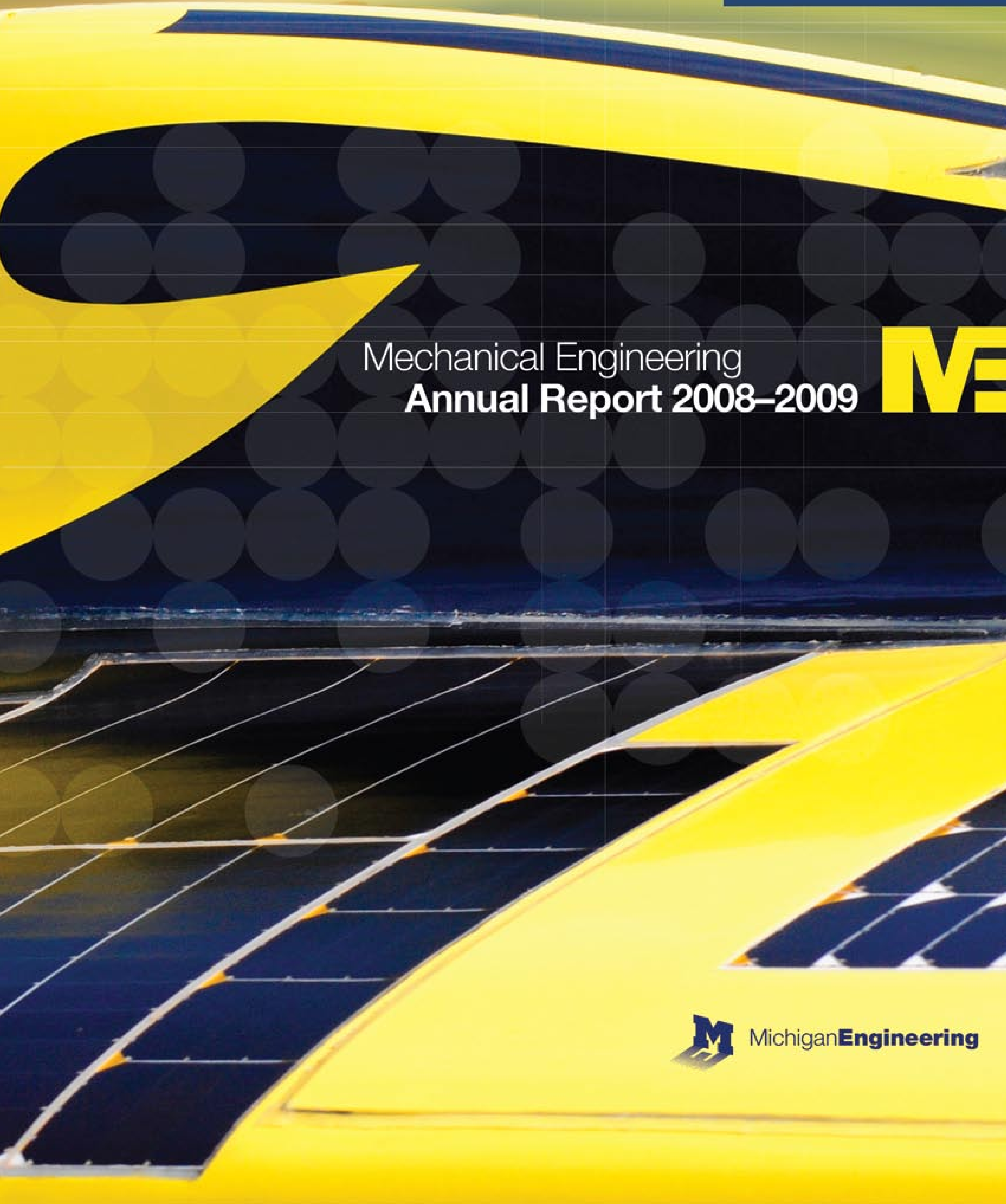
University of Michigan

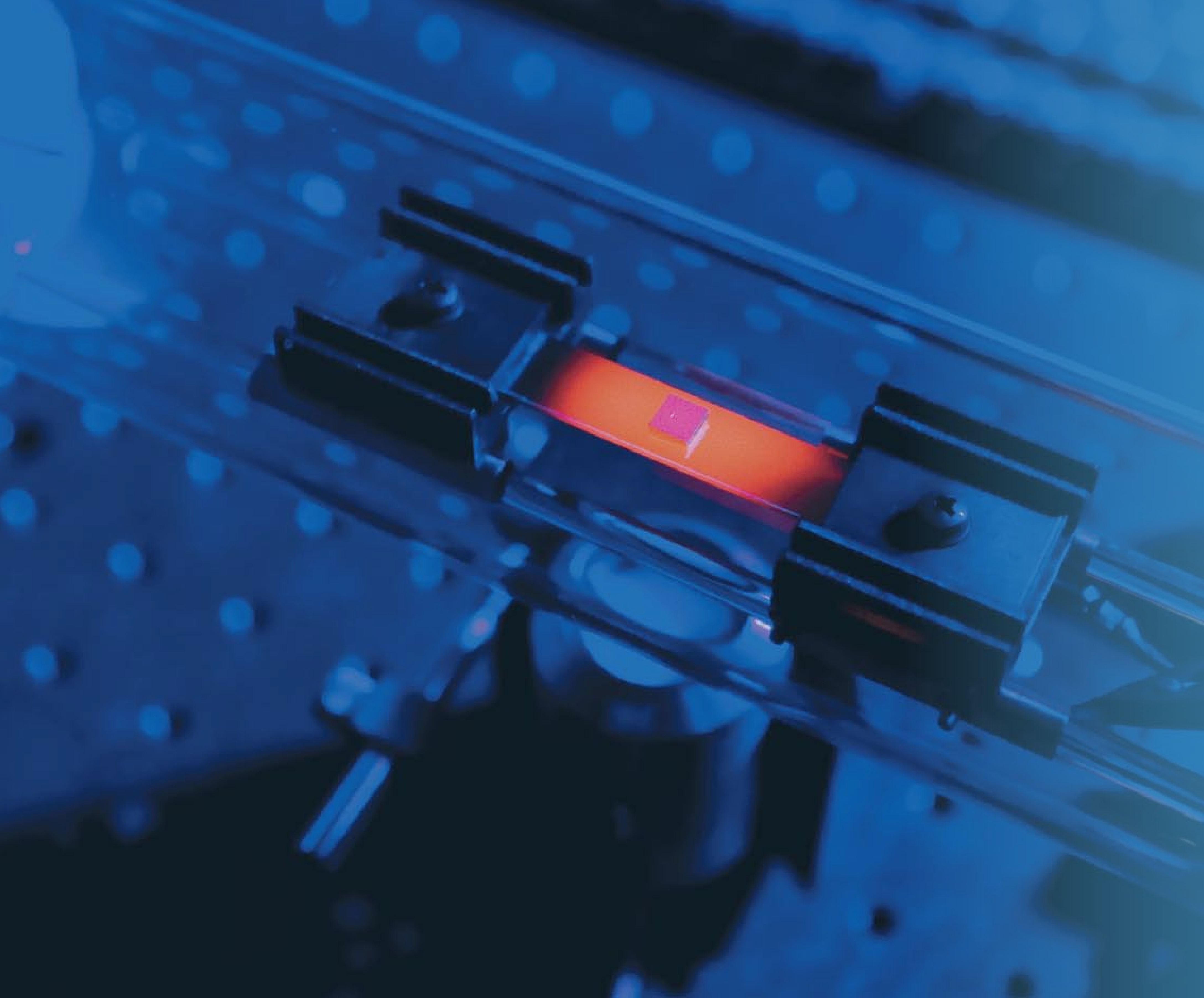
College of Engineering

Mechanical Engineering
Annual Report 2008–2009



MichiganEngineering

Mechanical Engineering **Annual Report 2008–2009**



Contents

Message from the Chair

It is with great pride that I present you with this annual report, the highlights of the activities and events in the Department during 2008–09. I am extremely excited about the accomplishments of the year now behind us, and for the years to come.

The Department of Mechanical Engineering (ME) at the University of Michigan (U-M), with its 58 tenured or tenure track faculty, 21 research faculty, 55 staff, over 600 undergraduate and 420 graduate students and well over 16,000 alumni, is a tremendous force in generating new paradigms in mechanical engineering. The Department's annual research expenditure is over $30 million, showing strong and continuous growth and placing us among the most highly funded ME programs in the nation. Our colleagues are recognized worldwide for their scholarly contributions, evidenced in part by the many awards they received. During this past year, we have had an election to the National Academy of Engineering, three NSF CAREER awardees and many recipients of prestigious societal awards: the ASME Daniel C. Drucker Medal, Rufus Oldenburger Medal, William T. Ennor Manufacturing Technology Award, James Harry Potter Gold Medal, Adaptive Structures and Materials System Prize, Gustus L. Larson Memorial Award, Pi Tau Sigma Gold Medal and the Society of Engineering Science William Prager Medal, to name a few. We have hired three outstanding new faculty members in the areas of energy storage, nano/bio systems and fluid mechanics this year, and will have multiple new openings to fill in the coming year.

The Department has always been strong in the core areas of mechanical engineering and mechanics as well as in various thematic areas. We have strategically built critical mass and cross-linked the new emerging fields with the traditional core disciplines. This year brought the initiation of several new multidisciplinary, center-type activities led by our faculty: the Advanced Battery Coalition for Drivetrains to explore advanced energy storage systems for future generations of drivetrains; a Multidisciplinary University

> "The U-M ME department continues to thrive and grow, making significant contributions to research, education and many other aspects of society."

Research Initiative on basic research into heat transfer at interfaces for more efficient heat removal or potentially converting waste energy into usable electricity; the Ground Robotics Research Center with a comprehensive program covering all aspects of mobile robots and autonomous vehicles and an NSF Emerging Frontiers in Research and Innovation program to explore linkages between the transportation and electric power grid infrastructures via plug-in hybrid electric vehicles. As you will also read in this report, our faculty have made ground-breaking research contributions at the frontiers of emerging biomedical, green-energy and nano-scale manufacturing, personalized production, energy and sustainable systems, environmentally friendly transportation, nanomechanics, MEMS and nanosystems, biomechanics and biosystems. These research efforts will continue to strongly impact the scientific community and our society.

Paralleling its tremendous success in research, U-M ME has also achieved educational excellence. This report highlights our strong leadership in global education in Asia, Europe and Africa; in new education programs in Energy Systems Engineering, Robotics/Autonomous Vehicles, Global Health and interdisciplinary Design Science and at the College's Design Expo, which was a rousing success again this year. Our faculty and students have further broadened their experience by actively participating in various team and entrepreneurial activities—one of many high notes included winning the North American Solar Challenge.

In spite of the recent global economic downturn, the U-M ME department continues to thrive and grow, making significant contributions to research, education and many other aspects of society. Building upon such excellence, our department continues to be a powerful force, actively defining and shaping the future of mechanical engineering.

I hope you enjoy your reading, and I look forward to sharing our continued progress again soon.

Kon-Well Wang

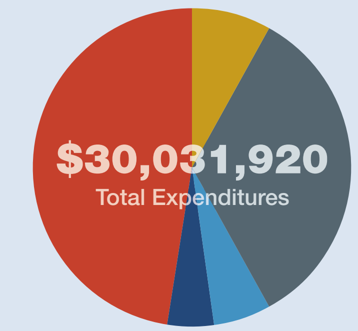
Chair and Stephen P. Timoshenko Collegiate Professor of Mechanical Engineering

Trends & Statistics

ME DEGREES CONFERRED TRENDS

	02-03	03-04	04-05	05-06	06-07	07-08
BSE	242	209	229	223	247	258
MSE	133	136	151	115	153	140
PhD	27	35	46	40	61	53

ANNUAL RESEARCH EXPENDITURES



NSF	$2,460,177
DoD	$10,195,017
DoE	$1,773,858
NIH	$1,403,643
All Other	$14,199,225

FACULTY PROFILE

5 # of Current NAE Members (Includes primary and joint ME appointments)

51 # of Society Fellows

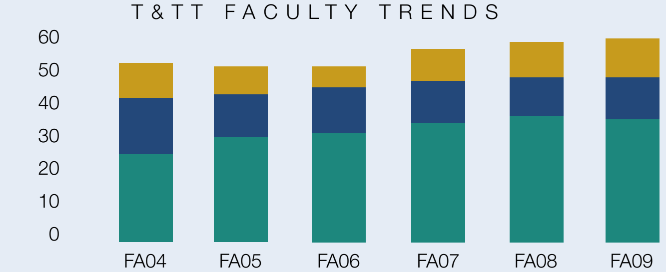
4 # of NSF PECASE or PFF Awards

26 # of NSF CAREER or PYI Awards

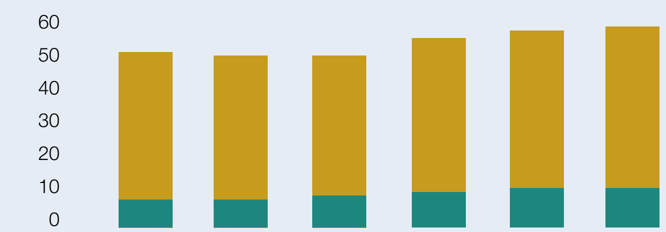
5 # of Current Journal Chief Editors

65 # of Current Journal Editorial Members or Associate Editors

T&TT FACULTY TRENDS



	FA04	FA05	FA06	FA07	FA08	FA09
Assistant	10	8	6	9	10	11
Associate	16	12	13	12	11	12
Professor	25	30	31	34	36	35
Total Faculty	51	50	50	55	57	58



	FA04	FA05	FA06	FA07	FA08	FA09
Male	44	43	42	46	47	48
Female	7	7	8	9	10	10
Total Faculty	51	50	50	55	57	58

In the News

ME Professor Dennis Assanis Elected to National Academy of Engineering

The National Academy of Engineering (NAE) recently announced the election of 65 new members to its ranks, and among them is Dennis Assanis, Jon R. and Beverly S. Holt Professor of Engineering. Assanis was elected to the NAE for his "scientific contributions to improving fuel economy and reducing emissions of internal combustion engines, and for promoting automotive engineering education."

Membership in the NAE is extremely selective, honoring engineers who have made significant and lasting contributions to engineering research, practice or education. Charles M. Vest, a U-M Mechanical Engineering alumnus and president emeritus of the Massachusetts Institute of Technology, currently serves as NAE president.

"I feel greatly honored to have been selected to be among this very prestigious group and I gratefully acknowledge my students and collaborators for their contributions," Assanis said. "I feel an even greater level of responsibility to address the global energy and environmental challenges that we're facing."

Professor Assanis is recognized internationally for his innovative development of modeling methodologies and experimental techniques to shed light into complex thermal, fluid and chemical processes in internal combustion engines and powertrain systems so as to improve their fuel economy and reduce emissions (see story on page 21).

Among other accomplishments, Assanis' work on homogeneous charge compression ignition contributes significantly to operating engines in low temperature combustion, ultra clean and fuel economical regimes that constitute a paradigm shift from today's practices. The engine system simulations he has developed with his students and collaborators are being used in industry and national laboratories.

Assanis directs the Walter E. Lay Automotive Laboratory and the Automotive Research Center, both highly productive research environments for faculty, students, government and industry. He also co-directs the Engine Systems Collaborative Research Laboratory with General Motors and heads the Multi-University Consortium on Homogeneous Charge Compression Ignition Engines.

In addition to his election to the NAE, Professor Assanis is a fellow of the Society of Automotive Engineers in recognition of his significant impact on society's mobility technology, and a fellow of the American Society of Mechanical Engineers for significant achievements and contributions to the engineering profession.

Three ME Faculty Win NSF CAREER Awards

Three assistant professors of Mechanical Engineering have earned National Science Foundation Faculty Early Career Development (CAREER) awards. CAREER awards are among the National Science Foundation's most prestigious. They support junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research.

Congratulations to Shorya Awtar, Pramod Sangi Reddy and Kathleen Sienko.

SHORYA AWTAR

PRAMOD SANGI REDDY

KATHLEEN SIENKO

SHORYA AWTAR:
Elastic Averaging: A Nature-inspired Methodology for Flexure Mechanism Design

Elastic averaging, a design paradigm enabled by distributed compliance, makes jointless structures inherently robust and high-performing despite local failure and defects—for example, the millions of setae on gecko feet, or the intricate web of a spider. Awtar plans to create a mathematical foundation for understanding and leveraging elastic averaging in the analysis and synthesis of parallel-kinematic flexure mechanisms.

Flexure mechanisms are "engineered" jointless structures that rely on elastic deformations to provide small but smooth and precise motions. Their lack of friction, wear and backlash makes them essential elements of machine design. In the design of flexure mechanisms, elastic averaging represents a radical shift from long-standing exact constraint design principles and opens up a new, so far unrecognized, design space. Awtar will leverage this research to create technological innovations in applications including nanopositioning systems, minimally invasive surgical tools and turbomachinery seals.

This CAREER award will also help Awtar establish research collaborations, recruit doctoral students and continue his outreach activities with the Ann Arbor Hands-On Museum. As part of his plan, Awtar will redesign undergraduate-level Design & Manufacturing II (ME350) and graduate-level Mechatronic Systems Design (ME552) to incorporate modern multidisciplinary machine design practice.

PRAMOD SANGI REDDY:
Heat and Charge Transport in Metal-Molecule-Metal Junctions

Reddy's project will explore the transport of heat and charge transport phenomena in nanometer-sized molecular junctions. He will work to develop an experimental technique to enable the study of novel phenomena that are expected to arise in nanometer-sized molecular junctions. Using his techniques, experiments will subsequently be conducted on a variety of single molecule and multiple molecule junctions to elucidate—for the first time—the relationship between the structure of molecular junctions and their thermal transport and thermoelectric properties.

Reddy's work will potentially impact the field of thermoelectric energy conversion; once the dependence of transport properties on the structure of the molecular junctions is understood, it will be possible to tune the heat and charge transport in these junctions to create inexpensive and efficient thermoelectric materials.

KATHLEEN SIENKO:
Improving Postural Balance and Rehabilitation Outcomes Using Vibrotactile Sensory Substitution

Sienko's project will focus on the evaluation and use of vibrotactile feedback to improve balance impairments among the elderly and those with vestibular deficits, peripheral neuropathy, traumatic brain injuries or history of stroke. The goals of her research are to design and build a sensory substitution platform to augment current balance rehabilitation best practices and to assess the capability of sensory substitution to improve stability. She also will evaluate the associated cognitive workload, effects on fall prevention and retention of balance improvements over time.

Sienko "hopes to ultimately develop an ergonomic, affordable and wearable sensory substitution prototype to enable balance-impaired individuals to perform activities of daily living with improved quality of life." Used in a rehabilitation setting, the device could impact the rate and extent of balance function recovery. Her project emphasizes end-user input during engineering design through collaborations with several medical centers and universities. She also will apply the co-creative design process to the design of low-cost medical technologies for resource-limited settings through education initiatives such as the Multidisciplinary Design minor: Global Health Design specialization she helped to create.

Meet New ME Faculty Members Don Siegel, Jianping Fu and Eric Johnsen

DON SIEGEL

JIANPING FU

ERIC JOHNSEN

Don Siegel has joined the Mechanical Engineering department as an assistant professor.

Siegel earned his bachelor's degree in mathematical physics from Case Western Reserve University and a PhD in physics from the University of Illinois at Urbana-Champaign. His research interests lie in the areas of energy storage and the mechanical properties of lightweight alloys.

Since 2005, Siegel has been a scientist for Ford Motor Company, where he led a team of professionals in the company's Fuel Cell and Hydrogen Storage Materials division. He said he's learned first-hand that the transportation sector is a microcosm for some of the most pressing issues facing the U.S. (energy independence)—and mankind (renewable energy, energy storage and greenhouse gas emissions).

"Technology will play a large role in surmounting these obstacles," he said. "In the ME department, I'll have the opportunity to expand my research into advanced technologies for energy storage and sustainable mobility."

Accepting a position at U-M was an easy decision. "The ME department at U-M is one of the best in the country," he said, "and there's no shortage of outstanding faculty to collaborate with."

Jianping Fu has joined the Mechanical Engineering department as an assistant professor.

Fu earned his bachelor's degree from the University of Science & Technology of China and a master's degree in mechanical and aerospace engineering from the University of California, Los Angeles. After earning his PhD in mechanical engineering from the Massachusetts Institute of Technology, Fu received a postdoctoral fellowship from the American Heart Association and conducted his postdoctoral training at the University of Pennsylvania.

Fu intends to build upon his biological engineering experience and continue conducting research into micro/nanofluidics and bioMEMS/NEMS, ultra-sensitive single molecule biosensors, micro/nanosystems for engineering synthetic *ex vivo* stem cell microenvironments, and mechanobiology and stem cell differentiation.

Fu says U-M's highly regarded ME department attracted him to his current position. "The Department has a very diverse research portfolio with faculty members working on many different fronts," he said. Additionally, he was drawn to the core facilities available, such as the Lurie Nanofabrication Facility. "The cleanroom microfabrication facility and the top-ranked Medical School will provide great opportunities for me to establish my research program."

Eric Johnsen will assume the position of assistant professor in January 2010.

Johnsen received his bachelor's degree in mechanical and environmental engineering from the University of California, Santa Barbara, and a PhD in mechanical engineering from the California Institute of Technology. There, he was awarded the Centennial Prize for best doctoral thesis in mechanical engineering. He then became a postdoctoral fellow at the Center for Turbulence Research at Stanford University.

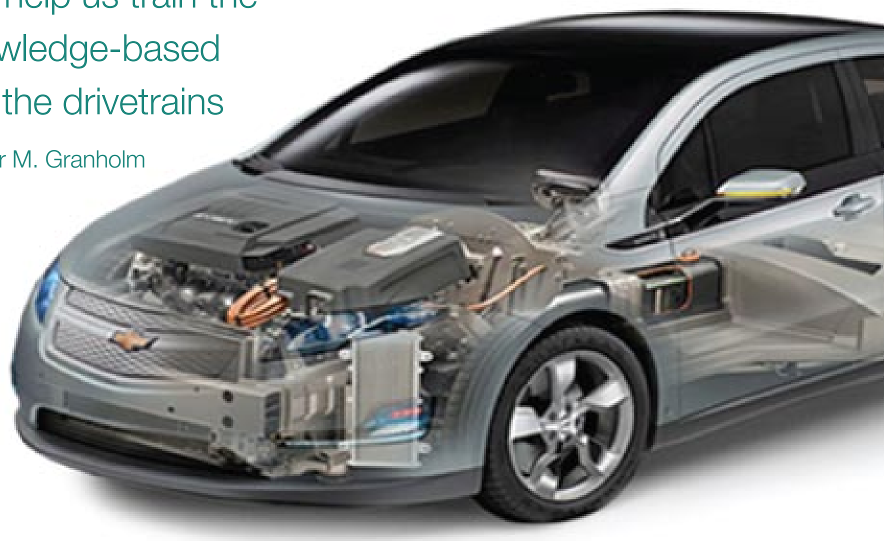
Johnsen's research centers on understanding fundamental problems in fluid mechanics such as bubble dynamics and multiphase flows. While pursuing his PhD at Caltech, he developed a numerical method for studying the role of bubble collapse in shock wave lithotripsy, used to treat kidney stones. His post-doctoral research at Stanford focused on turbulent mixing in shock-accelerated flows to better understand the physics of supernova explosions. At U-M, Johnsen plans to further investigate bubbles and droplets and their roles in phenomena ranging from erosion of propeller blades and steam turbines to drug delivery and exchange of CO_2 between the atmosphere and the ocean.

Johnsen was impressed with the academic excellence and the level of collegiality in the Department from his first visit. "Not only will I be able to pursue my own research interests, but there also are many excellent collaboration opportunities within the Department and in other disciplines."

NEW 2009–10 FACULTY SEARCHES

The U-M ME department seeks candidates for multiple full-time tenure-track faculty positions in 2009–10. To learn more, visit our website at: www.me.engin.umich.edu

"The partnership between the University of Michigan and General Motors will help us train the type of workers we need in a knowledge-based economy to successfully develop the drivetrains of the future." —Michigan Governor Jennifer M. Granholm



Advanced Battery Coalition for Drivetrains:

A GM/U-M CENTER AT THE UNIVERSITY OF MICHIGAN

REGIONAL PARTNERSHIP, GLOBAL IMPACT

When General Motors announced the Volt, a game-changing vehicle in clean, lithium-battery-powered propulsion, the company knew it would need knowledge workers and superior technology to execute its plans. At the time, U-M had just established a master's program in Energy Systems Engineering (ESE), dedicated to training workers in advanced technology at the grid-vehicle interface, led by faculty with expertise in key electrification technologies.

The synergy was evident, and today the joint GM/U-M Advanced Battery Coalition for Drivetrains (ABCD) and the ESE program involve the participation of over 70 professionals, 180 students, additional university partners, a national laboratory, the State of Michigan and several government leaders. Their common goal is to create an ecosystem in Michigan to support research, development and execution of electric drive technologies and the education of workers who will electrify the vehicle. Committed support of ABCD projects exceeds $10 million and includes funds from General Motors, the U.S. Department of Energy, the Michigan Economic Development Corporation (MEDC) and the GM Foundation.

Ann Marie Sastry, Arthur F. Thurnau Professor of Mechanical, Biomedical and Materials Science and Engineering, and Robert Kruse, GM's executive director of Hybrids, Electric Vehicles and Batteries, co-lead the ABCD. The center spans basic research, technology development and graduate education. The ESE master's program, which Sastry directs, is closely linked with the ABCD, giving students immediately relevant technology problems to solve.

L TO R: **Mr. Robert Kruse, Rep. John Dingell, Sen. Carl Levin and Prof. Ann Marie Sastry**

> "We are committed to ensuring the success of the GM/U-M ABCD and the ESE programs, and we consider both to be critical elements of our global advanced propulsion technology strategy." —GM Vice Chairman Thomas G. Stephen

CURRENT ABCD PROJECTS

- Comparisons of Battery Performance under U.S. Advanced Battery Consortium and Newly Developed Experimental Protocols, Specific to Plug-in Hybrid Electric Vehicle Profiles and Usage
- Advanced Cell Experimentation: Aging, Lifetime and Performance
- Model Validation: Aging Mechanisms and Lifetime
- Surrogate-Based Cell and Pack Design
- Advanced Controls Algorithms for Li-Ion Packs
- Microscale Modeling of Li-Ion Battery
- Modeling Electrochemistry and Transport Mechanisms in Model Electrodes
- Multi-Objective Optimization to Maximize Battery Life, Efficiency and Performance

A clear vision is making the ABCD successful from the start: "Our shared ambition is to see electrified drivetrains in a large number of vehicle types and applications," said Sastry. "That means we need to reduce the design cycle in both time and cost. Working with GM allows us to make an impact on a large scale, to create curricula that are immediately useful and to transfer our science to practice quickly and effectively."

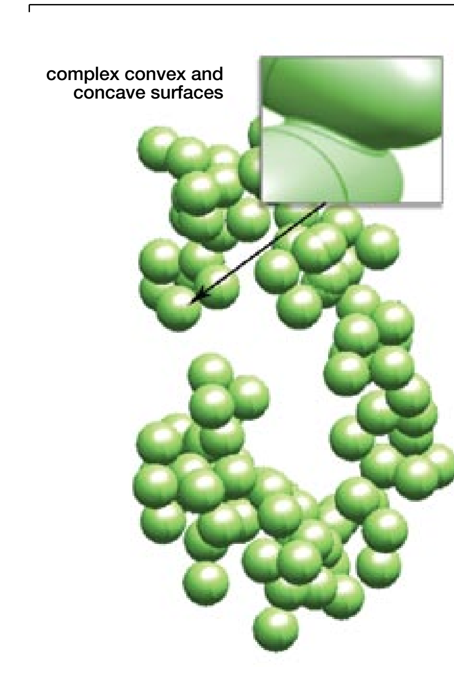
"From my perspective in Engineering, the combination of research, development, education and technology transfer with the GM/U-M ABCD gives us an enormous running start on our next-generation product goals, and is giving us the science-based engineering, and engineers, we need today," said Mark Reuss, vice president, Global Vehicle Engineering. Adds Kruse, "This partnership has created new ways of working together, and is resulting in outstanding new technology, and outstanding new and retrained workers for our company. Advanced battery technologies confer a competitive edge in the auto industry, and GM's relationship with U-M gives us a tremendous advantage."

TECHNOLOGY DEVELOPMENT

The ABCD will accelerate development of advanced batteries through experimentation and simulation to better understand and resolve issues related to battery life and performance. And to speed insertion of storage technologies into electric vehicles, the ABCD relies on such tools and technologies as advanced simulation, experimentation, optimization and battery control.

Key U-M faculty in the ABCD and ESE program include: Wei Shyy, chair of Aerospace Engineering; Wei Lu, associate professor of Mechanical Engineering; Anton van der Ven, assistant professor of Materials Science and Engineering; Christian Lastoskie, associate professor of Civil and Environmental and Biomedical Engineering and Margaret Wooldridge, Arthur F. Thurnau Professor of Mechanical and Aerospace Engineering. Greg Plett, associate professor of Electrical Engineering at the University of Colorado at Colorado Springs, is also a team member. The group's work spans optimization, materials analysis, atomistic and molecular simulation, energy infrastructures and chemical synthesis.

Integrated thermal, electrochemical and structural finite element simulations, informed by standardized battery experimentation, are an essential element in smoothing the transition to the battery's



ABOVE: **Dr. Myoungdo Chung prepares advanced battery materials for characterization and cycling.** RIGHT: **Fracture in particles in battery cell cathodes is being studied. The problem is challenging because of the complex architecture of the systems.**

emergence as a mass-marketed automotive component, Sastry explained. Improved packaging of batteries, incorporating cooling and service strategies will be enabled by these fundamental research efforts.

These technologies, collectively, support the supply chain for critical component development, which the MEDC has been working to build.

"We engaged with Dr. Sastry because of her expertise in modeling and design of advanced batteries," said MEDC Vice President of New Business Development Doug Parks. "By supporting the GM/U-M collaboration, we continue to further that objective, which is a key one for the State."

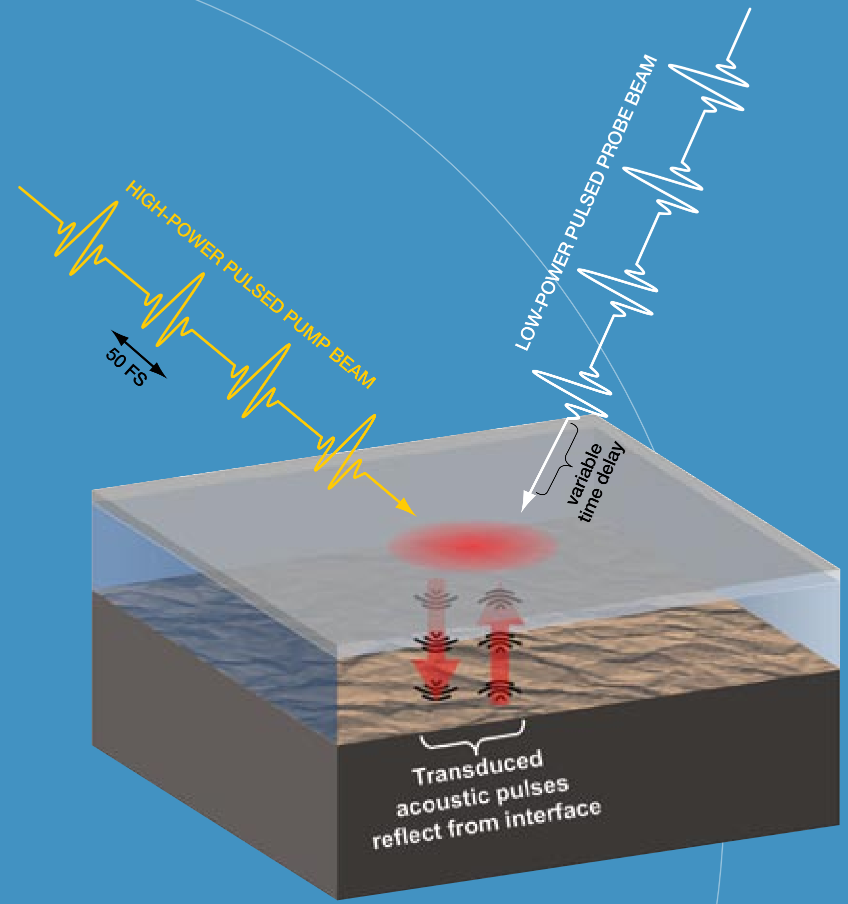
"We could not be prouder of what has been started here in Michigan and look forward to the dividends—highly trained engineers, good paying jobs and green technology," said Sen. Carl Levin, who joined with Rep. John Dingell to celebrate the launch of the effort in a campus event.

Jim Queen, GM's group vice president of Global Engineering and the initiator at GM of the collaboration, summarizes the effort and its impact: "Curricula, research programs and progress—these all are accelerating our shared vehicle electrification plans."

WORKFORCE: INTEGRATING EDUCATION AND RESEARCH

Transforming the drivetrain into an electrical system not only requires engineers specializing in automotive technologies but also engineers who will transform the grid and our energy infrastructure.

The multidisciplinary ESE master's program, launched in 2007, includes science, engineering and the development of policies that promote sustainable energy systems. The curriculum spans nuclear engineering, energy storage, hydrogen production and utilization, lighting and portable systems, complemented by economic modeling, lifecycle analysis and geological sciences. Over 150 students currently are enrolled, and it is one of the fastest-growing programs on campus. As a strategic partner, GM is making the degree program available online to employees. DTE Energy also is a key partner, with a growing intern program led by Professor Christian Lastoskie of Civil and Environmental Engineering.



Pipe's group is utilizing ultrafast laser techniques that can generate short vibrational pulses and detect how they are reflected or transmitted by an engineered interface.

Multidisciplinary University Research Initiative

EXPLORING HEAT TRANSFER AT INTERFACES

Controlling heat transfer between materials, whether for a jet engine, a computer or a nanoscale transistor, is a major challenge for engineers. A team led by Kevin Pipe, assistant professor in the Mechanical Engineering department, received a five-year, $6.8 million, Multidisciplinary University Research Initiative (MURI) award in 2008 from the Air Force Office of Scientific Research to explore the fundamental science underlying heat transfer at interfaces.

In addition to Pipe, the research group at U-M includes Materials Science and Engineering professors Rachel Goldman and John Kieffer and Assistant Professor Max Shtein, as well as Roberto Merlin, professor of Physics. Other members of the team include four physics and engineering faculty at Brown University, Stanford University and the University of California at Santa Cruz.

The U.S. Department of Defense MURI program is designed to focus on large, multidisciplinary topic areas that intersect several traditional disciplines, bringing together scientists and engineers with different backgrounds to accelerate both basic research and the transition to practical applications.

The MURI effort Pipe is leading is focused on basic science. "Our overall goal is to understand the fundamental properties that control heat transfer at interfaces," he said. "A number of technologies, such as thermoelectric generators, thermal interface materials and thermal barrier coatings, critically depend on the ability to engineer interfaces to either increase or limit heat flow."

According to Pipe, scientists don't yet fully understand how heat transfers from one material to another. It is well known, however, that there is usually a resistance to heat transfer at the interface where two different materials meet.

"On a microscopic scale," he explained, "the majority of heat in a solid is typically carried by either electrons or atomic vibrations. When these vibrations move through a material, they act as a propagating heat wave. When that heat wave hits an interface, some of it is transmitted and some of it is reflected. Much like a mirror reflects light, an interface can be designed to reflect heat."

Military electronics are one application in which interface heat transfer can limit performance. Made primarily from crystalline semiconductors such as silicon, which transport heat through vibrational waves, electronic devices can generate a large amount of heat and need to be cooled efficiently. This is often accomplished by mounting the semiconductor chip on a heat sink made from a high thermal conductivity material such as copper or diamond. However, heat is typically carried in the heat sink either by electrons or by vibrational waves at a different range of frequencies than in the semiconductor chip. The requirement that the vibrational waves in the chip must transfer energy to electrons or waves of a different frequency in the heat sink leads to a heat flow resistance at the interface. Pipe's team is researching ways to bridge this heat transfer mismatch at the interface in order to more efficiently remove heat from the chip.

Conversely, the military is also interested in thermoelectric generators as a method for converting waste heat energy into usable electricity. In this case the efficiency of energy conversion relies on materials with low thermal conductivity, which can be accomplished by engineering interfaces within a material that restricts the flow of heat.

To explore the effects of physical or chemical nanostructure at an interface on heat transfer, Pipe's group is utilizing ultrafast laser techniques (as shown in the figure) that can generate short vibrational pulses and detect how they are reflected or transmitted by an engineered interface. Furthermore, Pipe's team is utilizing a technique that combines ultrafast lasers with time-resolved X-ray diffraction. Developed by team member Professor David Reis, the technique allows researchers to directly watch the atomic vibrations that occur as heat is transferred across an interface. Pipe and his colleagues can thereby examine how heat flow is altered by the presence of precisely nanoengineered structures at the interface.

"Because interfaces are very thin and heat transfers across them very quickly," Pipe said, "it's important to have techniques that can offer high spatial resolution and high time resolution. Ultrafast lasers can easily generate pulses that are less than 100 femtoseconds long—that's 10^{-13} seconds, or about the amount of time it takes light to travel through a piece of Saran Wrap."

Ground Robotics Research Center Launches

The multidisciplinary, multi-university Ground Robotics Research Center (GRRC), directed by ME Professor A. Galip Ulsoy, had its official launch on August 11, 2008. United States Senator Carl Levin, chairman of the Senate Armed Services Committee, was among the guests who attended. "Robotics will play an increasingly critical role on the battlefield," Sen. Levin said. "In a world where the challenges are very, very different, we're going to rely more on robotics to meet those challenges."

The new GRRC, comprised of a consortium of Michigan universities, is primarily funded by the U.S. Army. Its overarching goal is to develop autonomous ground vehicles, mobile robots, robotics research expertise and related curricula at several universities in Michigan. In addition to U-M, other academic partners include Lawrence Technological University, Michigan State University, Michigan Technological University, Oakland University, University of Detroit Mercy, U-M Dearborn and Wayne State University.

"Our vision is to help establish southeastern Michigan as an international center of activity for these emerging technologies by supporting programs in research and education," said Ulsoy. "A robotics research center like this can bring together major partners from government, industry and academia in a way that individual uncoordinated activities cannot. By doing so, our center will be able to increase the impact and speed of delivering cutting-edge robotics technologies."

The U.S. Army's Tank-Automotive Research, Development and Engineering Center (TARDEC), located in Warren, Michigan, sponsors many GRRC research projects. Projects fall into one of five major thrust areas:

- Unmanned Ground Vehicle (UGV) architecture for intelligence, vision and man–machine interface
- UGV energy, power and propulsion
- UGV dynamics and navigation, including ground and vehicle interface
- UGV reliability and manufacturing
- UGV integration and demonstration testbeds

Twenty-one projects already are underway at participating universities (see p. 13). The GRRC's interdisciplinary research agenda calls for collaboration among numerous fields and disciplines, including: mechanical engineering, electrical engineering, computer science, aerospace and industrial engineering.

ABOVE: **U-M Mobile Robotics Lab researcher Adam Borrell demonstrating the OmniTread OT-4 at the recent GRRC kickoff workshop.** Photo credit: John M. Galloway

OPPOSITE PAGE: **The OT-4 is a serpentine robot designed to traverse extremely difficult terrain and can pass through small holes and climb over tall obstacles.**

The GRRC also works with private companies that design and manufacture autonomous vehicles, components and software, including ABB; John Deere; Ford Motor Company; Foster-Miller, Inc.; General Dynamics; General Motors; iRobot; Microsoft; Soar Technology and Toyota.

Making sure autonomous ground vehicles and mobile robots operate reliably covers a wide range of issues, explained Ulsoy. "And they all are critical because a battlefield is a very bad place for failure. How can they operate in an environment with people so it's safe to interact with these technologies? How do users handle failures that occur in the hardware and software components? How can they be reliably and efficiently produced or manufactured?" These are just some of the larger questions the GRRC is answering.

"There are robotics activities going on around the world. But from the point of view of a center that really focuses in on the reliable operation of autonomous ground vehicles, we believe the GRRC is unique."

Since the center's launch less than a year ago, it has focused on basic research problems. "As investigators' research results become available and as the research activity matures, it will lead to testbed demonstrations," Ulsoy said.

A pedestrian-tracking project, called the Personal Dead-Reckoning (PDR) system, is already under demonstration. The PDR system tracks and records or transmits the location of a walking person or robot relative to a known starting position. The PDR system works by using an inertial measuring unit (IMU) mounted on the user's boot.

"Our vision is to help establish southeastern Michigan as an international center of activity for emerging [ground robotics] technologies by supporting programs in research and education."

— GRRC Director A. Galip Ulsoy

Research Areas	Research Topic
UGV ARCHITECTURE FOR INTELLIGENCE, VISION AND MAN–MACHINE INTERFACE	• ADVANCED TACTICAL BEHAVIORS • ADJUSTABLE AUTONOMY FOR SAFE, COORDINATED CONTROL • AUTONOMOUS EXPLORATION OF NOVEL, HUMAN-OCCUPIED ENVIRONMENT • HETEROGENEOUS HUMAN/MACHINE INTERFACING FOR TELEOPERATION OF UGVs • SUPERMEDIA ENABLED HUMAN/MACHINE INTERFACING FOR TELEOPERATION OF UGVs • WARFIGHTER-FOCUSED UGV SYSTEM DESIGN: AUGMENTED REALITY-ENHANCED HUMAN ROBOT INTERACTION FOR UGV OPERATIONS
UGV ENERGY, POWER AND PROPULSION	• INTEGRATED POWER SYSTEM FOR IMPROVED MOBILITY AND MISSION OF GROUND ROBOTICS • POWER USE, INVENTORY AND LOGISTICAL EVALUATION • COMBUSTION OPTIMIZATION OF ENGINE-DRIVEN ROBOTS
UGV DYNAMICS AND NAVIGATION, INCLUDING GROUND AND VEHICLE INTERFACE	• SAFE OPERATIONS VIA UN-COOLED FAR-INFRARED IMAGE SENSORS • COOPERATIVE MULTI-UGV MAPPING AND NAVIGATION • HIGH-FIDELITY HAPTIC INTERFACE FOR TELEOPERATION • FRAMEWORK AND ARCHITECTURE FOR THE COORDINATION OF HUMAN AND ROBOT FORMATIONS • UWB TRACKING OF MULTIPLE UGVs
UGV RELIABILITY AND MANUFACTURING OF AUTONOMOUS VEHICLES	• RELIABILITY AND MANUFACTURING IN ROBOTICS • ANALYSIS OF EXISTING DATABASES FOR RELIABILITY ISSUES CONCERNING UGVs IN OPERATION • DEVELOPMENT OF ADVANCED MANUFACTURING TECHNIQUES FOR SMALL UGVs
UGV INTEGRATION AND DEMONSTRATION TESTBEDS	• PERSONAL DEAD-RECKONING (PDR) SYSTEM • UWB RADIO CHARACTERIZATION AND IMPLEMENTATION • SMART MICRO-SENSOR DEVELOPMENT AND INTEGRATION • WARFIGHTER-FOCUSED UGV SYSTEM DESIGN; HUMAN FACTORS ENGINEERING FOR ARMY TECHNOLOGY OBJECTIVE EXPERIMENTATION

ABOVE: **Professor Dawn Tilbury (L), Mr. Russ Miller (C) and Research Professor Johann Borenstein (R) controlling ground mobile robots at GRRC**

Innovative algorithms correct the drift of the accelerometers in the IMU with every step, which prevents the accumulation of errors. The PDR system requires no GPS or other beacon or reflector systems that must be preinstalled in the work environment, making it highly suitable for emergency responders or military personnel entering unprepared buildings. The PDR system does not require any training or matching to the user, and it works with different walking patterns. To date, when equipped with a high-grade IMU, the PDR system produces position errors of under two percent of the distance traveled for walks of up to 15 minutes.

"A system like PDR is a significant advancement over even GPS," said Ulsoy. "In environments like cities where GPS is not reliable or available, we can keep track of where people or vehicles are by using a means that doesn't rely on GPS. That's already one of the first outcomes from the GRRC so far, and I think it's only a small indication of the potential to be found within this huge multidisciplinary center."

For more information on the GRRC, visit http://grrc.engin.umich.edu.

NEW MASTER'S PROGRAM IN ROBOTICS AND AUTONOMOUS VEHICLES

In conjunction with the launch of the Ground Robotics Research Center, the College of Engineering established a new Master of Engineering in Robotics and Autonomous Vehicles. The first students have already enrolled, and active recruitment is underway to bring new faculty and students on board. ME Professor Huei Peng, who also directs Interdisciplinary Professional Programs, is heading up the degree program.

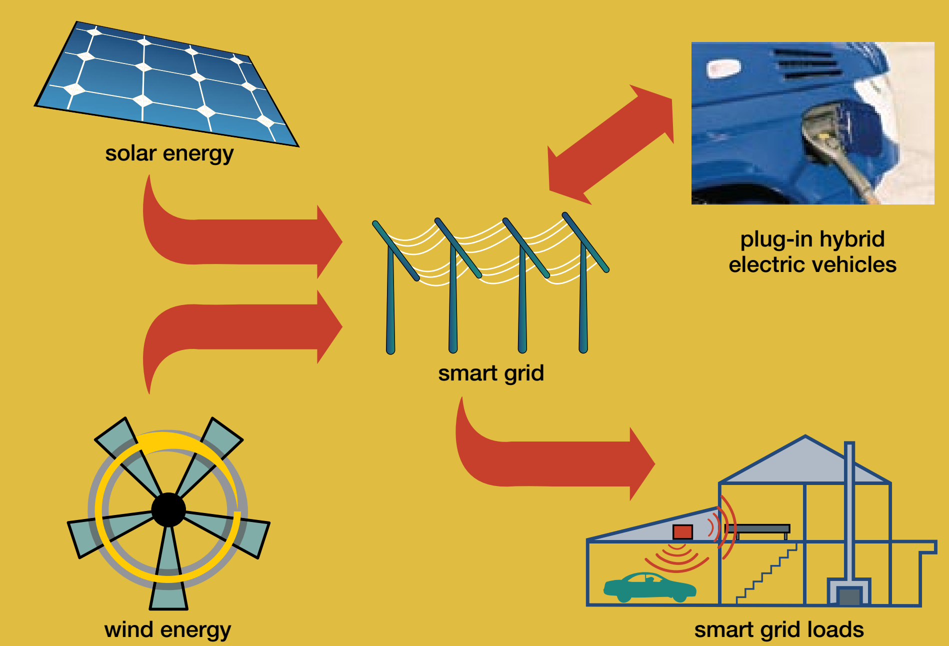
EDUCATIONAL EFFORTS AND OUTREACH

The GRRC spearheads and hosts a twice-monthly student seminar series. Video conference links to the other universities enable all researchers and students to stay informed about—and to contribute to—each others' work.

Another major event in the young life of the GRRC occurred on October 17 when an all-day research review meeting was held at the U.S. Army's TARDEC center. With more than 100 people in attendance from industry and the Army, U-M and other GRRC partner schools made technical presentations to unveil their research plans and projects.

NSF Emerging Frontiers in Research and Innovation

SUPPORTS INFRASTRUCTURE CONNECTIONS



The future of the country's power and transportation systems became clearer in 2008, when an interdisciplinary U-M team, led by ME Professor Jeff Stein, was awarded a $2 million, four-year grant from the National Science Foundation (NSF) Emerging Frontiers Research Initiative (EFRI) program. The team will focus on the development of tools for the resilient and sustainable design of technologies that couple infrastructures together.

The collaborative, multidisciplinary work will explore linkages between the transportation and electric power grid infrastructures via plug-in hybrid electric vehicles, or PHEVs. Investigators will also explore how the integrated modeling, design and control optimization of PHEVs and their operation on the grid influences the sustainability and resilience of the resulting integrated infrastructures.

Team members hail from departments and schools across the U-M campus. In addition to ME, faculty from the School of Natural Resources and Environment, U-M Transportation Research Institute, Naval Architecture and Marine Engineering department and the Michigan Memorial Phoenix Energy Institute also participate. A faculty member from the Department of Electrical Engineering at Missouri University of Science and Technology also has joined the team.

"The EFRI program is targeted toward multidisciplinary areas considered high risk and of prime concern to the nation," said Stein, the project's principal investigator. Through the EFRI's Resilient and Sustainable Infrastructures (RESIN) program, "We are exploring how to take two existing infrastructures that have been functioning relatively independently and use a modern technology to connect those two

Other than subways, electric trains and streetcars, the nation's power grid and transportation sector have remained essentially uncoupled since their creation. The PHEV changes that.

infrastructures," Stein added. "We're specifically looking at the PHEV as a connector between the transportation system and the electrical infrastructure of the country. How do you think about the design of this new technology so as to sustain and make resilient those newly linked infrastructures?"

Other than subways, electric trains and streetcars, the nation's power grid and transportation sector have remained essentially uncoupled since their creation. The private vehicles people use for transportation operate separately from the electrical grid. The PHEV changes that.

Over time the team will develop a set of tools that will support the design of multi-role intermediaries—that is, interface technologies that are not only sustainable and resilient themselves, but that also support the infrastructures that they link.

"We're trying to figure out what the basic algorithms are—the basic techniques in our respective fields that each of us understands in isolation—and see how we can combine them to work as a collection of tools to solve the problem of designing resilient, sustainable, coupled infrastructures," noted Stein. "How do you think about how you design, build and control a PHEV so that it is the best PHEV it can be by itself, but also that it makes the electrical grid and the transportation system as a whole more sustainable and resilient? We don't want to make existing infrastructures less sustainable by introducing this new technology."

Once these tools are developed, the team will publish results, present papers at conferences and incorporate lessons learned into specific graduate courses. The group

ABOVE: **EFRI researchers; from left to right: Rahul Ahlawat, Professor Jeffrey Stein, Dr. Hosam Fathy, Ben Pence, Joel Formank, Scott Moura, Dr. Tulga Ersal**

even has plans to develop software for a game about PHEVs, the electrical grid and transportation—similar to SimCity—as an outreach to primary and secondary school children.

Plug-in hybrid electric vehicles make for a rich subject of study compared to current gas/electric hybrid vehicles because of the ramifications of coupling two previously unconnected infrastructures. Issues related to renewable power sources (such as their intermittent power generation), electric power load leveling (the difference between peak and base loads), vehicle life cycle analysis and health of vehicle batteries are just a few of the complexities that must be addressed.

The team also is exploring an exciting possibility: the potential for an entirely new distributed energy grid. "When you plug a PHEV into the grid, you're 'filling up your tank,' storing the energy to be used at some future time," Stein explained. Currently, there is little storage capability in our electric grid; power companies have to continuously produce electricity to meet current demand. "If there were a million PHEVs, all of their battery packs mean you would have a lot of electricity stored in a million different places around the country. Of course, the logistics are daunting, but I believe with the NSF support, our work is going to make a significant difference in how we understand the complexities and opportunities involved in using PHEVs to couple these two critical infrastructures," said Stein.

New Frontiers in Manufacturing

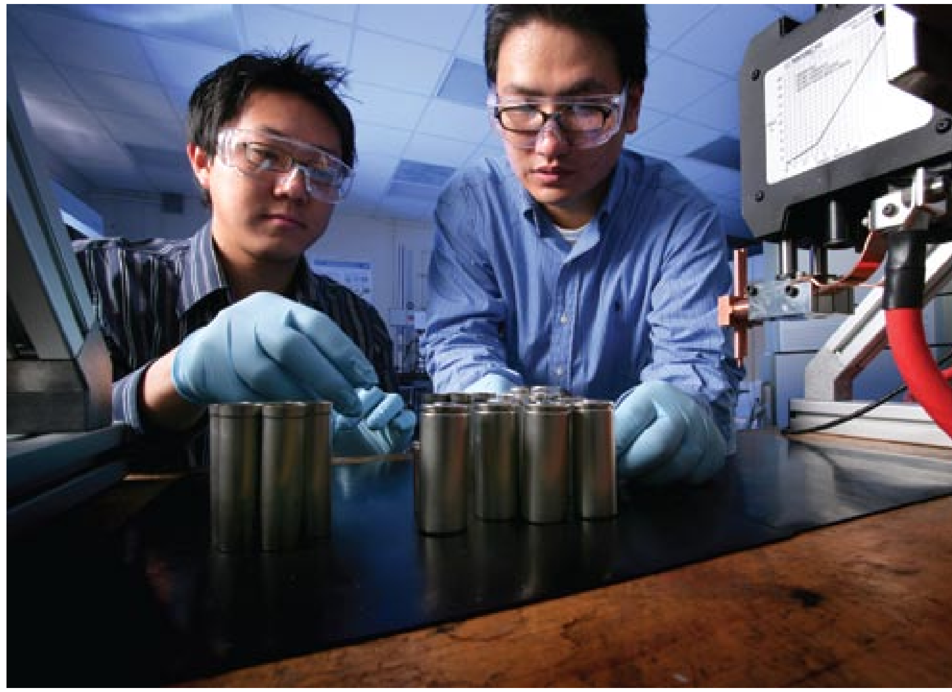
The recent international financial crisis has underscored the indispensable role of the manufacturing sector; "making things" is gaining traction again and is a tremendous source of both jobs and wealth.

The need for innovation and new approaches in manufacturing is more important than ever to help the United States maintain its competitive advantage. "We need to sustain manufacturing by creating new products and jobs," said Professor S. Jack Hu. "And we need to create the processes and systems that support these products quickly."

Several factors are driving a new generation of manufacturing and manufacturing research, explained Hu. The United States is seeking new ways to increase competitiveness, improve healthcare, reduce environmental impact and limit dependency on foreign resources. Aging populations of industrialized nations are demanding new healthcare solutions, including personalized solutions through individualized products and services. Clean energy products that reduce environmental impact require fundamentally different "green energy manufacturing," or GEM, techniques. In addition, nanoscience and biotechnology open the door to novel materials, processes and devices.

With so much change underfoot, new challenges and, of course, new opportunities arise.

Mechanical Engineering manufacturing faculty comprise an internationally recognized group. Three professors—Yoram Koren, Jyoti Mazumder and Jun Ni—have received the prestigious American Society of Mechanical Engineers (ASME) William T. Ennor Manufacturing Technology Award for significant contributions to forward-looking manufacturing technology and implementation for societal benefit (in 1999, 2006, 2009 respectively). In addition, Professor Elijah Kannatey-Asibu received the ASME Blackall Machine Tools and Gage Award. Professors Jack Hu, Jun Ni and Steven Skerlos each were selected the Society of Manufacturing Engineers' Outstanding Young Manufacturing Engineer. Assistant Professor John Hart won the ASME Pi Tau Sigma Gold Medal, and Professor Albert Shih was selected as a Fulbright Scholar.



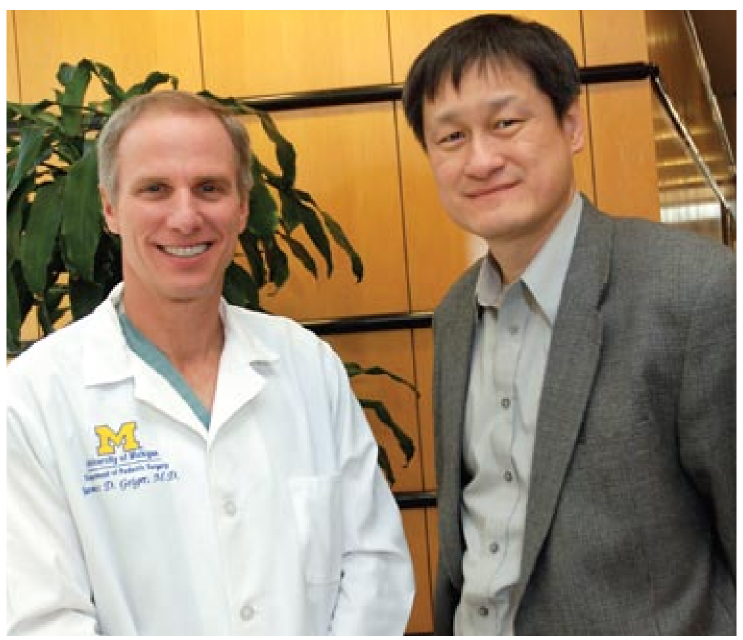
ABOVE: **Green energy manufacturing—graduate student Shawn Lee and Research Investigator Tae Kim in Professor Jack Hu's group conduct battery cell experiments.**

Faculty share a common perspective and vision: Manufacturing research drives economic growth by creating methodologies, machines, processes and systems that unite broad areas of fundamental science with large-scale commercial applications and personalized needs. In the next decade, manufacturing will be even more critical to society because it will enable innovations in key areas: personalized production; efficient, sustainable transportation; energy production and storage; healthcare for an aging society and biomedical devices.

PERSONALIZED PRODUCTION

With massive over-capacity in production and the proliferation of advanced communications, the next manufacturing paradigm for domestic markets is personalized production, driven by customer demand for products that meet their specific needs without the cost of a custom item. Personalized products will

In the next decade, manufacturing will be even more critical to society because it will enable innovations in key areas: personalized production; efficient, sustainable transportation; energy production and storage; healthcare for an aging society and biomedical devices.



ABOVE: **Manufacturing for healthcare—Professor Albert Shih (R) and Dr. James Geiger (pediatric surgeon) are co-founders of the U-M Medical Innovation Center.**

OPPOSITE PAGE LEFT: **Scanning electron microscope image of carbon nanotube (CNT) microstructures grown from a lithographically patterned catalyst, where there are more than 20 billion CNTs per square centimeter.**

OPPOSITE PAGE RIGHT: **Assistant Professor John Hart (R) and students Erik Polsen and Sei Jin Park observe growth of carbon nanotube microstructures using a chemical vapor deposition process developed in their laboratory.**

range from automotive interiors and kitchen islands to medical implants. Such customer-oriented production requires short delivery times in order to compete with inexpensive imports. Domestic personalized production has the potential to boost economic recovery in the United States.

BIOMEDICAL MANUFACTURING

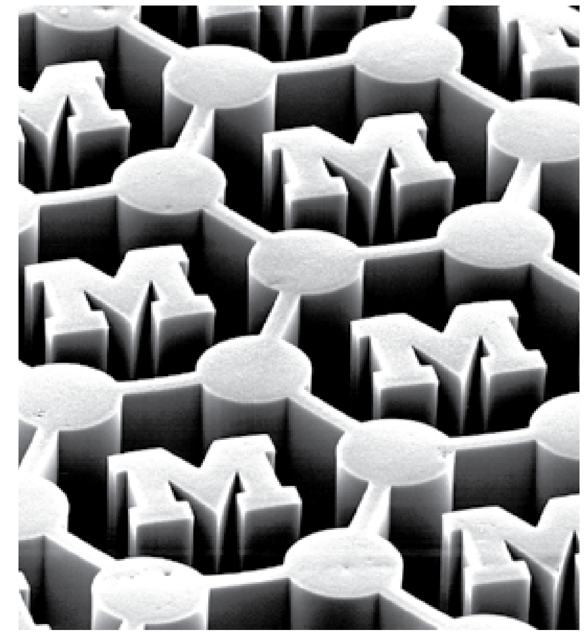
Healthcare is a large and growing segment of the U.S. economy and "represents a new frontier and great opportunity for manufacturing," according to Professor Albert Shih, who is leading numerous efforts to expand manufacturing in the healthcare field through "biomedical manufacturing." This refers to applying manufacturing technology to meet the grand challenges of healthcare: improving safety, quality, efficiency, speed and cost.

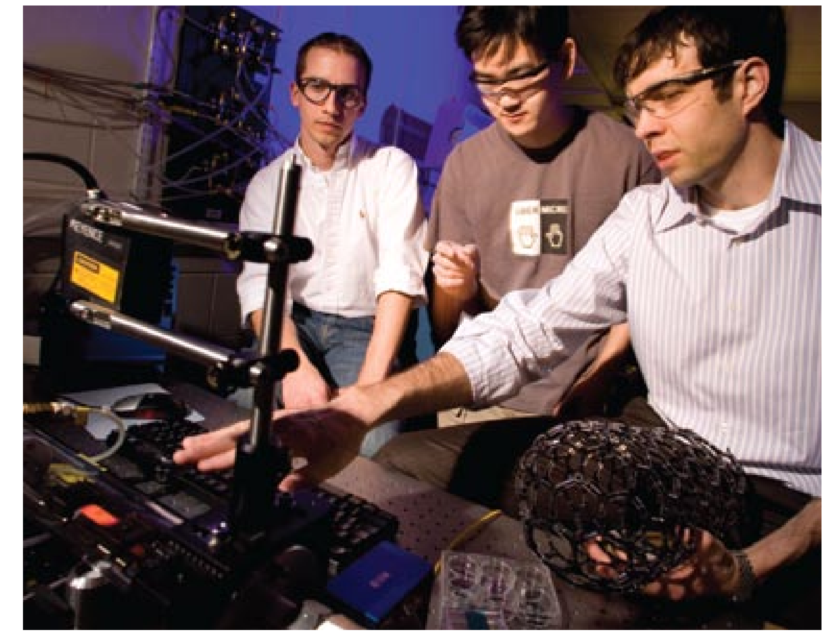
Toward these grand challenges, Shih has worked on several projects with faculty at U-M Medical School. For example, using expertise in machining, he has helped develop new needle biopsy systems for more effective and less invasive sampling of tissue during biopsies of the prostate, kidney and pancreas. He has also led a team to develop a surgical thermal management system to prevent thermal damage to collateral tissue, thereby reducing the serious and often permanent side effects from surgery. Shih works closely with faculty in the Medical School's Anesthesiology department to develop new alarm and patient monitoring and display systems to improve safety in the operating room.

Shih has co-founded the U-M Medical Innovation Center with long-time collaborator and pediatric surgeon James Geiger, MD, to broaden and accelerate the application of manufacturing technology to solve healthcare challenges that require multidisciplinary solutions.

GREEN ENERGY MANUFACTURING (GEM)

The manufacture of devices and systems for renewable energy production, storage and distribution—wind turbines and batteries, for instance—have the potential to improve energy diversity as well as the energy independence of the nation. Hu runs the Assembly and Manufacturing Systems Laboratory, which focuses on manufacturing processes and systems to achieve





efficiency, responsiveness and sustainability, including lower-energy manufacturing processes. In the past he developed comprehensive models for the assembly of proton exchange membrane fuel cells, a promising power source for automotive applications, including contact resistance, stack mechanical deformation and gas flow transfer on the performance of fuel cells.

Currently Hu is undertaking projects related to production systems for lithium-ion (Li-ion) batteries at both the individual cell and pack level. No volume production systems presently exist for automotive Li-ion batteries, and since automotive Li-ion battery cells are large and subjected to harsh environments, the quality and reliability requirements are significantly higher. Hu's research group develops in-line quality evaluation techniques for the assembly and joining of Li-ion cells and modules.

NANOSCALE MANUFACTURING

John Hart, who leads the Mechanosynthesis Group, is exploring important manufacturing questions at the nanoscale. His work focuses on the synthesis, properties and applications of nanostructures. These tiny structures will serve as building blocks for many technological advances that cut across industries.

"If you look back at many transformative technologies, success happens only when invention is combined with a manufacturing process that enables mass production," said Hart. "And, new materials have been the cornerstone of countless innovations."

Many of Hart's current projects center on carbon nanotubes—long molecular structures with exceptional properties, including mechanical stiffness and strength exceeding steel, high electrical and thermal conductivity and unique chemical and optical functionalities.

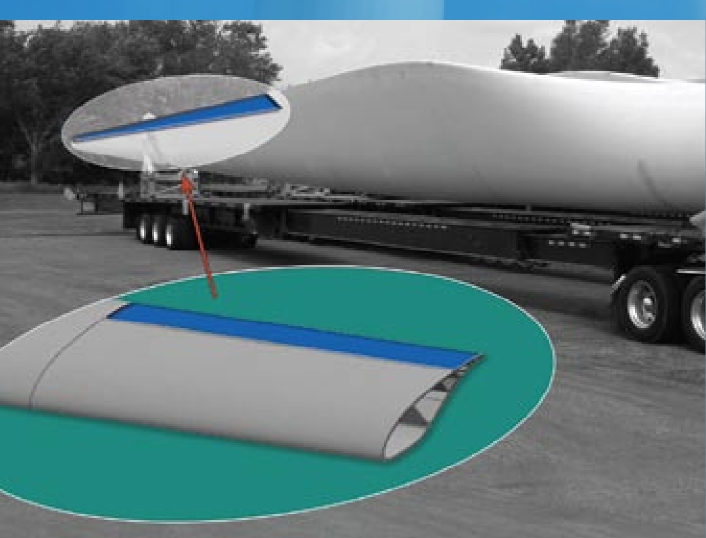
Not surprisingly, process control at the nanoscale is significantly different from traditional manufacturing. Machine design, controls and process optimization must all be applied at the atomic level. Characterization, too, is critical to quality control of the industrial process. With new processes and materials comes the need for standards, and Hart serves on the IEEE 1784 working group to define a standards roadmap for the use of nanomaterials in electronics.

Compliant Design for Wind Energy Harvesting:

FROM BASIC RESEARCH TO COMMERCIAL APPLICATION

Motivated by the need to produce microscale mechanisms without joints for MEMS applications, ME Professor Sridhar Kota has been investigating compliant mechanisms since the 1990s. He pioneered the concept, inspired by nature, of distributed compliance and, through the technology transfer process, is applying innovative basic research to aerospace and wind turbine applications.

"Designs in nature are compliant; they can adapt their geometry to perform optimally under different environmental conditions," said Kota. Manmade compliant designs confer many advantages: elimination of joints, reduced parts and assembly operations, and less friction, wear and need for lubrication while enabling customized performance through variable geometry and uniform distribution of strain energy.



Professor Kota's invention applied to adaptive trailing edge flap of wind turbine blades for more effective energy harvesting

"Resulting designs can undergo large deformations or shape changes while limiting local elastic strain to very low levels, which improves fatigue life," Kota said.

Distributed compliant design has many applications, including in the aerospace industry, where for decades researchers worldwide have been studying wing morphing, including variable camber and twist, to suit different flight conditions. But efforts have failed because the resulting designs are too heavy, cumbersome and consumed too much power due to use of rigid members and multiple actuators.

By exploiting the new paradigm of compliant design, Kota has developed a commercially viable solution: variable geometry control surfaces such as leading and trailing edges for aircraft and wind turbine applications. His spin-off firm, FlexSys, has produced lightweight, seamless adaptive control surface airfoils, which have demonstrated significant drag reduction and fuel savings and potential noise reduction and enhanced maneuverability of long-range military and commercial fixed wing aircraft.

Like aircraft, wind turbines operate under turbulent and unpredictable environmental conditions. During high winds and sudden gusts, loads on utility scale turbine blades—typically 100 to 150 feet in length—vary over time intervals that are much shorter than response times of variable speed rotors or active blade pitch mechanisms. Loads also vary over different sections of blades at any given time. Research has shown that these stochastic loads can be reduced with fast-response, active aerodynamic load-control devices, such as trailing edge flaps. Kota's seamless trailing edge flaps represent an ideal solution since they are significantly less vulnerable to rain, ice and debris exposure and generate less noise than conventional flaps or tabs.

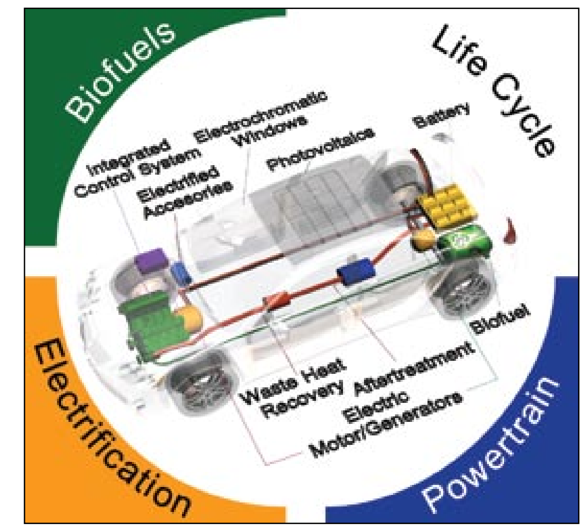
Kota's invention continuously senses incoming wind and adjusts the trailing edge camber to alter the blade's lift and drag characteristics. This minimizes the blade tip deflection, drastically reducing fatigue load on the blades and infrastructure, allowing for greater energy capture with longer blades. Sandia National Laboratory recently completed extensive analysis and simulations of the Adaptive Edge technology and found that the benefits are transformational, offering a 10 percent to 15 percent increase in energy capture as well as 75 percent reductions in blade fatigue damage compared to current technology. The results were presented at the 2009 American Wind Energy Association annual conference.

Kota is now helping lead a College-wide initiative dedicated to wind energy. The new Center for Wind Energy coalesced in early 2009 and includes more than a dozen faculty members from several departments.

"There's an excellent match between the technology challenges of offshore wind energy systems and the expertise of the faculty associated with the Center," said Kota. In addition, several studies have shown that the Great Lakes region has enormous potential for offshore wind energy production.

In addition to wind power generation research, the College is establishing a master's degree program in wind energy to educate next-generation engineers in this sector.

The Road to Carbon Neutral Vehicles



High pressure lean burn (HPLB) combustion has the potential to dramatically improve the fuel economy of internal combustion gasoline engines, but it's not without obstacles. Achieving breakthrough efficiencies in an engine system presents a "very challenging objective" to meet, according to Dennis Assanis, the Jon R. and Beverly S. Holt Professor of Mechanical Engineering and the principal investigator of a new three-year, $3 million grant from the U.S. Department of Energy (DOE).

"There has been interest in lean burn engines since the 1970s," said Assanis, "but we have a much better chance of revolutionizing the auto industry now because of better tools and diagnostics, better ignition and injection systems. Such enabling technologies as advanced turbochargers, multiple pulse fuel injectors and inexpensive pressure transducers for active combustion control open up new opportunities to push beyond current constraints."

The goal of the project, which is being carried out by a consortium that also includes researchers from the Massachusetts Institute of Technology and the University of California at Berkeley, is to enhance the physical understanding and expand the experimental knowledge base in order to develop and validate predictive modeling tools. These tools will help overcome the obstacles and shorten the path to commercialization of HPLB operation in engine systems.

The team's technical approach will focus on light duty automotive engine applications using gasoline and gasoline-alcohol blends as fuels. The research agenda addresses several areas: thermodynamics of engines and engine cycles operating in advanced combustion modes, fuel and thermal stratification and its interaction with fuel properties and heat transfer, advanced multi-mode ignition and combustion and novel fuel opportunities for improved efficiencies with low emissions.

"We have an ambitious research agenda, but we're well poised to tackle it," said Assanis. "This project builds on our successful experience with earlier DOE-sponsored work with the Homogeneous Charge Compression Ignition/Low Temperature Combustion university consortium. We're fortunate to have the benefit of well-established relationships with colleagues at MIT and UC Berkeley as well as national laboratories and industry partners." The team also will benefit from existing experimental test set-ups, including "hardware-in-the-loop" engine simulation.

High Pressure Lean Burn engines can offer diesel-like efficiencies, with less cost and complexity in after-treatment needs. If commercialized, these engines can reduce petroleum use and CO_2, NOx and particulate mass emissions. Successful development of HPLB engines also has the potential to offer added opportunities for the nation's manufacturing workforce.

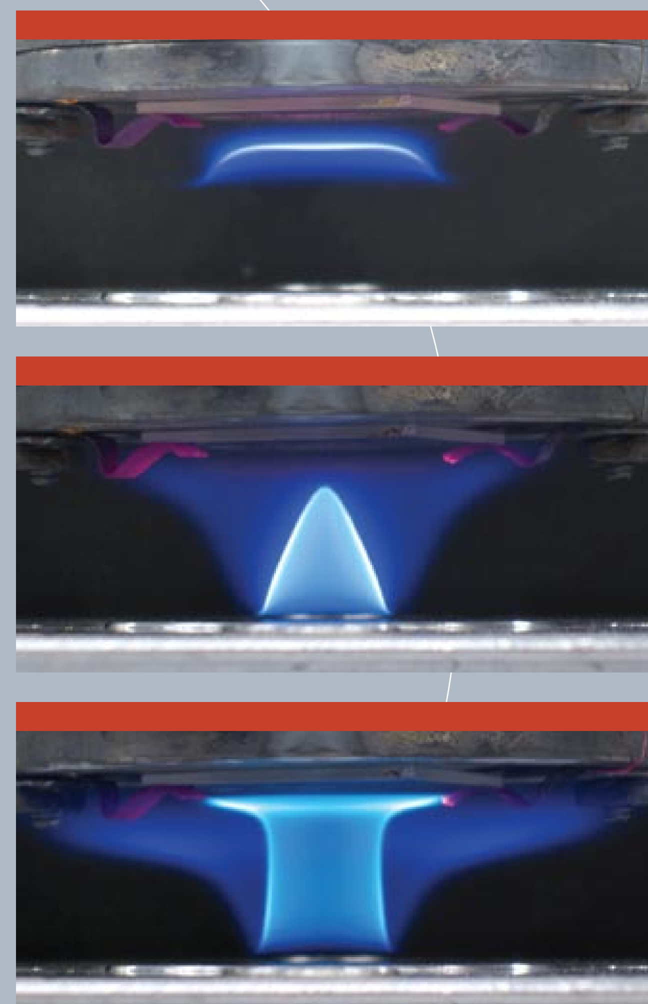
While the 20 to 40 percent gains in efficiency of HPLB engines represents "a giant step in the right direction," said Assanis, "we still need to do four or five times better in terms of moving the transportation sector toward sustainability. How do we get from here to there? That's really the holy grail," he added.

The current DOE project lays a strong foundation for expanding that vision to encompass a carbon neutral vehicle (CNV). To make that a reality, further work will be needed to incorporate blends of renewable biofuels and low carbon electricity, integrated with highly efficient propulsion technologies that leverage advanced materials and components to convert, harvest and store energy.

According to Assanis, "this will require an overarching life cycle design and optimization framework to guide technology integration in order to achieve highly efficient designs and operating systems. The current HPLB work, supported by the DOE, will accelerate our progress towards the carbon neutral vehicle goal."

Assanis was recently elected to the National Academy of Engineering for his "scientific contributions to improving fuel economy and reducing emissions of internal combustion engines, and for promoting automotive engineering education" (see story on page 4). He directs the Walter E. Lay Automotive Laboratory and the Automotive Research Center and co-directs the General Motors Engine Systems Research Collaborative Research Laboratory, which recently received renewed funding for the next five years.

Wooldridge and her group are studying the fundamental chemistry of catalysts to identify catalysts that work effectively under harsher, more demanding conditions.



Developing Novel Catalysts

For the Combustion and Environmental Research Laboratory group in the Department of Mechanical Engineering, 2008 was a highly productive year, exploring fuel chemistry and sustainable biofuels, advancing high efficiency engine strategies, developing novel sensors and exploring the fundamentals of heterogeneous combustion systems.

"We have made quite a bit of progress in understanding combustion of esters, the oxygenated compounds that comprise biodiesels," said Professor Margaret Wooldridge, who heads the Combustion and Environmental Research Laboratory. "Biodiesels consist of a broad spectrum of esters that differ based on the feed stock materials used to make the fuels. These oxygenated compounds behave differently in engines and combustors than their hydrocarbon petroleum-based counterparts. We've been quantifying those effects and working toward understanding how to successfully implement these potentially sustainable fuels into the transportation and power infrastructure. We also want to understand what the potential penalties might be from using biofuels."

Some key questions in particular need to be answered: How should the composition of biofuels be regulated? Should biofuels be blended with hydrocarbon fuels to maximize utility and penetration to market, and what should be the basis for blending biofuels? What emissions benefits can be expected, and what additional challenges may be created? "Reducing particulate emissions through the use of biofuels is well documented," Wooldridge noted, "but the possible increase in aldehyde emissions must be evaluated, as well as the impact on exhaust-gas treatment strategies for CO, unburned hydrocarbons and NOx."

Wooldridge's research group has also made significant contributions related to catalytic combustion in the past year. "We have examined both the traditional and non-traditional roles of catalysts on combustion systems." Most people are familiar with catalysts that are used in cars to remove toxic pollutants. However, catalysts can enable extracting power from fuels as well. "One important aspect of our research is our ability to compare a diverse array of combustion catalysts on an even playing field. From the results, we can identify new approaches and materials for both current and novel applications."

James Wiswall, about to finish his PhD, is leading the catalyst research in Wooldridge's laboratory. "Our results show how both traditional and novel catalyst materials can be used to mitigate exhaust gas pollutants and how they can be coupled with advanced combustion technologies to increase efficiency," Wiswall explained. "For example, nitric oxide production from a jet engine can be significantly reduced by low temperature combustion stabilized by catalytic partial-decomposition of the fuel. We have quantified the chemical activity of catalyst materials at low temperatures and over a range of reference fuels, which can also be applied to the design of future automotive catalysts."

In an attempt to address these issues, Wooldridge and her group are studying the fundamental chemistry of catalysts to determine how they can be applied to more targeted applications and to identify catalysts that work effectively under harsher, more demanding conditions. They started with materials such as platinum and are now expanding their efforts to materials such as tin dioxide and tin dioxide doped with metal additives. Such methods can yield catalysts with high chemical activity at low temperatures while reducing or eliminating the need for precious metals.

In the coming year, the Combustion and Environmental Laboratory group is expanding its fuels studies to aviation fuels, including the effects of sustainable and biorenewable fuels on the air transportation system. The group is also enhancing its facilities and capabilities to conduct research on longer-chain hydrocarbons and esters, which are more representative of real fuels.

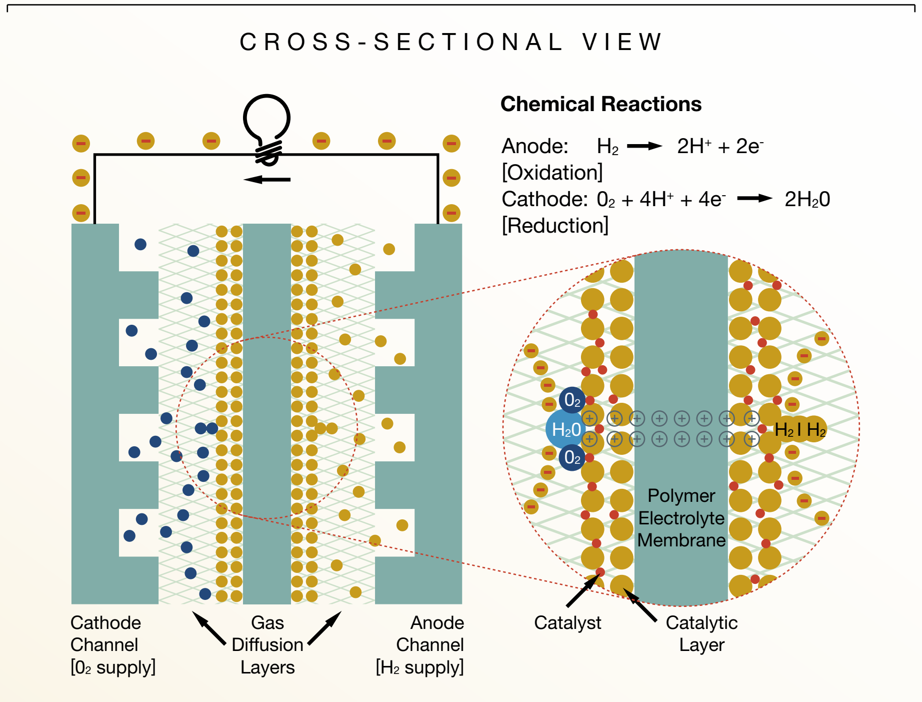
OPPOSITE PAGE:
Images of catalytically assisted combustion Photo credit James Wiswall

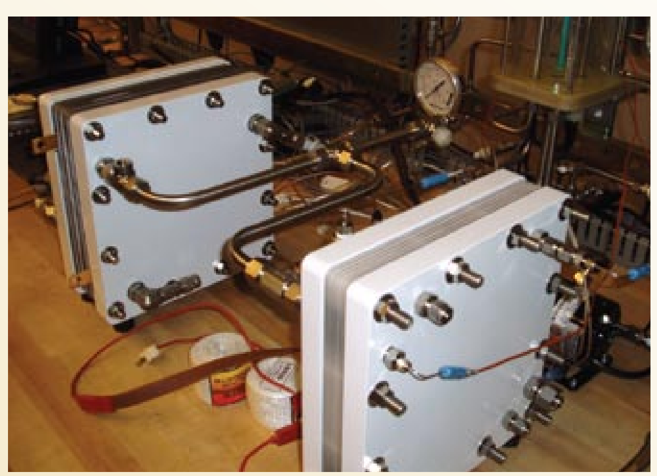
Fuel Cell Control Laboratory

Fuel cells combine hydrogen and oxygen to produce electricity with high efficiency. Without combustion, the electrochemical process is clean and efficient. The main by-product of the reaction is water, a seemingly innocuous emission—but not for the Fuel Cell Control Laboratory (FCCL), headed by ME Professor Anna Stefanopoulou, who is working diligently to understand and control the water dynamics.

Water is responsible for two degradation mechanisms in the fuel cell membrane electrode assembly. First, electrode carbon corrosion and platinum loss are associated with hydrogen starvation during start-up and shut-down, or during water flooding or nitrogen blanketing in the anode. Second, membrane failures are associated with cyclic swelling caused by variations in water accumulated in the fuel cell. Both degradation mechanisms occur during large spatiotemporal variations in the volume of water inside the fuel cell as shown in the neutron imaging of the water accumulation inside a fuel cell before and after a hydrogen purge. Water flooding also causes large cell-to-cell variability. Water can form stationary, cyclostationary or erratic patterns inside proton exchange membrane (PEM) fuel cells, making it hard to statistically assess or physically model the impact on degradation.

The FCCL's experiments explore the natural and statistically repeatable flooding patterns arising during dead-ended anode operation. The objective is to predict non-equilibrium conditions during fuel cell start-up and shut-down, which are believed to be critical for durability. Dead-ended-anode operation of PEM fuel cells can achieve high hydrogen utilization and self-humidification with low component complexity,





which yields a promising configuration for mobile and portable power systems.

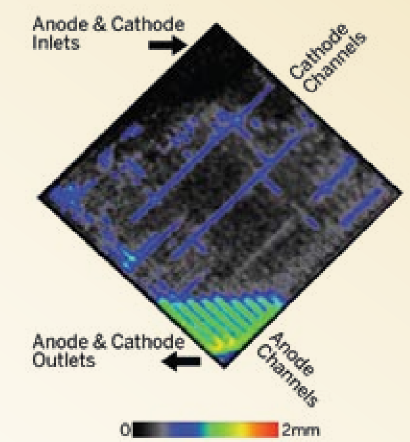
"Water is one of the main reasons that fuel cells are not yet competitive with power generation from internal combustion engines," Stefanopoulou said.

With the support of National Science Foundation funding, the FCCL uses control techniques and experimental methodologies coupled with industrial and international collaboration to improve fuel cell systems. Industrial collaborators include United Technologies, Bosch and Ford Motor Company; international collaborators include Sabanci University of Istanbul, Turkey, and the Swiss Federal Institute of Technology (ETH), Zurich, Switzerland. Stefanopoulou and collaborators use neutron imaging of the liquid water accumulation in the fuel cell and mass spectroscopy measurements of the gas concentration in several locations along fuel cell channels in combination with *ex-situ* post-mortem micro-structural evaluation of the catalyst and membrane degradation to verify the spatiotemporal patterns and their impact on degradation and catastrophic fuel cell failures.

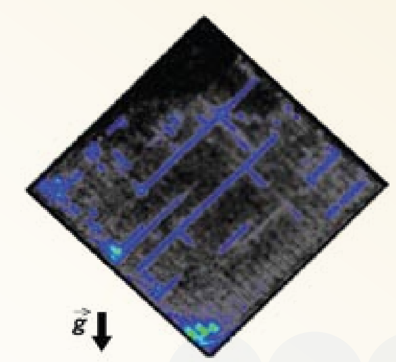
Stefanopoulou's PhD students have developed a broad array of algorithms for fuel cell hybrid electric vehicles. Ardalan Vahidi, now an assistant professor at Clemson University, developed control algorithms for safely managing the load drawn from the fuel cell. Kyung-Won Suh, now fuel cell group leader at Hyundai, addressed fuel cells' parasitic loads for autonomous start-up. Amey Karnik, now at Ford Motor Company, addressed the control and pressure balancing to prevent membrane rapture. Jay Pukrushpan, now at Kasetsart University in Bangkok, Thailand, developed an automatic controller for fast hydrogen generation from natural gas. Denise McKay, now an assistant professor at Smith College, designed highly efficient humidification systems for fuel cells. Buz McCain, now manager of technology transfer at Ballard Power Systems, defined stability and minimal realizations for water management.

Stefanopoulou also hosted many visitors in her laboratory, including: Ari Ingimundarson from Iceland's ENEX, who worked on detection of hydrogen leaks in fuel cells; Eric Muller from ETH Zurich, who worked on controlling fuel cell thermal dynamics and deriving algorithms for accelerated but safe warm-up and Ole Sundstreom, from Chalmers, Sweden, who worked on sizing hybrid fuel cell vehicles.

BEFORE ANODE PURGE



AFTER ANODE PURGE



OPPOSITE PAGE TOP: **Diagram depicting fuel cell electricity generation** (from B. McCain's PhD thesis)

LEFT: **Professor Anna Stefanopoulou (R) with students**

ABOVE: **The temporal variability in the voltage measurements from a 24-cell stack**

Unraveling Vortex Cavitation

> "The flow around the tip of a lifting surface is very complex, and we are studying how mass injection can alter the flow and resulting cavitation inception."
>
> —ME Professor Steve Ceccio

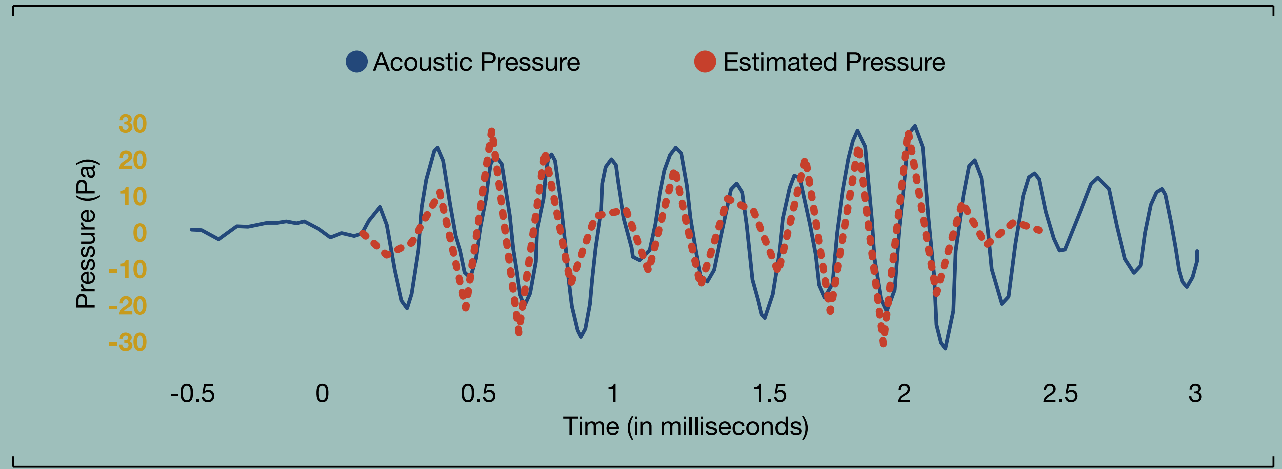
For more than 20 years, ME Professor Steve Ceccio has studied cavitating flows. Both the positive and negative effects of cavitation—the formation and collapse of vapor bubbles in a liquid in response to a drop in pressure—have important implications for a variety of applications and processes. The motivation for Ceccio's interest in hydrodynamic cavitation, he explained, is to solve related problems affecting turbo machinery, propulsion and the lifting surfaces of underwater vehicles. Cavitation is a particularly important problem for the U.S. Navy because cavitation can generate the earliest detectable noise from a ship's propulsion system. Hence, support for this work has come from the Office of Naval Research.

Most recently Ceccio and researchers in the Cavitation and Multiphase Flow Laboratory have been investigating vortex cavitation, a phenomenon in which small bubbles will explosively grow in the low-pressure core of a liquid vortex. Postdoctoral Research Fellow Natasha Chang works closely with Ceccio and has been exploring noise produced by bubbles that form, oscillate and collapse in the core of single and multiple interacting vortices.

"The interaction of vortices in the wake of a lifting surface is an interesting topic in itself, and the formation of elongated vortex cavitation bubbles adds a new dimension," said Ceccio. "For example, the interaction of a single cavitation bubble with the surrounding vortical flow can produce an audible 'squeak' or 'chirp,' which is very distinctive of the flow that created it," as discussed in work recently published in *The Journal of Fluid Mechanics.*

In other work published in the *Journal of the Acoustical Society of America*, Chang worked with ME Professor David Dowling to develop an acoustic array system for using multiple transducers to detect and localize cavitation in a volume. Acoustic detection and localization have advantages over optical methods when the flow location or configuration would obscure direct optical detection. And, in many instances, vortex cavitation bubbles can be heard well before they can be easily seen.

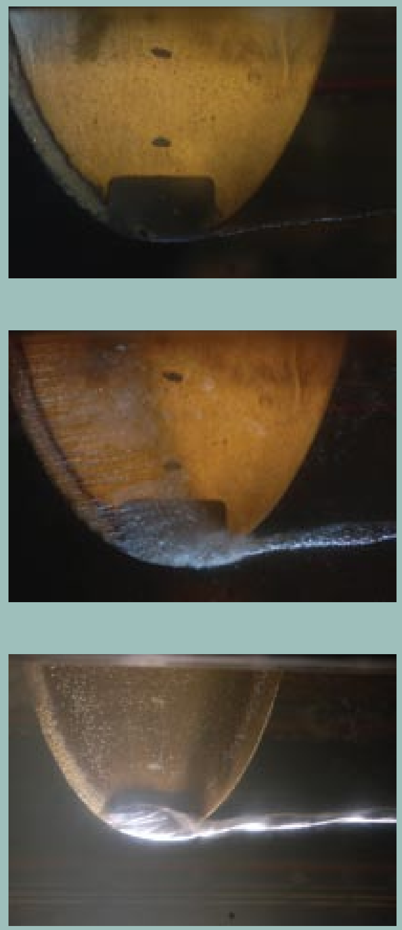
Chang made recordings of cavitation activity using 16 hydrophones mounted to the periphery of a water tunnel and then used the recordings to detect and localize the cavitation bubbles in three dimensions.



Tunnel reverberation, background noise and unknown pulse emission times present significant challenges, but the research team was able to devise a signal processing scheme to overcome these issues with a straight-ray acoustic propagation model and Monte Carlo techniques for compensating ray path, sound speed and hydrophone location uncertainties. The technique was developed and validated while studying the cavitation inception of two counter-rotating vortex pairs.

Ceccio's group is now looking at novel ways to actively suppress foil-tip vortex cavitation through the injection of water or a polymer solution at the foil tip. "The flow around the tip of a lifting surface is very complex, and we are studying how mass injection can alter the flow and resulting cavitation inception," he said. Chang has been working with two graduate students, Ryo Yakushiji and Harish Ganesh, who have shown suppression with injection of water and polymer solutions of varying viscoelasticity.

In August 2009, the U-M campus hosted the 7th International Symposium on Cavitation. The meeting, CAV2009, brought together some 150 researchers interested in cavitation from around the world and across numerous disciplines, including hydrodynamics, manufacturing, medicine and automotive engineering. Ceccio served as meeting host and co-chair; Chang and several ME faculty served on the program committee. "Our work is only part of the cavitation research going on at U-M, and my colleagues and I are excited to bring this community to Ann Arbor," Ceccio said.



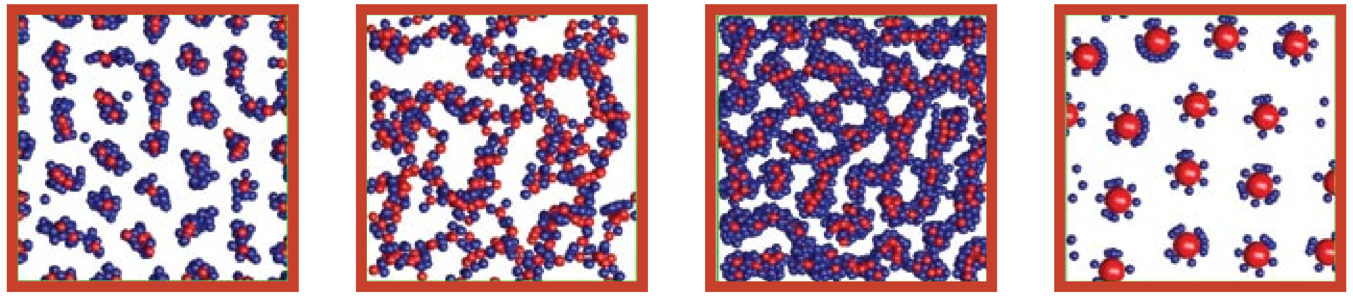
OPPOSITE PAGE: **The merger of two co-rotating cavitating vortices**

TOP: **Estimated and measured tonal emission of a vortex cavitation bubble**

SERIES AT RIGHT: **Developing cavitation on a hydrofoil**

Nano Mechanics:

UNDERSTANDING THE SELF-ASSEMBLY OF NANOSTRUCTURES



By using high-resolution imaging techniques—scanning tunneling microscopy and atomic force microscopy, for instance—investigators have discovered various exciting nanoscopic phenomena. A particularly intriguing observation is the self-assembly of atoms into ordered structures. What drives nanostructures to self-assemble? How do they organize into diverse patterns? These questions have been unclear to scientists.

Associate Professor Wei Lu and his Nanostructures Laboratory have developed advanced simulation and computational tools along with a thermodynamic framework to study the behavior and patterning of nanostructures on solid surfaces. Recent accomplishments include revealing the refining effect of surface stress; developing guided self-assembly with surface chemistry and strain fields and establishing the scientific basis of patterning nanostructures via molecular dipoles and double layer charges. This work has many possible applications, including microelectronics circuits, advanced coatings, solar cells, batteries and low-cost fabrication of large-area devices.

In work published in *Applied Physics Letters* in 2008, Lu investigated the morphology control of binary nanoparticles with an electric field. His work revealed rich patterns as well as how superlattice structures—from functionally gradient columns to chain networks—form. The results suggest it's possible to control and guide the assembly of binary nanoparticles into new materials.

"We are very excited," Lu said. "It's promoting new thoughts in this arena. The study reveals essential features of structures formed by binary nanoparticle systems under an electric field. Assembling different nanoparticles systematically into ordered binary superlattices can lead to more complex materials from which multifunctionalities may emerge."

Lu's group has also honed advanced simulation techniques for complex materials systems, which address challenges of decreasing length scale, material innovation and structure integration. The team recently proposed a hybrid level-set approach that includes an extraction/insertion algorithm. This allows accurate characterization of complicated interface motion, such as coalescence and separation, and many nanoscale behaviors. The work was published in the *Journal of Scientific Computing*, and Lu has given several related invited talks and presentations.

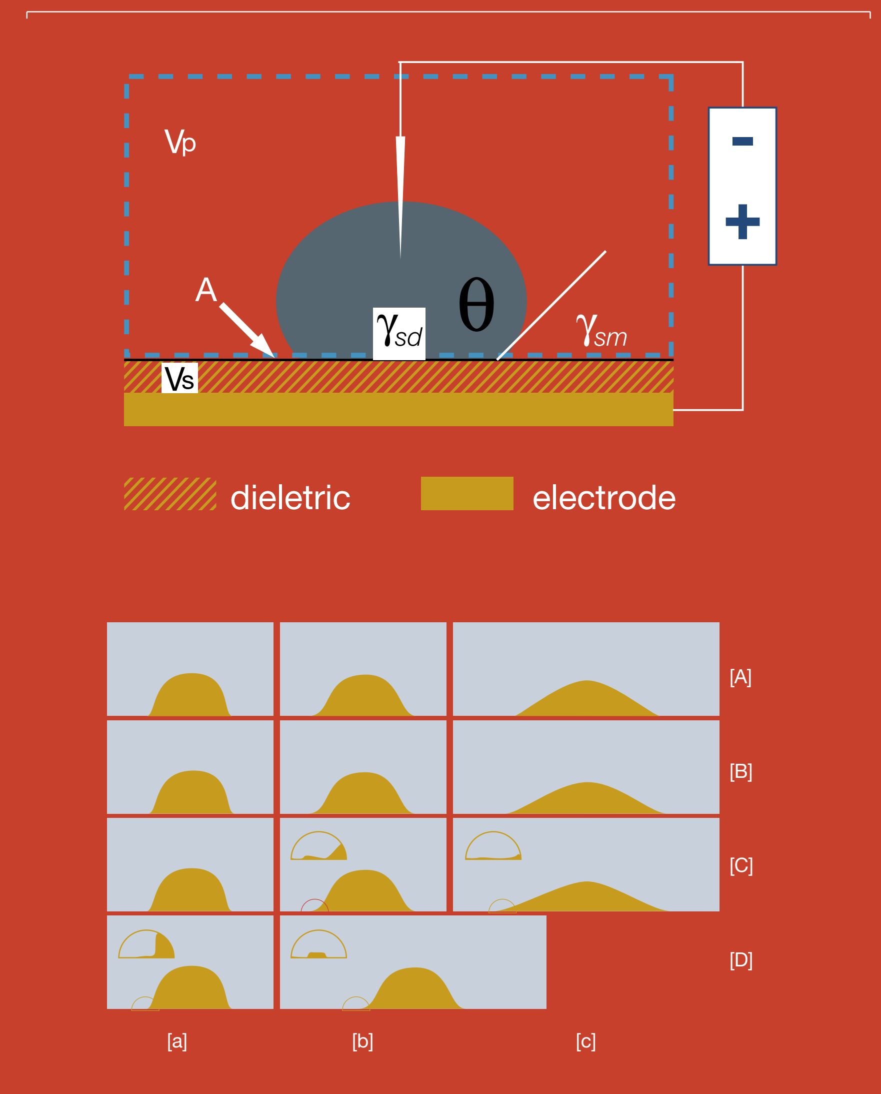
Working with metallic quantum dots and molecular patterns, which have wide applications in optical, electronic and energy conversion devices such as solar cells, Lu has established the scientific basis of patterning nanostructures through molecular dipoles and double layer charges. His group's important contributions include:

- A theory to account for the interaction of molecular dipoles in multi-layers, integrating the dielectric property of the substrate, buried layers and embedded electrodes
- Simulations that reveal self-assembly dynamics and behavior
- The ability to tune the size and ordering of molecular domains, allowing patterning molecules into designed two- and three-dimensional hierarchal nanostructures

"Our study suggests exciting possibilities for engineering nanoscale features," Lu said. "The work has led to a novel concept of nano-lubrication, where mobile molecular lubricants are directed to the contact surfaces by exploiting the interaction of molecular dipoles with external electric field to form optimized configurations.

TOP: **Associate Professor Lu proposed morphology control of binary nanoparticles in an electric field.**

OPPOSITE PAGE: **The wetting angle of a liquid droplet on a dielectric substrate can be tuned by an applied electric field.**

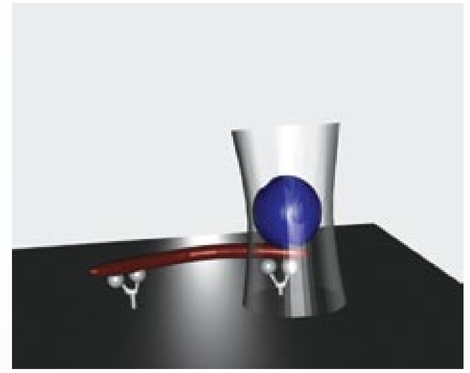


NANO/MICRO STRUCTURE EVOLUTION (ME574) PROMOTES COLLEGE-WIDE NANOTECHNOLOGY EDUCATION

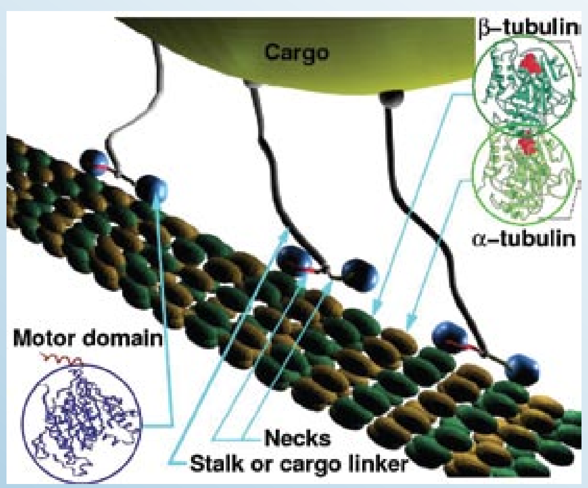
A graduate course Lu first offered in 2002 in the ME department has been offered to students across the College of Engineering. "The course represents continuing efforts to prepare engineering students to meet the ever-increasing educational demands of the rapidly growing nanotechnology field," said Lu.

Highly interdisciplinary in nature, ME574 integrates phenomena and processes in solid mechanics, materials, physics and electronics and focuses on scientific understanding and computational techniques. "The course has provided a unique opportunity for students with different backgrounds to work together," Lu added.

Modeling Molecular Motors



Biomolecular motors—tiny micro- and nano-scale motors that move genetic and other critical material inside cells—hold tremendous promise. Potential applications span drug delivery systems that may fight cancers to biomolecular technologies like sensors and highly specific molecular sorters. A fundamental understanding of the dynamics of molecular motors may also teach scientists more about key cellular processes that rely on such motors, including how cells divide, the role of motors in neurodegenerative diseases or how the ear's cochlea detects sound.



But to date, scientists have only had a fragmented understanding of the complex nonlinear dynamics that govern these motors and transport processes inside cells.

ME faculty Bogdan Epureanu, associate professor, and Edgar Meyhöfer, professor, are changing that. The two have been working to develop chemo-mechanical and stochastic models and experimental techniques to understand how groups of motors transport cargoes. The team focuses on kinesins, a family of proteins responsible for converting chemical energy to mechanical work in cells. These motors transport vesicles along microtubules inside cells.

Previous work by several groups, including Epureanu and Meyhöfer, has led to theoretical models of how single kinesin motors transport material inside cells, but increasing evidence points to collective efforts of kinesin. Recent experiments suggest that many intra-cellular transport processes actually involve between two and ten motors, and Epureanu and Meyhöfer have been exploring the dynamics among multiple motors driving a common cargo.

The models developed at U-M have offered some valuable insights. "Our model predicts that the degree of synchronization among multiple motors attached to a common cargo varies based on several factors: the mechanical properties of the particular motors, the load they're driving and the number of motors involved in the process," said Epureanu. The motors increase their degree of coordination when the stiffness of cargo attachments increases or the load is larger. This increased synchronization may also lead to higher velocities of the cargo.

"Interestingly, our models predict that when the motors encounter an obstacle within the cell, they coordinate their responses to overcome it," said Epureanu. "That mechano-chemical self-regulating mechanism of cooperative dynamics is very intriguing and may be exploited for applications such as the development of novel, cutting-edge molecular sorters." Results from modeling work can now be tested experimentally in Meyhöfer's lab at U-M and, eventually, used to build a test bed.

Funding for the work on understanding the dynamics of molecular motors has come from the National Institutes of Health and the National Science Foundation.

The ability to model and predict how these biomolecular machines cooperate to transport a common cargo forms the critical link to biotechnological device development, including "lab-on-a-chip" applications and many others. Collaborations with U-M Medical School researchers are already underway, looking at transport problems *in vivo*.

"We've had very little quantitative data in the past," said Meyhöfer. "The models now help us devise critical tests to understand how biological cargoes get sorted in cells. If we can adapt the molecular mechanisms underpinning these biological functions and apply them to analytic and diagnostic problems, we should be able to dramatically improve the design of past microscale chips using such technology and do hundreds of analyses at once. And this would improve the cost, speed and sensitivity of analysis and diagnosis."

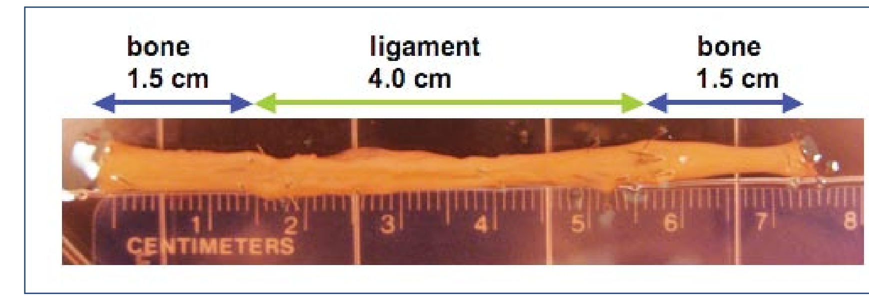
TOP RIGHT:
Schematic depiction of three kinesin motors carrying a common cargo

ABOVE:
Diagrammatic representation of an *in vitro* motility assay, where a microtubule (shown in brown) is cooperatively transported by two kinesin motor molecules attached to a glass substrate.

Cell and Tissue Mechanics:

INSIGHTS INTO BIOLOGICAL SYSTEMS

Many cellular functions require mechanical actuation, and deciphering the fundamental mathematics, physics and mechanics at play in cellular and tissue growth and cell migration may change the way biologists approach—and clinicians treat—common injuries and diseases in the coming decades. To that end, Mechanical Engineering Associate Professor Krishna Garikipati develops mathematical and computational models of the mechanical processes and forces of cell migration, work that has direct application to cancer tumor growth and metastasis. Professor Ellen Arruda builds analytical and computational models of the biomechanics of ligament, tendon, muscle and of tissue she engineers.



Arruda has developed micromechanical models of both ligament and tendon that are capable of capturing the qualitatively different stress relaxation responses of these two tissue types. Now she is fabricating an apparatus for high strain rate testing of native ligament and tendon to examine the biomechanics, and to develop computational models, of the knee joint under impact loading—to better understand the biomechanics of anterior cruciate ligament, or ACL, tears.

With colleagues in the Physiology department of the U-M Medical School, Arruda also has been investigating novel tissue engineering methods. She begins with harvested bone marrow stromal cells (BMSC), a mesenchymal cell that can differentiate into various cell types. While driving these cells *in vitro* along multiple differentiated pathways such as bone or ligament, she applies mechanical constraints as the cells contract and remodel their self-generated extra-cellular matrix.

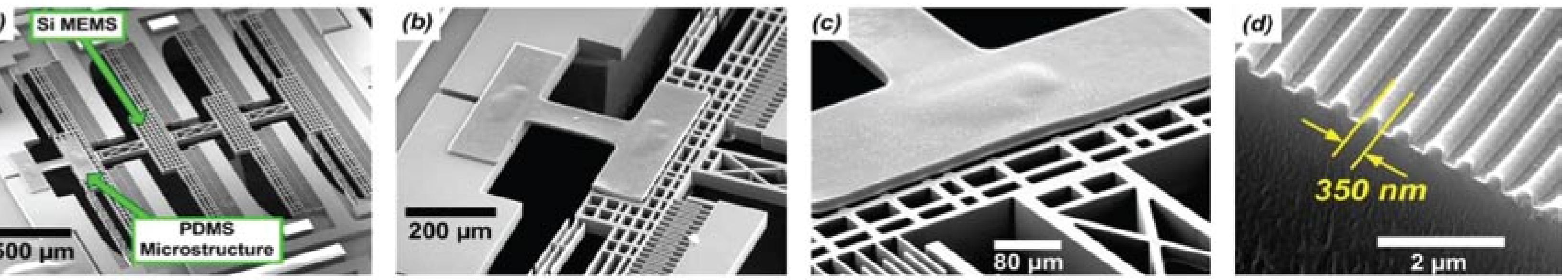
Recently Arruda demonstrated the ability to engineer co-cultured bone–ligament–bone (BLB) constructs from BMSC. The team has successfully implanted the constructs into a rat model and verified that the engineered bone forms a mechanically viable interface with native bone. The engineered ligament region grows physically in size, increases its mechanical stiffness and develops a functional gradient that is comparable to its native tissue counterpart. Overall the BLB construct restores function to the knee joint. This work will appear in the August 2009 issue of the *Journal of Biomechanical Engineering*.

Together, Arruda and Garikipati have created a theoretical model of the dynamics of focal adhesions (FA) under force. FA are protein complexes that bind a cell's cytoskeleton to the extracellular matrix (ECM), a substrate or scaffolding of sorts. When cells generate force on the exoskeleton, and thereby the FA, the FA grow and appear to slide. It has also been observed that if the cell doesn't exert force, the FA fails to grow. "Clearly the whole structure grows under force," said Garikipati. "We're trying to explain how chemistry, physics and mechanics interact to lead to this phenomenon."

In collaboration with Medical School faculty, Garikipati is working to explain and model the mechanics of cancer cells. "Cancer cells do many things that are mechanical in nature; they migrate or metastasize, and in certain situations they're more compliant than normal cells, which may allow them to move more easily," he said. Cancer cells also need and use energy in myriad ways—to proliferate, migrate, lay down ECM and dissolve ECM, for instance.

"One can describe a tumor system mathematically through equations that govern all these processes," Garikipati said. "We can then sort out where the energy goes and how it's used. There may be things we can do that force cancer cells to be very inefficient energetically, and that may offer a route to new types of treatment."

In June 2008, Garikipati and Arruda organized the International Union of Theoretical and Applied Mechanics (IUTAM) Symposium on Cellular, Molecular and Tissue Mechanics held in Woods Hole, MA. The event drew more than 60 investigators who use mechanics to study biological systems at the molecular, cellular or tissue levels. "This symposium was notable for the fact that a third of the participants were biophysicists and biologists, who share our view that mechanics plays an important role in determining the form and function of biological systems at all scales," said Garikipati. "Now, a year since the symposium, we are seeing increasing evidence of the interactions between biology and mechanics that it has spurred."



The mirrors move rapidly and reflect scanning laser light. As they do, the system reveals molecular and early physiological changes up to one-half millimeter from the tissue surface.

MEMS-Based Cancer Detection

Three ME faculty are working at the forefront of cancer detection through a new National Institutes of Health-supported center. The University of Michigan has been named a Center in the Network for Translational Research (NTR), and the Center's focus is optical imaging in multi-modal platforms.

An international network, the NTR works to develop translational research programs to advance novel multi-modality methods for molecular imaging. The NTR team at U-M is headed by Thomas Wang, MD, PhD, an assistant professor of Medicine and Biomedical Engineering. ME faculty including Associate Professor Katsuo Kurabayashi, Assistant Professor Kenn Oldham and Professor Albert Shih work closely with Dr. Wang.

Other academic members of the Center include the Mayo Clinic, Stanford University and the University of Washington. Olympus Medical Systems Group and STI Medical Systems have joined as industrial partners.

Center investigators are devising a new medical instrument for detecting colon cancers. Despite advances in technology and increased awareness of the importance of colon cancer screening, the disease still leads to some 50,000 deaths annually in the United States. Current screening methods not only miss some precancerous polyps; they also often fail to detect flat and depressed lesions, which recent research suggests may be even more likely to lead to cancer. And by the time anatomical changes in tissue are detected, it may be too late for existing therapies to be effective.

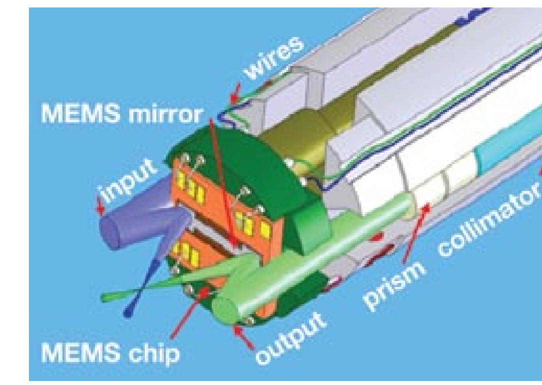
The U-M center, instead, is focusing on how to identify molecular changes in tissue that suggest an increased risk for future development of cancer. The Center's researchers are both engineering a new endoscopic system and developing novel molecules that can preferentially bind to pre-cancerous tissue in the colon, explained Kurabayashi.

The new microendoscope system is comprised of a multi-modal platform that includes wide area endoscopy and confocal microscopy. The system, small enough to be housed in a conventional colonoscope, integrates a three-axis scanning microsystem that includes tiny mirrors—less than three millimeters square—and Z-axis microactuators that employ piezoelectric thin-films, designed in Oldham's laboratory. The mirrors move rapidly and reflect scanning laser light. As they do, the system reveals molecular and early physiological changes up to one-half millimeter from the tissue surface.

A further advanced system builds off Kurabayashi's earlier work on multi-spectral image acquisition technologies (see 2007 Mechanical Engineering Annual Report, page 20). Currently the endoscopic system relies on single-color imaging to detect the light emitted from the molecular probes. Increasing the number of species of probes and colors detected will only improve sensitivity of the system and allow for earlier detection. In addition, the technology would help clinicians more accurately stage—and therefore better treat—colon cancer. And researchers can more clearly learn how anticancer drugs are absorbed by cancerous tissue as well.

Currently the team is fabricating the first-generation of the MEMS components and microactuators with plans to complete the entire system integration by end of 2009. Pre-clinical testing will follow.

"We'll continue to refine our design and system performance over the next four years—that's our goal," said Kurabayashi. The effort began in late 2008. "It's a challenging and ambitious project," he added.



ABOVE: **Endoscope compatible dual axes microscope incorporating MEMS technology**

But worthwhile. "Current screening methods don't let doctors see this molecular level of detail. And because of that, colon cancer is still the second most prevalent cause of death among cancer diseases in the United States," Kurabayashi said.

"If you can map regions of tissue while doing a conventional colonoscopy, you can precisely target the areas which might potentially develop lesions—that's why this is such an important breakthrough from a clinical standpoint."

Simultaneous work is underway to apply the integrated peptide probes and MEMS-based imaging approach in the esophagus and pancreas. The system also may help detect cancer in other types of epithelial tissue, such as in the stomach, cervix and bladder.

*Power*ful Walking

In the near future, people who need a little extra motivation to work out may have a *power*ful reason: to recharge their cell phone or iPod.

ME Professor Art Kuo, head of the U-M Human Biomechanics and Control Laboratory, and two colleagues from Simon Fraser University in Canada and the University of Pittsburgh have developed a new energy-capturing knee brace. The device can generate enough electricity from walking to operate a portable GPS locator, a cell phone, media player or even motorized prosthetic joints or implanted nerve stimulators used to improve ankle function after stroke or spinal cord injury. The team published their work in the journal *Science* in February 2008.

The Bionic Energy Harvester is, in essence, a tiny wearable generator that unobtrusively produces electricity from the natural motion of walking. Initially a 3.5-pound prototype created for proof of concept, it now resembles a typical orthopedic knee brace with the electronics carried on the hip. In its current version, the device weighs less than two pounds and generates over seven watts of electricity from the two legs—about 14 times the amount needed to operate a mobile phone.

The team has launched a spin-off company in Vancouver, British Columbia—BionicPower—to handle all business interests related to the device.

Kuo, who called the invention a "cocktail-napkin idea," said that knee joints are uniquely suited for this work. "You can use effort expended from various places in the body to generate electricity, but the knee is probably the best place," Kuo explained. "While walking, you dissipate energy and you have to make up for this by performing work with your muscles. The Bionic Energy Harvester works much like regenerative braking, which charges the batteries in hybrid cars. Regenerative brakes collect the kinetic energy that would otherwise be dissipated as heat when a car slows down. This device harvests the energy lost when a human "brakes" the knee after swinging the leg forward to take a step."

The idea of human-powered generators—such as those operated by hand crank or pedal—is not new. But such devices require energy to generate electricity. "The problem is when you're generating power you're basically busy solely doing that, and you have to expend your own food energy to do it," Kuo said. By contrast, his team's device harvests energy wasted by a human during a productive activity such as walking.

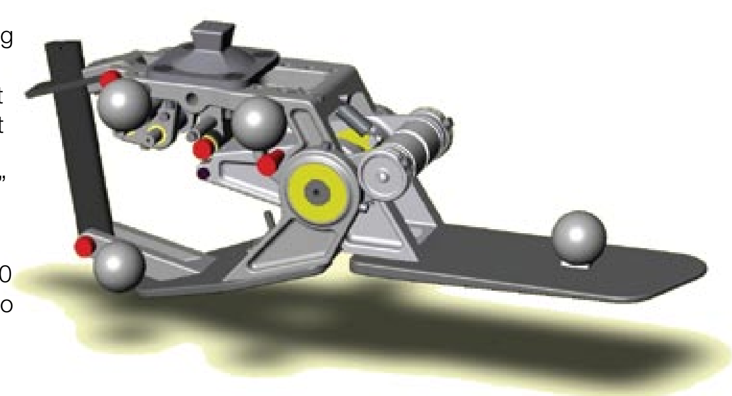
As it is further refined, the potential uses for the device are likely to be limited only by imagination: from military personnel to public safety officials working in disaster sites; from individuals using battery-powered medical devices to road warriors and even recreational hikers. As long as someone is walking, it can recharge batteries or serve as a direct power source to operate equipment.

"The people who are going to be most interested in this are those who are out in the field and dependent on having access to electricity, such as the military" said Kuo. When soldiers go out on a 72-hour mission, they may carry 30 pounds of batteries—up to 25 percent of their overall load. "They're completely dependent on the electronics integrated into their communication equipment and night vision goggles," he said. "Also, the military has built a huge infrastructure just to get batteries to remote locations. So there are huge costs as well as the huge burden for the soldiers."

BionicPower is continuing to refine the harvester and is pursuing partnerships within the medical, consumer, public safety and military markets. For more information about the Human Biomechanics and Control Laboratory, visit: www-personal.umich.edu/~artkuo/Lab/. For information on the Bionic Energy Harvester, visit www.bionic-power.com/.

ABOVE: **Energy-harvesting knee brace generates electricity from the human walking motion.**

BELOW: **Intelligent prosthetic foot is being developed for lower limb amputees and is designed to mimic normal ankle function.**



Giving Control *and* Sensation to Artificial Limbs

Individuals with upper extremity prosthetic devices may one day gain greater control over and sensation from their device, thanks to novel work being done in the Haptix Laboratory, led by Associate Professor Brent Gillespie.

Gillespie and collaborators from the University of Maryland, Drexel University and Rice University have devised a prototype interface system that emulates the sense of touch in people with upper extremity prostheses. The system is comprised of a haptic display attached to the residual limb and a motorized gripper with sensors on the gripping device.

"What we do is relay sensory feedback from the distal end of the prosthetic device to the residual limb," Gillespie said. "If we do a good job with the interface, then pretty soon the amputee will forget about the display on the residual limb and will think he is feeling things with physiological sensors on the end of the prosthetic device. We do it with mechatronic sensors and actuators, but the tendency of a human user is to adopt and use well-designed machines as extensions of the body," Gillespie explained. And he's hopeful: "A well-designed prosthetic device even becomes a part of one's body image."

Few technological leaps have been made in prosthetic design since World War II. There have been some mechanical design improvements recently, but little has been done to advance the interface between residual limb and prosthetic. Sensory feedback, in particular, has remained a major challenge.

The team's prototype uses myoelectric control to transmit electrical signals from muscles in the residual limb to a motor that drives the aperture in a terminal device. Various contact, position and force sensors on the terminal device drive haptic displays on the cuff worn on the residual limb. Vibrotactile motors display contact events; mid-size motors vibrate tendons to cue changes in aperture and larger motors acting through an exoskeleton reflect load forces back to residual muscles. Without this sensory feedback, patients have to watch the terminal device to know whether it's doing what they want it to do—whether, for example, it's at the right aperture to pick up an object.

"Sensory substitution—in this case, vision—is a poor substitute for sensory feedback," said Gillespie.

The team has also been conducting brain imaging studies using electroencephalography (EEG) and functional near-infrared (fNIR) techniques. Early results have already shown activation in the right and left hemispheres of the pre-frontal cortex, indicating that cognitive demands are quite different with and without sensory feedback. "We're trying to keep cognitive demand low by making what the amputee feels as much as possible like what they would have felt with an intact limb," he added.

Seed funding to develop the prototype was provided through the National Academies Keck *Futures Initiative*.

To transmit loads back to the muscles, a cuff, or exoskeleton, is worn around the elbow. By loading the same muscles from which the electromyogram signals are tapped for control, the hope is to give the amputee a sense of effort. "Appropriate action/reaction pairs are established, and in effect we are asking the brain to adapt as if the muscle had undergone a (non-surgical) tendon transfer," Gillespie said. "If motor adaptation happens, you get control and sensory feedback without additional cognitive processing."

RIGHT: **The motorized arm brace allows an able-bodied user to feel grasp forces while the gripper moves in response to electrical activity detected at the bicep muscle.**

Engineering Around the World

A busy curriculum at home doesn't stop U-M engineering students from seeking experience abroad, and Mechanical Engineering students are no exception. The number of students engaged in international programs grew rapidly in 2008, reflecting the College's goal that at least 50 percent of its undergraduates have international experience before they graduate, according to ME Professor Volker Sick, who also chairs the International Programs Committee.

Mechanical Engineering students studied on semester-long programs in locations such as Australia, Austria, Brazil, Chile, France, Germany, Japan, Mexico and the United Kingdom. But the most popular option is still a summer experience. ME students pursued a range of activities from business internships in France to renewable energy studies in Iceland. For example…

A new program with Nagoya University, Japan, helps undergraduate and graduate students gain a global perspective on the automotive sector. The Nagoya University Summer Intensive Program (NUSIP) features a course in advanced technology and tasks in automobile engineering. Lectures from industry experts and company visits complement the course, while students are immersed in the rich culture of Japan.

Renewable energy is the theme of the "Energy Tomorrow" program at the University of New South Wales in Sydney. One of the laboratory projects at the International Engineering Summer School (IESS) at the Technical University of Berlin also focuses on renewable energy; other projects address clean diesel engines, and micro-controllers. The IESS is sponsored by the IAV Group, and past participants are returning to take advantage of IAV internship offers.

ME student Joseph Perosky, a participant in the 2008 U-M Global Intercultural Experience for Undergraduates (GIEU) in Ghana, is returning to the country in summer 2009. He is conducting research in local clinics as part of the College's new Multidisciplinary Design minor.

After racing in Japan in 2006 and the United Kingdom in 2007, the Formula SAE MRacing team is heading to Germany in 2009 to compete and share experiences with student teams from all over the world.

And finally, the University of Michigan-Shanghai Jiao Tong University Joint Institute continues to grow (see related story on p. 37).

TOP: **International Engineering Summer School in Berlin**

MIDDLE: **U-M GIEU students in Ghana**

BOTTOM: **U-M students in China**

UM-SJTU JI Expands Programs and Research

The University of Michigan-Shanghai Jiao Tong University Joint Institute (UM-SJTU JI), based in Shanghai, was created in 2006 and it's been growing fast. According to its dean, ME Professor Jun Ni, more than 800 full-time undergraduate students were enrolled last year. In addition, 47 U-M students spent the spring/summer semester at the JI. Seventy JI students came to study in Ann Arbor, with 13 dual-degree undergraduates enrolled in Mechanical Engineering.

A new combined undergraduate/graduate program between the JI and the U-M College of Engineering was approved by the College of Engineering and Rackham Graduate School. Those classes will begin later in 2010. A new doctoral program was also started in 2008 at the Joint Institute. A dozen students currently are enrolled.

Research flourished in 2008, too. A joint workshop between U-M and SJTU faculty in automotive manufacturing was held, with another workshop related to energy systems in early 2009. Such joint working sessions promote collaborative research, joint student supervision and student exchange in their respective technical fields.

"As a result of last year's workshop, we have eight visiting graduate students coming to the U-M from SJTU," said Ni. "And this year we're trying to arrange for U-M graduate students to take advantage of the facilities in Shanghai."

Ni also noted that General Motors and Ford Motor Company are both working to foster trilateral relationships between the automakers, U-M and STJU. GM is funding collaborative research laboratories both in Ann Arbor and Shanghai. Ford Motor Company has created a strategic partnership with U-M and SJTU. The efforts will ultimately help coordinate and maximize research initiatives.

U-M–KAIST Relationship Going Strong

Seven years after it began, a partnership between the University of Michigan Department of Mechanical Engineering and the Korea Advanced Institute of Science and Technology (KAIST) is still going strong. Associate Professor Hong Im of U-M serves as co-director with Professor Sangmin Choi from the Mechanical Engineering department at KAIST.

Twelve KAIST graduate students participated in the annual Engineering Graduate Symposium held in November 2008. A college-wide event focusing on doctoral and master's programs and graduate student research, the symposium is open to all current undergraduate and graduate students in the College, as well as prospective graduate engineering students from other institutions. Coming from the fields of mechanical engineering and aerospace engineering, the KAIST students gave oral and written presentations during the day's poster sessions.

"KAIST has been participating in this symposium on a regular basis since 2004," said Im. "We're glad these 12 students were able to attend and to actively participate."

Two visiting graduate students from KAIST also spent six months in Im's laboratory during 2008 as part of the U-M/KAIST collaboration. Their research focused on coal combustion for power generation.

Engineering for the Greater Good:

NEW SPECIALIZATION IN GLOBAL HEALTH DESIGN

College of Engineering undergraduates who want to explore how engineering can solve global health problems have a new opportunity: the specialization in Global Health Design.

"Aileen Huang-Saad, a lecturer in Biomedical Engineering, and I developed the specialization—part of the Multidisciplinary Design minor—in order to better prepare our undergraduate students to make sustainable contributions to the improvement of international health," said Kathleen Sienko, assistant professor.

Eligible engineering students will begin the specialization coursework during their junior year, in which they'll take a cornerstone course related to their specific cohort theme and participate in an International Programs seminar series. The first cohort will focus on maternal and infant health.

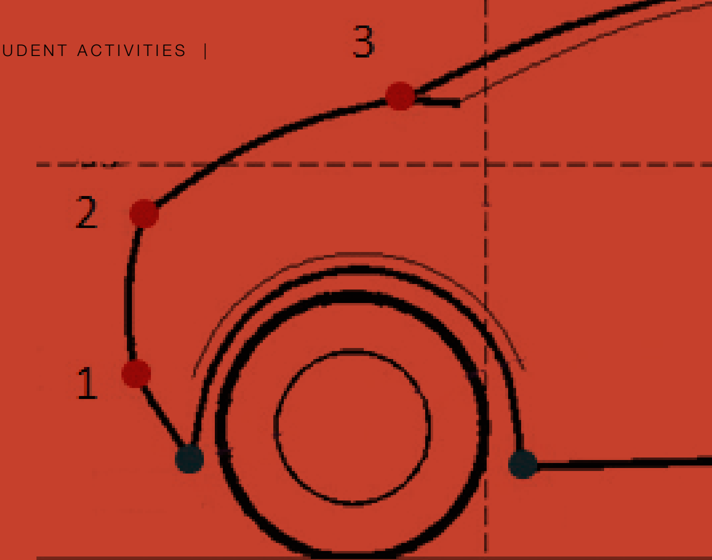
During the summer preceding their senior year, the students will travel to a clinical field site to observe and co-define an engineering design project with prospective end users. Upon their return, student teams will enroll in a sequence of two design and manufacturing courses to pursue development of a device conceptualized at the field site.

Over winter break of their senior year, one or more member(s) of each team will return to the field site to test their prototype and get feedback from clinical collaborators. Next-generation devices will be fabricated upon students' return, using materials and manufacturing processes available in the field site region. Students also will submit project results to journals, develop a commercialization plan and present at the College's Design Expo.

Joseph Perosky, a senior, accompanied Sienko to Ghana in summer 2008 for a month-long clinical immersion experience as part of the Global Intercultural Experience for Undergraduates. As a result, he built a prototype for a reconfigurable obstetric delivery bed that is low-cost and easy to clean and maneuver to serve patients during all three stages of labor in rural primary health care facilities. Currently Perosky is in Ghana evaluating his prototype.

"A lot of students want to apply engineering design for the greater good," said Sienko. "This program provides them experiences as undergrads that force them to co-define a pressing problem in international health. The process becomes part of their learning, which doesn't stop after they build their first prototype."

ABOVE: **U-M interdisciplinary students studied maternal health issues in Ghana, led by ME faculty Kathleen Sienko.**



Design From Many Angles

ME faculty are playing a major role in U-M's interdisciplinary Design Science doctoral program, established by the Rackham Graduate School in 2006. "Mechanical engineers for a long time have had a commitment to and a thirst for design," said ME Professor Panos Papalambros, who directs the Design Science program.

The University-wide collaboration among the College of Engineering, School of Art & Design, Ross School of Business, Taubman College of Architecture + Urban Planning, and the Psychology department in the College of Literature, Science, and the Arts now has eight PhD candidates enrolled, with more admitted for fall 2009. Each student must have two dissertation co-advisors from different schools and must establish a design research problem that transcends current disciplines. Faculty commit to work with each student from the start on formulating an interdisciplinary problem.

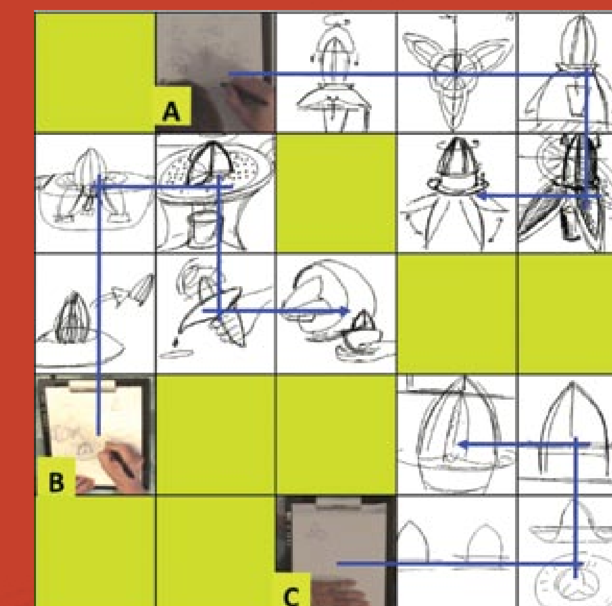
Design science has only been recently recognized as a new field, with an interdisciplinary focus on the elements that affect how we create things and embed them in our physical, psychological, economic and social environment, explained Papalambros. Research areas include—but are not limited to—the integration of marketing, economics and engineering; sustainable and life-cycle design; design for an aging population; and the psychology of design.

A project sponsored by the UM-Ford Motor Company Innovation Alliance had Design Science students investigating what makes vehicles more sustainable from an engineering perspective—such as fuel economy and emissions—as well as perceptions by the users. "Everybody knows what a luxury car looks like, regardless of the brand. But it's harder to identify what a 'sustainable' car looks like," he said.

The Ford project also included creating mathematical models for linking engineering performance and other characteristics with how products perform in the market. The sophisticated mathematics-based framework students and faculty are developing will help producers make design decisions about products, in addition to how to price them and introduce them in the marketplace, Papalambros explained.

Several Design Science faculty also have been involved in a major project funded by the Michigan Memorial Phoenix Energy Institute, a University initiative to explore sustainable energy issues. The Design Science faculty team is preparing a project demonstration to show how decision-making that goes into both government regulations and private manufacturer production is tied to specific products—and to market economics, market equilibrium and vehicle design.

For more information about the Design Science program, visit http://designscience.umich.edu.



Seda Yilmaz, Design Science PhD candidate, gave a presentation at the Korea–Japan Engineering Workshop, 2008. The presentation was a collaborative effort between the Sungkyunkwan University, Creative Design Institute and University of Michigan Design Science program as it was part of the internship defined by the program, and titled as the Effects of Cognitive Activities on Designer Creativity and Performance. Using three professional designers' protocol studies, it demonstrated the application of the Visual Reasoning Model in the analysis of concepts generated in the early phase of the design process.

ABOVE: Identification of a variety of correlations between the performance in each cognitive phase and the creativity of generated concepts using the Visual Reasoning Model.

Design Expo: Innovation in Action

Twice each year, the Design Expo draws hundreds of people to see innovation in action. The event, founded by the ME department close to two decades ago, has become a College-wide institution—and a public forum where undergraduate teams showcase novel solutions to difficult engineering challenges.

"From an educational standpoint, the Expo event showcases the validation of engineering concepts that result from a design process, which occurs over the course of each semester," said Steve Skerlos, associate professor and course leader of the Department's capstone senior design course (ME450) from 2002 to 2008.

"At the beginning, students are uncertain and tentative. They learn to embrace unstructured creativity as part of a structured design process that is fundamentally supported by engineering analysis," said Skerlos. "Detailed specifications developed along the way are proven out in substance at the Expo. Having to explain the evolution and engineering basis of their work to others at the Expo is a driver and catalyst of the learning."

Students ranging from early undergraduate to graduate—in design courses such as ME 250, 350, 450, 455, 552 and 559—learn the product development process firsthand and participate in the Expo. Often they interview project sponsors and prospective customers, review the scientific literature and background materials and develop concepts. They also conduct engineering analyses, optimize their designs and build prototypes to prove that their concepts meet specifications.

Projects run the gamut, from a bicycle with hydraulic regenerative brakes to a lift with moveable seating for surgeons, or from a new nanoscale process for layer-by-layer prototype assembly to a machine to convert farm waste into biofuel. Recently, ME450 has been run within thematic areas such as Sustainable Water and Energy Systems, Global Health Design and Personal Wearable Devices. As the success of design courses has spread across the College, new opportunities for students to continue work on capstone projects for multiple semesters have emerged, allowing students to earn a new minor degree in Multidisciplinary Design.

"U-M is a recognized leader in project-based learning, and ME has led at U-M for decades," said Skerlos. The Design Expo is clearly a focal point, but to continue our leadership in the twenty-first century, it's no longer enough for our students to solve the problems that are handed to them; we must teach them to also identify the important engineering problems for society and to implement the solutions they come up with. ME efforts to support the new minor degree in Multidisciplinary Design are doing just that."

U-M's Winning *Continuum*

The University of Michigan's Solar Car Team won the North American Solar Challenge for the fifth time, continuing their winning ways in a car aptly named *Continuum*. The team crossed the finish line in Alberta, Canada, after more than 50 hours of racing during a nine-day sprint from Plano, Texas. The car, averaging around 45 mph, finished 10 hours before the second-place team.

The victory further proved what *Continuum* is made of: after a crash—and a lost day of racing—in the 2007 World Solar Challenge in Australia, the team still placed seventh.

According to John Federspiel, engineering division director, and Gerald Chang, mechanical engineering division director, *Continuum* had another first in 2008: "We were the first three-wheel, single front to qualify," said Chang.

Prior to the 2008 North American challenge, most cars had developed a similar style that hewed to race regulations. Then those rules changed, requiring each driver to be upright and putting a new limit on the amount of solar cells attached to the car.

"The idea was to slow the cars down and promote innovation," said Federspiel. "About 95 percent of the systems on *Continuum* were completely new. In Australia we never really had the chance to show what the car was capable of, so the North American win was really gratifying."

With more than 100 members, Solar Car Team is one of the University's largest student organizations. ME Associate Professor Kazu Saitou serves as engineering faculty advisor, along with Associate Professor Scott Moore of the Ross School of Business, who serves as business advisor. The team includes students from the College of Engineering; College of Literature, Science, and the Arts; Ross School of Business; School of Art & Design and School of Education.

More information about the U-M Solar Car Team is available at http://solarcar.engin.umich.edu/

2008 SAE Baja: Wins Plus Milestones

The University of Michigan Society of Automotive Engineers (SAE) Baja team had an extremely successful 2008 racing season. The team placed first in dynamic events at two competitions and seventh overall at the 2008 SAE Baja Montreal Competition. Along the way, the team reached two major milestones: the first SAE Baja car under 300 pounds, and the first car to complete a 100-foot acceleration run in under four seconds.

In SAE Baja, student teams build a prototype off-road vehicle intended for mass production and sale as a safer alternative to an all-terrain vehicle, or ATV. A new car is built from the ground up each year to compete against more than 200 collegiate teams from around the world. Students design and manufacture every vehicle component, using analysis tools and manufacturing processes that, often, students take the initiative to learn outside of class.

The Baja team must meet specific rules and requirements before it can compete, and those rules change every year. While keeping safety top of mind and working within the rules' constraints, the U-M team has a reputation for pushing the envelope of different manufacturing techniques in its efforts to get the highest performance out of the vehicle.

ME Associate Professor and Faculty Advisor Brent Gillespie wasn't surprised by the team's success in 2008. "It's a high-functioning team," he said. "They learn by doing, and the more senior team members mentor the junior ones. They do a really good job of preserving knowledge from one year to the next and passing it on. This shows in the competitions. In the last three or four years, they've started consistently coming in first place in at least one category. They've come to the winning edge in a short period of time."

Formula SAE Team Bounces Right Back

For the University of Michigan's Formula SAE team, MRacing, the May 2008 national competition was a bittersweet experience, according to Ryan Kraft, the team's technical director and chief designer.

"We were very ambitious with the design of last year's car and pushed it too far," he said. "We paid the consequences in terms of problems with reliability." The team built the lightest car with a turbocharger in the history of the competition—397 pounds, which is some 20 pounds lighter than any turbocharged car ever. But some serious engine problems at the competition kept it from competing in the dynamic speed events.

The team did participate in the competition's static events and, despite the problems, placed eleventh out of 120 teams, an impressive feat. After the competition, the team went back to work, refined and tested the car all summer, and came back with a new design for 2009, finishing work on that vehicle a month early.

The hard work paid off. The team placed seventh of 120 at the 2009 FSAE Michigan event held in May. The team also took third place in the acceleration event and participated in the design semifinals, where it underwent a four-hour evaluation with industry experts. In addition, *Wolverine* placed third among four-cylinder engine vehicles in the fuel economy event. "It was a great first step for the 2009 team before we attend the Formula student competition in Germany this August," Kraft said.

In Formula SAE competitions, SAE student members conceive, design, fabricate and compete using small formula-style racing cars. Restrictions on the car frame and engine challenge students' knowledge, creativity and imagination. More competition details can be found at the U-M's Formula SAE website: http://mracing.engin.umich.edu.

In 2008 the U-M SAE Student Chapter (www.engin.umich.edu/soc/sae/) once again won the Outstanding Collegiate Chapter Award, which recognizes exemplary performance. ME Professor Volker Sick, faculty advisor to both the Formula SAE team and the U-M SAE student chapter, also was recently elected a fellow of SAE International, the highest grade of membership bestowed by the organization. The designation recognizes outstanding engineering and scientific accomplishments that have advanced automotive, aerospace and commercial vehicle technology.

Pi Tau Sigma Hosts National Convention

Michigan Pi Rho, the University of Michigan's chapter of Pi Tau Sigma (PTS), hosted the February 2009 national convention of PTS, the National Mechanical Engineering Honor Society.

According to co-convention chairs Dayna Anderson and Lisa Perez, planning for the convention took more than two years, with a committee of about 10 other PTS members. But the work and forethought paid off: "The overwhelming sentiment among the guests and U-M Pi Tau Sigma members involved with the convention was that it was a wonderful experience and everyone had a great time," they agreed.

Michigan Pi Rho hosted delegates from 70 other universities. Speakers played a significant role during the event. This year the convention theme was ethics, and speakers focused their advice on building an ethical community and individual decision-making. In addition, there was a panel discussion about ethics.

Delegates also participated in tours of the University's campus and the Mechanical Engineering department. They took part in breakout committee meetings, a career fair, a graduate school information session and many networking events.

Financial support for the convention was provided by Schlumberger, Shell, ITT Space Systems, Lockheed Martin Corporation, IAV Automotive Engineering, BP, Toyota and Consumers Energy. Associate Professor Bogdan Epureanu, the ME faculty advisor for PTS, gave student organizers guidance.

Pi Tau Sigma is a member of the Association of College Honor Societies. More information about the Michigan Pi Rho chapter of Pi Tau Sigma can be found at the chapter's website: www.engin.umich.edu/societies/pts.

Sastry and Wooldridge Honored with Arthur F. Thurnau Professorship

ANN MARIE SASTRY NAMED ARTHUR F. THURNAU PROFESSOR

Professor Ann Marie Sastry was recognized as one of six new Thurnau professors in 2008. Thurnau professorships honor and reward a select group of five to six tenured faculty members for their outstanding contributions to undergraduate education.

Sastry is professor of Mechanical Engineering, Biomedical Engineering, Materials Science and Engineering, director of the Energy System Engineering program and co-director of the General Motors/University of Michigan Advanced Battery Coalition for Drivetrains. She is known for her availability and responsiveness to students, and "her rare ability to be both demanding and supportive."

Sastry teaches a wide range of courses and is known for her approach to teaching Senior Laboratory, which she revamped to emphasize advanced design of experiments and statistics, in addition to other laboratory skills. Her innovation in the classroom resulted in an appointment to the College Engineering Teaching Academy. One student wrote: "She leads me to the door and challenges me to open it myself."

Criteria for the award include a strong commitment to students and to teaching and learning, excellence in teaching, innovation in teaching and learning, a strong commitment to working effectively with a diverse student body and a demonstrable impact on students' intellectual and/or artistic development.

MARGARET WOOLDRIDGE NAMED ARTHUR F. THURNAU PROFESSOR

Professor Margaret Wooldridge has been named an Arthur F. Thurnau Professor in 2009 for her outstanding contributions to undergraduate education.

Wooldridge, whose research and teaching focuses on energy systems, combustion, heat transfer and thermodynamics, is known for her ability to invigorate core undergraduate courses. She has recently created a course, Advanced Energy Solutions, on next-generation methods to provide energy for a global society and a new undergraduate concentration on energy. Her research is deeply integrated with her undergraduate teaching and focuses on bridging the gaps in our understanding of the mechanisms limiting biofuels, gas sensing and catalysts to name a few.

Dedicated to promoting diversity in engineering, Wooldridge devotes significant time to mentoring students, creating an inclusive classroom environment, using distance learning tools and engaging high school and elementary school students.

Wooldridge has been the recipient of several awards for research and teaching. In 2008 she was named a fellow of the American Society of Mechanical Engineers.

The professorships are named after alumnus Arthur F. Thurnau and supported by the Thurnau Charitable Trust. The Thurnau professors retain the titles throughout their careers at the University of Michigan.

Hu and Perkins Recognized with Named Professorships

JACK HU NAMED G. LAWTON AND LOUISE G. JOHNSON PROFESSOR OF ENGINEERING

Professor S. Jack Hu has been appointed to the G. Lawton and Louise G. Johnson Professorship of Engineering. Also the associate dean for research and graduate education for the College of Engineering, Hu serves as University co-director of the General Motors Collaborative Research Laboratory for Advanced Vehicle Manufacturing. The lab conducts research in areas that are of critical importance to GM's vehicle manufacturing operations, in particular, key manufacturing processes and systems that support vehicle electrification, including lithium-ion battery pack manufacturing processes and systems and processes for lightweight structures. Hu and his students are developing mathematical models and software for production system design and improvement, as well as innovative materials joining technologies.

Working in automotive assembly plants in the early 1990s, Hu developed methodologies for improving automotive assembly quality that are still in use by companies such as GM and Chrysler. His research interests include manufacturing systems, assembly and materials joining, metal forming and statistical methods.

Hu began his graduate study at U-M in 1985 and received his PhD in 1990. After four years of service as an assistant research scientist, he was appointed a tenure track assistant professor in 1995. Since then, he's found great satisfaction in working with students in research and is looking forward to continuing. "With a named professorship I hope to recruit even better students; not just to my own research group, but to the general area of manufacturing, and to the College," he said.

NOEL PERKINS NAMED DONALD T. GREENWOOD COLLEGIATE PROFESSOR OF MECHANICAL ENGINEERING

Professor Noel Perkins has been appointed to the Donald T. Greenwood Collegiate Professorship of Mechanical Engineering.

The appointment was made by the Regents of the University of Michigan, and it is an honor well deserved for Perkins, an Arthur F. Thurnau Professor of Mechanical Engineering. Perkins' research training lies in dynamics and, particularly, in nonlinear and computational dynamics and vibrations. His current research program involves both theoretical and experimental studies on the mechano-chemistry of single molecule DNA and protein-DNA interactions, the development of wireless MEMS inertial measurement systems for human motion analysis and engineering structural dynamics.

Using modeling concepts from engineering, Perkins and his collaborators are addressing fundamental questions concerning gene regulation and repair as well as DNA transcription and replication. "The models enable us to test hypotheses about DNA structure to a level of detail that far exceeds the resolution limits of experimental methods," he explained. His work in the development of miniature, wireless MEMS-based inertial measurements units for use in tracking human motion—and his love of fly-fishing—has moved beyond the research lab and into commercial use.

Perkins says he's honored by the appointment. "It means a great deal to me that this professorship bears Don's name and with it, an association with his tremendous reputation and scholarship. His treatise, *Principles of Dynamics*, remains the standard reference for students and scholars worldwide."

Faculty Awards & Promotions

EXTERNAL AWARDS

DENNIS ASSANIS
ASME Internal Combustion Engine Award, 2008
Elected to the National Academy of Engineering, 2008

SHORYA AWTAR
NSF CAREER Award, 2009
R&D 100 Award, 2008

JAMES BARBER
ASME Daniel C. Drucker Medal, 2009

CLAUS BORGNAKKE
ASME James Harry Potter Gold Medal, 2009

ZORAN FILIPI
SAE Forest R. McFarland Award, 2009

JOHN HART
ASME Pi Tau Sigma Gold Medal, 2009
DARPA Young Faculty Award, 2008
Holcim Next Generation Award for Sustainable Construction, 2008
R&D 100 Award, 2008

NOBORU KIKUCHI
Doctor honoris causa of Universite de Liege, 2008

YORAM KOREN
SME Gold Medal, 2008

JUN NI
ASME William T. Ennor Manufacturing Technology Award, 2009

KENN OLDHAM
DARPA Young Faculty Award, 2008

JWO PAN
ASME Sam Y. Zamrik Literature Award, 2008

KEVIN PIPE
DARPA Young Faculty Award, 2009

PRAMOD SANGI REDDY
NSF CAREER Award, 2009

ANN MARIE SASTRY
Trevor O. Jones Outstanding Paper Award, 2008

VOLKER SICK
Silver Combustion Medal of the Combustion Institute, 2008

KATHLEEN SIENKO
NSF CAREER Award, 2009

STEVE SKERLOS
SAE Ralph Teetor Award, 2008

ANNA STEFANOPOULOU
ASME Gustus L. Larson Memorial Award, 2009
ASME Rudolf Kalman Best Paper Award, 2009
NASA Tech Brief Award, 2008

MICHAEL THOULESS
University of Cambridge ScD degree, 2009

A. GALIP ULSOY
ASME Rufus Oldenburger Medal, 2008
SME Albert M. Sargent Progress Award, 2008

KON-WELL WANG
ASME Adaptive Structures and Materials System Prize, 2008

ALAN WINEMAN
Society of Engineering Science William Prager Medal, 2009

MARGARET WOOLDRIDGE
GM Technical Education Program Outstanding Distance Learning Faculty Award, 2008

NEW FELLOWS

ASME (American Society of Mechanical Engineers)
ELLEN ARRUDA
KARL GROSH
ZHENG-DONG MA
HUEI PENG

IEEE (Institute of Electrical and Electronics Engineers)
ANNA STEFANOPOULOU
DAWN TILBURY

SAE (Society of Automotive Engineers)
VOLKER SICK

SES (Society of Engineering Science)
ELLEN ARRUDA

U-M AWARDS

DENNIS ASSANIS
Rackham Distinguished Faculty Achievement Award, 2009

DAVE DOWLING
CoE Education Excellence Award, 2009
U-M ASEE Outstanding Professor Award, 2009

HOSAM FATHY
CoE Outstanding Research Scientist Award, 2009

KRISHNA GARIKIPATI
ME Achievement Award, 2009

KARL GROSH
CoE Education Excellence Award, 2008
Engineering Translational Research Fund Award, 2009

JACK HU
G. Lawton and Louise G. Johnson Professorship in Engineering, 2008

GREG HULBERT
CoE Neil Van Eenam Teaching Award, 2009

MICHAEL KOKKOLARAS
CoE Outstanding Research Scientist Award, 2008

YORAM KOREN
CoE Stephen S. Attwood Award, 2008

PANOS PAPALAMBROS
CoE Stephen S. Attwood Award, 2009

NOEL PERKINS
Donald T. Greenwood Collegiate Professorship in Engineering, 2009
Engineering Translational Research Fund Award, 2009

continued on next page

Faculty Awards & Promotions

CONTINUED

KEVIN PIPE
ME Achievement Award, 2008

ANN MARIE SASTRY
Arthur F. Thurnau Professorship, 2008

VOLKER SICK
CoE Service Excellence Award, 2008

KATHLEEN SIENKO
Engineering Translational Research Fund Award, 2009

STEVE SKERLOS
ME Achievement Award, 2009

ANNA STEFANOPOULOU
Faculty Recognition Award, 2008

DAWN TILBURY
CoE Service Excellence Award, 2009

A. GALIP ULSOY
Distinguished University Professorship, 2009

ANGELA VIOLI
ME Achievement Award, 2008

MARGARET WOOLDRIDGE
Arthur F. Thurnau Professorship, 2009

FACULTY PROMOTIONS

STANI BOHAC, to Associate Research Scientist, 2009

ZORAN FILIPI, to Research Professor, 2008

ART KUO, to Professor with tenure, 2008

ANGELA VIOLI, to Associate Professor with tenure, 2009

Graduate Student Honors & Awards

’08

COE ALEXANDER AZARKHIN SCHOLARSHIP, 2008
Woo Kyun Kim

COE DISTINGUISHED ACHIEVEMENT AWARD
Gaurav Bansa

COE DISTINGUISHED LEADERSHIP AWARD
Scott Moura
Diane Peters

COE WILLIAM MIRSKY AWARD
Saurabh Gupta
Arjun Krishnan
Evan Pineda
Yifeng Tang
Monica Toma

IVOR K. MCIVOR AWARD
Adam Hendricks
Taeyong Lee
Jesse Thomas

MARIAN SARAH PARKER PRIZE
Diane Peters

ROBERT M. CADDELL MEMORIAL UG AWARD
Youngseob Lim

’09

AIAA JEFFERSON GOBLET BEST STUDENT PAPER AWARD
Siva Shankar Rudraraju

COE ALEXANDER AZARKHIN SCHOLARSHIP
Andrew Sloboda

COE DISTINGUISHED ACHIEVEMENT AWARD
Brendan O’Connor

COE DISTINGUISHED LEADERSHIP AWARD
Tahira Reid

COE WILLIAM MIRSKY AWARD
Chul Woo Jung
Amy Siwek

COE SCHOLAR POWER AWARD
Katie Whitefoot

IVOR K. MCIVOR AWARD
Kiran D’Souza

MORTAR BOARD FELLOWSHIP
Steven Hoffenson

NSBE BCA SCHOLAR
Michael Alexander

RACKHAM PREDOCTORAL FELLOWSHIP
Gaurav Bansal

U-M OUTSTANDING STUDENT LEADER AWARD
Kiran D’Souza

U-M OUTSTANDING STUDENT LEADER AWARD
Bart Frischknecht

Undergraduate Student Honors & Awards

’08

ARIEN R. HELLWARTH AWARD
Rosa Abani

CLEANTECH VENTURE CHALLENGE
Jim Beyer

COE DISTINGUISHED ACHIEVEMENT AWARD
Ryan Doss

COE DISTINGUISHED LEADERSHIP AWARD
Rosa Abani
Elizabeth Coon
Patricia Pacheco

HARRY B. BENFORD AWARD FOR ENTREPRENEURIAL LEADERSHIP
Brian Ignaut

J. A. BURSLEY PRIZE
Kelly Bryan
Brett Muller

LLOYD H. DONNELL SCHOLARSHIP
Andrew Olson

LUBRIZOL SCHOLARSHIP AWARD ’08
Marc Michener
Benjamin Pascoe

MESLB FUTURE LEADER AWARD
Lisa Perez
Craig Spencer

MESLB IMPACT AWARD
Donald Tappan

MESLB OUTSTANDING SERVICE AWARD
Charles Wineland

MESLB TRANSFER STUDENT AWARD
Brian Justusson

NORTH AMERICAN DIE CASTING ASSOC DAVID LAINE SCHOLARSHIP
Christopher Berry

OUTSTANDING STUDENT ENGINEER OF THE YEAR BY ESD
Andrew Kneifel

R & B MACHINE TOOL COMPANY SCHOLARSHIP
David Hiemstra
Benjamin Pascoe
Katherine Peretick
Jonathan Williams

ROBERT M.CADDELL MEMORIAL UNDERGRADUATE AWARD
Joseph Shaktman
Galip Ulsoy (faculty)

SAE LEADERSHIP DEVELOPMENT PROGRAM
Phillip Scott

TAU BETA PI FIRST YEAR STUDENT AWARD
Michael Reinker

’09

COE DISTINGUISHED ACHIEVEMENT AWARD
Dayna Anderson

COE DISTINGUISHED LEADERSHIP AWARD
Lisa Perez

J. A. BURSLEY PRIZE
Lisa Perez

JEFFERSON GOBLET BEST STUDENT PAPER AWARD
Siva Rudra Raju

LLOYD H. DONNELL SCHOLARSHIP
Matthew Carpenter

MSAE SAE STUDENT CHAPTER
3rd Place SAE Detroit Student Exhibit Competition

PROFESSOR AND MRS. GRAEBEL TOP SCHOLAR
Christopher Goldenstein

R & B MACHINE TOOL COMPANY SCHOLARSHIP
Peter Curran
Brian Kirby
Kyle Safford

ME External Advisory Board

Nearly twenty distinguished friends and alumni of the Department of Mechanical Engineering, from industry, academia and government, comprise the ME External Advisory Board (EAB). The EAB is a valuable resource to the ME chair and the Department as a whole in shaping and meeting strategic goals. The EAB members meet on campus twice every year to discuss departmental vision, strategies and issues and provide advice to the chair.

AT RIGHT: **ME External Advisory Board members at their fall 2008 meeting**

ME Welcomes New EAB Member

Dr. Paul D. Rogers
Executive Director of Research and Technical Director, Tank Automotive Research, Development and Engineering Center

In 2008, Dr. Paul Rogers was selected to join the ME External Advisory Board. Dr. Rogers is currently serving in the dual-hat position as the executive director of research and technical director, U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC). TARDEC-Research is the lead organization for Army research and development in Ground Vehicle Power and Mobility, Survivability, Intelligent Systems, Vehicle Electronic and Architecture Systems, and High Performance Computing/Simulations Technology areas. As executive director, he manages the technology base programs and leads a 350-person workforce through five technical business area associate directors. He is also responsible for executive oversight for the Joint Center for Robotics. As technical director, Dr. Rogers serves as the key executive responsible for TARDEC science and technology strategic planning, program selection, funding allocation, execution and transition to acquisition programs. Dr. Rogers leads programs to align ground-based systems science and technology research objectives with the U.S. Army's future war fighting and logistic needs.

Alumni News

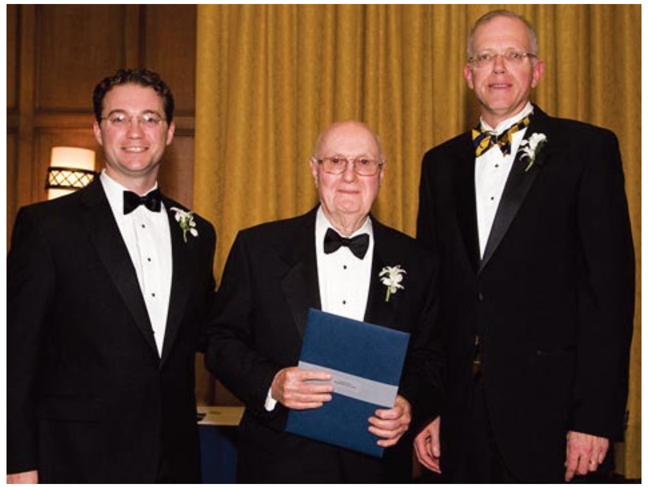
ALUMNI SOCIETY DISTINGUISHED SERVICE AWARD: EDWARD E. MOON

Edward E. Moon (BSE ME '47) has earned the Alumni Society Distinguished Service Award, which honors College of Engineering graduates who have given generously of time and talent to further College projects and activities.

Moon has served as Class of 1947E chair for more than 15 years, raising over $300,000 for two North Campus icons: the Class of 1947E Reflecting Pool situated between the Robert H. Lurie Engineering Center and Phoenix Memorial Laboratory; and "Fred's Fountain," a cascading water feature that complements the reflecting pool. Moon also helped the Class raise over $300,000 for the Class of 1947E Scholarship, and he has organized the Emeritus-year celebration as well as other class reunions, including the 60th.

In addition to working with alumni, Moon also has recruited many outstanding students to the College through his service on the Alumni Society Board of Governors Recruiting Committee.

Outside the College, Moon served as regional representative for the American Society of Mechanical Engineers Materials Handling Section. His distinguished career spans 40 years, during which time he worked for several major material handling systems corporations, holding various engineering and management positions. He has several design innovations to his credit as well as a patent. An accomplished writer, he has penned articles for leading industry publications.



LEFT TO RIGHT: **Paul Bauerschmidt (President of the College of Engineering Alumni Society Board of Governors), award recipient Edward Moon and Dean David Munson**

COLLEGE OF ENGINEERING ALUMNI SOCIETY MERIT AWARD: DAVID E. COLE

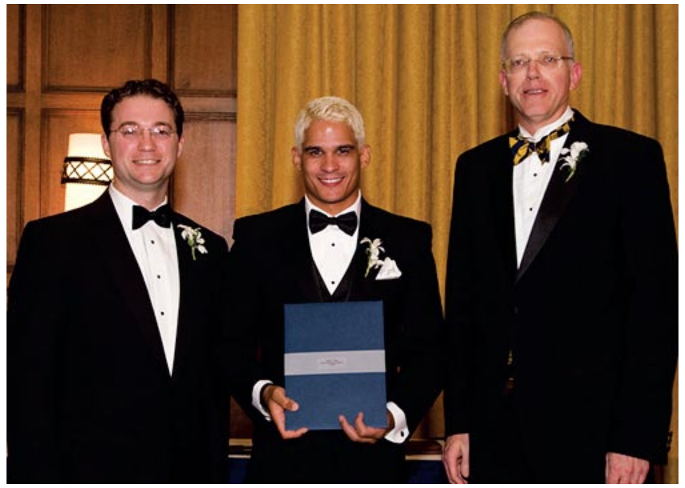
The Department of Mechanical Engineering has presented David E. Cole (BSE ME '60, MSE '61, PhD '66) with a College of Engineering Alumni Society Merit Award. Cole currently serves as chair of the Center for Automotive Research in Ann Arbor. He is a past director of the Office for the Study of Automotive Transportation at the U-M Transportation Research Institute.

Cole's research has focused extensively on internal combustion engines and vehicle design. More recent work has delved into strategic issues related to the restructuring of the North American auto industry and trends in globalization, technology and workforce requirements. Many corporations and government agencies have benefited from Cole's technical and policy consulting expertise. His business acumen has led to the formation of five startup firms.

Cole has amassed a distinguished record of service and honors. He is a director of the Automotive Hall of Fame, the Original Equipment Suppliers Association and of five automotive suppliers. He serves on the executive committee of the Michigan Economic Development Corporation and was recently appointed by the governor to the Michigan Technology Tri-Corridor Steering Committee. He has been recognized with awards from France and Sweden and is active in—and a fellow of—both the Engineering Society of Detroit and the Society of Automotive Engineers.

Alumni News

continued



LEFT TO RIGHT: **Paul Bauerschmidt (President of the College of Engineering Alumni Society Board of Governors), award recipient Shawn Ward and Dean David Munson**

ALUMNI SOCIETY RECENT ENGINEERING GRADUATE AWARD: SHAWN J. WARD

Shawn J. Ward (BSE ME '96) has received the College's Alumni Society Recent Engineering Graduate Award. The award was established to honor College of Engineering graduates who have contributed substantially to their fields within the first 10 years of graduation from the College or are no more than 35 years old.

Ward is president, chief executive officer and co-founder of Detny Footwear, Inc., a fashion company that launched designer footwear labels SHANE&SHAWN and Detny by SHANE&SHAWN. The brands, which combine sophisticated designs with the comfort of high-performance athletic shoes, are sold online and in boutiques and fine department stores throughout North America. The shoes incorporate a patent-pending Luxury Liner insole and injected rubber durability pods to extend the life of the outsole. Ward founded the business in 2003 with his twin brother, Shane, a U-M School of Art & Design alumnus.

Prior to starting the company, Ward spent five years working as a product engineer for DaimlerChrysler. He then moved to New York and worked as a day trader on the NASDAQ stock exchange. The brothers soon started a freelance athletic-footwear design studio that quickly grew to be one of the most highly sought in the industry. From there, they created their own brands and launched Detny Footwear, Inc. The company now is listed on the Frankfurt Stock Exchange.

Ward earned a bachelor of science in engineering degree in Mechanical Engineering. He was selected an Evans Scholar and is a member of the international fraternity Omega Psi Phi.

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