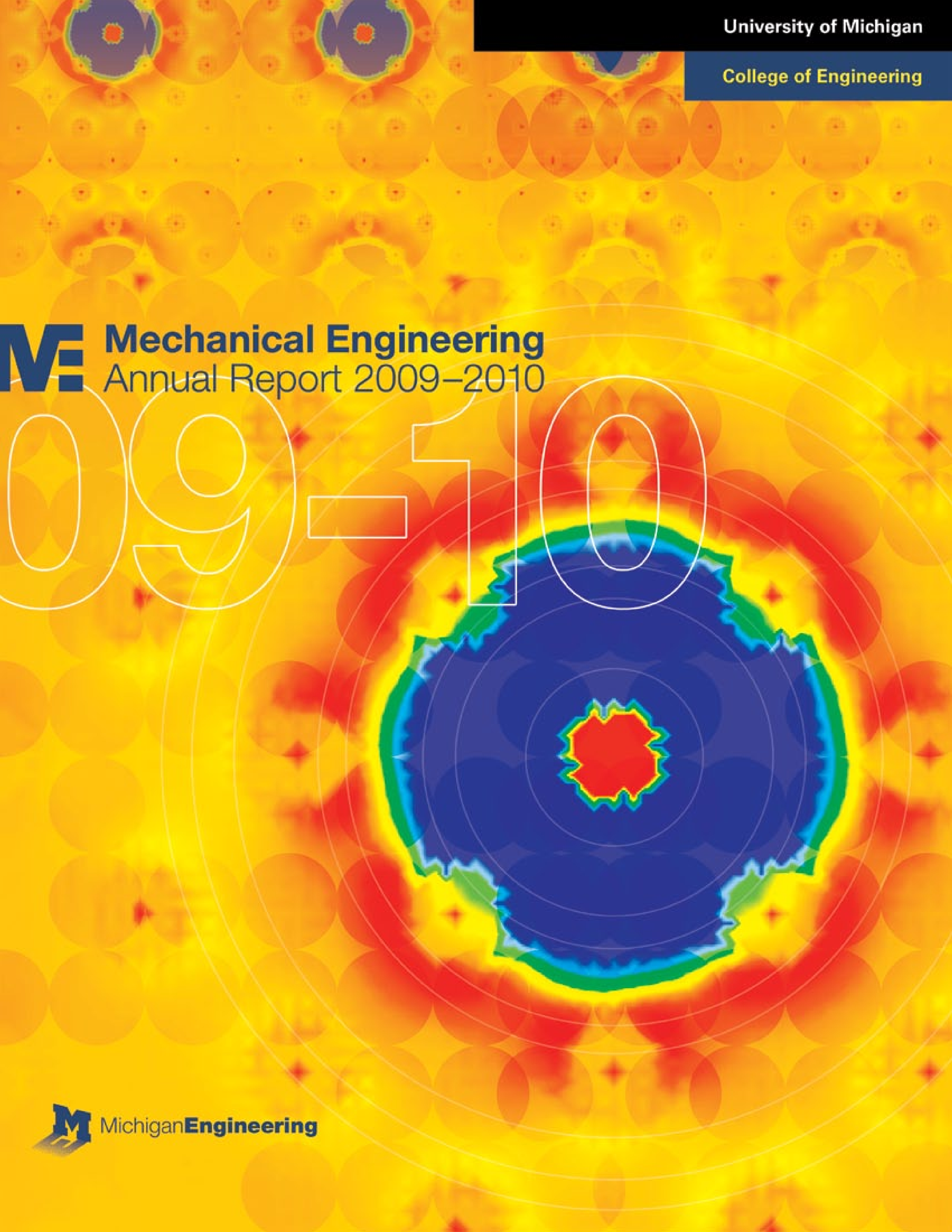
University of Michigan

College of Engineering

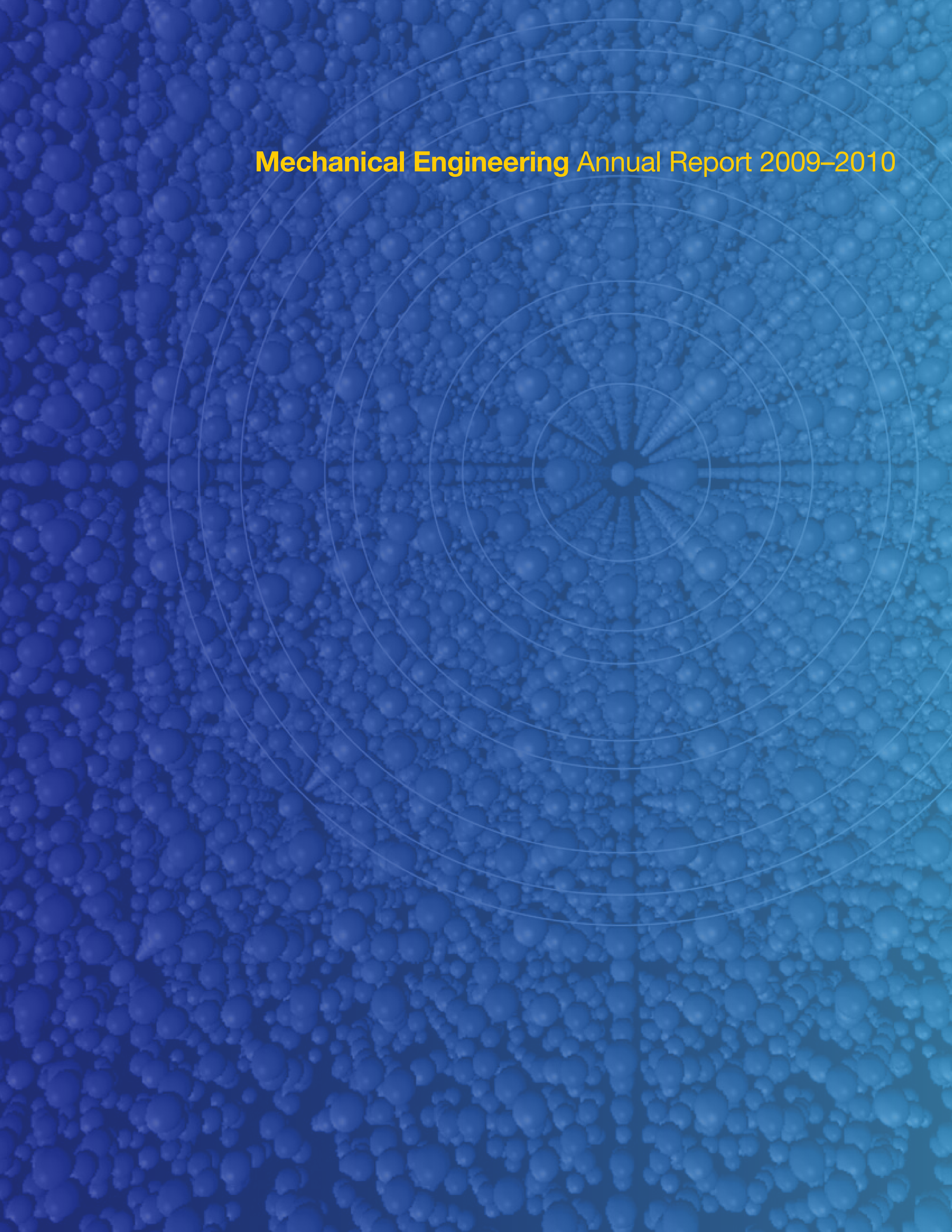


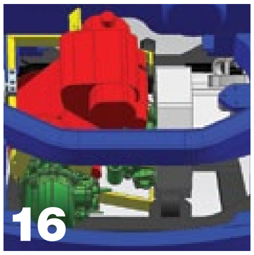
Mechanical Engineering
Annual Report 2009–2010

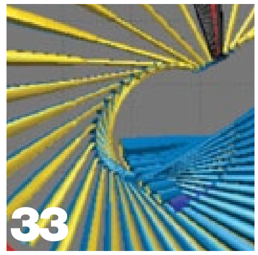
09-10

MichiganEngineering

Mechanical Engineering Annual Report 2009–2010







Contents

Message from the Chair

I am proud to present the 2009–2010 Annual Report to you. It is filled with numerous highlights of activities over the past year involving our faculty, staff, students and alumni, demonstrating that the Department of Mechanical Engineering (ME) at the University of Michigan (U-M) is a leader in forging new paths in research and education and having a strong and positive impact on our community.

Our faculty at all levels are well recognized for the foresight, innovation and reach of their work, evident by the many distinguished awards earned from professional societies. Some of the recent awards include the American Society of Biomechanics Borelli Award, the American Society of Mechanical Engineers Daniel C. Drucker Medal, Rufus Oldenburger Medal, William T. Ennor Manufacturing Technology Award, James Harry Potter Gold Medal, Gustus L. Larson Memorial Award as well as the Pi Tau Sigma Gold Medal and The Society of Engineering Science William Prager Medal.

Our junior faculty are recognized for their early-career successes with highly competitive young investigator awards, such as the National Institutes of Health Director's New Innovators Award, the Early Career Research Award from the U.S. Department of Energy, the National Science Foundation CAREER Award and the Young Faculty Award from the Defense Advanced Research Projects Agency. This year we hired three new assistant professors; each brings valuable talent to the U-M ME community. We will have multiple new faculty openings to fill in the coming year as well.

The Department's research efforts are having significant impact on the scientific community as well as on our society. In the pages that follow, you will read about the discoveries and breakthroughs in both fundamental and applied research in myriad areas: sustainability, energy, nanoscale particles and materials, mechanics of advanced materials, mechatronics and controls, MEMS transducers, biosystems and biomechanics. In addition, our colleagues play important leadership roles vis à vis the national agenda with examples highlighted in this report: one of our faculty is serving as assistant director of advanced manufacturing at the White House Office of Science and Technology Policy; and a National Academy of Sciences report co-authored by another ME faculty member was cited in a presidential memorandum written to effect fuel efficiency standards.

"The Department of Mechanical Engineering at the University of Michigan is a leader in forging new paths in research and education and having a strong and positive impact on our community."

The ME department excels and takes much pride in our education initiatives and efforts. Our faculty members have recently spearheaded two multi-million dollar major educational programs: a naval engineering education center and a transportation electrification education consortium. As you will read, numerous ongoing programs allow students to gain unique and meaningful study experiences both in Ann Arbor and abroad. Our student teams excel, too—in fact, the U-M Solar Car Team just won the American Solar Challenge for the third consecutive year.

We are proud of our vast and ever-supportive alumni network. Our graduates not only are successful in their careers, they also are always generous with their time, knowledge and resources—several examples are highlighted in this year's report.

As you can tell, and will read in the pages that follow, it has been another productive and fruitful year!

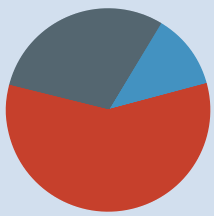
Thank you for your interest.

Kon-Well Wang

Stephen P. Timoshenko Collegiate Professor and Chair, Department of Mechanical Engineering

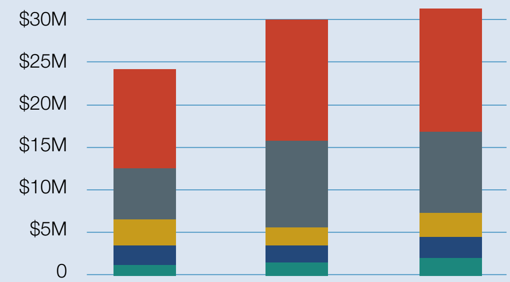
Trends & Statistics

ME DEGREES CONFERRED 2008–2009



BSE 243
MSE 124
PhD 50

ANNUAL RESEARCH EXPENDITURES



	07–08	08–09	09–10
NIH	1,232,517	1,403,643	1,996,237
DoE	1,885,113	1,773,858	2,390,860
NSF	3,099,414	2,460,177	2,701,330
DoD	6,030,570	10,195,017	10,992,316
All Other	12,076,860	14,608,221	13,792,756
Total	**$24,324,474**	**$30,440,916**	**$31,873,499**

FACULTY PROFILE

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

57
# of Society Fellows

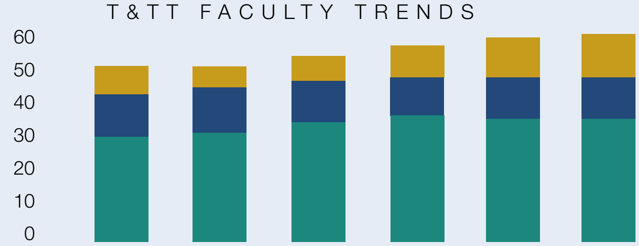
4
# of NSF PECASE or PFF Awards

27
# of NSF CAREER or PYI Awards

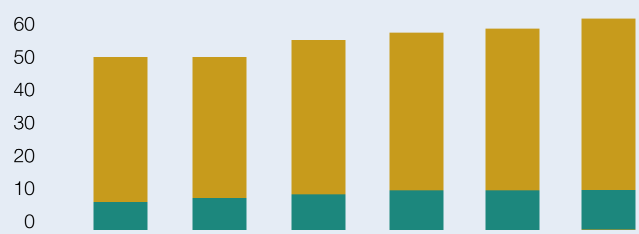
6
# of Current Journal Chief Editors

68
# of Current Journal Editorial Board or Associate Editor Appointments

T&TT FACULTY TRENDS



	FA05	FA06	FA07	FA08	FA09	FA10
Assistant	8	6	9	10	11	12
Associate	12	13	12	11	12	12
Professor	30	31	34	36	35	36
Total Faculty	50	50	55	57	58	60



	FA05	FA06	FA07	FA08	FA09	FA10
Male	43	42	46	47	48	50
Female	7	8	9	10	10	10
Total Faculty	50	50	55	57	58	60

IN THE NEWS

ME Faculty Win Prestigious Societal Awards


1


2


5


3


4

THIS PAGE: **1** Jun Ni with his wife, Ying Wang, at the awards ceremony; **2** James Barber accepting the 2009 ASME Daniel C. Drucker Medal; **3** Alan Wineman; **4** Claus Borgnakke; **5** A. Galip Ulsoy accepting the Rufus T. Oldenburger Medal.

OPPOSITE PAGE: **6** Award-winning medals; **7** John Hart receiving the SME Outstanding Young Manufacturing Engineer Award; **8** James Ashton-Miller; **9** Anna Stefanopoulou.

The contributions and impact of the research advances made by ME faculty are widely and frequently recognized by professional societies with prestigious awards. Many faculty have received coveted honors in recent years for the breadth, depth and creativity of their work. Several are highlighted below (more awards are listed on pages 52-53):

Professor **James Barber** earned the 2009 American Society of Mechanical Engineers (ASME) Daniel C. Drucker medal in recognition of his distinguished contributions to the field of applied mechanics and mechanical engineering through sustained research, teaching and service to the community. It is one of the highest career distinctions a mechanics scholar can achieve.

Professor **Alan Wineman** earned The Society of Engineering Science (SES) William Prager Medal in 2009. Wineman was selected for the Prager medal for his outstanding research contributions in theoretical solid mechanics. As the recipient of the medal, Wineman was invited to give the plenary lecture at the 2009 joint American Society of Civil Engineers-ASME-SES Conference on Mechanics and Materials.

Professor **A. Galip Ulsoy** is a recent recipient of the Rufus T. Oldenburger Medal, another top ASME award recognizing lifetime achievement in the field of automatic control. Ulsoy earned the medal for "fundamental and wide ranging contributions to the analysis and control of dynamic systems with a broad range of applications, from automotive systems to manufacturing systems." Ulsoy was the founding director of the Ground Robotics Reliability Center and currently serves as deputy director.

The ASME awarded Professor **Jun Ni** the 2009 William T. Ennor Manufacturing Technology Award for Ni's significant contributions to an innovative manufacturing technology, the implementation of which has resulted in substantial economic and/or societal benefits. Ni directs the S.M. Wu Manufacturing Research Center and serves as deputy director of the National Science Foundation Engineering Research Center for Reconfigurable Manufacturing Systems at U-M.

6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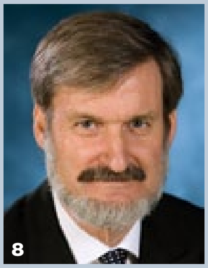
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Associate Professor **Claus Borgnakke** received the 2009 James Harry Potter Gold Medal, also bestowed by the ASME. The Medal recognizes eminent achievement and distinguished service in the science of thermodynamics in mechanical engineering. The award is based on contributions to teaching and use of thermodynamic principles in research, development and design.

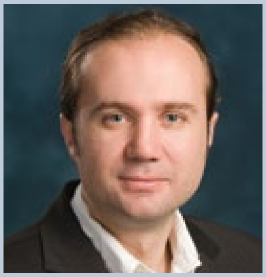
Albert Schultz Collegiate Research Professor **James Ashton-Miller** was honored with the Borelli Award at the annual meeting of the American Society of Biomechanics (ASB) in August 2009. The award recognizes Ashton-Miller for his research in biomechanics and is the highest honor bestowed by the ASB.

Ashton-Miller serves as director of the Biomechanics Research Laboratory. His research interests include mobility impairments in the elderly; trips, slips and falls; elderly decision-making and risk-taking in physical tasks; birth related injury; female stress urinary incontinence; spine biomechanics; athletic injuries and occupant vehicular safety.

Professor **Anna Stefanopoulou** is the 2009 recipient of the ASME Gustus L. Larson Memorial Award, which honors engineering graduates who have shown outstanding achievement in mechanical engineering within ten to twenty years of earning their degrees. Stefanopoulou was recently appointed director of the Automotive Research Center (see related story on page 51).

Assistant Professor **A. John Hart** is the recipient of the 2009 ASME Pi Tau Sigma Gold Medal. The medal is awarded to young engineering graduates who have demonstrated outstanding achievement in mechanical engineering within ten years following receipt of the baccalaureate degree. Hart also received the Society of Manufacturing Engineers (SME) 2010 Outstanding Young Manufacturing Engineer Award. This award recognized Hart for his exceptional contributions in manufacturing.

Junior Faculty Win Early Career Awards


NIKOS CHRONIS


SAMANTHA DALY


KENN OLDHAM


KEVIN PIPE

Several ME faculty may be in the early stages of their careers, but their work is already drawing attention and showing results. The following junior faculty have been recognized in 09–10 for their innovative and creative approaches to problems and the promise and tremendous potential of their work.

Assistant Professor **Nikos Chronis** (PhD, UC Berkeley) received the National Institute of Health (NIH) Director's New Innovators Award. He is one of about 50 investigators in the early stages of their careers honored with the award in 2009. The prize supports exceptional creativity among new investigators working on innovative projects. The work also must have the potential for high impact.

Chronis is developing a biochip that monitors the immune status of HIV-infected populations in resource-limited societies. The biochip uses a microelectromechanical systems-based imaging system to count the number of CD4 cells in HIV-positive patients (see related story on page 38).

Assistant Professor **Samantha Daly** (PhD, Cal-Tech) has received an Early Career Research Award from the U.S. Department of Energy. Daly is one of 69 research scientists from across the nation to win five-year grants under the American Recovery and Reinvestment Act. The grant will support her research on "Deformation and Failure Mechanisms of Shape Memory Alloys" to better understand the fundamental mechanics driving the deformation and failure of this unique group of metallic alloys (see related story on page 28).

Daly's work will have an impact on scientific research well beyond SMAs. The findings from her experiments are representative of a wide class of materials, and the new experimental methodologies she is using can be applied to a range of future investigations into the mechanics of materials.

Assistant Professor **Kenn Oldham** (PhD, UC Berkeley) has won a NSF Faculty Early Career Development (CAREER) Award for his research on "Power Optimization in Autonomous Microsystems via Integrated Motion Control." CAREER awards recognize junior faculty for outstanding research and education.

The primary application of Oldham's research is the control of terrestrial, autonomous micro-robots with insect-like mobility that rely on piezoelectric MEMS actuators. The power-saving algorithms that Oldham is applying to his robotics work also can be applied to other microsystems, such as capsule endoscopes and other biomedical devices whose small size imposes power constraints. As part of the award, Oldham plans to develop an educational simulation tool to teach students about power sources and how force is transferred (see related story on page 36).

Assistant Professor **Kevin Pipe** (PhD, MIT) has been selected by the Defense Advanced Research Projects Agency to receive a Young Faculty Award. Through the grant, Pipe will study heat transfer in high power/high speed transistors that are used as amplifiers in advanced military and commercial communications systems. Efficient heat removal is critical to getting maximum performance from and ensuring reliability of such devices. More specifically, Pipe will examine methods to efficiently remove the heat carried by vibrational modes very near to the transistor itself.

Pipe has recently been promoted to associate professor with tenure.

Going Green: ME for Green Vehicle Education

Professor **Huei Peng** and the ME department will be a driving force in the electric and hybrid vehicle movement, thanks to a $2.5 million grant from the Department of Energy's Advanced Electric Drive Vehicle Education Program, announced in August 2009.

Peng, who also serves as the executive director of Interdisciplinary and Professional Engineering Programs in the College of Engineering, took the lead on the proposal that won the award for new educational activities in transportation electrification.

The grant, funded by the American Recovery and Reinvestment Act, will allow U-M to create ten graduate and undergraduate courses on topics such as hybrid vehicles, batteries and green power. Seven of the ten courses will be taught in Ann Arbor; the rest will be offered to students at U-M–Dearborn and Kettering University in Flint.

In addition, Peng will oversee the establishment of two new labs: an Integrated Hybrid Electric System Laboratory and an Automotive Power Electronics Laboratory. These will be housed in Ann Arbor and will support the newly developed courses. Short courses for professionals will be offered in person and through distance education. Outreach to students in grades K through 12 will include classes, hands-on learning modules and a summer camp experience. A Saturday morning seminar series and other consumer-oriented events also will be developed to increase awareness of green vehicle technology.

The goal of the new initiative is to educate students in electrical power generation, delivery, conversion and controls—both at the grid and the vehicular levels. Graduates will then go on to comprise the next generation of engineers who can conceptualize, design and manufacture green vehicles.

"We want to develop all opportunities so the workforce in Michigan can be transformed," Peng said. Besides laying the foundation for education with a clean energy focus, the Advanced Electric Drive Vehicle Education Program also will create industrially relevant engineering jobs and will support the nation's transition to green manufacturing.

The grant is part of more than $1 billion going to Michigan-based companies and universities. Reflecting its leadership in clean-energy manufacturing, Michigan is receiving the largest share of grant funding of any state.

ABOVE: **Students in the Fuel Cell and Hydrogen Storage class got a chance to ride in the fuel cell prototype vehicle brought to class by guest lecturer Mark Mathias of General Motors.**

U-M to Lead New Naval Engineering Education Center

A new Naval Engineering Education Center (NEEC), spearheaded and led by U-M, has an ambitious and important goal: to develop and educate the next generation of world-class naval systems engineers.

The center was established through a $3.2 million contract award from the Naval Sea Systems Command (NAVSEA). The contract includes five additional years of optional extensions that could total $49.9 million. The ground-breaking program, under the direction of ME Professor **Steve Ceccio**, is among the largest in the history of the College of Engineering.

Since the end of the Cold War, the U.S. Navy has experienced significant challenges to its ship design capabilities, and the ship design workforce is aging. To meet these needs, U-M partnered with NAVSEA to form the NEEC. This new Center will develop a large number of uniquely educated students to help rebuild the Navy's design expertise with the next generation of naval systems engineers for the Navy's civilian engineering, acquisition and scientific workforce. The Center's educational programs will not only benefit the Navy, however; they also will provide outstanding learning and career opportunities for U-M students as well as those from the Center's partner institutions.

Fifteen top colleges and universities from across the United States comprise a consortium, along with the American Society of Naval Engineers and the Society of Naval Architects and Marine Engineers.

The NEEC also will work to recruit and retain world-class faculty who specialize in naval engineering. It will coordinate employee development opportunities to retain naval engineering talent for the Navy, and it will expand naval engineering education programs and courses across universities and colleges nationwide.

The NEEC students will engage in project-based learning and gain hands-on naval engineering experience. NEEC project teams, joined by NAVSEA engineers and scientists, will address the latest technical challenges, such as the development of alternative energy sources and energy conservation methods, design and use of unmanned vehicles, advancement of ship design methods and manufacturing capabilities, and the reduction of the Navy's operational costs. Students will participate in NAVSEA internships and at-sea experience on Navy ships to better understand the Navy's mission and needs.

The American Society of Naval Engineers and the Society of Naval Architects and Marine Engineers are partnering with the NEEC, and the two organizations will help develop K–12 outreach programs to spark children's interest in pursuing science, technology, engineering and math courses and careers. All of these activities will be coordinated with the U.S. Navy's Center for Innovation in Ship Design.

The NEEC brings together U-M, Virginia Polytechnic Institute, the Massachusetts Institute of Technology, the Pennsylvania State University, the Georgia Institute of Technology, the Webb Institute, Florida State University, Florida Atlantic University, Old Dominion University, Tennessee State University, Stevens Institute of Technology, the University of New Orleans, the University of Iowa, the University of Texas-San Antonio and the University of Washington.

"Michigan has a long and proud tradition of education and research in support of the Navy, and we're proud to be leading the NEEC and to be working with all of these partners to nurture the next generation of naval engineers," said Ceccio, who is also a professor of Naval Architecture and Marine Engineering.

PHOTO: U.S. NAVY MASS COMMUNICATION SPECIALIST 2ND CLASS JASON R. ZALASKY

Meet New Faculty

KIRA BARTON

CHINEDUM OKWUDIRE

GÁBOR OROSZ

Kira Barton
Assistant Professor

Barton comes to U-M from the University of Illinois at Urbana-Champaign, where she completed an American Society of Mechanical Engineers Graduate Teaching Fellowship and earned her PhD in mechanical engineering.

Barton's work intersects controls and manufacturing and focuses on development of novel control algorithms for improving the coordination and precision motion control of manufacturing systems. Her research combines innovative manufacturing processes with enhanced engineering capabilities. The potential impact ranges from building DNA sensors for biological applications to controlling the coordination between satellites in space.

Barton is pioneering a micro/nanomanufacturing process called electrohydrodynamic jet, or E-jet, printing. This printing technique is particularly viable for high-resolution patterns or functional devices such as electrical or biological sensors. Recent advances have increased throughput capabilities by four orders of magnitude. Earlier this year her desktop E-jet printing system was named a finalist in the Lemelson-MIT Illinois Program, which recognizes innovation and invention.

Barton plans to continue work on the E-jet process at U-M and address similar control needs in other manufacturing processes. She looks forward to the many collaborative opportunities to be found within the ME department and other departments as well.

"My work is highly interdisciplinary, and I am extremely excited to have the opportunity to work with so many outstanding researchers," said Barton.

Chinedum Okwudire
Assistant Professor

Okwudire earned his PhD degree in mechanical engineering from the University of British Columbia (UBC) in Vancouver, Canada.

Okwudire's research centers on the modeling and control of high-speed motion control systems, or feed drives, in order to improve the quality and productivity of manufacturing operations. While completing his doctoral studies at UBC, he worked closely with the Mechatronics Support Team of Siemens Linear Motor Systems. Most recently, he has worked at Mori Seiki's Digital Technology Lab where he is collaborating on the development of an ultra-precision five-axis machine tool that is capable of nanometer level surface finishes.

At U-M, Okwudire plans to extend his research to developing motion control methods and material handling techniques that will reduce energy consumption and waste in manufacturing.

"I'm excited about continuing research work that will contribute to re-shaping the manufacturing industry to make it better and more sustainable," he said.

Gábor Orosz
Assistant Professor

Orosz earned his PhD degree in engineering mathematics from the University of Bristol in England. He continued as a postdoctoral fellow at the University of Exeter, also in England. Most recently, Orosz completed a postdoctoral fellowship at the University of California, Santa Barbara.

Orosz's recent research has focused on traffic dynamics and understanding how traffic jams with no discernible cause develop on highways. Through that work, he has gained a deeper understanding of the collective dynamics of vehicle systems, and future work will shift toward controlling such dynamics. His research will target traffic control schemes that act at the level of the individual vehicles, with the goal of developing algorithms for autonomous cruise control devices that can keep traffic flowing smoothly.

"U-M is a leader in the area of transportation, dynamics and control, and there are excellent opportunities for scientific collaboration," said Orosz, who also plans to continue his work on the dynamics of biological networks.

Educating future engineers is one of the many opportunities Orosz is looking forward to at U-M.

NEW 2010–11 FACULTY SEARCHES

The U-M ME department seeks candidates for multiple full-time tenure-track faculty positions in 2010–11. To learn more, visit our website at: www.me.engin.umich.edu

From U-M to the White House: Kota Advancing Manufacturing

Professor **Sridhar Kota** currently is serving as the assistant director of advanced manufacturing and American Society of Mechanical Engineers fellow at the White House Office of Science and Technology Policy (OSTP). His assignment in Washington, D.C., began in September 2009.

The OSTP advises the President and others within the Executive Office on the effects of science and technology on domestic and international affairs. The OSTP also leads interagency efforts to develop and implement sound science and technology policies and budgets.

The advanced manufacturing position is a recent addition to the Technology Division of the OSTP. "The President and the Administration are committed to strengthening the U.S. manufacturing base," said Kota. The ASME originally offered Kota a congressional fellowship, but when the need for leadership in manufacturing arose, the OSTP selected him for the position after a further round of interviews.

Kota accepted the assignment. "I believed this would provide me an opportunity to experience policy-making at the highest level," he said.

Kota's responsibilities focus primarily on identifying promising technologies and effective strategies to strengthen the nation's manufacturing base. He looks for gaps in current federal research and development in advanced manufacturing and devises strategies to address them. He is creating policy recommendations to foster commercialization and manufacturing of advanced technologies. The need to re-establish a robust manufacturing sector domestically is especially crucial right now given the recent economic downturn.

As both an engineer and a researcher, Kota says he is gaining "an understanding of the big picture and how university research impacts real societal needs. The perspective that I am gaining is extraordinary."

Kota also sees the assignment as valuable to his work as an educator. "I'm learning how best to fill the 'innovation gap' through engineering education and research. We still have some of the best universities and research institutions in the world, and we must continue to invest in basic research. But fundamental research is only the first step in achieving national, economic and energy security. We must also mature the technology and manufacturing readiness of our scientific discoveries and engineering inventions. That's where translational research, engineering and entrepreneurship will help fill the gap between scientific discovery and U.S.-based manufacturing."

Effecting National Standards:
Assanis' Work Cited in Presidential Memo

The work of ME Professor **Dennis Assanis** and two other University faculty members was cited in a May 2010 presidential memorandum. Assanis, a member of the National Academy of Engineering and director of the Michigan Memorial Phoenix Energy Institute (see related story on page 12), was a contributor to a National Academy of Science (NAS) report on medium- and heavy-duty truck regulation. In the memo, President Obama requests that the U.S. Environmental Protection Agency and the National Highway Traffic Safety Administration immediately start working on establishing fuel efficiency and greenhouse gas emissions standards for commercial medium- and heavy-duty vehicles—and that the two agencies consider the findings and recommendations in the NAS report. The standards would begin with vehicle model year 2014, with the aim of issuing a final rule by the end of July 2011.

Thouless Bestows University Commencement Honors

PHOTO: AUSTIN THOMASON, U-M PHOTO SERVICES

ME Professor Michael Thouless (standing, second from right)**, chair of the Senate Advisory Committee on University Affairs, hoods President Obama during the conferring of honorary degrees.**

ME Professor **Michael Thouless** had the privilege of hooding the honorary doctoral degree recipients, including President Barack Obama, during the spring 2010 commencement at the University of Michigan. President Obama delivered the commencement address and received an honorary Doctor of Law degree. Thouless was accorded the honor because of his role as chair of the Senate Advisory Committee on University Affairs (see related story on page 51). University of Michigan ME alumnus and president of the National Academy of Engineering Charles Vest also received an honorary Doctor of Law degree. Vest is president emeritus of the Massachusetts Institute of Technology and has served as dean of the College of Engineering and provost at the University of Michigan. Vest delivered the 2010 ME Korybalski Lecture in May (see related story on page 54).

ME Faculty Directs U-M Energy Institute

Dennis Assanis, the Jon R. and Beverly S. Holt professor of engineering and an Arthur F. Thurnau professor, has been appointed director of the Michigan Memorial Phoenix Energy Institute (MMPEI).

The MMPEI is serving as the hub of energy-related research and education throughout the College of Engineering and U-M. The Institute's mission is to develop pathways to a secure, affordable and sustainable energy future. Tackling society's energy problems requires a multidisciplinary approach, and the MMPEI spearheads and promotes collaboration among the ME department, the College and many units across campus that encompass the basic sciences, natural resources, the environment, business, public health, law and public policy. Housed in the remodeled Phoenix Memorial Laboratory, formerly home to the Ford Nuclear Reactor until it was decommissioned, the Institute is charged with bringing the University's energy research, policy studies and educational activities together under one roof.

Assanis is a natural fit for the Energy Institute's directorship. His research explores new transportation technologies that minimize the use of fossil fuels and generate reduced greenhouse gases and pollution. He is leading efforts toward a carbon-neutral vehicle for sustainable mobility while simultaneously making fundamental contributions to the fields of biofuels synthesis and utilization, clean combustion, electrified propulsion and materials science within an overarching lifecycle design and optimization framework. His goal is a four- to five-fold reduction in use-phase carbon dioxide emissions as well as advances in energy harvest and storage materials.

ABOVE: **Example of a lithium-ion battery pack for automotive applications.**

MMPEI's primary research thrusts include: carbon neutral electricity sources; energy storage and utilization; transportation and fuels; and energy policy, economics and societal impact.

"The Energy Institute is developing solutions to reinvent a predominantly fossil fuel-based energy infrastructure into a sustainable model," said Assanis. "We are committed to enabling basic science discovery with a path toward technology and market-ready innovation in order to advance renewable energy generation, dramatically improve storage capacity and transform the energy distribution infrastructure. Addressing global energy supply, demand and utilization challenges requires interdisciplinary system analysis to assess different scenarios for energy policy and market strategies." Furthermore, raising societal awareness of vexing energy, climate and human habitat issues is a prerequisite to modify behavioral patterns and tap into the power of energy conservation, he added.

The work of many ME faculty overlaps considerably with MMPEI's research priorities, and a number of ME faculty serve as faculty fellows for the Institute. For example, the Alternative Energy Technologies for Transportation (AETT) program, led by the

Institute in partnership with Fraunhofer Gesellschaft, Germany, is focused on moving crucial research discoveries from laboratories to industry and involves ME professors Volker Sick and Jyoti Mazumder. In addition, ME Assistant Professor Donald Siegel was part of a junior faculty multi-disciplinary cluster hire spearheaded by the Institute and recently won a grant to develop advanced lithium-air batteries as part of a campus-wide initiative to promote collaborative research in renewable energy between U-M and Shanghai Jiao Tong University in China.

With support from MMPEI and the National Science Foundation, ME Associate Professor and Graduate Chair Steve Skerlos is developing new systems analysis methods and integrating them into a framework for sustainable design of environmental policies for the transportation sector.

ME Professor Michael Thouless and ME Associate Professor Wei Lu are among nine U-M faculty participating in an Oak Ridge National Laboratory-led consortium that has won the first, highly competitive U.S. Department of Energy Energy Innovation Hub for Advanced Simulation of Light Water Nuclear Reactors. Additional ME faculty are involved in a variety of initiatives in the different research areas of the Institute.

For more information about MMPEI and its research thrusts, visit www.energy.umich.edu.

"We are committed to enabling basic science discovery with a path toward technology and market-ready innovation."

Advancing the Three Pillars of Sustainability

For ME Associate Professor **Steve Skerlos**, the concept of sustainability reaches far beyond developing new technologies to reduce environmental impact. Skerlos and his team consistently challenge conventional paradigms by looking at environmental sustainability through a hard-nosed economic lens while asking broader questions about whether technology solutions work for everyone who might be affected. In this way the technologies and methodologies developed by his group address the so-called "triple bottom line": helping people, business and the planet at the same time.

Skerlos' research team also performs environmental and economic assessments of existing products, while analyzing the role market factors and government policies play to help or hinder the adoption of more sustainable technologies. These assessments do not stay on the shelf—they are used by the team to create options for policymakers that make sustainable products and technologies more attractive to consumers, less resisted by industry and more effective at addressing environmental challenges.

At the heart of his approach is a high-level, systems view that evaluates existing technology and develops technology or policy solutions for previously insoluble problems in high-need areas. "We look at the big picture—environmental impact, economic impact and societal impact—and let megatrends drive our interests to develop new technology," he said. "We work from sustainability problems to solutions rather than the other way around."

Sustainable Design

The team currently is developing quantitative methods to help find answers to the myriad questions manufacturers often have at the start of the design process, whether an automotive firm is considering a new plug-in hybrid vehicle or an appliance maker a new high-efficiency washer and dryer. The main advance is a unique integration of economic market simulation with environmental assessment techniques, which allows a simultaneous prediction of how both markets and emissions would change with modifications in design.

The research group has shown this approach can work with government policy design too; regulators can use the same methodologies and models when weighing new subsidies or tax credits. Using its methodologies, the group currently is evaluating possible effects of the 2012 government fuel economy regulations for cars on vehicle sales and expected greenhouse gas emissions.

Sustainable Manufacturing

Skerlos and his students have worked on energy and water conservation projects at large manufacturing facilities. His research group also has developed new metalworking fluid technologies to replace existing fluids, which have long been a problem for manufacturing: They grow bacteria rapidly, deteriorate over time and are formulated with up to 20 different chemicals in water. Workers breathe and touch these fluids daily, and fluid disposal harms aquatic ecosystems.

Instead Skerlos' approach eliminates water altogether, taking waste carbon dioxide from ethanol production and compressing it to its supercritical state. In this state the carbon dioxide can carry lubricants with very high efficiency. The resulting metalworking fluid adheres to the triple bottom line: Health hazards for workers are eliminated; there is no need for waste disposal or water consumption; and cutting tools actually cut faster and last longer, meaning higher profits for the manufacturer. This advancement has led to the formation of Skerlos' second startup company, which has completed several successful pilot trials in industrial settings.

Sustainable Water Systems

Working in collaboration with colleagues in Civil and Environmental Engineering, Skerlos also is developing novel systems to treat sewage so it can be safely returned to ecosystems while producing energy at the same time, either in the form of algae biofuel or methane. One system uses an anaerobic

"We look at the big picture—environmental impact, economic impact and societal impact—and let megatrends drive our interests to develop new technology. We work from sustainability problems to solutions rather than the other way around."

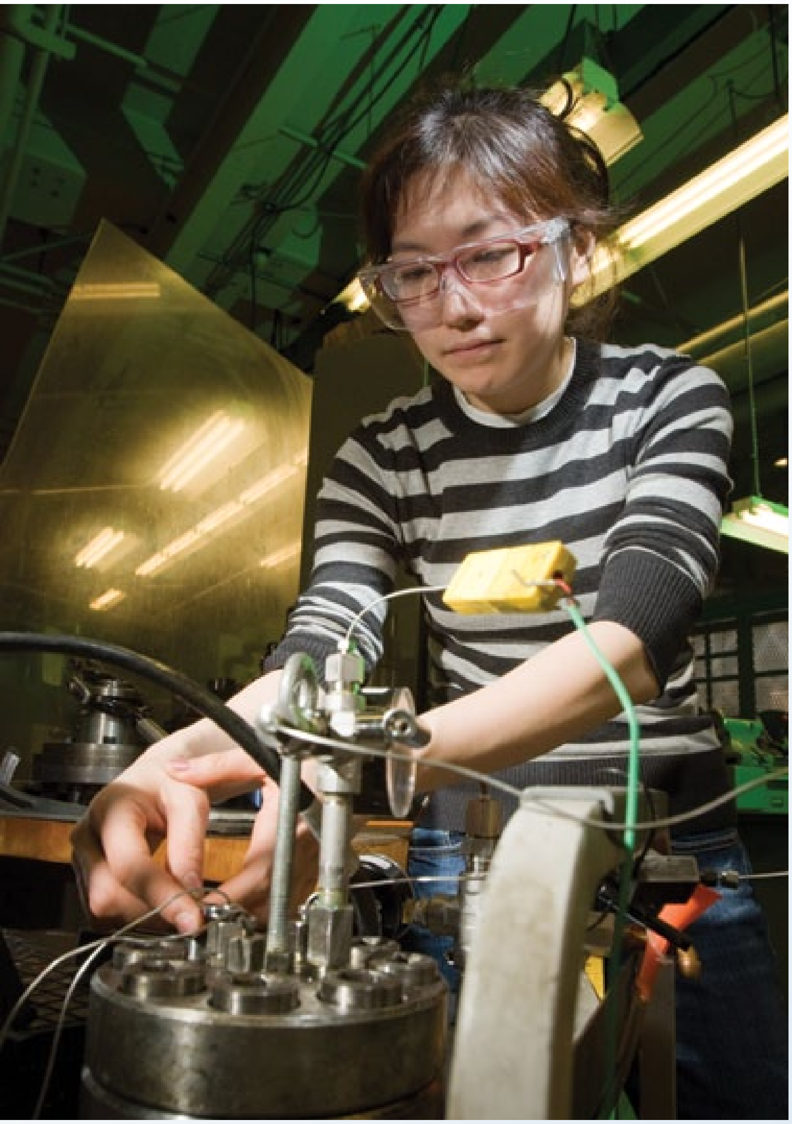


PHOTO: SCOTT GALVIN, U-M PHOTO SERVICES

ABOVE: **Angela Park prepares prototype supercritical spray delivery in her research on tool life improvements, achievable using environmentally benign technology.**

OPPOSITE PAGE, TOP: **Using supercritical sprays as cutting fluids protects worker health, eliminates water pollution and increases profits.**

OPPOSITE PAGE, LEFT: **Clean water is produced from waste water while creating energy using anaerobic membrane bioreactor technology.**

membrane bioreactor, which produces recoverable methane as a byproduct. "Here's a system that takes sewage and produces clean water and energy. It looks like a real option for municipalities, and it moves us in a sustainable direction, both economically and environmentally," Skerlos said.

In a related investigation he and colleagues are considering the environmental impacts of different disposal methods for unused pharmaceuticals: take back to the pharmacy, landfill disposal or flushing down the toilet. This study is the first to look at tradeoffs between water pollution from trash or toilet disposal and air pollution from driving unused pharmaceuticals back to the store and shipping them to incinerators.

Sustainable Development

A wide range of projects also are underway in the BLUELab (Better Living Using Engineering Laboratory), which Skerlos co-founded with students. The organization works to find sustainable solutions to development problems around the world. For instance, students have developed a biodigester that takes food scraps and animal waste and converts them into biogas for cooking and heating gas for rural areas of China, India and the Philippines. Also in progress is the implementation of a human-powered water pump to irrigate farmland in South America.

External funding for Skerlos' work comes from industrial and government sources, including the National Science Foundation, the Environmental Protection Agency and the Water Environment Research Foundation.

Alternative Propulsion Systems: Hybrid Vehicles are Changing the Transportation Landscape

Energy security and climate change concerns provide strong impetus for work on alternative propulsion systems. Pioneering work by the ME faculty has already shown that hybrid vehicle concepts can play a transformative role.

Current research programs, led by Research Professor **Zoran Filipi**, investigate solutions for both light passenger cars and heavy vehicles. A three-year program funded by Bosch-Rexroth and the Michigan 21st Century Jobs Fund is focused on hydraulic hybrid platforms for medium trucks. A new Center for Engineering Excellence through Hybrid Technology has recently been launched with a $1.34 million grant from the U.S. Environmental Protection Agency (EPA) to explore concepts for ultra-efficient small urban hybrid vehicles. In addition, Filipi is working with students and colleagues to shed light on the impact of plug-in hybrid electric cars on the electrical grid under real-world conditions.

Hybrid vehicles enable large efficiency improvements without sacrificing performance or utility. Key mechanisms for improving fuel economy include harvesting braking energy, optimizing engine operation and eliminating idling. Plug-in hybrid electric vehicles (PHEV) utilize energy from the power grid, thus displacing petroleum as a sole source of energy for transportation. However, one technology alone will not solve all problems. Rather, we need different concepts tailored for particular applications.

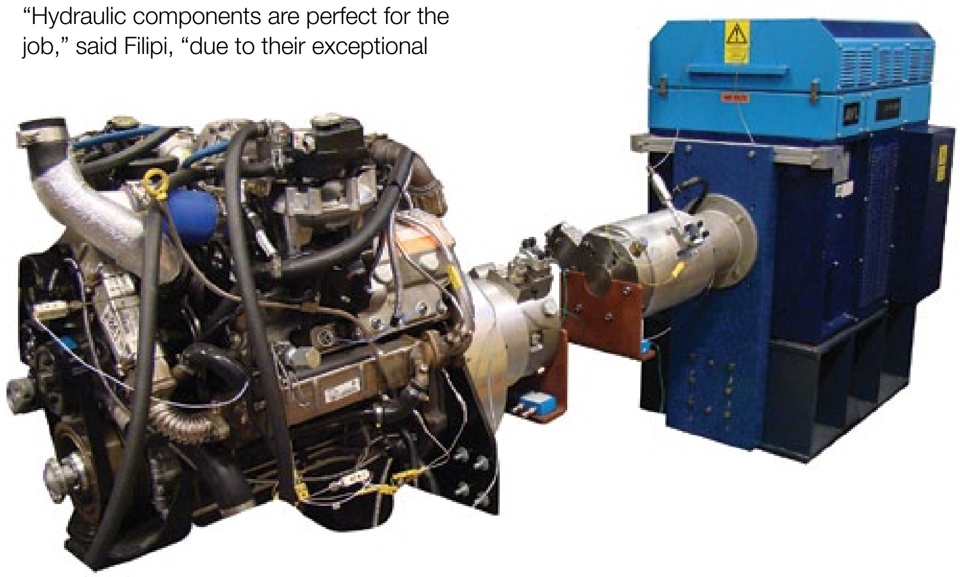
Hybrid Hydraulics for Trucks

Filipi is leading an ongoing $1.25 million research program focused on hydraulic hybrids for medium-duty vehicles, such as delivery vans, refuse trucks and school buses. These vehicles operate in urban areas and experience frequent stop-and-go. Energy flows through the system are huge due to large weight, so there are significant opportunities for regeneration.

"Hydraulic components are perfect for the job," said Filipi, "due to their exceptional power density and energy conversion efficiency. A hydraulic accumulator accepts charging at high rates—rates otherwise unattainable with batteries."

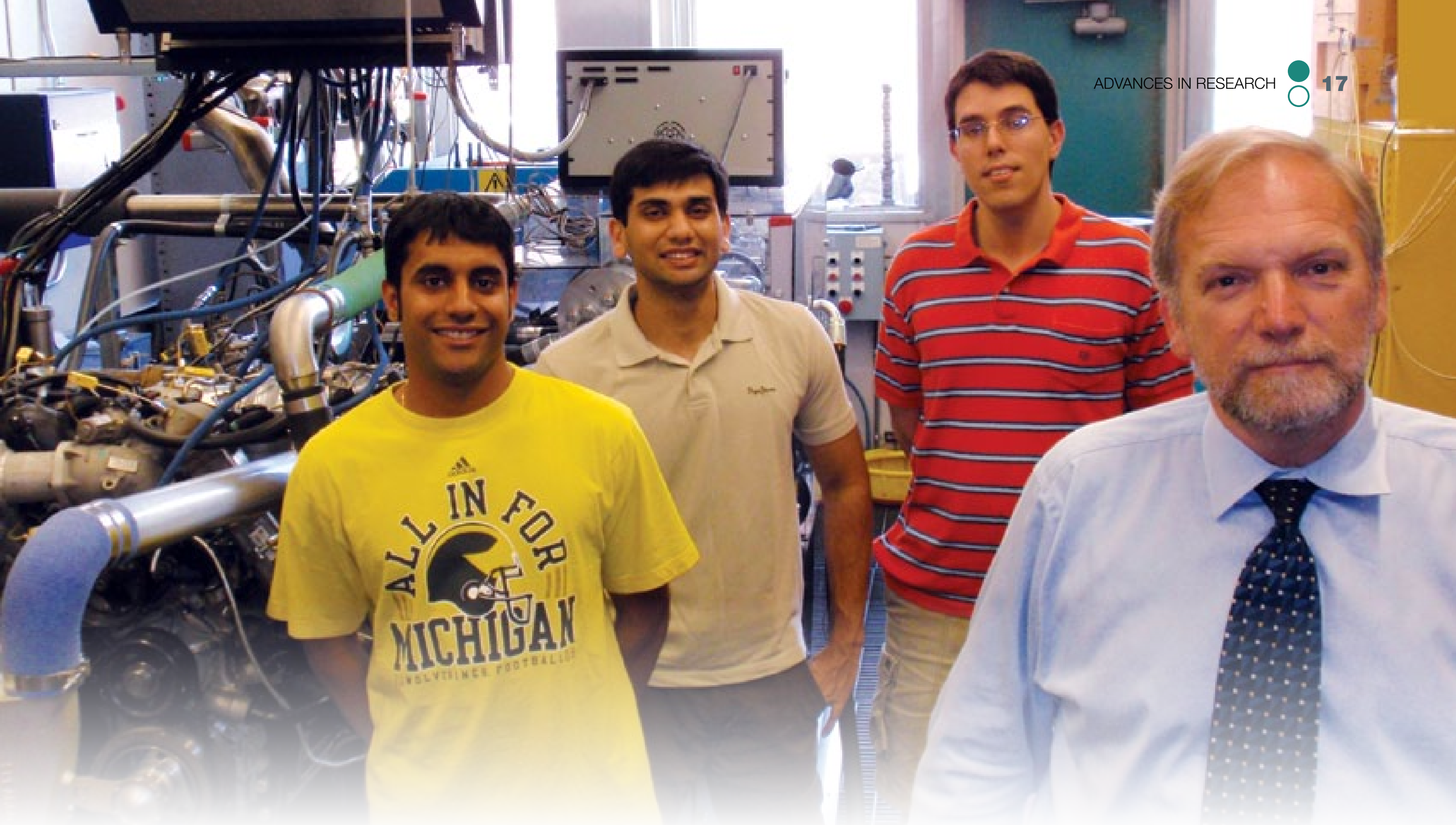
Work with industry partner Bosch-Rexroth has resulted in a prototype hydraulic hybrid system capable of improving fuel economy of a five-ton vehicle by 72 percent in city driving and cutting down the diesel soot emission by two thirds. A synergistic effort combines Bosch-Rexroth's innovative DigitalDisplacement™ hydraulic pump/motor technology and the ME team's pioneering effort on development of a powertrain-in-the-loop facility.

"Integrating the advanced diesel engine and hydraulics with a virtual vehicle simulated on a computer allows a physical system in the lab to function just as it would in a real vehicle," explained Filipi, "providing an in-depth look at combustion and emissions under transient conditions." The insights enable strategy optimization with novel neuro-dynamic programming techniques. The overall capability provides a unique way to transition results of basic research and accelerate commercialization.



ABOVE: **Packaging of the series hydraulic hybrid powertrain for a personal vehicle: three-cylinder diesel engine (red) is coupled to a hydraulic pump (green) to form a power-generation sub-system. Propulsion motor (green-behind the yellow bracket) is coupled to the transmission (gray) for optimized performance.**

RIGHT: **Hybrid propulsion system coupled to the advanced dynamometer in the W.E. Lay Automotive Laboratory and setup for testing in-the-loop with a virtual vehicle. Hydraulic pump is coupled to the diesel engine in the front, and a motor is connected to the dynamometer (painted blue).**



Ultra-Efficient Urban Vehicles

The strategic goals of the EPA include improving vehicle efficiency and reducing greenhouse gas emissions. Hybrid propulsion systems have been identified as a key technological area, and a Center for Engineering Excellence through Hybrid Technology was competitively awarded to the team led by Filipi in 2010.

"We started many years ago with exploratory projects," said Filipi, "and this new EPA grant allows us to go from basic research and analysis of concepts to design and fabrication of prototype vehicles." The Center will create outstanding opportunities for graduate students and foster a culture of innovation, he added.

Projects include ultra-high efficiency hydraulic hybrid propulsion for personal transportation, plug-in electric hybrid with hydraulic regeneration systems and high efficiency free-piston engine (FPE) with direct hydraulic power takeoff. The FPE concept provides unprecedented freedom in controlling combustion and a unique synergy with hydraulic hybrid propulsion.

Plug-In Hybrid Passenger Cars

Another effort focuses on optimal design of PHEVs and assessment of their impact on the power grid. PHEVs change the paradigm of personal transportation, but their large-scale introduction will depend on complex interdependence of consumer attitudes, markets, policy, technology and the power grid.

"When the U.S. Department of Energy initiated a multidisciplinary U-M effort, we decided to develop a simulation-based framework for determining tradeoffs between PHEV electric range and cost, rather than making *a priori* assumptions," said Filipi.

A critical missing piece was the understanding of real-world driving. "I was fortunate enough to learn about the Field Operational Tests of safety systems conducted by Research Professor Tim Gordon and his group at the U-M Transportation Research Institute (UMTRI). It became apparent that databases are a gold mine for vehicle energy studies," said Filipi.

The UMTRI data allowed a first glimpse into naturalistic driving. The new PHEV Pilot Program, funded by the Michigan Public Service Commission and DTE Energy, allows Filipi to extend the research with larger data sets, including information about vehicle departure and arrival times, to determine loads on power distribution networks.

The optimal PHEV design study was presented to a standing-room only audience at the Society of Automotive Engineers World Congress in April 2010.

"Integrating the advanced diesel engine and hydraulics with a virtual vehicle simulated on a computer allows a physical system in our lab to function just as it would in a real vehicle, providing an in-depth look at combustion and emissions under transient conditions."

ABOVE: **Hydraulic Hybrid System integration team, left to right: Ashwin Salvi, Rajit Johri, Fernando Tavares and Research Professor Zoran Filipi**

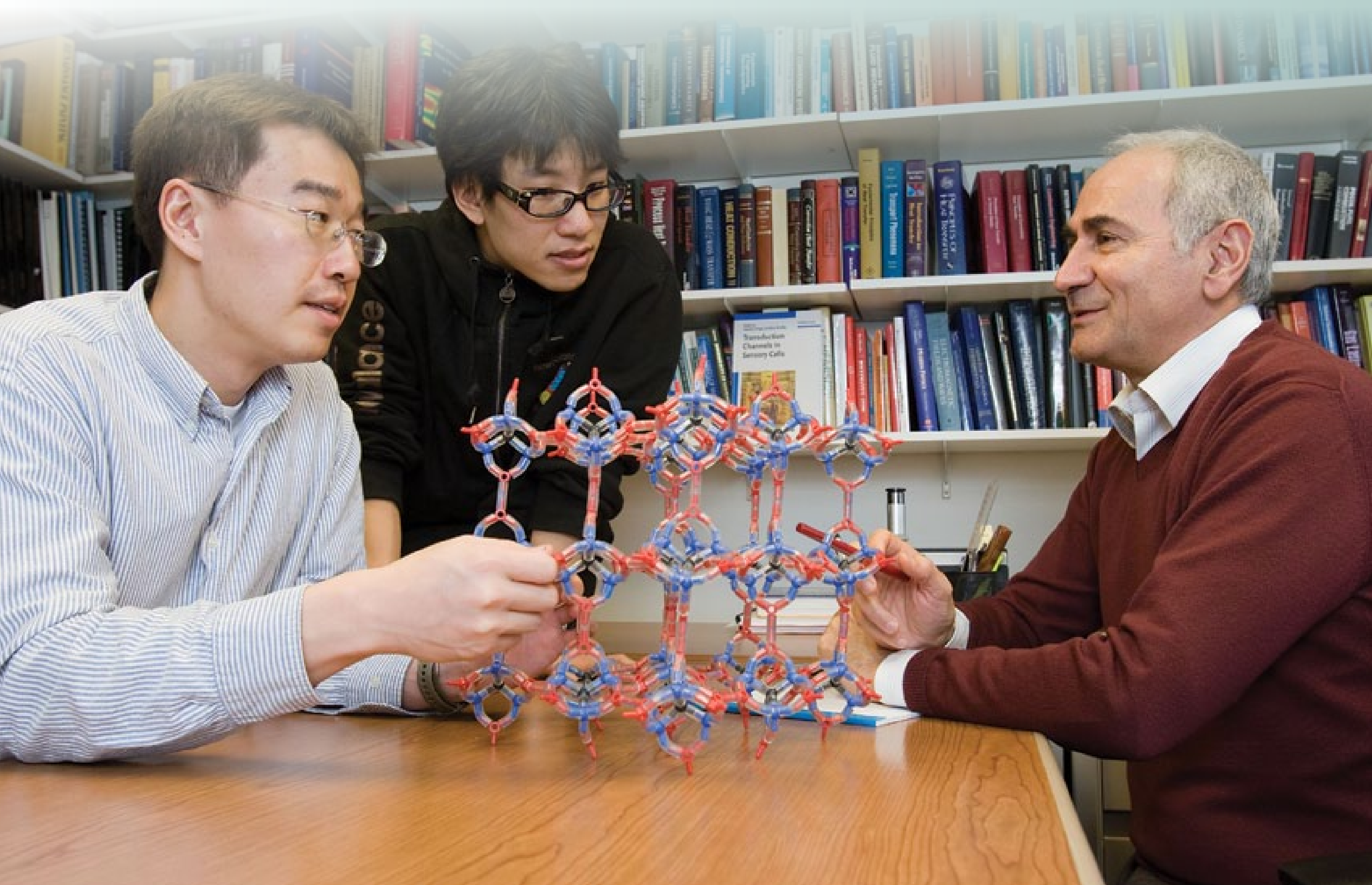
Heat Transfer Physics:
Recycling Atomic Vibrational Energy

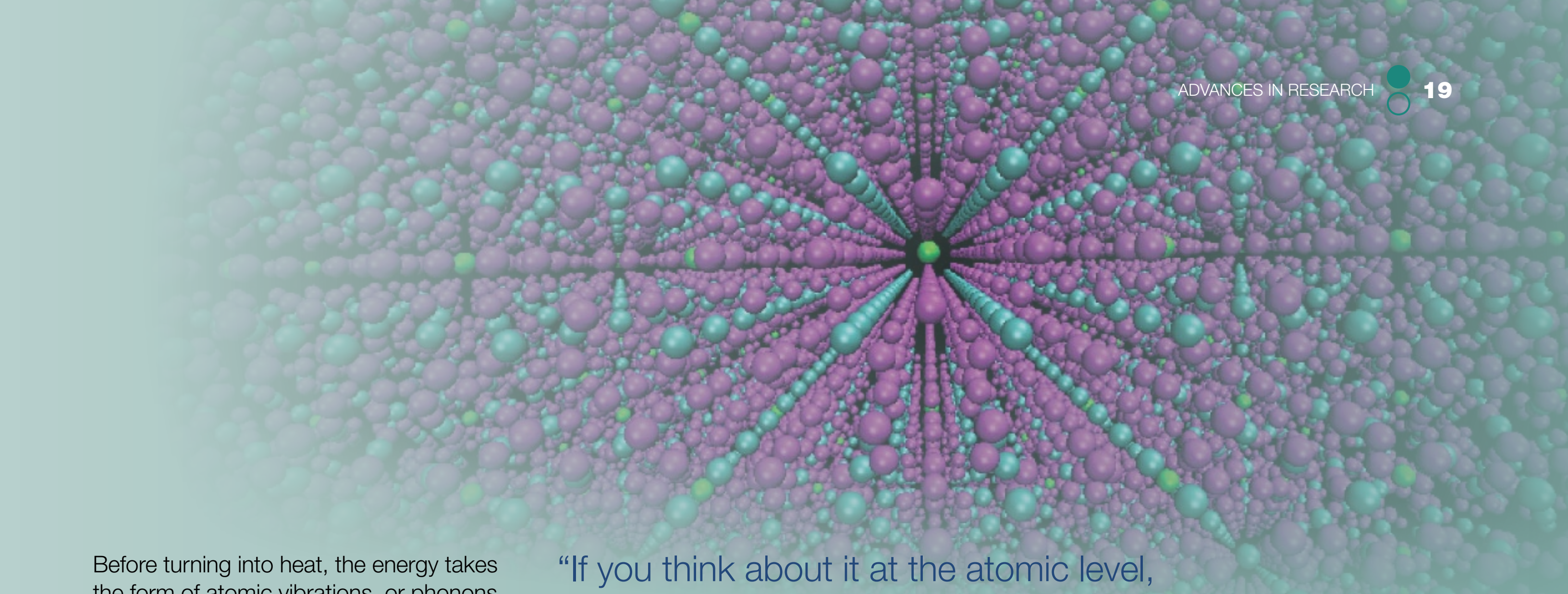
Innovative and efficient energy transport and conversion lay the foundation for novel and improved photonic devices, including lighting and high-power lasers. As applications increase in complexity, they require progressively more atomic tailoring of principal energy carriers—phonons, electrons, fluid particles and photons. Synthesizing materials from the atomic level on up—a molecular foundry, of sorts—can yield desired atomic-level energy kinetics.

Professor **Massoud Kaviany** directs the Heat Transfer Physics laboratory at U-M, which focuses on atomic structure design and material synthesis as well as optimization of carrier energy kinetics for improved energy-related functionality. When materials are improperly designed, inefficiencies in thermal energy—the kinetic energy of atomic-level motion in the solid and fluid phases—lead to undesirable heat generation, which is lost and wasted.

Kaviany uses the analogy of an automobile. "You have fuel that's turned into force and displacement and work, and the rest of that energy turns into heat, some of which is removed by coolant; the rest comes out as exhaust. Something similar happens at the atomic level," he explained. For example, not all of the electricity used for lasing or lighting, as in a light emitting diode or LED, goes into the resulting light; some of it turns into heat.

Currently high-power lasers require complicated mechanical cooling systems that impede the use of efficient, portable systems. Radiation-balanced laser systems can offer alternatives to mechanical cooling, but these systems present new challenges themselves.





Before turning into heat, the energy takes the form of atomic vibrations, or phonons, which are the smallest unit of vibrational or acoustic energy. These phonons have particular frequencies, or resonances, and they can be recycled and put to work in special processes designed to use them. Doing so requires extremely fast—on the order of picoseconds—and nanometer-scale encounters with them.

Kaviany's group performs theoretical atomic-level examinations and shows that initially this thermal energy has quantum features and that the energy can be recycled and used in processing. This absorbs phonons, called the anti-Stokes processes, before it is rendered less useful by being distributed among other vibration modes. The phonons remain and raise the temperature during processing, although this energy is not as useful as the initial resonance energy.

In work published in *Applied Physics Letters*, Kaviany and doctoral student Jedo Kim laid the theoretical groundwork and predicted that 30 percent of emitted phonons can be recycled and that even further recycling may be possible, depending on the atomic properties of the dopant and host.

Recycling energy, particularly phonons, in ion-doped lasers is novel and fundamental. Phonon recycling through anti-Stokes cooling leads to lower operating temperatures. Although more work remains, Kaviany's findings may one day open the door for new high-power lasers that don't require complex cooling systems. "If you think about it at the atomic level," said Kaviany, "what we found can allow us to design nanostructures and to develop interaction kinetics that use thermal motion *before* it turns into heat."

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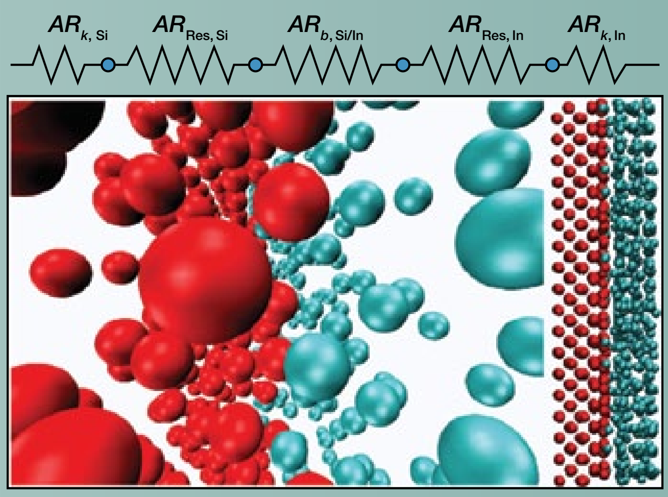
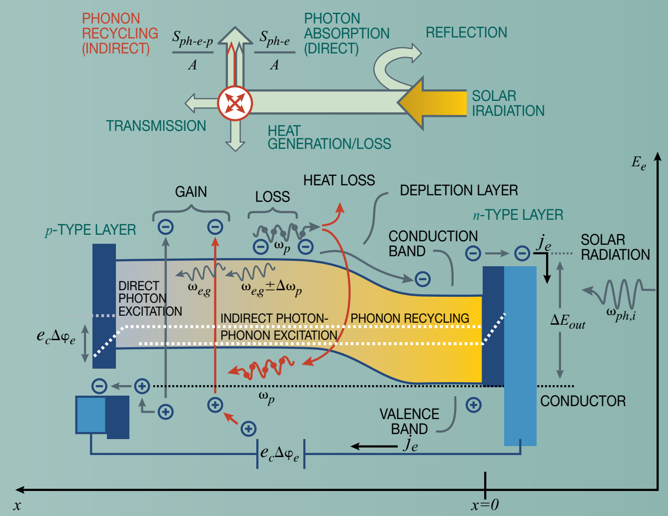




BACKGROUND IMAGE: **Nonground atomic structure high thermoelectric (TE) performance of Ba (green) filled (CoSb3)4. Phonon conductivity reduction by fillers, etc., is key to new TE materials.**

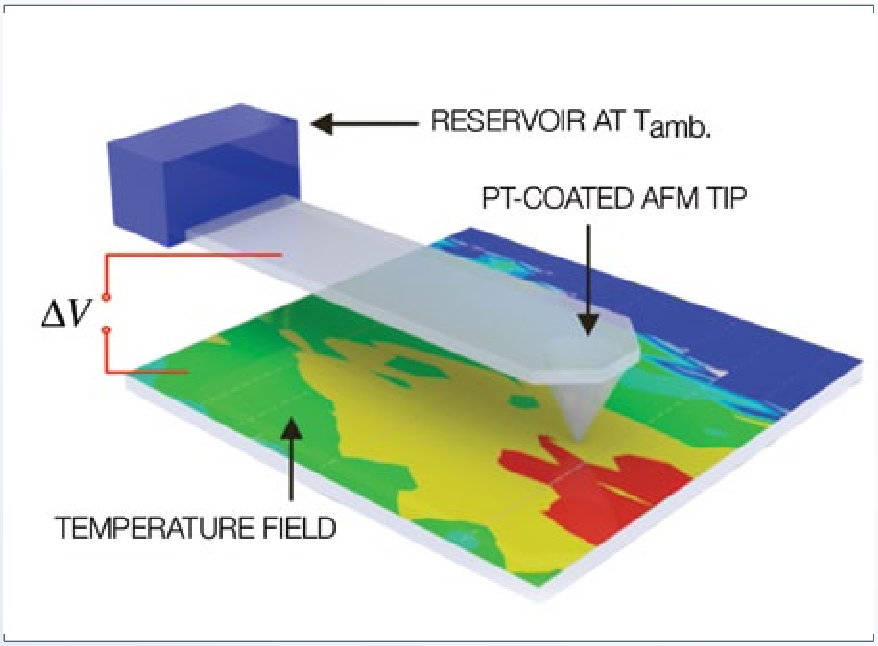
TOP LEFT: **Interfaces of hard and soft solids (Si and In are shown) are restructured and this affects the interfacial heat transfer.**

LEFT: **Phonons are emitted as inefficiency of photon-electron energy conversion (such as lasers and photovoltaic), and phonon recycling aims at higher efficiencies.**

OPPOSITE PAGE: **Professor Massoud Kaviany (right) with students Gisuk Hwang (far left) and Seungha Shin.**

PHOTO: MARTIN VLOET, U-M PHOTO SERVICES

Probing Nanoscale Energy Phenomena



Reddy's new scanning tunneling microscope combines an ultra-high vacuum scanning probe with an ultra-sensitive micro device that can resolve heat currents as small as one picowatt.

ABOVE AND OPPOSITE PAGE: **Schematic view of the nanoscale point contact thermocouple setup used to determine the temperature of metallic surfaces with nanometer resolution.**

Probing temperature and understanding charge and energy transport at the nanoscale are essential to building novel energy conversion devices. Assistant Professor **Pramod Sangi Reddy** has been investigating these nanoscale transport phenomena and developing techniques to better understand them. Ultimately, his work will enable the design and development of efficient solid state energy conversion devices, such as power generators and refrigerators.

Temperature measurements help characterize some of the novel thermal transport and energy dissipation phenomena, particularly in nanoelectronic and nanophotonic devices. Atomic force microscopy (AFM) techniques have been used in the past to determine temperature, but they have limitations.

"AFM techniques to date require one to micro- or nanofabricate special probes. In some cases you also need to have a high vacuum environment, both of which are impractical and add time and cost to experiments," explained Reddy.

Reddy and his research group have developed a technique that overcomes these constraints and is capable of mapping thermal fields with less than 100 nanometer spatial resolution and approximately 10 milli-kelvin temperature resolution. Their technique makes it possible to take a direct measurement of the temperature field of a metallic surface at ambient conditions without using specially fabricated scanning temperature probes. The work was funded by the U.S. Department of Energy through U-M's Energy Frontier Research Center.

"Given the simplicity and elegance of this technique, we believe it will be useful to many researchers around the world in a variety of important studies of nanoscale energy transport and dissipation in nanoelectric devices," said Reddy.

A simultaneous focus of inquiry for Reddy and his research team is experimental work on heat and charge transport properties in metal-molecule-metal junctions (MMMJs). Due to the close confinement of phonons and electrons, novel heat transport phenomena would be expected to occur in nanometer-sized MMMJs. Theoretical studies predict novel effects in the MMMJs, such as a change in heat flow or phonon-filtering.

"But in spite of their technological importance, these predictions remain largely untested," said Reddy. "Principally, this is due to a lack of tools to directly probe transport in MMMJs," he added.

In order to better understand the electronic structure, thermoelectric properties and heat transport properties of molecular junctions, Reddy is developing a novel ultra-stable scanning tunneling microscope. The new device will enable study of transport properties of single molecule junctions, something that has not been possible before.

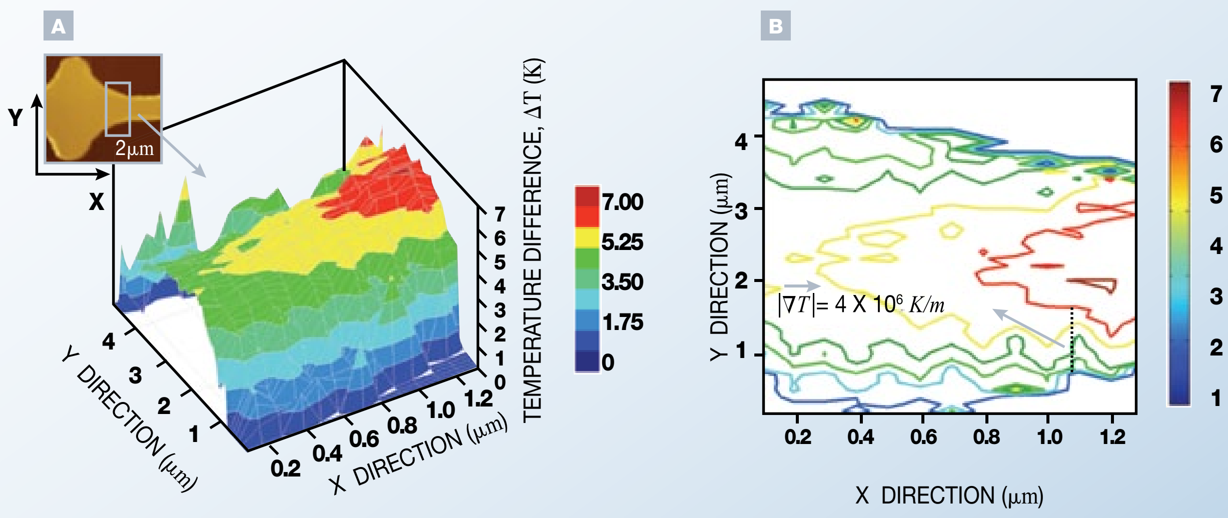
The MMMJs are formed by trapping either a single organic molecule or multiple organic molecules between two metal electrodes. The resulting junctions have already attracted attention from other investigators, due to the junctions' promise as molecular electronic devices. "The MMMJs also have significant but yet unexplored potential for the development of inexpensive and efficient thermoelectric devices," Reddy said.

He and his team have taken preliminary steps toward measuring the novel effects in MMMJs. In work that was published in *Science* in 2007, Reddy helped develop techniques to apply temperature differentials across MMMJs in order to study thermoelectric effects. Still, measuring heat transport in MMMJs has remained largely impossible until now. His new scanning tunneling microscope combines an ultra-high vacuum scanning probe with an ultra-sensitive micro device that can resolve heat currents as small as one picowatt. Using this technique, the research team will be able to conduct experiments on a variety of single and multiple molecule junctions in entirely new ways.

"The relationship between the structure of the MMMJ and its thermal conductance will be revealed for the first time ever," said Reddy. "The new microscope also will allow us to look at the effect of structure on the electrical conductance and thermopower of MMMJs." The ongoing project was funded through a CAREER Award from the National Science Foundation as well as an award from the U.S. Department of Energy.

The knowledge of transport properties in nanostructures has tremendous potential to create inexpensive solid state energy conversion devices, Reddy explained. "These organic-based devices could possibly revolutionize the field of thermoelectrics."

"Given the simplicity and elegance of this technique, we believe it will be useful to many researchers around the world in a variety of important studies of nanoscale energy transport and dissipation in nanoelectric devices."



Environmental Nanoparticles:
From Combustion to Human Health Effects

The combustion process is the dominant pathway through which mankind continuously injects particulate matter into the atmosphere. Experiments have shown that nanoparticles that form as a result of combustion are quite prevalent and stabilize a remarkably large number of radical sites on their surfaces. The high concentration of radical sites and small particle size suggest serious health implications when inhaled.

"Nanoparticles are of a scale and chemical composition to be at home in many biomolecular environments, and they share characteristics with key biological molecules such as lipids and proteins," explained Associate Professor **Angela Violi**, who heads the Multiscale Computational Nanoscience Group.

Violi works to understand nanoparticle formation processes and human health effects in order to develop novel control strategies. Her work on multiscale processes in reactive systems crosscuts numerous fields and disciplines, from combustion to nanoscience and biology.

The formation of nanoparticles from various fuels is a multiscale process in which the time scale of gas-phase chemistry bridges the physical and chemical time and length scales of particle formation and the further agglomeration that eventually leads to soot.

"It's a fascinating process that requires a multiscale computational approach to understand the atomistic interactions underlying nanoparticle formation and growth in various environments," said Violi. She has pioneered the use of kinetic Monte Carlo and molecular dynamics methods to bridge time scales in the growth of carbon nanocluster systems from various fuels, preserving the chemical and physical aspects of the processes.

ABOVE: **Example of combustion-generated nanoparticle produced with a novel multiscale computational approach.**

Violi's advanced modeling methods provide new analytical tools to the scientific community. Her work has been widely published and recognized by the combustion community as exceptionally original. Her last paper was recently highlighted by the *Journal of Chemical Physics*.

Violi's work also is important to alternative energy. She uses *ab initio* electronic structure calculations to understand the reactions of biofuels in combustion environments and what emissions they produce.

As novel fuels from different feedstocks are developed, scientists, public health officials and regulators will need assessment methodologies for the particles formed during combustion.

Modern diesel engines are a major source of these combustion-generated nanoparticles. Although the total mass of particulate emissions has been significantly reduced with improved combustion efficiency and emissions control systems, nanoparticles are exceedingly difficult to control.

Environmental regulations of diesel engines and other combustion sources based on particle mass or volume, instead of particle number, miss the dangerous nanoparticle component of such emissions.

Violi's work also explores the interactions of carbon-based nanoparticles, both from combustion and synthetic sources, with biomolecular structures representative of those at the cellular scale. Ultrafine particles have been shown to act on biological systems. Deposition on epithelial cells in the lungs triggers a number of responses: inflammation, blood clotting and changes in breathing and heart rate control.

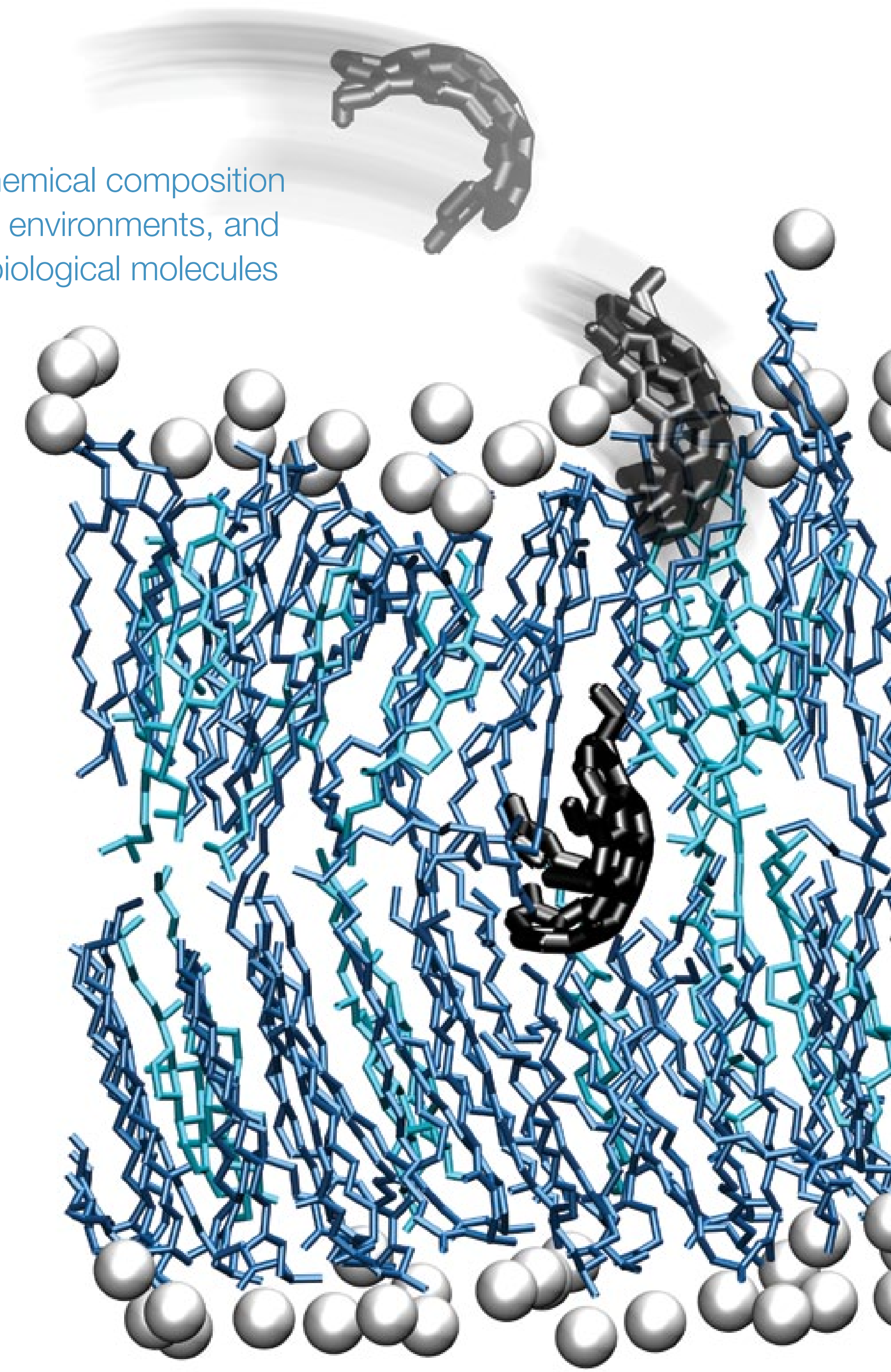
Using multiscale computational methods, her research team looks at the cytotoxicity of nanoparticles embedded in cellular membranes through inhalation, for example. These nanoparticles can disrupt the dynamics of cells' transmembrane metabolic and signaling proteins. The resulting abnormal physiology may be an important factor in the etiology of many medical conditions, including tumor growth.

To address concerns from the public about environmental risk assessments, a call for standardization of nanoparticle toxicity measurement techniques is necessary. To this end, an international regulatory consortium, including the U.S.

"Nanoparticles are of a scale and chemical composition to be at home in many biomolecular environments, and they share characteristics with key biological molecules such as lipids and proteins."

Environmental Protection Agency, has specified a set of prototypical nanomaterials for toxicological testing, of which carbonaceous molecules are represented by C_{60} and nanotube-shaped molecules.

Violi's group recently looked at the interactions of C_{60} and combustion-generated nanoparticles of similar size to understand their effects on biological membranes. Using molecular dynamics simulations, she found significant variance and sensitivity of the permeability coefficients based on particle morphology. Her work, forthcoming in *Biophysical Journal,* indicates that C_{60} alone may not adequately represent similarly sized combustion-generated nanoparticles with respect to toxicity assessments, and she suggests that a broader spectrum of particle parameters, in addition to size, needs to be included to correctly assess the associated health risks.



RIGHT: **Snapshots from molecular dynamics simulations of a nanoparticle entering a lipid membrane, one of the main components of a cell.**

Exploring Defects: Using Quantum Mechanics to Predict Material Behavior

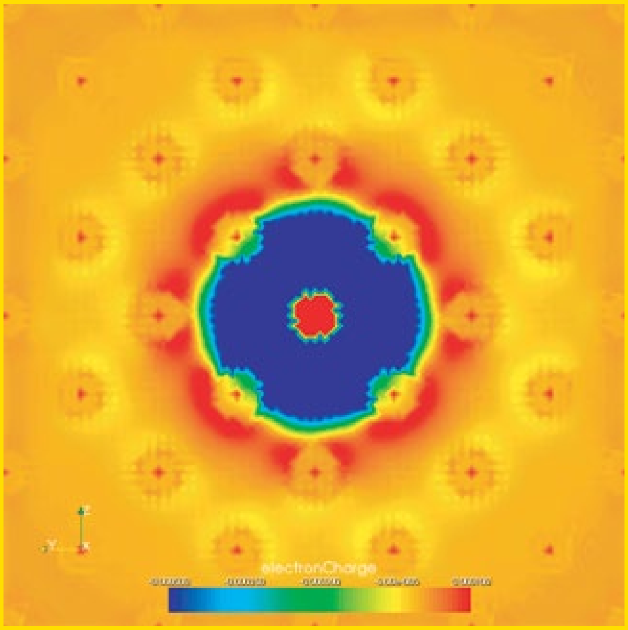
The properties and functionalities of materials can advance technologies in many fields, from transportation and manufacturing to energy and defense. Novel materials with enhanced properties can improve energy efficiency and safety and durability, expand functionality and reduce cost and environmental impact. Increasingly investigators are using computational modeling and simulations in order to better understand the properties and behavior of materials and to develop new materials with specific functionalities. But the success of computational modeling and simulations is dependent upon the predictive nature and accuracy of the materials theories used.

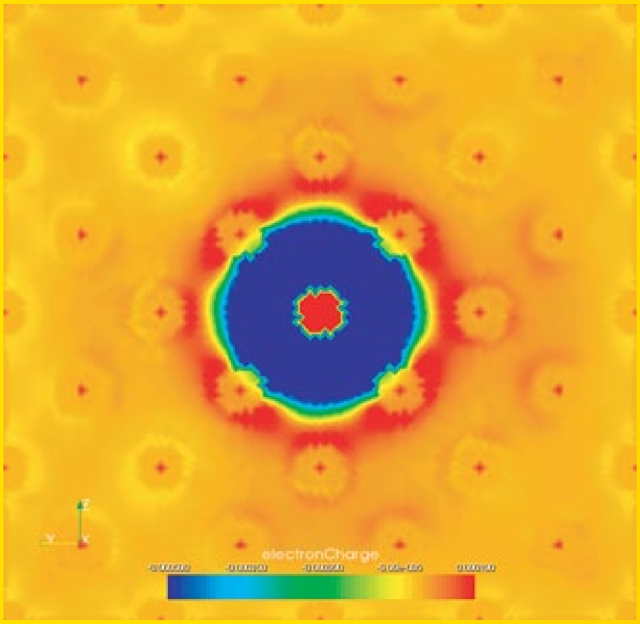
"For a theory to be predictive, it must include fundamental physics with as little empiricism as possible," explained **Vikram Gavini**, assistant professor. "The electronic structure theories that are currently available to us today describe materials properties from a quantum-mechanical perspective and therefore are predictive," he added, "but their complexity makes computations restrictive, and they are often applicable only to small systems with a few hundred atoms."

Since most materials properties are influenced by various defects, such as vacancies, dopants, dislocations as well as cracks, scientists must be able to glean an accurate understanding of both the quantum-mechanical interactions at the defect core as well as the long-ranged elastic effects on the continuum, or macro, scale. This has been a long-standing challenge in materials science—to bridge length scales from quantum mechanics to the macro level in a seamless way. Doing so using only quantum mechanics requires the ability to perform electronic structure calculations on multimillion-atom systems.

Gavini continues to develop novel mathematical and computational techniques to perform electronic structure calculations at macroscopic scales, thereby bridging the quantum-mechanical and macroscale mechanics chasm. His research group's work incorporates several approaches: developing real-space formulation for electronic structure theories, finite element discretization of field equations, and coarse-graining using adaptive numerical techniques. Combining these theories and techniques has made electronic structure calculations in multimillion-atom systems possible for the first time ever. His work represents a significant breakthrough in the computational sciences.

"We believe we are paving the way for the first complete and accurate quantum-mechanical description of defects in materials," he said. "What people have missed in the past is to simultaneously account for both the nature of chemical bonding, governed by quantum mechanical interactions, at the core of a defect as well as the long-ranged elastic effects, both of which significantly influence the behavior of defects," he said. In particular, his work has demonstrated that the physics on these





vastly different length scales are inherently coupled and have a distinct effect on the material behavior mediated through defects.

Now Gavini and his team are further refining the techniques he developed and use them to study different phenomena arising from defect interactions. For instance, the group is looking at the effect of radiation on metals, including the embrittlement that can result when metals are irradiated. Using his computational techniques, he is looking at the nucleation, growth and migration of prismatic dislocation loops, or line defects in materials, which scientists believe contribute to the loss of fracture toughness.

Recent results show that prismatic dislocation loops may be formed as a result of the collapse of a cluster of vacancies, or missing atoms, and that loops as small as those formed from seven vacancies are stable. The nucleation size of these defects was not previously known. Now he is working to quantify the effect of prismatic loops on material fracture toughness, which is necessary in order to develop radiation-resistant materials for next-generation nuclear reactors.

Gavini also is investigating how materials fail under shock loading, for instance during an automobile crash. Results from his work show that vacancies spontaneously nucleate under shock loading, which further coalesce into voids and lead to material failure. Quantum-mechanical interactions, which have been neglected in the study of defects until now, are proving critical to understanding the behavior of defects in materials undergoing shock loading.

Gavini's work not only explores how defects lead to material failure but also how mechanical strength of materials can be improved. Experimental investigations by other scientists have shown that the yield strength of a nanostructure increases by a factor of between 50 and 100 compared with a bulk material. Yet materials that are too small become soft due to nucleation of surface defects. "There is a critical size where the paradigm of "smaller is stronger" breaks down. We're interested in determining this critical size and estimating the maximum achievable strength of materials by controlling feature size," he said.

Extending the techniques already developed to more sophisticated electronic structure theories that can accurately predict the properties of a wide range of materials also is a priority. "This will enable us to look at all length scales simultaneously and to study any material without being restricted by the material system," Gavini said. "We can also study material properties beyond just mechanical properties, such as electronic, magnetic, thermoelectric and optical, which is crucial to the development of multifunctional materials."

Gavini's work is funded by the National Science Foundation, the Air Force Office of Scientific Research and the Army Research Office.

OPPOSITE: **Contours of electron-density perturbation around a vacancy, depicting the core of a vacancy, with no imposed volumetric strain (left) and 0.3 volumetric strain (right) computed from large scale electronic structure calculations. These contours are plotted with a reduced range from -0.0005(blue) to 0.0001(red) to highlight the changing features in the electronic structure with volumetric strain. The little red dots denote the positions of atoms. These contours are a qualitative demonstration of the significant influence of macroscopic deformations on the nature of defect-core. With increasing volumetric deformation, we find the defect-core shrinks and becomes anisotropic. Quantitatively, we find the defect core-energy to be significantly influenced by macroscopic deformations, and this dependence is found to alter the nucleation and kinetics of vacancies.**

"We believe we are paving the way for the first complete and accurate quantum-mechanical description of defects in materials."

From Atom to Application:
Exploring Laser-Material Interactions

Lasers increasingly are being used in many fields, from manufacturing and material processing to biomedical device development. The work of **Jyotirmoy Mazumder,** the Robert H. Lurie Professor of Mechanical Engineering, spans “atom to application,” he explained. Mazumder looks for “socially relevant, day-to-day problems” and explores novel laser-based tools, techniques, mathematical models for laser-material interaction, control strategies and applications to solve them.

Mazumder’s research approach involves atomic level understanding through spectroscopic measurement of laser-induced plasma to measure electron behavior, including temperature and density. This serves as input for mathematical models of laser-materials interaction, which provide the quantitative relationship between lasers and materials. Armed with this fundamental information, he ventures into various applications starting from laser machining of micro-channels for artificial lungs to fabrication of functional engineering components straight from “art (or CAD, computer-aided design) to part.”

One of Mazumder’s major foci over the past three decades has been to “solve the puzzle of laser-induced plasma: what’s within the plasma and what’s underneath shrouded by plasma,” he explained. Doing so is yielding new insights. Plasma is created when a high intensity laser hits a material and atoms break down. Plasma is essentially a collection of electrically charged particles. Mazumder is developing new ways to analyze laser-generated plasmas to improve manufacturing processes since plasma clouds hamper visibility.

“Instead of working with plasma as if it were the enemy—an unwanted consequence—I try to work with it as a friend,” he said.

Mazumder has developed and patented a technique to see through the plasma using another laser with a different wavelength and by monitoring the reflected beam to study the meltpool hidden under the plasma. By looking at electron density, specific line strength and relative strength and applying statistical techniques and atomic calculations, Mazumder and his students found signatures of defects such as blow holes, porosity, under cut and bead separation within 20 milliseconds during the welding process. Several manufacturers have expressed interest in a field trial, which will take place in summer 2010.

Mazumder also enlists the plasma characterization to determine the microstructure of materials during fabrication. His team discovered a strong correlation between relative line intensity and phase transformation to form new phases. He recently demonstrated the predictive quality of plasmas in three alloys: titanium-iron, nickel-aluminum and nickel-titanium. When any material solidifies or goes through certain thermal cycles, its crystal structure changes based on the composition and thermal history. That also changes the properties of the materials and thus its service performance.

Currently no method exists to determine the microstructure during fabrication; instead materials scientists conduct *postmortem* analyses once the material has solidified by using a labor-intensive process of mounting, polishing, etching and microscopic examination. Then post-processing is necessary to build a microstructure that possesses the desired properties. By contrast, *in situ* phase identification during fabrication has the potential to improve current methods of material processing and synthesis. The University has applied for a patent for this *in situ* technology.

“Now you don’t have to go to a microscope,” explained Mazumder. “Just by looking at the plasma, you can tell what to expect from the microstructure.”

Both the technique and the optical sensor that enable spectroscopic analysis of plasma during laser cladding and alloying and welding are among the first in the world. “We know we can save industry an enormous amount of time and money now spent analyzing materials’ microstructure; for scientists, we can help them create novel materials with the desired microstructure, which opens up a lot of possibilities,” Mazumder said.

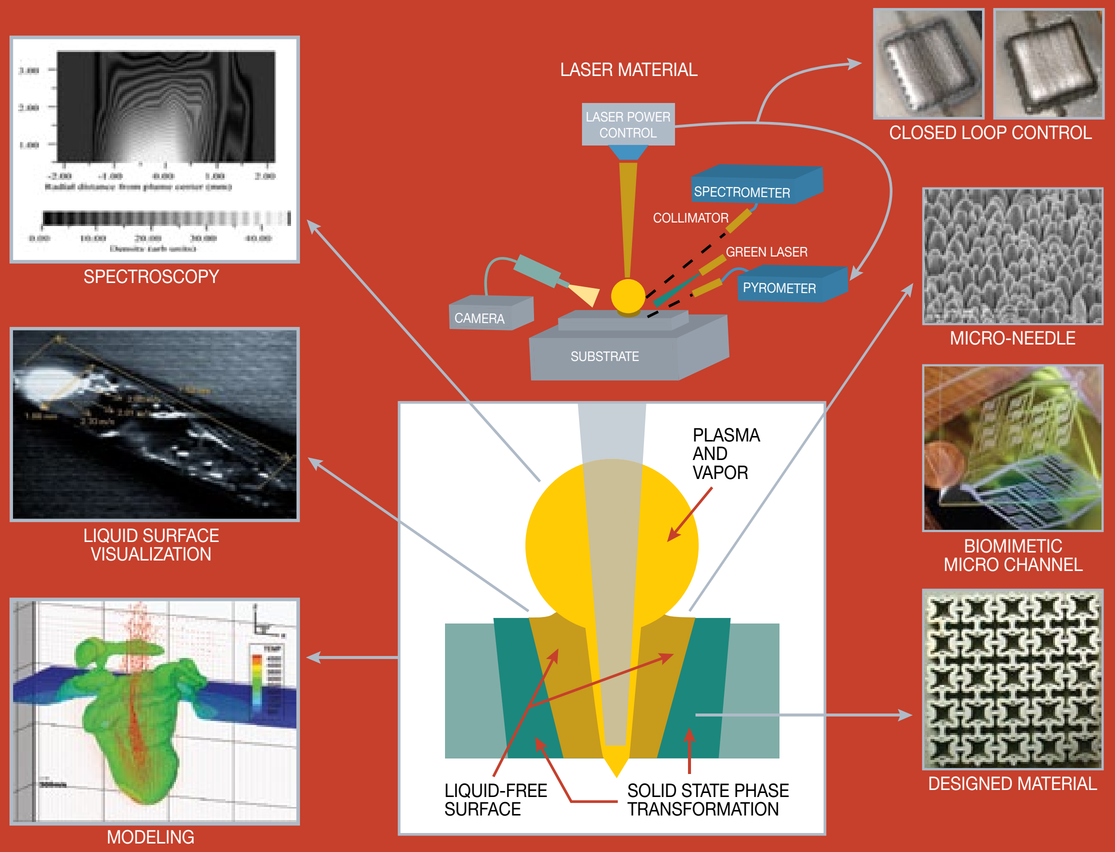
Mazumder also has been working on developing three-dimensional self-consistent mathematical models to describe various laser processing techniques to develop quantitative relationships between lasers and materials. His recent effort involves modeling of laser cutting of electrodes for lithium-ion batteries.

Using information from the light associated with laser processing, Mazumder also has developed and patented a closed loop technology to fabricate near-net shape functional parts by melting powder with lasers. Machines based on his technology are used in America, Asia, Australia and Europe.

Working with colleagues in the U-M Medical School, Mazumder is collaborating on an artificial lung. He is using lasers to micromachine the biomimetic vascular networks on a silicon chip, which is then used as a mold to make 10-micrometer-wide micro-channels on PDMS, a biocompatible polymer, for artificial lung models.

“Vascular networks bifurcate following a distinct mathematical relationship, and laser allows us to mimic that relationship and create the channel in three dimensions,” he said.

"Now you don't have to go to a microscope. Just by looking at the plasma, you can tell what to expect from the microstructure."



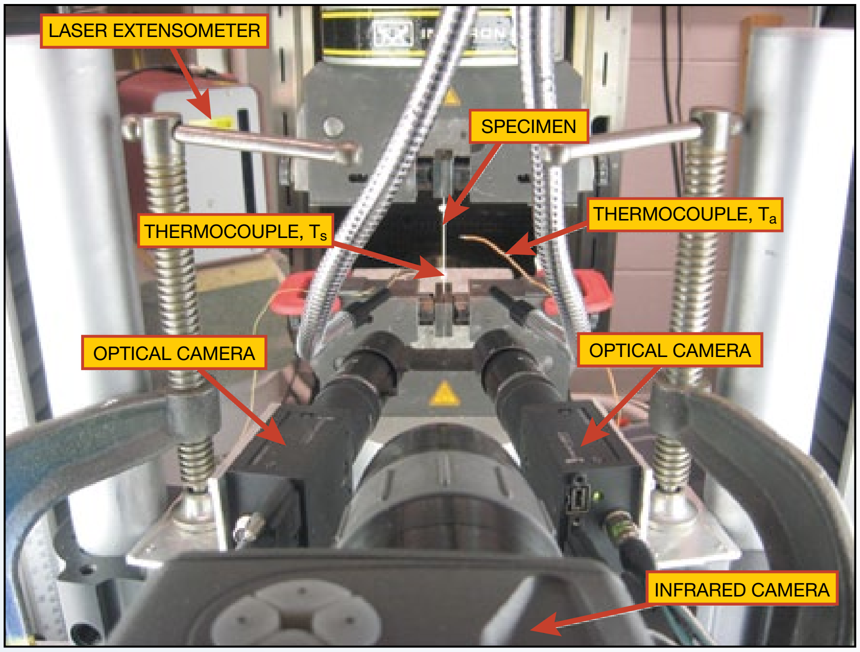
Shape Memory Alloys: Seeing the Forest *and* the Trees

Exploring the relationships between the microstructure of materials and their macroscale properties is critical to predicting the behavior of structural materials such as metals and ceramics. Assistant Professor **Samantha Daly** and the research team in her Active Materials and Mechanics Laboratory (AMML) work at the intersection of mechanics and materials science to explore these relationships at multiple length scales. She is particularly interested in phase transformations in active materials, and her team uses novel experimental methods coupled with theoretical and computational modeling in order to better understand the mechanics of how these materials deform, fatigue and fracture.

"Virtually every material is made up of different structures at different length scales," explained Daly, "and we need to understand the connections between length scales, from the atomistic to the macroscale, in order to accurately predict and control material behavior."

Daly recently was awarded a five-year grant from the U.S. Department of Energy that will support her research on shape memory alloys (SMAs), specifically solid-to-solid phase transformations in a nickel-titanium (NiTi) alloy (see related story on page 6). The NiTi alloy is superelastic, meaning it can recover from large amounts of deformation. This property results from an atomistic phase transformation from a cubic atomic lattice structure to a monoclinic structure, similar to a three-dimensional parallelogram. The superelasticity of NiTi makes it extremely useful in numerous applications, including MEMS and biomedical devices such as catheters and stents.

But phase transformation also can result in regions of localized deformation in the material that are "quite complex in nature," Daly noted. Despite the widespread use of NiTi, scientists don't yet have a detailed understanding of how this atomic rearrangement

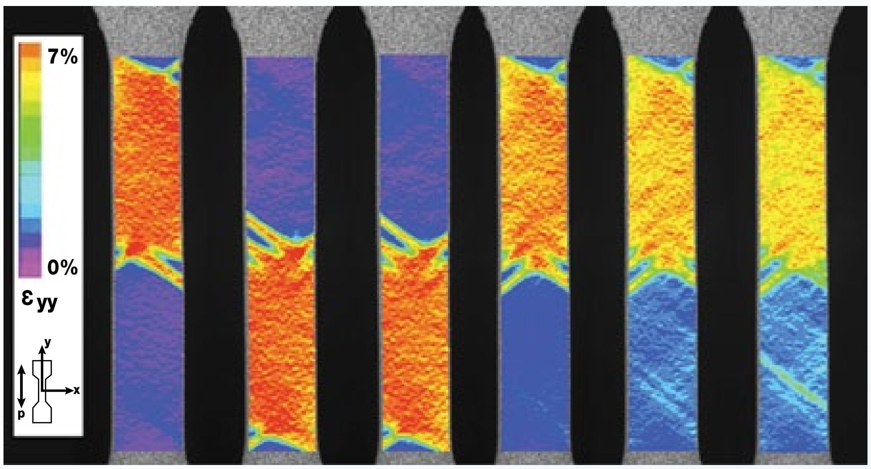


affects deformation and fatigue behavior. Daly is changing that with her research, which includes some of the first quantitative full-field maps of phase transformation in NiTi.

Daly's team simultaneously uses synchrotron radiation, a type of high-energy, electromagnetic radiation, to examine atomic lattice statistics, and two high-resolution cameras to image the localized deformation over the surface of the specimen. The cameras take simultaneous images from different angles of a NiTi specimen that is covered with thousands of random tracking dots. Daly's group uses various techniques to apply these dots depending on the length scale of interest, ranging from a type of spray paint at larger length scales to platinum markers deposited with a focused ion beam at microscopic-length scales. By measuring how those dots move and deform in relation to one another when the NiTi sample is strained, the Daly group creates three-dimensional quantitative maps of deformation on the surface of the sample. These and other experimental techniques provide insight into the mechanical underpinnings of phase transformation in NiTi.

Daly and her team have been able to see a strong pattern memory in the way the phase transformation nucleates and propagates from cycle to cycle during fatigue testing. This pattern memory persists with surprisingly high fidelity, which suggests that fatigue behavior can be strongly controlled by tailoring the initial microstructure.

"Seeing how these phases are retained in the granular structure of the material from cycle to cycle is an interesting and exciting discovery from a fundamental scientific viewpoint," she said. "Looking at the macroscopic information like the load-displacement curve, along with other information such as lattice statistics obtained from synchrotron radiation, gives us a coherent



"Looking at the macroscopic information like the load-displacement curve, along with other information such as lattice statistics obtained from synchrotron radiation, gives us a coherent picture of what's actually going on across multiple length scales."

picture of what's actually going on across multiple length scales."

In addition to the U.S. Department of Energy, funding for Daly's research efforts comes from the National Science Foundation, General Motors and U-M. Moving forward, the Daly group will continue to examine local damage nucleation and propagation in metals and composites at the micro-scale and to explore multiple length scales simultaneously. The Daly group currently collaborates with Professor John Shaw of the U-M Aerospace Engineering department on studies of SMA hierarchical structures and with Professor J. Wayne Jones of the U-M Materials Science and Engineering department on ultrasonic high-cycle fatigue studies.

Identifying the links and relationships among properties, structure and behavior at multiple length scales is the common thread running through Daly's work. "Sometimes you can look at trees and not see the forest," she said. "We want to look at the forest and the trees and see it all at once—the leaves, branches, everything. You have to tie all of the length scales together, from extremely small scales to macroscopic behavior, in order to really understand the entire picture."

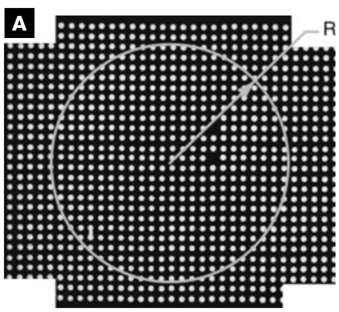
ABOVE: **Pattern memory during repeated cycling of a nickel-titanium sample where strain fields are mapped in the middle of transformation during cycles 1, 2, 5, 10, 25, and 50. Red is indicative of the monoclinic lattice phase ("martensite"); blue is indicative of the cubic lattice phase ("austenite").**

OPPOSITE PAGE: **A typical experimental setup. Here, two optical cameras are used to track random markers and calculate 3-D deformation fields. A laser extensometer is used to track displacement on the ends of the specimen. Infrared imaging and thermocouples are used to map temperature variations.**

Epoxy Curing: New Models for New Materials

Sophisticated, lightweight composite materials for aerospace, automotive and many other applications increasingly are being sought by industry and the military for the materials' improved performance, lower cost and improved energy efficiency over earlier-generation composites.

Professor **Alan Wineman**, who has spent much of his distinguished career developing mathematical models of the microstructural changes in rubber and polymers, more recently has been exploring the optimization of these materials, specifically the curing of epoxy within the interstices of braided carbon fiber textile composites. The models he is creating of the curing process will help optimize material performance.



An initially flat sample (A) **was pressurized by glycerine at 125°C for 25 hours** (B)**. The glycerine was removed and the membrane was cooled to room temperature** (C)**. The membrane developed a permanent set. This is explained by a process consisting of the scission of macromolecules and crosslinking in the current.**

Modern methods for manufacturing composite structural components start with a woven sheet of carbon fibers, or glass, in a mold. Liquid epoxy resin mixed with hardener is drawn into the mold and heated so that the epoxy cures in place.

"The process is complicated," said Wineman. "The chemistry of curing involves time dependent exothermic reactions and contractions due to curing as well as thermal expansion—you have complicated interactions among many different processes."

Using ideas developed in his earlier elastomeric work, he is developing mathematical models to predict the evolution and distribution of stresses, deformation and material properties in the epoxy matrix as a result of curing and the presence—and characteristics—of the woven fiber sheet. With respect to the woven sheet, geometry, fiber architecture, thickness and arrangement of layers in addition to internal stresses produced during manufacturing processes all have an impact on deformation and performance.

The research team includes colleagues Professor Anthony Waas of Aerospace Engineering, John Kieffer, professor of Materials Science and Engineering, and several graduate students. Waas is an experimentalist and characterizes composite structural response; Kieffer measures numerous micro-scale properties *in situ* as the polymer cures; and Wineman uses the data to refine the models.

"We're able to predict stress-developing structures as the material cures, which is important because they affect the mechanical response of components, for example, energy absorption of automobile side panels during a crash," he said. The work has been supported by the Automotive Composites Consortium of the United States Council for Automotive Research, LLC, through the U.S. Department of Energy.

The findings of the recent work included somewhat unexpected size effects. "We saw competition between heat conduction from the material as it cured and heat generation within the material due to exothermic reactions," Wineman explained. When the material volumes were small, the research team didn't observe locally high stresses, but when the volumes increased the team saw greater inhomogeneities in curing rates and stress and temperature distributions. These and other findings are being further examined in continuing research.

Models to predict curing and performance of composite materials are of interest to the U.S. Air Force and aerospace industry. "There are many aircraft applications given the problems that arise in curing and thermo-oxidative degradation at high temperatures," explained Wineman. "There's real interest in a new generation of aircraft materials."

In addition Wineman's team is extending its work to biomechanical applications. The underlying ideas are applicable to the study of the consequences of changes in biological tissue due to non-mechanical factors such as aging, disease and the impact of drugs on tissue response. "Perhaps the biggest impact of this modeling work may be in biological materials," said Wineman.

Until recently, most structural engineering modeling was confined to determining the response of "passive" materials, say a metal, with fixed properties under a specific set of conditions. The engineering of sophisticated modern composite materials and biological materials will couple the traditionally independent disciplines of mechanics, material science, chemistry, electricity, magnetism and optics. "Our work," said Wineman, "exemplifies this evolution to multidisciplinary analytical modeling of active material systems."

New Technology for Better MEMS Microphones

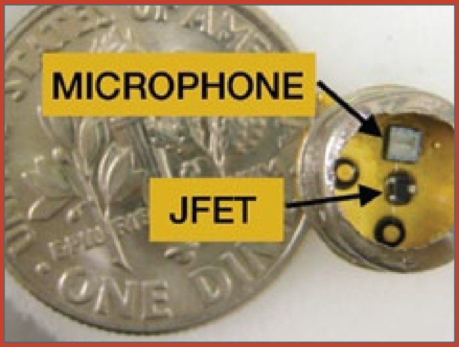
When the electret condenser microphone was introduced in the early 1960s, it revolutionized the microphone industry. Small, easy to manufacture, with good performance, these microphones served many applications—from hearing aids and headsets to computers and cell phones—for decades. More recently, smaller MEMS-based condenser microphones have been replacing the older technology. Condenser microphones transduce sound through an electrical circuit that senses pressure-induced changes in the capacitance of a parallel plate capacitor.

But modeling and experimentation conducted during the PhD research of Robert Littrell, a former student working with ME Professor **Karl Grosh**, suggested that the thin layers and fine spatial resolution made possible by more recent MEMS technology actually lend themselves better to a different transduction strategy, one based on piezoelectricity.

Taking the findings a step further, Grosh and Littrell, working with researchers in the U-M Vibrations and Acoustics Laboratory, have developed novel piezoelectric technology that improves upon both traditional as well as MEMS-based capacitive microphones. Their work has the potential not only to replace the venerable electret microphone in many applications but also to enable new applications, such as submerged sensing, which is not possible with condenser technology.

Piezoelectric MEMS microphones have been a research topic for over twenty years, however, achieving a low noise floor in these devices has been an elusive goal. The noise floor refers to the electronic "crackling" that can be heard through a microphone or headset even when there is complete silence. Because of this high noise floor, the technology has not yet transferred from the research lab to industry. By combining novel modeling, design and fabrication techniques, Grosh and Littrell have found a way to overcome the high noise floor of piezoelectric MEMS microphones. The key to unlocking this potential was their development optimization parameter that maximizes the ratio of electrical power output to the pressure input squared, rather than simply optimizing sensitivity, as had been previously attempted.

The small size and low level of intrinsic noise make it an appealing solution for many commercial applications, such as studio-quality microphones, hearing aids and handsets.



ABOVE: **Prototype piezoelectric MEMS microphone chip and amplifying transistor (JFET) in a simple package. Sensing chip is 1.5 mm by 1.5 mm.**

Novel processing, including controlling residual stresses in the fabrication and depositing of high quality piezoelectric materials, such as aluminum nitride, enables prototypes that behave as designed. The resulting device features a sensor element that is as small as a rice kernel but has a much lower noise floor. It also has a dynamic range that is a thousand times greater than comparably-sized capacitative microphones. The small size and low level of intrinsic noise make it an appealing solution for many commercial applications, such as studio-quality microphones, hearing aids and handsets.

Littrell has graduated and is now president of a spin-off company, Baker-Calling, Inc., created with Grosh in order to commercialize their invention and potentially take their product to market—a large market. More than 1 billion mobile phones alone are sold each year, and each one of those contains at least one microphone.

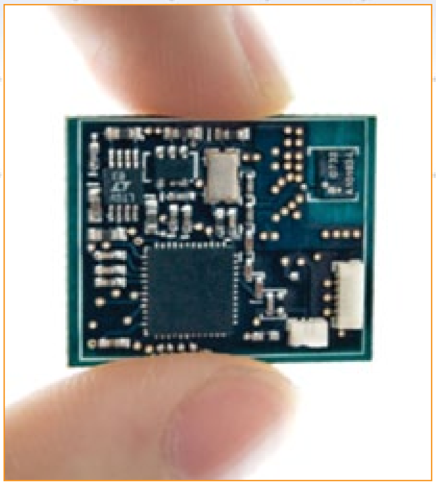
"We believe our design can have some impact. It would be exciting if something we designed at U-M could be in everybody's cell phone," Grosh said. Currently, he and Littrell are working with industry leaders, end users and development engineers to better understand their needs, specifications and requirements.

"The next step is to demonstrate that the devices can be fabricated efficiently in large numbers and meet the specifications of the industry," he added. He and Littrell also are investigating ways to enclose the microphones in robust outer casings.

The new piezoelectric MEMS-based microphone technology evolved from Grosh's ongoing work on an artificial cochlea for improved acoustic sensing and also potentially for use by individuals with hearing loss or impairments.

"I was not expecting to find such an exciting design in such an established area. Research takes an interesting path," Grosh said, "and part of that path sometimes results in a technology that outperforms what currently exists."

Measuring Human Motion:
Miniature Wireless Inertial Sensing



ABOVE: **Highly miniaturized wireless inertial measurement unit (IMU) believed to be the world's smallest.**

"It quickly became clear that if we could build a technology for a sport like golf, it would have an immediate spillover effect in nearly every other sport."

Understanding human movement is key to progress in many fields, from sports training to medicine. Ask any athlete if practice alone makes perfect, and you will likely get a laugh. Sports enthusiasts and pros alike certainly benefit from practice, and knowing precisely what motions to practice—and avoid—is what leads to genuine and sustained improvement. Currently available technologies used to study human movement and provide constructive feedback have historically been based on cameras. Yet camera-based motion capture set-ups can be costly and are often confined to specialized indoor laboratories.

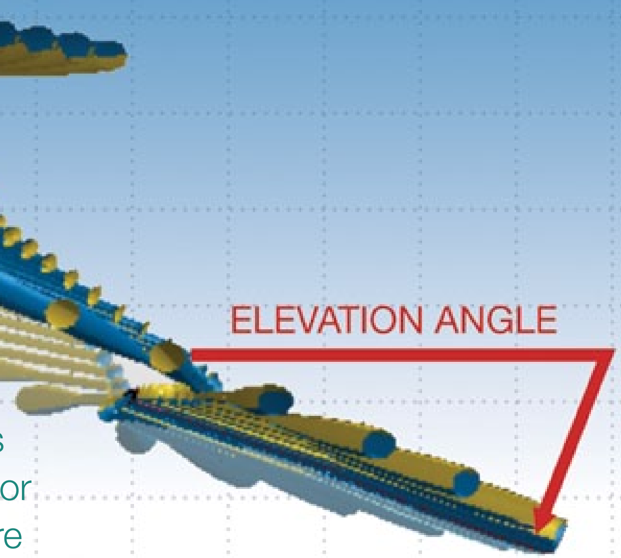
Professor **Noel Perkins** and postdoctoral researcher Kevin King have developed an alternative, and their MEMS-based wireless inertial sensor system is already helping athletes, sports enthusiasts, trainers and researchers more accurately measure and analyze human movement. The inertial measurement unit, or IMU, relies on MEMS accelerometers and angular rate gyros that measure acceleration and angular velocity, respectively. From these data, one can then reconstruct the velocity, position and orientation of any type of sports gear. In golf, for example, successfully hitting a long drive down the middle of the fairway depends on the motion imparted by the player to the club head. The velocity, position and orientation of the club head directly affect impact with the ball and the first moments of the ball's flight.

Observing the subtle movements that occur in the milliseconds prior to and just after impact is extremely difficult, but measuring them with the wireless IMU is not. The highly miniaturized, wireless unit is about the size of a postage stamp and weighs approximately three grams. Designed originally for sports training applications, the IMU integrates technology for three-axis sensing of acceleration and angular velocity with a microcontroller for analog to digital conversion. A low-power radio frequency transmitter for wireless transmission sends data to a host computer via a USB-enabled receiver. When mounted on or embedded within sports gear, such as golf clubs, baseball bats or fly fishing rods, the IMU provides essential information needed to resolve the motion of the gear and, ultimately, to provide actionable feedback players can use to improve their game.

In the world of sports training technology, the wireless IMU provides a rugged, portable quantitative way to evaluate athletic performance, and it has diverse sports applications. "It quickly became clear that if we could build a technology for a sport like golf, it would have an immediate spillover effect in nearly every other sport," said Perkins. An avid fly fisherman, he and his business partner Bruce Richards launched Cast Analysis LLC in 2005, a start-up company that uses IMU technology to help fly casters improve their technique. Perkins' research for golf originally was sponsored by golf equipment company PING, and the technology is currently licensed to about-Golf. Commercialization plans also are in place with potential licensees in baseball/softball, basketball, soccer and bowling.

From the Field to the Research Lab

The IMU is being used, or will soon be used, in many research laboratories around the U-M campus, too. A departmental collaboration between ME and Kinesiology will use IMU technology to study knee biomechanics to better understand anterior cruciate ligament tears and repair. In other work, Kinesiology researchers will use the technology to measure infant walking under vibration stimulus to understand neuromuscular



"There are vast numbers of existing applications and yet-to-be-determined uses for a small sensor that lets us understand human movement. We're on the tip of the iceberg now; we're just scratching the surface."

control issues. Orthopedic surgeon Neal Chen, MD, will use the IMU system to measure rotations across the shoulder and elbow to address injuries in young pitchers. ME Professor Art Kuo is using IMU sensing as a portable gait monitor to electronically evaluate a patient's gait over time, which is especially beneficial for people with debilitating diseases such as diabetes or Parkinson's disease. The IMU platform also is being used to monitor human balance in patients with vestibular disorders in collaboration with the laboratories of ME Assistant Professor Kathleen Sienko and Professor Michael King of Otolaryngology in the U-M Medical School.

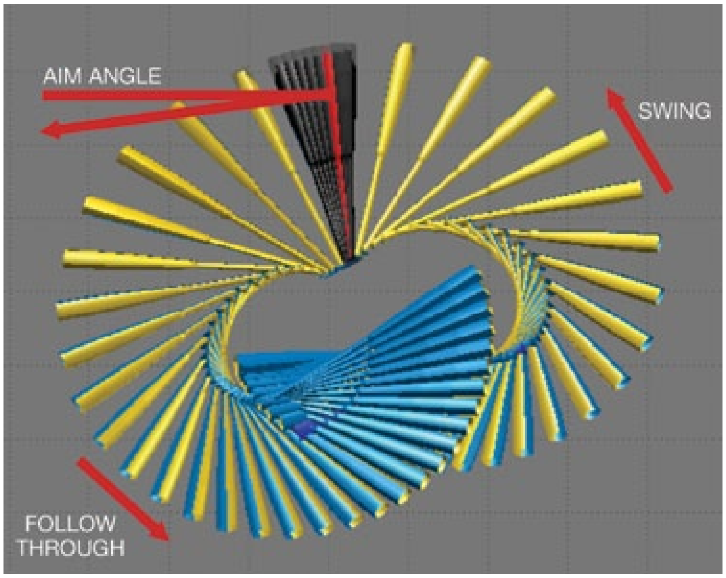
In a collaborative project with faculty from the College of Engineering and the Medical School, the IMU is employed to measure the fine motor skills that surgeons need to master in order to hone their surgical techniques. King and Perkins developed a miniaturized IMU system that can be mounted on surgical instruments and enables researchers to capture the motion of the instrument and evaluate how an expert surgeon's technique compares to that of a novice.

In the coming year, King and Perkins expect to introduce a next-generation design with added features, including the ability to transmit data not only to computers but also to smartphones using standard WiFi. The new design will feature a wireless sensor array. This allows the system to send synchronized data from multiple sensors simultaneously, a new capability that will enable further applications.

"There are vast numbers of existing applications and yet-to-be-determined uses for a small sensor that lets us understand human movement," said Perkins. "We're on the tip of the iceberg now; we're just scratching the surface."

ABOVE: **The "catcher's view" of the swing reveals the swing plane defined by the elevation angle.**

BELOW: **The "bird's eye view" of the swing reveals the critical aim angle, which determines the angle where the ball is hit.**



Inventing New Devices:
Smart Materials Yield Smart Solutions

Metals expand when heated and contract when cooled, but the change is so minute—often on the order of one-tenth of one percent for a change of 50°C—it's not easily discernible. A shape memory alloy (SMA), however, can change in length by nearly eight percent when heated through the small temperature change required for its phase transformation and can handle significant loads in the process. When heated, these alloys can "remember" their original shape. SMAs provide simple, inexpensive, light alternatives to current motors in applications requiring small to moderate work output and enable functionality beyond the conventional actuators of today; their applications in this range are nearly limitless.

"New materials, such as SMAs, enable potentially revolutionary technologies beyond the imagined need, opening the door for leapfrog opportunities in the marketplace," said Associate Professor **Diann Brei,** who incorporates advances in smart materials into device innovation and design.

Working broadly across multiple disciplines and fields and in close partnership with Assistant Research Scientist Jonathan Luntz, Brei uses SMAs to invent breakthrough technologies by bridging the gaps among materials, systems and novel device architectures. Their work spans industries and applications, including automotive, medical and military.

Brei co-leads the Smart Materials and Structures Collaborative Research Laboratory in conjunction with General Motors (GM) to harness the emerging capabilities of SMAs and other smart materials. One recent research avenue has focused on the use of SMAs to transform passive rubber seals on automobile doors into active seals. Creating a quality seal on a car door is a challenging problem due to the inherent design compromise between the low closing effort consumers desire and the high sealing forces that ensure water and noise stay out.

The research team is de-coupling that design tradeoff by incorporating a shape metal alloy inside the rubber weather stripping. When the SMA is turned off, the rubber is compliant and makes the door easy to close. When the SMA is activated, the active seal becomes stiffer and creates an exceptional seal. With the support of GM, Brei is identifying the optimal human interaction with the seal and door and developing new seal paradigms that address these consumer preferences.

Shape memory alloys also have many potential medical applications, and Brei's team has seen significant success applying

them to a clinical device for treating short bowel syndrome (SBS) in humans. Insufficient bowel length affects some 200,000 individuals in the United States and results in high rates of morbidity and mortality. Current therapies often are ineffective, and they carry a high risk of complications. Brei's team has been investigating a new treatment modality based on mechanotransduction, a process through which mechanical tensile loading on the bowel induces longitudinal growth.

Recent investigations, done in collaboration with Daniel Teitelbaum, MD, a professor of surgery at the U-M Medical School, have yielded promising results. "There is no room in the bowel for a regular motor, but SMA is ideal for the job—enabling a medical breakthrough that was technically not possible before," explained Brei.

When tested *in vivo* within pigs, the bowel responded to mechanical stresses and resulted in confirmed growth. Further investigations will examine different methods for applying mechanotransduction and determine which method produces the best and fastest growth. Brei and her team plan to translate this research into a clinical device that can ultimately be implanted into humans with SBS to lengthen the bowel. Funding for these investigations comes from a variety of sources, including The Hartwell Foundation, the National Institutes of Health and the U-M Medical Innovation Center.

Taking a cue from nature, which relies upon a very small number of organic compounds to create the world around us, Brei's group is building actuators with smart materials using innovative cellular architectures. Recent work has demonstrated that literally knitting SMA wire using different stitches results in vastly different movement and performance, depending only on the stitch. For example, when knitted into a garter stitch and heated, the material contracts by 70 percent in length. When SMA wire is knitted using an I-cord stitch and heated, the cord twists into a compact helix. When knitted in a stockinette stitch, it curls into a tight tube. These form the mechanical basis of force, moment and torque, making any motion possible through different combinations.

"By coupling SMAs with different architectures, we can get huge, distributed and complex three-dimensional motions with true force generation, which has not been achieved before," said Brei. The U.S. Air Force is interested in active knit structures for its many military and medical applications, including morphing wings, deployable satellites and active bandages that can facilitate faster wound healing.

"New materials, such as SMAs, enable potentially revolutionary technologies beyond the imagined need, opening the door for leapfrog opportunities in the marketplace."

ABOVE: **Tizoc Cruz-Gonzalez** (left) **and Suhant Ranja** (right)**, graduate students in the UM/GM Smart Materials and Structures Collaborative Research Laboratory, design active automobile seals along with Dr. Jonathan Luntz and Associate Professor Diann Brei.**

OPPOSITE PAGE, TOP: **Brent Utter, a graduate student in the Smart Materials and Structures Design Lab, performs adjustments on a novel SMA actuated bowel lengthening device.**

OPPOSITE PAGE, BOTTOM: **Julianna Abel, a graduate student in the Smart Materials and Structures Design Lab, inspects an SMA knitted textile that produces complex three-dimensional motions.**

PHOTOS: SCOTT GALVIN, U-M PHOTO SERVICES

Micro-Robotics: New Strategies for Control and Optimization

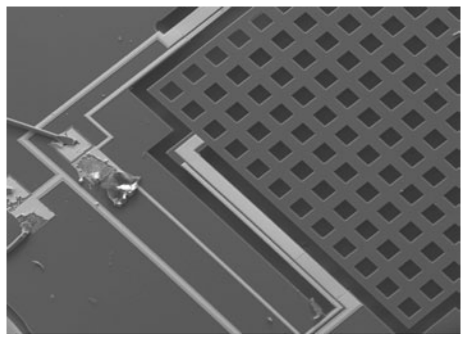
Picture a tiny, insect-like terrestrial robot that can locate survivors among disaster wreckage or aid in reconnaissance missions for the military. Such innovative micro-robotic devices hold tremendous promise for providing access to places humans can't—or shouldn't—go. But power availability and constraints due to small device size pose a significant challenge.

Under the direction of Assistant Professor **Kenn Oldham**, investigators with the U-M Vibrations and Acoustics Laboratory are developing new control and optimization strategies to overcome the obstacles and dramatically reduce total energy consumption in small-scale, micro-mechatronic systems.

Micro-mechatronic systems incorporate actuation, sensing and control systems to provide micro-scale functionality. Many of the most powerful actuators today rely on piezoelectric materials, which expand or contract when voltage or an electric field is applied and generate motion from a structure. Oldham focuses on the design and control of these piezoelectric systems, and his work over the past year has concentrated on integrating high-force, low-power piezoelectric micro-actuators into a range of micro-robotic devices.

Working with collaborators from the U.S. Army Research Laboratory, Oldham designs and studies MEMS-based structures that use piezoelectric materials. Oldham analyzes the non-linear behaviors and applies either dynamic systems or control theory in order to achieve peak performance from the resulting actuators.

The energy needs to control motion at such a small scale not surprisingly differ markedly from those at larger scales. "At larger scales, reducing actuator power consumption is where you typically create energy savings, but that's not necessarily where the savings happen when you're trying to do motion control at this small scale," Oldham explained.



ABOVE: **A prototype vertical piezoelectric actuator for biomedical imaging instrument applications, with embedded sensors for high-precision feedback control (device fabricated at Army Research Laboratory).**

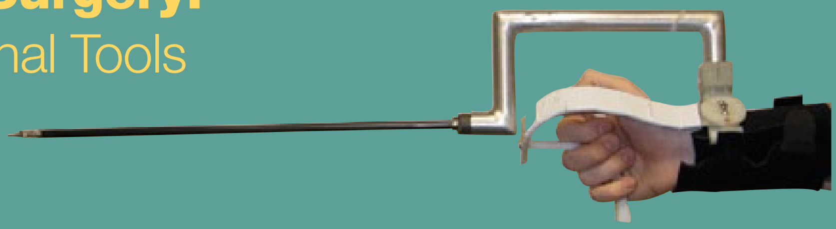
The novel power control strategies that he and his research group are developing coordinate motion control with active regulation of power electronics and sensor circuitry. The strategies are based upon switching control theory, whereby various components of a microsystem are regulated by the proper timing of a finite number of commands. Also important are control strategies that can tolerate significant uncertainty about exact properties of the micro-system being controlled and/or its environment. In turn, these switching commands can be implemented especially efficiently in miniaturized systems.

Oldham recently was awarded a National Science Foundation Faculty Early Career Development (CAREER) award that will allow him to continue exploring new control strategies that reduce the power consumption of autonomous microsystems (see related story on page 6). The low power control strategies developed through his ongoing work have myriad applications in addition to defense and disaster relief: implantable medical devices, unattended sensors, and other applications where energy conservation is critical also would benefit.

In addition Oldham is collaborating with colleagues in ME as well as Biomedical Engineering on several new imaging techniques for cancer detection. Within this group, Oldham is working on piezoelectric scanning mechanisms and actuators to move lenses and mirrors in order to change the focal point in the tissue being examined. The microscopy techniques being studied can focus on points up to 500 microns below the surface. Miniaturized instruments would mean that cross-sectional images of tissue could be obtained during endoscopic examination, potentially eliminating the need for some physical biopsies. In these applications, the goal is improved accuracy rather than increased power savings. To that end the team has integrated sensors into the actuators themselves in order to receive direct feedback on their motion without the need for external measurement. Initial prototypes have worked well, and now the team is extending the range and working toward more sophisticated control and an even higher level of accuracy of motion.

"There's great benefit to combining the design of microsystems with the control of microsystems," said Oldham. "You can accomplish much more with miniature devices when you're smart about the control systems you develop to operate them."

Minimally Invasive Surgery:
Affordable and Functional Tools



ABOVE: **FlexDex: An enhanced-dexterity and intuitively controlled minimally invasive surgical tool developed by Assistant Professor Shorya Awtar.**

Since their introduction in the 1990s, minimally invasive, or laparoscopic, surgery techniques have gained traction in nearly all surgical specialties. Minimally invasive techniques can be performed through much smaller incisions than conventional procedures and can significantly reduce patient trauma, blood loss, pain, scarring, recovery time and hospital length of stays. With such significant benefits, laparoscopic techniques are often touted as a "game changer" in the future of health care. Yet despite a successful track record and the strong demand for increasingly complex minimally invasive procedures, practical limitations to current laparoscopic tools hinder advances.

Assistant Professor **Shorya Awtar** has developed a novel and cost-effective tool that may soon pave the way for more complex minimally invasive procedures. In collaboration with Associate Professor James Geiger, MD, of the U-M Medical School, Awtar has designed and developed the FlexDex™, a laparoscopic technology platform that provides enhanced dexterity, intuitive control, greater precision and natural force feedback—all in a low-cost, mechanical tool.

In late 2009 Awtar's invention was selected by the U-M Tech Transfer office as one of the six most promising inventions and was showcased at the annual Celebrate Invention event. The development effort has been supported in part by the Michigan Initiative for Innovation and Entrepreneurship and funds from the ME department.

FlexDex technology development was initiated in the senior capstone design course, ME450, which was sponsored by ME Professor Sridhar Kota and supervised by Awtar. This nationally recognized design and manufacturing course is part of the X50 core design curriculum (see related article on page 44).

The student team carefully evaluated surgeons' needs in laparoscopic surgery and the limitations of existing laparoscopic tools. They learned that traditional hand-held tools lack the necessary dexterity for complex procedures and are not intuitive to operate. These limitations result not only in limited functionality for minimally invasive procedures but also in greater surgeon training time and fatigue. Robotic tools, on the other hand, can provide exceptional dexterity and control, but they can be cost-prohibitive for many hospitals even in the United States and a barrier to providing affordable health care in the developing world.

The FlexDex is a potentially game-changing laparoscopic technology primarily because it relies on a purely mechanical design without the use of sensors, actuators or computers and yet provides the functionality of existing multi-million dollar robotic tools.

Based upon its observations and investigations, the student team came up with a "virtual center" mechanism idea that held the potential for high dexterity and intuitive control in laparoscopic tools via a simple mechanical design. The seed planted in that course was nurtured and further developed by Awtar and his graduate students, who were supported in part by the ME department's graduate student fellowship.

"As an R&D team, our task has been to put the high functionality of a $1.5 million robot into a tool that would cost less than $1,000," said Awtar.

The FlexDex is a potentially game-changing laparoscopic technology primarily because it relies on a purely mechanical design without the use of sensors, actuators or computers and yet provides the functionality of existing multi-million dollar robotic tools.

Awtar's technology acts as a natural extension of the surgeon's forearm and hand through a novel mechanism at the tool input that projects a virtual center of rotation at the surgeon's wrist. This collocation enables one-to-one mapping between the surgeon's motions at the tool input and the end-effector motions at the tool output.

Because of the cost-effectiveness and ease of use of the FlexDex, Awtar and his team believe that it has the potential to make minimally invasive procedures more accessible to a larger population of patients undergoing surgery in a broad range of specialties. A group of U-M surgeons has tested a prototype of FlexDex with positive feedback and results. A beta prototype currently is being developed at the U-M Medical Innovation Center prototyping lab. The team is working with U-M Tech Transfer to create and execute a commercialization strategy.

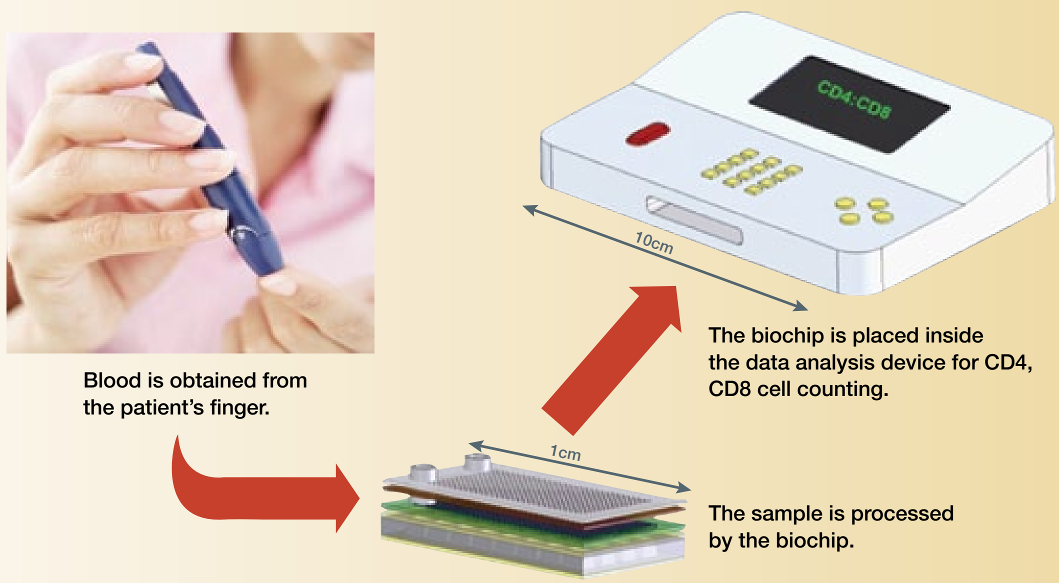
Novel Bio-MEMS Platform:
Monitoring HIV/AIDS in Resource-Limited Areas

Eventually, this biochip technology might make HIV monitoring as simple as the home glucose testing commonly done today by people with diabetes.

More than 33 million people worldwide are infected with HIV/AIDS, and nearly 90 percent live in underdeveloped locales. Despite the global charge to address the pandemic, monitoring infected individuals in resource-limited areas that lack infrastructure such as electricity, roads or trained medical personnel remains a tremendous challenge.

Consistent monitoring of the immune system of HIV-infected individuals can mean the difference between life and death. When the immune system is strong—as determined by a count of CD4+ T cells, a type of white blood cell that helps marshal the response to infection—an anti-retroviral medication regimen typically keeps symptoms and complications at bay. But if the immune system becomes weak, the risk of death in the near future significantly rises. If CD4+ T cell counts fall below 200 per cubic microliter of blood, more aggressive medications are needed promptly.

In the United States and other developed countries, simple blood tests let health professionals keep close watch on the viral load as well as CD4+ cell counts, but similar disease monitoring in resource-limited settings historically has been close to impossible. Assistant Professor **Nikos Chronis** is working to change that. He and his research team are developing bio-MEMS technology to easily and inexpensively monitor the immune systems of infected individuals without the need for advanced medical training or visits to specialized facilities.



The novel integrated platform developed by the Chronis Group will ultimately result in a point-of-care diagnostic device that can be easily used in the most remote of places. Eventually, this biochip technology might make HIV monitoring as simple as the home glucose testing commonly done today by people with diabetes, explained Chronis.

The portable system can simultaneously image up to 10,000 individual cells pre-assembled on the surface of a biochip. The biochip integrates a micro-fluidic single cell mechanical trap, which sorts white blood cells from red and assembles the white blood cells on the chip. A micro-optical component collects fluorescent light and excites the cells with it. The second unit then creates an image of the chip using an array of 10,000 on-chip fluorescent micro-microscopes to measure wavelength light. The biochip is placed inside a data analysis device that provides a read-out of each CD4+ cell.

The blood sample is collected using a simple finger-prick method. The biochip has a metering chamber that measures just one microliter of blood. In contrast to current methods of obtaining CD4+ counts cell by cell, such as with flow cytometry, Chronis' approach simultaneously images thousands of individual cells, pre-assembled on the surface of the biochip.

The novel, high-throughput and integrated methodology has the potential to change the course of HIV/AIDS monitoring globally. The availability of inexpensive, easily accessible disease monitoring has important implications for more efficient distribution of costly and often scarce medications, which can help save lives.

Chronis and his research team work in collaboration with Assistant Professor James Riddell, MD, of the U-M Medical School and Michael Savona, MD, an assistant professor of medicine at the University of Texas Health Science Center and a former fellow in hematology/oncology at U-M. The team has successfully created the trapping module and has demonstrated the capability of high-performance micro-lenses. The team's efforts are now focused on optimizing and further integrating all modules. Chronis expects that clinical trials might begin in about two years.

A single-cell, high-throughput imaging technology such as Chronis' system may have effects reaching far beyond HIV and immune system monitoring. "This is a platform that can be applied to many other applications," he said. "One could envision that such single-cell high-throughput imaging technology could be extended to cellular diagnostics for cancer screening and also for drug discovery assays."

OPPOSITE PAGE: **Lab-on-chip technology for HIV monitoring in resource-limited settings. An undiluted blood sample is drawn from the patient using a standard finger-stick method and loaded by the user into the point-of-care biochip that processes the sample. The biochip is inserted into the data analysis device and the CD+4 T-cell count is reported.**

The Biomechanics of Injury

Each year millions of Americans suffer unintentional injuries. In the year 2000 in the United States alone, over 50 million people suffered unintentional injuries that required medical attention, according to the Centers for Disease Control (CDC). Not only do these injuries cost billions of dollars in medical treatment and lost productivity; they also can lead to long-term and life-altering disabilities and impairments affecting quality of life.

James A. Ashton-Miller, Albert Schultz Collegiate Research Professor and Distinguished Research Scientist who directs the Biomechanics Research Laboratory, works to understand the mechanics of such unintentional injuries in order to better prevent them and their unwanted sequelae. His group currently is pursuing several research avenues that are reducing the risk of unintentional injury in a variety of arenas, from athletics to labor and delivery, where unintentional injuries occur that don't show up on the CDC's radar.

Ashton-Miller's research on balance and falls is being used to develop strategies for preventing hip and skull fractures in the elderly. He also is the technical member on an ASTM committee developing a new standard to improve the strength of sky-lights so workers don't fall through to their deaths, as well as on a National College Athletic Association Blue Ribbon Panel that monitors the performance of metal and composite baseball bats to lower the risk of injury or death resulting from baseballs driven off overly lively bats.

With several physical medicine and rehabilitation specialists at U-M, Ashton-Miller has invented a simple clinical screening device to measure reaction time so student athletes don't resume play too soon after suffering a concussion. Last year, his group also identified gender differences in the fastest possible human reaction time—in an analysis of data from sprinters competing in the 2008 Olympic Games in Beijing—and cross-checked their findings in a laboratory study of subjects warding off a ball aimed directly at their face. Both studies were presented as abstracts at national meetings and are in the process of being published.

In the past year, and building on two decades of work done in the Biomechanics Research Laboratory, Ashton-Miller and

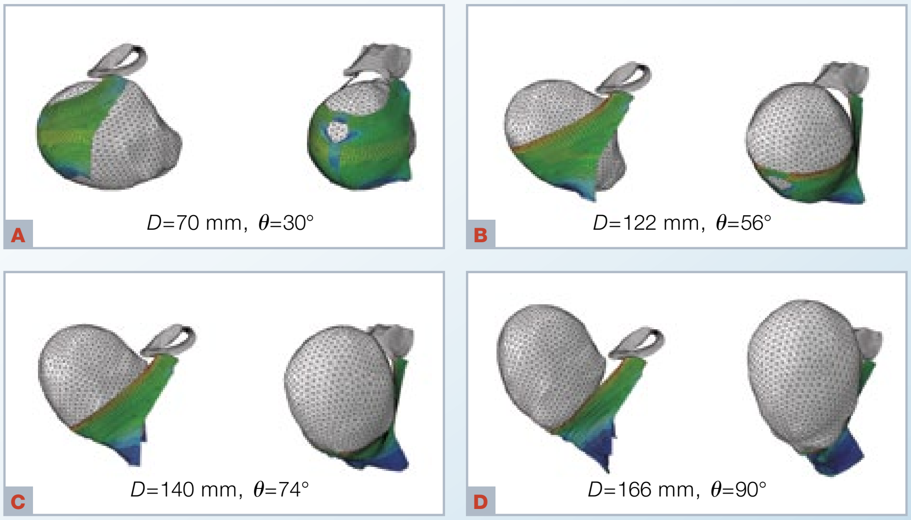
PHOTO: MARTIN VLOET, U-M PHOTO SERVICES

“If we can achieve that goal and, given the right resources I think we can, we will have helped women all over the world. At the same time we will be enabling women to be more active later in life, as well as reducing future health care costs.”

colleagues are investigating the mechanisms of maternal injury during childbirth, particularly the second stage of labor. Vaginal birth is the major risk factor for several conditions, including pelvic organ prolapse, or “fallen uterus,” and urinary and fecal incontinence. In the United States, about 11 percent of women undergo surgery for pelvic floor dysfunction at some point in their lives.

During prolonged labor, a mother can reach the point of exhaustion and then require instrumented delivery, which raises the risk of injury to both her and the child. In fact, Ashton-Miller and colleagues previously showed that instrumented delivery using forceps increases the risk of maternal injury 14-fold. He recently published a biomechanical analysis of voluntary pushing patterns in *Obstetrics & Gynecology*. This work is the first theoretical analysis of pushing patterns during the second stage of labor, and the findings help identify the most efficient strategies to prevent maternal exhaustion and injury.

In a review article published in the *Annual Review of Biomedical Engineering*, he and John O. L. DeLancey, MD, a colleague in the U-M Department of Obstetrics & Gynecology, show that the stretch ratio in pelvic floor muscles reach an “extraordinary” 3.26 by the end of the second stage. In another study, published in the *Journal of Biomechanics*, Ashton-Miller, Dr. DeLancey and doctoral candidate Luyun Chen developed the first three-dimensional simulation showing how and why maternal injuries during labor likely lead to the most common form of genital prolapse—cystocele, or bladder prolapse—later in life. Their insights help explain how bladder prolapse can develop over time and also provide a sound framework for future imaging studies in living women. The work won a national research award.



More theoretical and experimental work is needed to identify women at risk for injury before they reach the second stage of labor.

“Today we have reached the point where we can use MRI to identify the exact anatomic structures that are injured, and our computer models to tell us when the injury is likely to occur during labor. Our next problem is to figure out why the injuries occur in 10 to 15 percent of first time mothers. That will help us as we develop interventions to prevent these injuries and their unwanted sequelae,” said Ashton-Miller. “If we can achieve that goal and, given the right resources I think we can, we will have helped women all over the world. At the same time we will be enabling women to be more active later in life, as well as reducing future health care costs.”

ABOVE: **Finite element simulation results showing female pelvic floor muscle strain during the second stage of labor in a vaginal birth. Regions of highest strain are shown in red. When injuries occur they tend to occur near the pubic bone** (top left)**, as predicted by this model.** From Dejun Jing’s ME doctoral thesis, 2010.

OPPOSITE PAGE: **Albert Schultz Collegiate Research Professor James Ashton-Miller, adjusts optoelectronic markers for graduate student Hogene Kim as they debug an experiment designed to test the control of balance while stepping unexpectedly on something uneven. The end goal is to reduce the risk of injurious falls in patients with peripheral nerve disease, a frequent complication of diabetes.**

Novel Devices to Retrain Balance

"Exercises could be recorded by a physical therapist during rehabilitation sessions and then played back by patients during home-based training to ensure accurate replication of motions."

Smartphones may have a surprising capability in the not-too-distant future: a balance aid for the elderly and other individuals who suffer from balance disorders. That's just one example of novel technologies and devices under development in the Sensory Augmentation and Rehabilitation Laboratory (SARL) of Assistant Professor **Kathleen Sienko.**

Balance rehabilitation can improve the quality of life and ability to perform activities of daily living for countless individuals who suffer from vestibular disorders. The SARL arm of Sienko's research group designs, develops and evaluates medical devices for balance-impaired populations. Balance problems can arise from a multitude of causes, including neurological, orthopedic, vestibular and vascular conditions; sensory problems; stroke; head injuries; and aging.

Sienko currently is developing a low-cost, home-based balance aid device based on an iPhone. The cell phone balance trainer can help patients perform exercises that have been assigned by a physical therapist. People living in rural areas of the developing world who don't have access to balance therapy could also benefit.

Body motion is detected by on-board tri-axial accelerometers, and a tilt estimate is computed using a Kalman filter. The phone hardware is supplemented by specially-designed "tactor buds" comprising auxillary pager motors and an audio amplifier. The tactor buds provide real-time vibrotactile cues to the user of body tilt along two axes when the user exceeds a programmable tilt threshold (for example, one degree). Similar to ear buds, the tactor buds can be plugged into the head-phone jack and worn

A second generation prototype of the cell-phone-based balance device will include video demonstrations, auditory prompts and performance summaries.

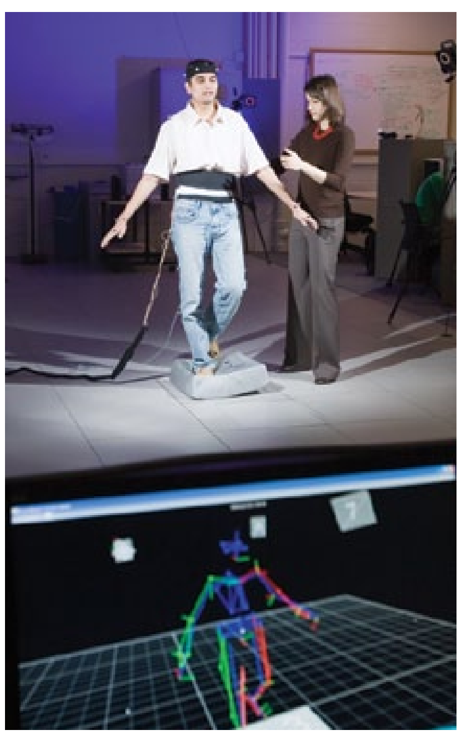
on different parts of the body to receive balance feedback. A user wears the phone and tactor buds around his or her waist and receives vibrotactile trunk tilt feedback along the axis of least stability: anterior-posterior vibrotactile trunk tilt feedback when standing and medial-lateral vibrotactile trunk tilt feedback when walking. Doctoral pre-candidate Beom-Chan Lee and master's student Tae Hoon Kang are furthering initial design efforts by recent graduate Jeonghee Kim and developing a second generation prototype that will include video demonstrations, auditory prompts and performance summaries.

Sienko has tested the device in young, healthy volunteers and preliminarily in those with vestibular disorders. Results indicate that individuals are able to use the feedback to significantly reduce their trunk sway and increase the percentage of time that they spend below the tilt threshold. In addition to acting as a tool to improve balance, the device offers the unique opportunity for scientists to collect long-term data on balance performance and characterize the impact of rehabilitative training in the home over extended periods of time.

Studies to understand the most effective form of feedback—visual, vibrotactile or both—to help the elderly perform balance exercises are also underway in Sienko's lab by doctoral pre-candidate Kelli Bechly. Other work by MD/PhD pre-candidate Dan Ursu and pre-candidate Stephanie Haggerty explores the safety and effectiveness of balance devices while older adults simultaneously are given additional cognitive tasks. For those with certain cognitive and motor deficits, such secondary tasks could potentially induce a fall. This research will determine if vibrotactile feedback can be used safely when users are multitasking and will inform the potential viability of such a device as a real-time balance aid versus a tool to train balance in a controlled setting.

Another device under development in Sienko's lab by Beom-Chan Lee helps patients more accurately practice exercises shown to them by a health care professional, such as a physical or occupational therapist. Dubbed MIMIC (Mobile Instrument for Motion Instruction and Correction), the wearable device system includes both expert and trainee modules. Each module includes a six degree-of-freedom inertial measurement unit (IMU), microcontroller unit (MCU), Bluetooth module data-saving module and battery. The trainee module also has an array of tactors that relay vibrotactile feedback to the wearer's skin.

An expert's body movements are sensed by the IMU in the MIMIC expert module and quantified by projection onto a motion basis set by an algorithm in the MCU. The expert motion representation is then transmitted wirelessly via Bluetooth to the trainee module. Based on the computed difference between expert and trainee motion, directional instructions are given in the form of vibrotactile stimulation to the trainee's skin. When the trainee moves in the direction of the vibration, the stimulus ceases. All information related to the body motion of the expert and trainee as well as tactor stimulation history are recorded in the data-saving module for post-processing and analysis.



"Exercises could be recorded by a physical therapist during rehabilitation sessions and then played back by patients during home-based training to ensure accurate replication of motions," said Sienko. Sienko plans to further prototype development to enable the devices to be sent home for clinical trial evaluation in a non-laboratory setting.

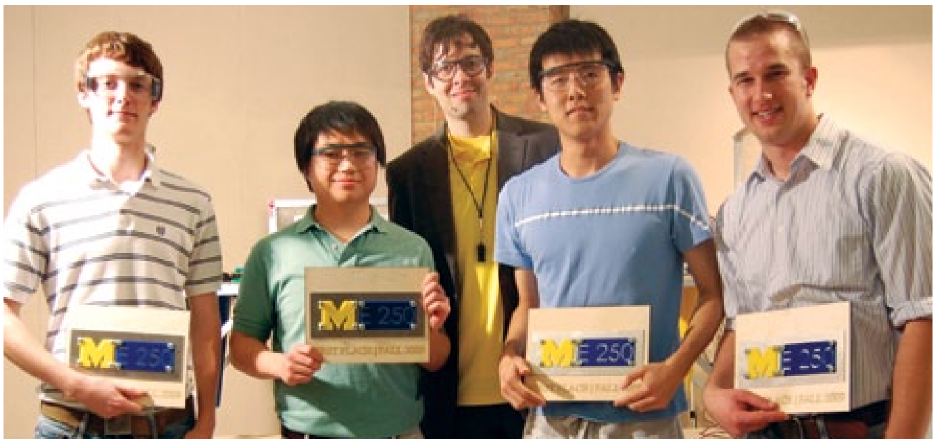
LEFT: **Assistant Professor Kathleen Sienko, and graduate student Vivek Vichare evaluate a vibrotactile feedback device for improving balance.**

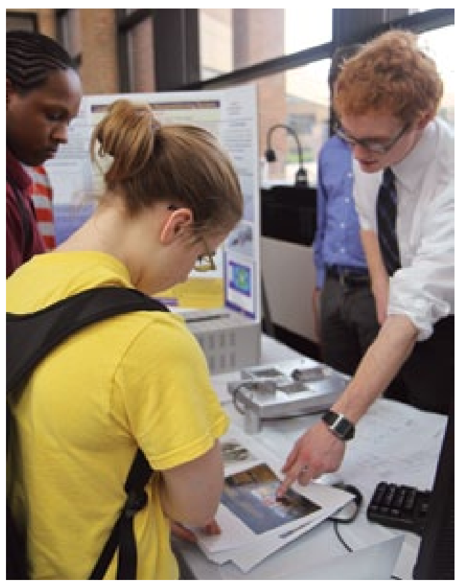
ABOVE RIGHT: **Cell phone based balance trainer prototype comprising an iPhone Touch, tactor buds, microcontroller and batteries.**

OPPOSITE PAGE: **Kathleen Sienko reviews motion capture data with graduate students Liang-Ting Jiang (ME) and Jeonghee Kim (EECS).**

PHOTOS: SCOTT GALVIN, U-M PHOTO SERVICES

X50 Design and Manufacturing:
Showcasing Creativity and Innovation





TOP: **ME250 Fall 2009 Slotbots competition winners, team "Murphy's Law": (left to right) Corwin Stout, Michael Wang, Assistant Professor John Hart, Vince Ji and Mac Van Loon.**

ABOVE LEFT: **An "Inverted Pendulum" exhibit developed by Assistant Professor Awtar's ME450 students for the Ann Arbor Hands-On Museum.**

ABOVE RIGHT: **2009 College of Engineering's Design Expo.**

OPPOSITE PAGE: **Two "slotbot" machine arms battling for ping pong balls during the Fall 2009 ME250 competition.**

The ME department is recognized nationally for its core design curriculum, also known informally as X50. In U-M design courses, students get hands-on experience in the design process, from idea conception through prototype fabrication and testing. They learn how to turn ideas into products and designs into real, physical systems.

Slotbots Compete at Design Expo

In Design and Manufacturing I (ME250), students learn the creative design process, principles of engineering materials and mechanical elements and prototype-scale manufacturing using machine shop tools. This culminates in a competition held at the College's Design Expo at the end of the semester.

In Fall 2009, the ME250 competition was "Slotbots." Each team of four students designed and built a remote-controlled slotbot machine to dig ping-pong and squash balls out of a narrow slot in a custom built two-by-eight-foot "arena." The slotbot with the fewest balls on its side of the arena after 120 seconds was declared the winner, and the contest proceeded in a single-elimination bracket until a champion was crowned.

In December 2009, 30 teams of four students competed after working all semester on their slotbot. Students' machines demonstrated a variety of strategies and mechanical designs, and the contest culminated in a final round between "Murphy's Law" and "Team Legend."

"We thought it was important to begin the X50 design sequence with an open-ended problem so students would learn about how to think creatively and funnel their creative ideas through the fundamental principles of design," said Assistant Professor **John Hart**, who led a transformation of ME250, including the introduction of the Slotbots

theme in Fall 2009. "Students learn to break the task down into the details and then translate those details into their machine. It's always exciting to see their creative solutions and hard work," he said.

Design Expo Hits Facebook, Showcases Breadth of Student Work

The 2009 and 2010 Design Expo events showcased dozens of capstone design projects. The April 2010 Design Expo made its social media debut, with a 1 Day, 100 Projects video event on Facebook, where members could vote on their favorite Expo project. ME student work included a device to help disabled babies crawl, a new piston concept for a hydraulic hybrid delivery truck and a telerehabilitative device to help stroke patients regain motor control in the hands.

Student Project Displayed at Ann Arbor Museum

Yet another Design Expo project featured an inverted pendulum balancing system, work that is now exhibited at the Ann Arbor Hands-On Museum. The popular Ann Arbor museum sponsored the ME450 capstone design and manufacturing course project. Students were tasked with designing an exhibit to educate patrons about mechatronics and feedback controls. Their design needed to be inherently simple, aesthetically pleasing, interactive, hands-on and durable. The Inverted Pendulum exhibit highlights the importance of feedback controls and balancing in natural and man-made systems. The human-transporter Segway relies on an inverted pendulum balanced via feedback controls, where the center of gravity is continuously adjusted to prevent the transporter from falling over, much like a person trying to balance a stick on his or her finger.

The students' museum exhibit includes a free vertical pendulum pivoted at the end of a horizontal arm, which is driven by a motor. Sensors measure the pendulum and motor angles, and a micro-controller uses this information to command the motor to keep the pendulum balanced in an inverted position.

"We sought an exhibit that could demonstrate the multidisciplinary nature of engineering and technology," said Mel Drumm, museum director. "The Inverted Pendulum exhibit does so in a manner that transformed a lab-based device into a professional interactive display suitable for constant interaction by our public visitors. The careful and thoughtful design reaches beyond engineering, science and technology and enters the realm of art."

Mechatronics Instructional Space Upgrade

Mechatronics, or the synergistic integration of mechanical disciplines, controls, electronics and computers in the design of high-performance devices or processes, is a core area of emphasis in the X50 undergraduate and graduate design and manufacturing curriculum.

Many consumer products manufactured today are mechatronic in nature, and industry demand for mechatronic designs are only increasing. Mechatronics represents a multidisciplinary systematic approach to hardware design, fabrication and testing, and so instructional areas require dedicated space for collaborative design, rapid realization, prototyping, assembly and testing.

The College and the Department have invested a $185,000 grant to equip a teaching lab with state-of-the-art mechatronics workstations, lab personnel and data acquisition hardware and software.

"With the new space and workstations, students will learn principles of machine design, modeling of multi-domain dynamic systems, controls theory, electronic circuits, real-time controls implementation and, most importantly, system integration," said **Shorya Awtar**, assistant professor. "Students will be able to prototype systems and learn about how advanced manufacturing techniques can help them convert their ideas and prototypes into real-world solutions."

Students of the World: Gaining a Global Perspective

From Germany and Ghana to China, ME students are learning about engineering—as well as people, languages and cultures—from multiple, global perspectives and locales.

Global Health Design: New Grants and Initiatives Provide Opportunities for Students

Recognizing the growing need for technologies that improve quality of life in the developing world, Assistant Professor **Kathleen Sienko** has initiated a number of research, instructional and experiential programs that offer students invaluable opportunities to develop and deploy health technologies in resource-limited settings.

As part of the new Global Health Design Specialization within the Minor in Multidisciplinary Design, 13 students—10 from the College of Engineering—will travel to Ghana in August 2010 to conduct clinical observations at the Komfo Anokye Teaching

Hospital in Kumasi to identify problems and projects related to maternal and infant health. Upon returning to U-M, student teams will work on technology prototypes in a special section of the senior capstone design and manufacturing course ME450 (see related story on page 44).

During winter break, a subgroup will return to Ghana to field test prototypes and get feedback from end users, refining prototypes during the winter semester design course. This work is partly sponsored by a grant Sienko is leading from the National Collegiate Inventors and Innovators Alliance to develop educational programs that teach sustainable medical device design.

Sienko is also the principal investigator on a Grand Challenges Explorations grant from the Bill & Melinda Gates Foundation for a safe circumcision project that will further develop and evaluate a prototype created in 2009 by one of Sienko's ME450 teams. The grant will enable field work to assess the cultural suitability of the device for sub-Saharan Africa and help define a path to low-cost production and distribution.

Sienko recently established a graduate course, Design for Global Health: Sustainable Technologies for the Developing World, that exposes students to the realities of designing technologies for resource-limited settings. As a course outcome, students built a database of technology case studies that highlights best and worst practices for addressing leading causes of

death in low-income countries. A student from the course is spending summer 2010 at the World Health Organization (WHO) in Geneva, compiling the database as part of an online resource for global health technologies. Sienko recently served on a WHO advisory board that evaluated innovative technologies.

Highlights from UM–SJTU Joint Institute

The University of Michigan–Shanghai Jiao Tong University Joint Institute (UM–SJTU JI) has had another fast-paced and productive year. The Institute concluded its tenth board of directors meeting in Shanghai in late June 2010. Several members attended the event via video conference. The Board was pleased with the significant progress of the UM-SJTU JI in its first four years, particularly in the areas of faculty recruitment, curriculum development and student education and placement.

Board members from U-M included: President Mary Sue Coleman; Vice President of Research Stephen Forrest; Dean Dave Munson and Associate Dean James Holloway of the College of Engineering; Dean Jim Woolliscroft of the U-M Medical School; Rich Rogel, chairman of the Michigan Difference Campaign; Professor Jun Ni, dean of the JI; Professor Ken Lieberthal, The Brookings Institution; Professor Mary Gallagher, director, Center for Chinese Studies; Jefferson Porter, associate vice president for development; Lin Cargo, associate director of advancement for the College; Amy Conger, director, International Engineering Programs; and Jen Zhu, coordinator, China Programs.

Global Faculty Recruitment

The JI has successfully recruited more than 20 full-time faculty members and lecturers using international evaluation standards. Almost all faculty candidates are graduates, postdoctoral fellows, and/or current tenured or tenure-track faculty at top universities worldwide, such as Massachusetts Institute of Technology, Oxford University, Harvard University and RWTH Aachen University.

Student Training and Placement

The JI curriculum combines the best educational features from both U-M and SJTU, and nearly 1,000 undergraduate students have been admitted to graduate programs in mechanical and electrical and computer engineering since the Institute was founded. "Joint Institute students are an outstanding group—academically strong, highly motivated and active participants in student organizations and volunteerism," said Professor **Jun Ni**, dean of the JI.

Among the first class of 165 JI graduates, over 76 percent will pursue graduate study in the United States and China. Of the 114 students who expressed interest in pursuing graduate studies in the United States, 90 percent have received at least two admissions from top 10 programs.

Thirty-eight U-M engineering students are participating in the JI's 2010 summer program, taking engineering courses along with introductory classes in Chinese language and culture. Eight U-M faculty are teaching in China during the summer session.

Recognition

The success of the JI has been highly praised by the Chinese government. On July 1, 2010, Honorable Madame Liu Yan-Dong, the State Councilor overseeing education, science and technology, culture and sports, met a delegation led by U-M President Coleman in Zhong-Nan-Hai, headquarters of the Chinese government. She spoke of the impact of the JI on the U.S.–China international exchange in engineering education. The JI has been considered a model of cooperative international programs.

Research Collaboration

President Coleman and Madame Ma De-Xiu, chair of SJTU, signed a resolution for major research collaboration between U-M and SJTU in the areas of renewable energy and biomedical technology. The ▶

ABOVE LEFT: **Students from Assistant Professor Kathleen Sienko's Global Health Design class and Nicaragua CARE workers pose before a rehabilitation clinic in Esteli, Nicaragua.**

ABOVE RIGHT: **Students interview Dr. Osman Palma (center), director of the Alfonso Moncada Guillen Hospital Amigo de la Niñez y de la Madre, located in Ocotal, Nicaragua.**

OPPOSITE PAGE: **Amir Sabet (MSE, BME) discusses the Nicaraguan health care system with Eric Sanchez, national public health administrator, via interpreter Marlon Rezo while in Esteli, Nicaragua.**

PHOTOS, THIS PAGE: COURTESY KATHLEEN SIENKO

two universities have committed $3 million dollars each to promote faculty-to-faculty research collaboration. Six teams also were selected from 30 proposal teams in the first round of open solicitation.

The U-M has teamed up with SJTU to submit a proposal for the establishment of a United States–China Collaborative Research Consortium on Clean Vehicles in response to a competition sponsored by the U.S. Department of Energy. The competition is part of the U.S. and Chinese governmental agreement to promote scientific cooperation in renewable energy.

Experience Abroad: International Engineering Summer School at TU Berlin

Sixteen College of Engineering students, six of them from ME, broadened their horizons and gained invaluable overseas experience through the 2009 International Engineering Summer School (IESS) at Technische Universität Berlin, or TU Berlin.

The students spent six weeks working on a wide range of laboratory projects, from alternative energy production and improving diesel engine performance to smart programming of camera controllers and image processors for high data throughput. In addition, they learned about German history and culture and took language courses.

"Professor Frank Behrendt from TU Berlin and I tailored the IESS to accommodate engineering students from a wide range of disciplines and German language skill levels," said ME Professor **Volker Sick**, faculty advisor to International Programs.

The IESS program, in its fourth year, continues to grow. Nineteen students from the College of Engineering are enrolled in the Summer 2010 session.

Instructed by TU Berlin faculty and PhD candidates, U-M students work in small groups to accomplish research work. Instructors from both universities evaluate the assigned weekly reports, final papers and group presentations. Two students extended their summer 2009 stay in Berlin to continue research on alternative energy.

Many College of Engineering departments recognize IESS credits as technical electives, and many students continue German language training upon returning to U-M. In addition, the industrial sponsor of the program, IAV GmbH, or Ingenieurgesellschaft Auto und Verkehr, invites students to intern at their locations in Germany. Several 2008 IESS participants returned to Berlin to work as summer interns in 2009.

The IESS program is approved as overseas experience for students pursuing the International Minor for Engineers. About 18 months after it was established, more than 160 College of Engineering students have declared the International Minor, the first minor in the history of the College. Nineteen students have already graduated with this credential.

CLOCKWISE FROM TOP LEFT: **1** A group of U-M undergrads at the zoo in Berlin, Germany during the Internal Engineering Summer School at TU Berlin; **2** View of the campus of TU Berlin; **3** Signing of a five-year Master Research Agreement between U-M and SJTU in the areas of renewable energy and biomedical research; **4** President Coleman talking to U-M students participating in the summer program at the JI.

Student Teams and Chapters Thrive

ME faculty lead student chapters and teams that are finding winning combinations

MRacing Takes Second Place

The University of Michigan Formula SAE® team, MRacing, finished second among the 120 teams competing in the 2010 Formula SAE competition, held at Michigan International Speedway (MIS) in May. The win brings the team's world rank to sixth place.

"We were all extremely excited about this finish—it was our best in 16 years," said Nathan Lusk, a team electronics engineer and 2011 captain. ME Professor **Volker Sick** serves as faculty advisor to the U-M MRacing team.

In addition to the second place finish, MRacing returned to Ann Arbor with trophies and prize money for taking first place in acceleration, second place in endurance, and second place overall in dynamic events. The U-M team also won the FEV Powertrain Development Award for outstanding fuel economy and acceleration (zero to 60 miles per hour in 3.1 seconds) and the Joe Gibbs Simulation Award as well.

The results are all the more impressive because "our team is not large by any means," said Lusk. "It consists of only 25 undergraduates and one graduate student driver. The fact that we can compete and do this well in competitions of this caliber is a great achievement." It's also a testament to the dedication of team members and the generosity of sponsors, such as title sponsor Borg Warner, and of the College of Engineering, he added.

A high-performing 2009 and 2010 come after a tough 2008 race year, when engine problems kept the team's car from finishing the MIS competition. In 2009, MRacing placed seventh at the MIS competition and fifth at Formula Student Germany.

The team is in the throes of preparation for the next and final event of 2010, which takes place at the Hockenheimring in Hockenheim, Germany, in August. "We're hoping for another top five finish at this extremely competitive event," Lusk said.

For more information, visit the chapter website: http://mracing.engin.umich.edu/

MSAE: Best Student Chapter

The U-M student chapter of the Society of Automotive Engineers (MSAE), also advised by ME Professor **Volker Sick**, kicked off its 2009–2010 year with its annual Car Show and lineup of industry speakers. Presenters included Dr. Chris Borroni-Bird from General Motors and Ted Miller from Ford Motor Company. Both talked about what their respective companies are doing in the field of alternative energy.

Students took tours of the GM Delta Township plant, where the company produces GMC Acadias and Chevrolet Traverses, and the GM Performance Build Center in Wixom. The Build Center produces engines for high-performance Corvettes.

At the SAE World Congress, the U-M chapter took honorable mention for their display in the competition. The chapter also won the Honeywell Outstanding Student Chapter Award. The year wrapped up with the Young Automotive Professionals Conference at GM's Milford Proving Grounds. "Three MSAE members attended, and the highlight for all was a 150 mile-per-hour hot lap in a Corvette ZR-1," said incoming chapter president Michael Merritt.

Currently the chapter is organizing its next annual Car Show, which will take place in early September, and adding industry speakers to its 2010–2011 roster.

For more information, visit the chapter website: http://www.engin.umich.edu/societies/sae/

SAE Baja: Innovation Leads to Learning

The 2009 race season for the Society of Automotive Engineers (SAE) Baja team was marked by both innovation and technical challenges, a learning experience that set the stage for a strong 2010.

Each year SAE Baja teams build a prototype off-road vehicle, intended for mass production and sale as a safer alternative to an all-terrain vehicle, or ATV. In 2009 the U-M team built a car with a solid rear axle, rather than the independent suspensions of years' past, and ran a differential, also a novel change.

"Where we ran into problems was finding the right balance between changes to improve performance and having time to validate the design," said Joe Furner, a 2010 ME graduate and team co-captain along with Alan Buehne and Jeff Walker.

ME Associate Professor **Brent Gillespie** advises the team.

“As a result, we weren’t able to finish the endurance events at either race we attended last year because of reliability issues.” Still, the team took second in the design report in one race and third in maneuverability in another. “That was one upside,” said Furner. “The new things we did with design were recognized.”

The lessons paid off in 2010. On the new car, the team went back to an independent rear suspension and manufactured a completely customized continuously variable transmission, something not commonly done by other teams. “That gave us a big advantage in that the transmission was a perfect fit for our vehicle; it was specific to our engine, without unnecessary weight,” said Furner.

The team not only completed the endurance events at both 2010 competitions; it also placed second in design report and fourth in cost in Baja SAE Washington in Bellingham in May. At the Rochester, New York, competition in June, the team came in first in the hill climb event and second in acceleration. Overall it took the eleventh spot among 70 teams.

The year represented a “pretty big step,” said Furner. “We’re starting to get to the point where we really know how to build a car that’s lightweight and durable. You can’t win unless you have both.”

Furner credits team sponsors, including TI Automotive and the College of Engineering, and a good balance of veteran and new team members for the success. “New members were one of our strengths this year. They bring fresh ideas and point out things you’ve been doing that might not be so smart.”

For more information, visit the chapter website: http://www.umich.edu/~baja/

Solar Car Defends National Title

The 2010 U-M Solar Car team has won its third consecutive American Solar Challenge and sixth national championship overall. After a six-day, 1,100-mile race, *Infinium* crossed the finish line more than two hours ahead of the second place team. The car averaged 40 miles per hour during the competition. The crew spent 15 minutes on the side of the road making a minor electrical repair, and at one point removed a black widow spider from the spare battery pack.

In October 2009, *Infinium* and its race crew battled brutal conditions in the Australian Outback to take a close third place finish in the World Solar Challenge. Despite a dust storm and a flu virus that sickened the crew, *Infinium* spent only four minutes at the side of the road during the 33-hour race. The team also won the 2009 Technical Innovation Award.

Team members hail from all units of the University, including the College of Engineering; Literature, Science, and the Arts and the Ross School of Business. ME students include Gerald Chang, the 2009 mechanical lead and 2010 crew chief; Ethan Lardner, operations director; and Troy Halm and Nicholas (Cole) Witte, both mechanical engineers. ME Professor **Kazuhiro Saitou** has been serving as an engineering faculty advisor to the team since 2008.

“The 2008 North American Solar Challenge was my first race,” said Chang. “I didn’t design anything major on the car—it just exposed me to how amazing the team is.” But Chang helped design and build *Infinium,* and winning the 2010 race was a huge reward.

“I had thought being on the team for my whole college career would tire me out, but now I’m excited and plan to be heavily involved in the next project,” he said. “I’ll help the Michigan Solar Car Team challenge the world again in the 2011 Global Green Challenge.”

For more information, visit http://solarcar.engin.umich.edu/.

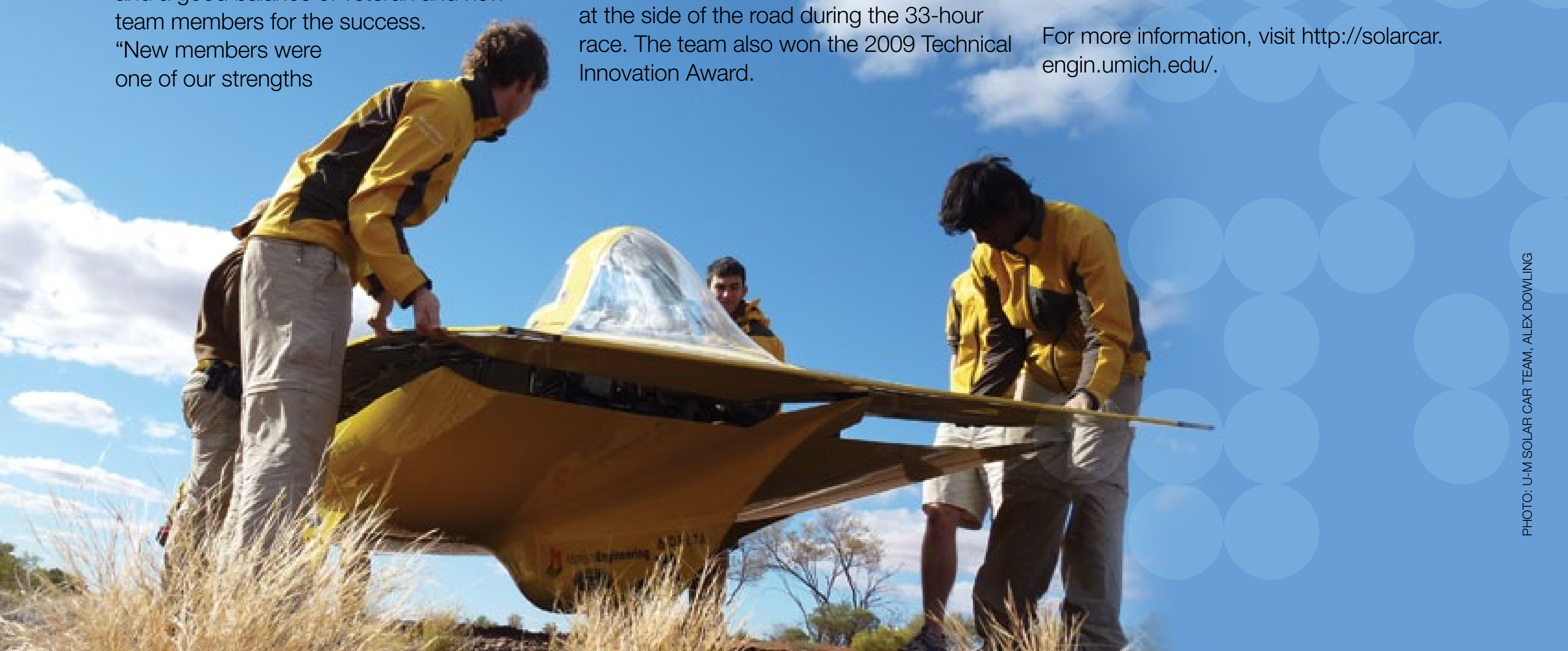


PHOTO: U-M SOLAR CAR TEAM, ALEX DOWLING

ME Faculty Take College and University Leadership Positions

MICHAEL THOULESS

S. JACK HU

ANNA STEFANOPOULOU

DAWN TILBURY

Thouless Elected Chair of SACUA

Professor **Michael Thouless** has been elected chair of the Senate Advisory Committee on University Affairs, or SACUA. By virtue of the position, Thouless also serves as chair of the University Senate and the Senate Assembly.

The Committee's major role is to advise and consult on behalf of the faculty in a variety of matters concerning University policy and to implement the actions of the University Senate and the Senate Assembly. SACUA's nine members each are elected to three-year terms.

Thouless was elected to SACUA after serving three years on the Senate Assembly. He was then elected by SACUA to serve a one-year term as vice-chair, before being elected chair.

Hu Appointed Associate Dean for Academic Affairs

Professor **S. Jack Hu** was appointed associate dean for academic affairs, effective September 1, 2009. Hu also holds the G. Lawton and Louise G. Johnson Professorship of Engineering.

As associate dean for academic affairs, Hu is working closely with the dean and other members of the College of Engineering administrative team. His responsibilities include faculty recruiting, appointment, promotion and tenure as well as overseeing merit reviews, budget reviews and planning, and space allocation and management.

Hu holds a joint appointment as a professor of Industrial and Operations Engineering. He also serves as the University co-director of the General Motors Collaborative Research Laboratory on Advanced Vehicle Manufacturing. His research interests include assembly and materials joining, engineering statistics and the design and performance analysis of manufacturing systems. He serves as editor-in-chief for the *Journal of Manufacturing Systems*.

Stefanopoulou Named ARC Director

Professor **Anna Stefanopoulou** was named director of the Automotive Research Center (ARC), effective October 2009.

The ARC is a University of Michigan-based U.S. Army Center of Excellence for advancing the technology of high fidelity simulation of military and civilian ground vehicles. It is a basic research partner of the U.S. Army Tank Automotive Research, Development and Engineering Center - National Automotive Center (TARDEC-NAC) in Warren, Michigan.

Stefanopoulou's expertise in powertrain control and automation issues associated with fuel cells, fuel processing, energy storage and internal combustion engines provide her a good perspective on the advanced power and energy landscape.

"There is perfect alignment in the current power and energy research needs between the military and commercial automotive sectors," said Stefanopoulou. "And I intend to strengthen the unique collaboration that the ARC has with TARDEC and leverage numerous public-private partnerships for quickly transferring our technology to the field and to soldiers."

Tilbury Named Robotics Center Director

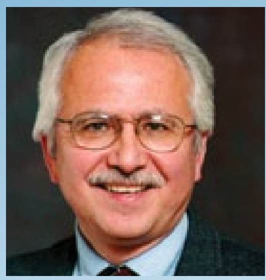
Professor **Dawn Tilbury** was named director of the Ground Robotics Reliability Center (GRRC) in October 2009. She assumed the role from Professor A. Galip Ulsoy, the Center's founding director. Ulsoy currently serves as deputy director.

Launched with a few projects in 2007, the Center's research advances four thrust areas: behavior reliability; power and mobility; design and control; testing, integration and validation. The thrust areas underscore the Center's goal to develop research expertise and curricula in support of the reliable performance and operations of unmanned ground vehicles (UGVs) and robotics. Increasing the speed and impact of innovative technology readiness for the military is also part of the Center's mission.

The GRRC's research projects are funded primarily by the Joint Center for Robotics (JCR) at the U.S. Army Tank-Automotive Research Development and Engineering Center (TARDEC). The U-M leads the GRRC, which also includes other academic and industry partners.

The Center helped launch a new Master of Engineering Program in Robotics and Autonomous Vehicles at U-M, which is led by Professor Huei Peng.

Tilbury's own research focuses on control strategies, techniques and algorithms to prevent failures and to mitigate the effects of those that do occur. She is developing new user interfaces using augmented reality to reduce operator mistakes and improve overall UGV system reliability.



A. GALIP ULSOY

Ulsoy Named Distinguished University Professor

Professor **A. Galip Ulsoy**, the William Clay Ford Professor of Manufacturing, has been awarded a Distinguished University Professorship, one of the highest honors the University bestows upon faculty.

The professorship, held until retirement, honors full or associate professors for exceptional work in their fields, national or international renown and superior teaching or mentorship. Ulsoy is the second ME professor to become a Distinguished University Professor; Chia-Shun Yih also was honored in 1968.

Ulsoy has taught at U-M since 1980, developed several courses and held numerous service positions University-wide, including founding director of the Program in Manufacturing, chair and associate chair of ME and chair of the ME Graduate Program. He also has held several national service positions, including director of the National Science Foundation Division of Civil and Mechanical Systems from 2003 to 2005 and editor of the American Society of Mechanical Engineers (ASME) *Journal of Dynamic Systems, Measurement and Control*. He was elected to the prestigious National Academy of Engineering and earned numerous other honors, including the 2008 Society of Manufacturing Engineers Albert M. Sargent Progress Award and the 2008 ASME Rufus T. Oldenburger Medal (see related story on page 4).

Ulsoy's work on dynamic modeling, analysis and control of mechanical systems has contributed significantly to manufacturing and automotive systems. He co-founded the University's National Science Foundation Engineering Research Center for Reconfigurable Manufacturing Systems and currently serves as its deputy director. Ulsoy also served as founding director of the Ground Robotics Reliability Center, launched in 2007 and sponsored by the U.S. Army.

Faculty Awards & Promotions

External Awards

JAMES ASHTON-MILLER
American Society of Biomechanics (ASB) Borelli Award, 2009

SHORYA AWTAR
NSF Faculty Early Career Development Award, 2009

JAMES BARBER
ASME Drucker Medal, 2009

ASEE Archie Higdon Distinguished Educator Award, 2010

CLAUS BORGNAKKE
ASME James Harry Potter Gold Medal, 2009

NIKOS CHRONIS
NIH Director's New Innovator Award, 2009

SAMANTHA DALY
DoE Early Career Research Program Award, 2010

DAVID DOWLING
Robert Caddell Memorial Faculty/Student Achievement Award, 2010

ZORAN FILIPI
SAE Excellence in Oral Presentation Award, 2009

SAE Forest R. McFarland Award, 2009

JOHN HART
ASME Pi Tau Sigma Gold Medal, 2009

SME Outstanding Young Manufacturing Engineer Award, 2010

ERIC JOHNSEN
Ralph E. Powe Junior Faculty Enhancement Award, 2010

MASSOUD KAVIANY
ASME James Harry Potter Gold Medal, 2010

JYOTI MAZUMDER
ASME Thomas A. Edison Patent Award, 2010

JUN NI
ASME Mfg Science & Engineering Best Paper Award, 2009

ASME Ennor Mfg Award, 2009

KENN OLDHAM
NSF Faculty Early Career Development Award, 2010

JWO PAN
SAE Arch T. Colwell Merit Award, 2010

HUEI PENG
Visiting Chang-Jiang Scholar at Tsinghua University, 2009

KEVIN PIPE
Defense Advanced Research Young Faculty Award, 2009

PRAMOD SANGI REDDY
NSF Faculty Early Career Development Award, 2009

ANN MARIE SASTRY
CNN Money.com's Innovators in Detroit List, 2010

VOLKER SICK
Fellow, Center of Smart Interface at TU Darmstadt, 2010

KATHLEEN SIENKO
NSF Faculty Early Career Development Award, 2009

ANNA STEFANOPOULOU
ASME Gustus Larson Memorial Award, 2009

JEFF STEIN
ASME Dedicated Service Award, 2010

MICHAEL THOULESS
U of Cambridge ScD Degree, 2009

Fellow, Overseas at Churchill College, 2011

ANGELA VIOLI
Monroe-Brown Foundation Education Excellence Award, 2010

KON-WELL WANG
ASME Rudolf Kalman Best Paper Award, 2009

ASME Adaptive Structures and Material Systems Best Paper Award in Structural Dynamics and Control, 2010

ALAN WINEMAN
SES William Prager Medal, 2009

New Societal Fellows

Acoustical Society of America
KARL GROSH, 2010

The American Academy of Mechanics
ELLEN ARRUDA, 2010

American Physical Society
STEVE CECCIO, 2009

American Society of Mechanical Engineers
JAMES ASHTON-MILLER, 2009
DAVID DOWLING, 2010
ZHENG-DONG MA, 2010

International Federation of Automatic Control
A. GALIP ULSOY, 2010

Society of Manufacturing Engineers
ALBERT SHIH, 2009

U-M Awards

DENNIS ASSANIS
Rackham Distinguished Faculty Achievement Award, 2009

DAVID DOWLING
ASEE Univ of Michigan Outstanding Professor Award, 2009

CoE Education Excellence Award, 2009

HOSAM FATHY
CoE Outstanding Research Scientist Award, 2009

ZORAN FILIPI
Research Faculty Achievement Award, 2010

KRISHNA GARIKIPATI
ME Achievement Award, 2009

JOHN HART
ME Achievement Award, 2010

JACK HU
G. Lawton and Louise G. Johnson Professorship in Engineering, 2009

ELIJAH KANNATEY-ASIBU
CoE Outreach & Diversity Award, 2010

Harold R. Johnson Diversity Service Award, 2010

REUVEN KATZ
CoE Kenneth M. Reese Outstanding Research Scientist Award, 2010

YORAM KOREN
Distinguished University Professorship, 2010

PANOS PAPALAMBROS
CoE Stephen S. Attwood Award, 2009

NOEL PERKINS
Donald T. Greenwood Collegiate Professorship in Engineering, 2009

ALBERT SHIH
Rackham Faculty Recognition Award, 2010

STEVE SKERLOS
ME Achievement Award, 2009

MICHAEL THOULESS
Professor of the Term by Pi Tau Sigma, 2009

ME Achievement Award, 2010

DAWN TILBURY
CoE Service Excellence Award, 2010

A. GALIP ULSOY
Distinguished University Professorship, 2009

ANGELA VIOLI
CoE Education Excellence Award, 2010

ALAN WINEMAN
CoE Research Excellence Award, 2010

MARGARET WOOLDRIDGE
Arthur F. Thurnau Professorship, 2009

Faculty Promotions

LAURO OJEDA
to Assistant Research Scientist

KEVIN PIPE
to Associate Professor, with tenure

KAZUHIRO SAITOU
to Professor, with tenure

Graduate Student Honors

MICHAEL ALEXANDER
MLK Spirit Award, 2010

JOSHUA BISHOP-MOSER
NSF Fellowship, 2010

JEREMY BROWN
NSF Fellowship, 2010

MATTHEW CARPENTER
Professor and Mrs. William Graebel Top Scholar Award, 2009–2010

VIPUL CHHAJER
Robert M. Caddell Memorial Scholarship, 2009–2010

MESLB Transfer Student Award, 2010

MATHIEU DAVIS
NSF Fellowship, 2010

JESSICA DENEWETH
NSF Fellowship, 2010

TERESA FRANKLIN
NSF Fellowship, 2010

JOSEPH GWIN
National Defense Science & Engineering Graduate Fellowship, 2009

MRINAL IYER
Azarkhin Scholarship, 2010

JEREMY KOEHLER
NSF Fellowship, 2010

BENJAMIN LAWLER
NSF Fellowship, 2010

YING YI LIM
Robert M. Caddell Memorial Scholarship, 2009–2010

RYAN MCGINNIS
NSF Fellowship, 2010

NHUNG NGUYEN
Vietnam Educational Foundation Fellowship, 2009

YOUKEUN OH
Young Investigator (Gold) Award (working under James Ashton-Miller, for paper), 2010

LISA PEREZ
MESLB Outstanding Service Award, 2010

ERIK POLSEN
National Defense Science & Engineering Graduate Fellowship, 2009

MEGAN ROBERTS
NSF Fellowship, 2010

ANDREW SLOBODA
Natural Sciences Engineering Research Council of Canada Fellowship, 2009

TIAGO SZVARCA
Lubrizol Scholarship, 2009–2010

Undergraduate Student Awards

ALEXANDER CICERONE
Lubrizol Scholarship, 2009–2010

ANDREW DOSS
Lloyd H. Donnell Scholarship, 2010–2011

LEROY HANSEN
ME Spirit Award, 2009–2010

SHANE LARKIN
Robert M. Caddell Memorial Scholarship, 2010–2011

MEREDITH MILLER
Robert M. Caddell Memorial Scholarship, 2010–2011

ANIRUDDHA RAINA
R&B Tool Scholarship, 2010–2011

JUSTIN RAJABIAN
R&B Tool Scholarship, 2010–2011

DEANDRE REAGINS
MESLB Future Leader Award, 2010

BRYAN SKULSKY
R&B Tool Scholarship, 2010–2011

MESLB Impact Award, 2010

EDWARD WAGNER
R&B Tool Scholarship, 2010–2011

JUSTIN WINSTON
MESLB Impact Award, 2010

EDWARD ZINGER
Professor and Mrs. William Graebel Top Scholar Award, 2010–2011

Korybalski Lectureship Brings Charles Vest, Roger McCarthy to Campus

Alumnus **Charles Vest**, president of the National Academy of Engineering and president emeritus of the Massachusetts Institute of Technology, gave the third annual Korybalski Lecture in Mechanical Engineering in May 2010. His address focused on "Engineering, Innovation and the Challenges of the 21st Century."

Vest's talk was a part of the annual lectureship endowed by Michael Korybalski, chair of the ME External Advisory Board and former chief executive officer of Mechanical Dynamics. The Korybalski Lecture brings high-profile speakers to the U-M community to promote engineers' impact on large societal problems, such as energy and environment, health and quality of life, national security and disaster prevention.

According to Vest, this is the most exciting era for engineering and science in human history. A new generation of engineers will be inspired by the great human challenges of this century and play a crucial role in addressing them. Globalization and the changing nature of science and technology are driving worldwide change and opportunity in higher education, R&D and innovation. Innovation is key to the future vitality of the United States, and our innovation system may be due for another major transformation.

Vest earned his master's and doctoral degrees in mechanical engineering from U-M in 1964 and 1967, respectively. He was appointed assistant professor at U-M in 1968, conducting research in heat transfer and engineering applications of laser optics and holography. After becoming a full professor, he served as associate dean and dean of the College until 1989, when he became provost of the University. He was president of MIT from 1990 to 2004. Throughout his career, he has worked to bring to public attention to issues concerning education and research and has served on numerous committees in order to strengthen national policy on science, engineering and education.

L TO R: **Professor Dennis Assanis, Dr. Charles Vest, Mr. Michael Korybalski and ME Chair Kon-Well Wang at the 2010 Korybalski Lecture.**

PHOTO: SCOTT C. SODERBERG, U-M PHOTO SERVICES

In 2009 the U-M College of Engineering welcomed alumnus **Roger McCarthy** to campus for the second annual Korybalski Lecture. McCarthy is chairman emeritus and retired chief executive of Exponent Inc., the largest engineering and scientific firm in the United States dedicated primarily to the analysis and prevention of scientific and engineering failures.

McCarthy's presentation, "Scale Happens," covered a number of major failures and disasters of the last 100 years and the role that scale, whether intentional or evolutionary, played in the ultimate disaster. He talked about engineers' roles in learning these lessons in order to prevent future failures.

McCarthy has participated in investigating many of the major disasters of modern times, including the collapse of the Kansas City Hyatt walkways, the grounding of the Exxon Valdez and the bombing of the Murrah Federal Building in Oklahoma City. In 1996 he testified in the second Menendez brothers murder trial and performed a murder reconstruction for the prosecution.

The inaugural Korybalski Lecture was given by Dr. Larry Burns in 2008, then vice president of research and development and planning for General Motors. Dr. Burns recently retired after a 40-year career with the company.

Raymond Wilcox

Strengthening Communications among Future Engineering Leaders

Alumnus and College of Engineering National Advisory Board member **Raymond Wilcox** (BSE ME '68) came to the University of Michigan from Florida in 1964, looking for a top-notch engineering program that would provide him with exposure to a wide array of people, ideas, disciplines and cultures.

"I found what I had hoped for. My U-M education helped prepare me for a career with an international company where technical expertise, leadership skills and a willingness to work and live around the globe were all important attributes," said Wilcox, who retired in 2008 as the president and chief executive officer of Chevron Phillips Chemical Company LLC. His career with Chevron spanned four decades and included assignments in North America, Asia, Australia and Africa.

Raymond and Peggy Wilcox

When Wilcox earned his U-M degree in mechanical engineering *cum laude* in 1968, he was completely unfamiliar with the oil industry. "I ultimately found the energy business to be one of the most fascinating, challenging, relevant and diverse careers one could hope for, and I fell in love with it," he said.

In turn Wilcox and his wife of 35 years, Peggy, have made it possible for others to pursue their engineering passion and to excel. In 1998 the couple established the Ray and Peggy Wilcox Fund in the College of Engineering. Over the past 12 years, the fund has provided support for faculty and student research, student scholarship and fellowship support, equipment purchases and support for guest speakers and lectures.

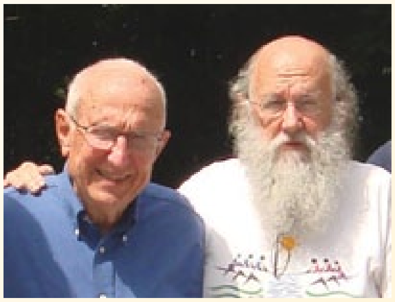
Wilcox is a proponent of combining strong technical expertise with the communications skills necessary to convey complex concepts clearly and effectively, in both written and oral forms. The Peggy and Ray Wilcox Fund has focused on faculty efforts that teach undergraduates the importance of good, clear communications and other activities that emphasize these skills.

"I recognized very early in my own career the importance of being able to clearly present and sell one's ideas and work to others, and the key role that communications plays in effective leadership," he said. "Peggy and I wanted to help others make that critical connection, too."

Carroll and Kit Haas

Longtime Friends, Supporters, of ME

When he returned from the Pacific Theater of World War II as a first lieutenant with the U.S. Army Signal Corps, **Carroll Haas** resumed his engineering studies at U-M. He earned his bachelor's of science degree in mechanical engineering in 1947 and, with his family, has since maintained a strong, six-decade relationship with the ME department.



Carroll and Kit Haas

Haas and his late wife Elaine, who also earned a U-M degree in education, had six children, four of whom attended the University. The couple's late son, "Kit" Carroll, Jr., earned bachelor's, master's and doctoral degrees in ME and lectured in the Department.

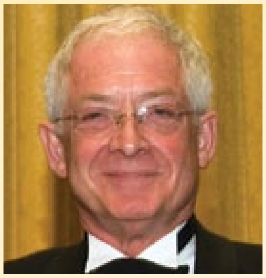
Haas was an original member of the ME External Advisory Board, serving until 2006. He also served on the Engineering Alumni Society Board from 1996 to 2001. In 1997, he and Elaine established an endowment fund that has supported many activities, including the Distinguished Lectureship in Manufacturing, essential equipment for manufacturing research and support of top junior faculty.

The couple also established the Carroll J. Haas Endowed Scholarship Fund to give need-based support to full-time undergraduates. Since 2006 the Fund has helped 18 engineering students pursue their degrees. In addition, Haas is a generous volunteer and supporter of the Class of '47E Scholarship Fund and numerous activities in the U-M Medical School. He established the Carroll Haas Cystic Fibrosis Research Fund and supports innovative research in nanomedicine.

A successful entrepreneur, Haas merged two firms and created Colonial Engineering in 1977. The company has plants in Michigan, Florida and California and distributes valves and pressure fittings for industry and irrigation systems worldwide.

Kit Haas also served as president of Colonial Engineering from 1992 to 2002. An avid traveler, he visited all seven continents and climbed three of the continental United States' tallest peaks.

Ray Pittman Receives Alumni Society Merit Award



RAY PITTMAN

Alumnus and entrepreneur **Ray Pittman** (BSE ME ’67, MSE ME ’68) has received an Alumni Society Merit Award. The awards, bestowed annually, recognize an alumnus/a in each department who has achieved significant professional accomplishments.

Pittman and his family are actively involved with the ME department. In 2007, he and his son RJ Pittman established the Raymond A. Pittman Endowed Scholarship Fund in honor of Ray’s father and RJ’s grandfather, who earned a joint bachelor’s degree from U-M in 1942 in both mechanical and aerospace engineering. Ray and RJ created the fund in order to carry on Raymond’s passion for motivating young people to pursue a university education.

Pittman is imbued with and carries forth his father’s passion for mentorship in numerous ways. He was integral to the development of the Michigan Engineering Zone, where more than 100 high-school students build robots for the FIRST Robotics Competition in a U-M College of Engineering-sponsored space in Detroit. In 2006 he served as a member of the Prospective Student Recruitment Committee of the Alumni Society Board of Governors and continues to recruit female students to the College. He currently is involved in the Center for Entrepreneurship and the Business Engagement Center and participates, with RJ, in the annual University of Michigan Bay Area Entrepreneurship Trip. He is a member of the Hutchins Society of the University.

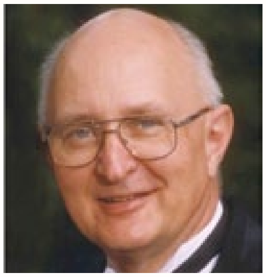
An international consultant, Pittman gained 33 years of experience at Ford Motor Company. He served as executive director of Powertrain for Ford Europe from 1998 until his retirement in 2002. Currently he serves as special advisor to the chief executive of Coherix, a privately held Ann Arbor firm specializing in three-dimensional machine vision.

In Memoriam

The ME department mourns the loss of three colleagues. As we continue to reflect upon their valued contributions, our thoughts are with their family and friends.

RICHARD SONNTAG

WEN-JEI YANG



LYNN BUEGE

Richard Sonntag, professor emeritus and former ME chair

Emeritus Professor and former U-M ME Department Chair **Richard Sonntag** (BSE ME ’56, MSE ’57, PhD ’61) passed away in February 2010. Sonntag played an important role in the history of the ME department. He spent his entire career at the University, starting as an assistant professor. He earned the rank of full professor in 1967. He served as acting chair from 1981 to 1982 and as chair from 1982 to 1992. In 1992, he received the Department’s Excellence in Service Award.

Wen-Jei Yang, professor emeritus

Professor Emeritus **Wen-Jei Yang** (MS ’56, PhD ’60) passed away in April 2010. He earned international recognition for his work, including the highly prestigious Max Jakob Award granted by the American Society of Mechanical Engineers and the American Society of Chemical Engineers. His many contributions included authoring or co-authoring 860 technical papers and 23 technical books. Among numerous other honors, he was a fellow of the American Society of Mechanical Engineers.

Lynn Buege, research technical manager

Lynn Buege of Ann Arbor, MI, passed away in February 2010. He attended U-M and was employed by the University since 1965 and the ME department since 1968. Buege worked as an engineer for ME, enthusiastically tackling a wide range of technical challenges to help faculty and students, before moving into a supervisory engineering role. He won a Staff Excellence Award in 1992.

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