, and then combine them using constraint functions. Consequently, the analysis takes on a modular approach, where additional complexities to the system are added into the model as needed without remodeling the entire system. An experimental model is being constructed for a wind tunnel test. The test will focus on measuring flutter speeds at different fold angles. The results of the test will be used to validate theoretical predictions of flutter speeds. Future work includes nondimensionalizing current equations to examine relative importance of parameters and applying more sophisticated aerodynamic theory to better model the 3-dimensional unsteady flow around the wing.

Future plans: Ivan graduated with distinction in ME in May 2009. He was awarded the Mechanical Engineering and Materials Science Faculty Award, given to the ME senior who has attained the highest level of scholastic achievement as determined by the ME faculty. Ivan will be going to graduate school at Duke and received the J.B. Duke Fellowship. He will conduct his PhD work under Dr. Earl Dowell, who was his Pratt Fellows Adviser.



Bryan Stem

Pratt Undergraduate Research Fellow
Mechanical Engineering

Major: mechanical engineering

Adviser: Lawrence Virgin, professor of civil and environmental engineering

Project title: Dynamics of Nonlinear Systems with Discontinuities: Modeling and Analysis of Non-smooth Dynamical Systems

Abstract: The goal of this research was to physically model and, where possible, digitally simulate a number of non-smooth systems to better understand and calculate their dynamics. Studies were conducted involving a mass attached to a string on a vibrating surface moving in 1D linear motion being tracked and recorded with a high-speed digital camera and computer software. This data was compared with the predicted results given by two software codes coded in Matlab and Simulink to model the motion of the mass. The same camera techniques were then applied to a 2D nonlinear system consisting of a ball in a shaped groove that could be pivoted and forced in an oscillatory manner. A number of parameters were adjusted, such as forcing frequency and amplitude, to accumulate a wide range of data, including Poincaré sections. The final non-smooth system constructed and studied consists of a block on a base that teeters and can be analyzed similarly with the high-speed digital camera and computer software. A number of techniques were created and refined through this investigation of nonlinear impact dynamics that can be expanded to range of other systems and applications. The major outcome has been the understanding of not only the systems studied, but the exploration of techniques allowing the study and analysis of non-smooth systems as a whole.

Future plans: Bryan will be working at Medtronic, Inc., in their Neuromodulation Department in Minneapolis, MN, as an associate mechanical design engineer. He was awarded a Medical Research Fellowship at Emory University after his sophomore year.

Graduation with Distinction

Kathryn Marie Dankovich, Matthew Aaron Kligerman, Adam Lee Nelson, Ivan Wang

Awards:

THE PI TAU SIGMA SCHOLARSHIP AWARD

James Colin Montupet from St. Louis, Mo. (Presented to an outstanding senior in mechanical engineering on the basis of academic excellence, engineering ability and leadership as judged by a faculty committee.)

THE MECHANICAL ENGINEERING & MATERIALS SCIENCE FACULTY AWARD

Ivan Wang from Vernon Hills, Ill. (Presented to the graduating mechanical engineering senior who has attained the highest level of scholastic achievement in all subjects.)

Duke Motorsports Team Finishes Its Best

A team of 25 Pratt engineering students, dominated by upper classmen, raced to the best showing by a Duke team in the annual Formula SAE competition sponsored by the Society of Automotive Engineers at the Michigan International Speedway in mid-May.

Out of 123 teams from across the world, Duke University Motorsports finished 11th, up from their previous best finish of 23rd last year. This is the largest student engineering competition in the world, with over 1,500 students from nine different countries participating in the Michigan event alone. Entrants are required to design and build their cars from scratch.

“For the most part, this team has been together for four years,” said St. Louis native James Montupet, the team’s chief engineer who graduated this spring. “When we first joined we didn’t really understand all that was involved. But by this year, we developed an understanding of what’s good design and will improve the car, and what won’t. For example, we shaved 40 pounds off last year’s 500-pound car. By improving the efficiency of our work, we had more test time to work the kinks out of the car.”

The team typically begins the academic

year by coming up with a design for an open wheel, single-seat race car. Before any tubes are cut and welded, the car is usually designed with CAD (Computer Aided Design) software. The final design is completed early in the year, at which point the focus switches to actually building the car.

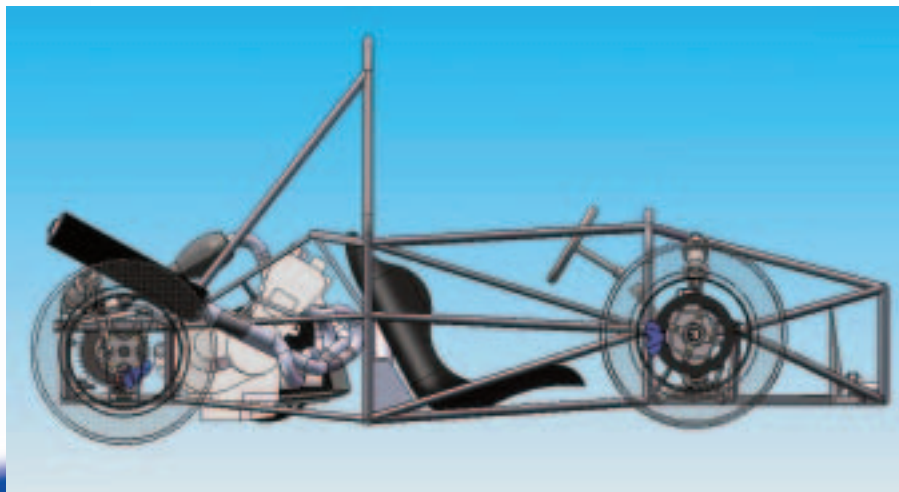
Most of the components of the racer, including the steel space-frame and the carbon fiber body, are manufactured by the students. Other parts, such as the engine, wheels and tires are purchased, but a great deal of customization takes place.

“I’ve spent all four years on team, and it’s been some of the best design experience I’ve had on campus,” Montupet said. “The technical skills needed to build a competitive car with a tight budget and time-frame are so much more difficult and at higher level than anything you’d get in a class. It was an incredible learning experience, both in engineering and in business, manufacturing operations and marketing.”

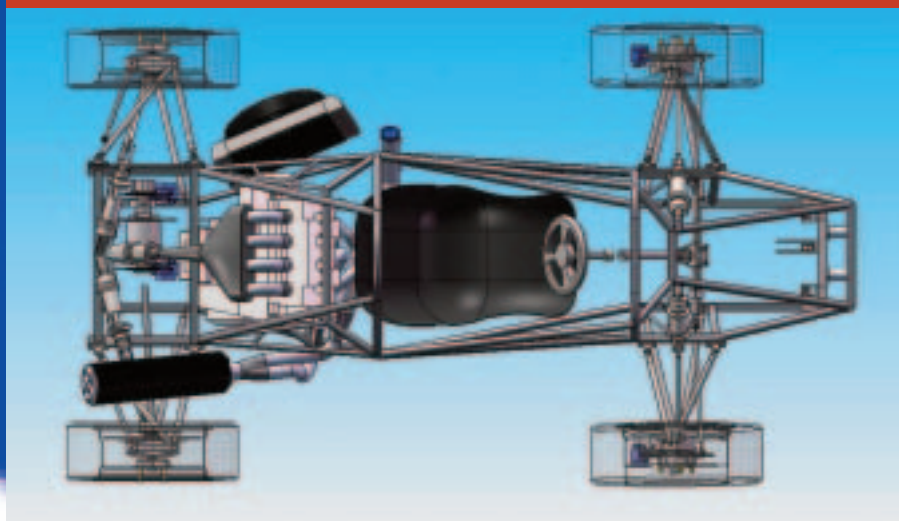




“...we shaved **40 pounds** off last year’s 500-pound car.”



Team leaders included: Will Gardner, team captain and engine design leader; David Coccarelli, electrical and data acquisition leader; Michael Spohn, drivetrain design leader; Hardy Shen, body design leader; and Ivan Wang, wheel and brakes design leader.



The remaining members of the team were Arjun Krishnaiah, Jason Ethier, Ryan Sellers, Paul Harraka, George Rossin, Brian Zorb, Ben Shelton, Blake Hechtman, Nikita Khylistov, Juan Pablo Garcia, Danny Lin, Alex Berghorst, Bharat Arora, David Piech, Felipe Mejia, Henry Ran, D.J. Shin and Shenren Xu.



Spotlight on Grads



Matt Johannes, a doctoral student under former dean Robert Clark, won the 2008 Best Paper Award from the Design Engineering

Division at the 2nd International Conference on Micro- and Nano Systems. He presented his paper titled "Enabling Soft Lithography Using Atomic Force Microscope" in New York in August 2008.

Second-year mechanical engineering doctoral student **Firas Khasawneh** won a \$500 student travel grant from the ASME Dynamics System and Control Division. He used the grant to attend the 2008 Dynamic Systems and Control Conference in Ann Arbor, Mich., and competed in a student paper competition. Khasawneh, who works with ME assistant professor Brian Mann, will present a paper titled "Explanation for low-speed stability increases in machining: application of a continuous delay model."

Mechanical engineering graduate student **Liz Bloomhardt** has won a NASA Graduate Student Researchers Program (GSRP) fellowship. The goal of NASA's GSRP is to cultivate additional research ties to the academic community by increasing the number of highly trained scientists and engineers in aeronautics and space-related disciplines. Liz's adviser is professor Earl Dowell.

Third year doctoral student **Krista Michalis** co-authored a paper titled "Prediction and Modification of Broadband Interior Noise in Enclosures Using Energy-Intensity BEM and Absorption Scaling," with adviser Donald Bliss.

Published in the Proceedings of ASME NoiseCon 2008, the paper and associated talk by Michalis won the student paper competition for the entire conference.



Alumni highlights

Sophia Santillan

For **Sophia Santillan**, mathematics turned out to be her gateway to engineering.

"I've always liked math, and engineering is an application of math," said Santillan, (B.S.E. '01, M.S. '05, Ph.D. '07), who is now in her second year at the U.S. Naval Academy as Assistant Professor of Mechanical Engineering.

Although she always had a keen interest in math, she hadn't always planned on a career in engineering. As an accomplished competitive pianist in high school, Santillan had thought she would pursue music at Northwestern University. She applied to Duke on a whim, not expecting to get in. After enrolling at Duke's Trinity College, she later transferred to Pratt and double majored in mathematics and mechanical engineering and materials science.

Though her entire academic life took place at Duke, her career took a small, but important, detour. After her undergraduate years, she taught math at two private high schools.



"I wasn't sure what I wanted to do after being an undergraduate," she recalls. "I happened to meet the dean of the faculty of Phillips Exeter Academy (New Hampshire), and decided to give teaching math a shot. I had a one-year fellowship to learn how to teach. I gained a greater appreciation of the fundamentals of teaching. It was a great experience."

She then taught math at St Georges School, Rhode Island, for a year before the engineering bug bit and she returned to Duke to pursue advanced degrees in mechanical engineering.

So far in her career, she has spent most of her time teaching, though she plans to begin her own research projects.

"The Naval Academy has great lab facilities, especially its system of experimental water tanks," she said. "I plan to use one of the smaller ones to look at subsea pipelines and figure out the different forces and stresses they experience. Then we can figure out how best to design pipes to be resistant to damage."

Philip Bayly

What **Philip Bayly** laughingly calls a "character flaw" in his own personality has inspired him to pursue challenges in many different areas, from high-speed machining to measuring abnormal heart beats to understanding the tiny hair-like structures lining human lungs.

What do these disparate pursuits have in common?

"Non-linear dynamics and chaotic vibrations," said Bayly (Ph.D. '93), Professor of Mechanical and Biomedical Engineering at Washington University for the past 16 years and recently named chair of Mechanical, Aerospace and Structural Engineering. "Each of these problems involves oscillations or disorganized behaviors. Even when I was a graduate student at Duke, my thesis went in several different directions. The great part of academic world is that you can explore wherever your interests take you."

"I have a hard time turning down interesting problems," he continued. "Non-linear dynamics have many applications to various and sundry questions. The reason I got involved in the heart study, for example, was that the cardiologists in the basic arrhythmia lab were interested in the fundamental reasons behind the often chaotic heartbeats they were studying. That sounded fascinating to me as away of applying engineering principles to the life sciences."

Bayly earned a bachelor's degree from Dartmouth College and a master's degree from Brown University before coming to graduate school at Duke. Four years ago, he was named the inaugural Lilyan and E. Lisle Hughes Professor in Engineering at Washington University.

"I continually look to Duke as an example of what we should be doing here at Washington University— it is a prototype in many ways of what we want to do here," he said. "In the type of environment I had at Duke, students are able and encouraged to explore different areas and the faculty members, such as Earl Dowell and Lawrie Virgin, are willing to nurture those efforts."

"Washington University is a lot like Duke, but without a Division One basketball team!"



Michael Todd

Wouldn't it be cool if an aerospace structure, such as an unmanned drone like the Predator, could continually monitor all its functions and report back any problems it was experiencing?

Michael Todd (B.S.E. '92, M.S. '93, Ph.D. '96) sees a day when this will become a reality. On the faculty of the University of California at San Diego (U.C.S.D.), Todd is a pioneer in the new field of "smart structures" engineering research. In fact, he helped create the country's first graduate degree program in structural health monitoring, damage prognosis, and validated simulations at U.C.S.D.

While his research covers civil, mechanical and aerospace structural systems, his focus recently has centered on aerospace applications. In simple terms, he combines his skills in hardware design and software development to create a far more

complex and sophisticated "check engine" light in cars.

"The whole idea of smart structures is to replicate some of functionality human beings have in communicating how they feel," said Todd, Associate Professor and Vice-Chair of Structural

Engineering. "We're trying to develop structures that help themselves by monitoring and communicating the state of their health. I'm working on the part of the puzzle that performs these self-diagnostic tests."

As a part of his research, he uses fiber optic sensor arrays and RFID-enabled sensor networks for making the measurements necessary for self-diagnosis. By integrating these sensor technologies with targeted processing algorithms, Todd creates smart structures that continually provide data regarding health and performance in an online, efficient manner for optimal decision-making, reconfiguration, performance enhancement and life safety.

Todd believes that these are exciting times, both for the field of smart structure research and the growth of his relatively new San Diego campus. In many ways, he sees similarities between U.C.S.D. engineering now and Duke engineering in the late 1990s as up-and-coming institutions.

"Both San Diego now and Duke then are suddenly being recognized as a new high-growth institution," Todd explained. "Where I am now reminds me of the transition Duke made from a regional institution to one with national and international aspirations. It's exciting to be in at the beginning of such a dramatic rise in size and prestige."



Christophe Pierre



Christophe Pierre (Ph.D. '85), dean of engineering at McGill University, learned some valuable skills about juggling the demands of administering a school while maintaining a productive research laboratory from a former Duke engineering dean.

"I left France in 1982 to do graduate work at Princeton University and studied under Earl Dowell," Pierre recalls. "A year later, when Earl moved to Duke to become dean, I followed him."

In fact, two years after arriving at Duke he had earned his Ph.D. in mechanical engineering and materials science.

"The speed of things just kind of happened," Pierre said. "One day, Earl gave me a research paper that had just been published on the localization of vibrations. That was very new topic for me. Before I knew it, I had done the Ph.D. The field was so new that we could progress so fast."

"At the time, the department was relatively small, both in terms of size and number of faculty," he continued.

"The trick, as I have learned, is defining priorities. It's a matter of organization, like putting together a good team to help achieve milestones and delegating certain responsibilities. It is something that is not taught in school, but learned on the job."

"The department was very welcoming, like a family. Princeton, by comparison, was much bigger and more anonymous. Also, as one of the dean's students, I had access to many things and people were more inclined to talk to me and help out. The experience prepared me well for a career in academic engineering."

Two weeks after his successful Ph.D. defense, he joined the faculty of the University of Michigan, where he ended up spending the next two decades, rising steadily from assistant professor to chaired professor and

associate dean. "Patience was never one of my virtues," he added, chuckling.

In 2005, he became McGill's engineering dean. All the while, he has directed a productive and vibrant lab.

"As a dean, Earl seemed to have that unique ability to handle many different responsibilities and handle them well," Pierre said. "The trick, as I have learned, is defining priorities. It's a matter of organization, like putting together a good team to help achieve milestones and delegating certain responsibilities. It is something that is not taught in school, but learned on the job."

Pierre's research focuses on vibrations, and their potential impacts on structures, like automobiles or aircraft. "In a car, unwanted vibrations can come in the form of noise and be an annoyance to the driver," he said. "However, in something like a jet's turbine, unwanted vibrations can lead to blade fatigue and ultimately the failure of the engine with catastrophic results."

Though he has been in contact with Duke professional colleagues such as Kenneth Hall, Julian Abele Professor of Mechanical Engineering and Materials Science, Pierre hasn't been on campus in quite a while. He does, however, have fond memories of his student housing, an apartment on Louise Circle.

"We lived in a two-story brick townhouse built in the 50s," he said. "It was inexpensive and very comfortable. I can still see in my mind the manager – a true southern gentleman who smoked cigars and drove a big Cadillac. He was quite the character."

DUKE MEMS GRADUATE STUDENTS

May 2009 Graduates

Nathan Jay Jenness, Ph.D.

Adviser: Robert Clark

Dissertation: Three Dimensional Holographic Lithography and Manipulations Using a Spatial Light Modulator

Randall Morgan Erb, Ph.D.

Adviser: Benjamin Yellen

Dissertation: Magnetic Manipulation and Assembly of Multi-Component Particle Suspensions

Debby Pei-Shan Chang, Ph.D.

Adviser: Stefan Zauscher

Dissertation: Mechanical and Tribological Study of a Stimulus Responsive Hydrogen and a Mucinous

Jianan Hou, M.S.

Adviser: Teh Tan

Thesis: A Model of the Growth Rate of Nanowires Produced by the Vapor-Liquid-Solid Process

Gregory Kealoha Fricke, M.S.

Adviser: Devendra Garg

Thesis: Comparative Analysis of Feedback Sensors for Localization and Calibration of a Mulei-Agent System



December 2008

Monica Rivera, Ph.D.

Adviser: Robert Clark

Dissertation: Atomic Force Microscope for Improved Dynamic Force Spectroscopy and Biochemical

Scott Matthew Wilson, M.S.

Adviser: Robert Clark

Thesis: Bell Model Parameters from Stochastic Simulations of Parallel-Loaded Multivalent Dynamic Force Spectroscopy

Staci Marie Van Lue, M.S.

Adviser: Stefan Zauscher

Samuel Curtis Stanton, M.S.

Adviser: Jonathan Protz

Thesis: Energy Harvesting from an Aeroelastically Coupled Plate: A stochastic Optimal Control Approach

Chai Hoon Quek, M.S.

Adviser: Kam Leong

Thesis: Evaluation of Potential Toxicological Effects of Engineered Nanomaterials

September 2008

Kristine Renee Obusek, M.S.

Adviser: Anne Lazarides

Meng Han Chiang, M.S.

Adviser: Chuan-Hua Chen

David S. Sebba, Ph.D.

Adviser: Anne Lazarides

Dissertation: Plasmonic Coupling in Biomolecule-Linked Nanoparticle Assemblies

Sidney Lebenthal, Ph.D.

Adviser: Kenneth Hall

Dissertation: Design and Optimization of a Flapping Nanoscale Aircraft

Yee Lam, Ph.D.

Adviser: Stefan Zauscher

Dissertation: A Nanomechanical Approach to Understanding Neutralizing Antibody Binding Behavior

SunWoo Kim, Ph.D.

Adviser: Adrian Bejan

Dissertation: Constructal Vascular Composites for Cooling and Heating

Hui Son, M.S.

Adviser: Benjamin Yellen

Thesis: Magnetically Actuated Assembly of Non-Magnetic Asymmetric Colloidal Structures

Krista Ann Michalis, M.S.

Adviser: Donald Bliss

Thesis: Prediction of Broadband Interior Noise Using an Energy-Intensity Boundary Element Method and Absorption Scaling

Andres Garcia, M.S.

Adviser: Stefan Zauscher

Thesis: Patterning Functional Surfaces at the Micro and Nanoscale: From Ferroelectric Materials to Non-Fouling Polymer Brushes



Department of Mechanical Engineering and Materials Science

Pratt School of Engineering
Duke University
144A Hudson Hall
Box 90300
Durham, N.C. 27708-0300

Non-Profit Org.
US Postage
PAID
Durham, NC
Permit No. 60