UNIVERSITY OF MICHIGAN COLLEGE OF ENGINEERING

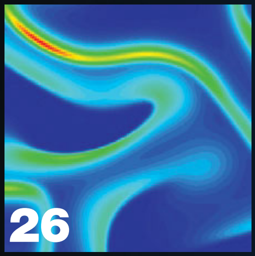
MECHANICAL ENGINEERING ANNUAL REPORT 2010–2011

ME

MichiganEngineering

MECHANICAL ENGINEERING ANNUAL REPORT 2010–2011

ON THE COVER AND THIS PAGE: High-fidelity simulation results of turbulent sooting flames. Direct numerical simulation provides fully resolved information of flow, temperature and chemical species. Colors indicate the soot density within turbulent flames, rendered by the realistic luminosity of soot radiation.



CONTENTS

MESSAGE FROM THE CHAIR

"It has been another year of advancement, breakthroughs and impact on many levels."

I feel privileged to present you with the University of Michigan (U-M) Mechanical Engineering (ME) 2010–11 annual report. It has been another year of advancement, breakthroughs and impact on many levels.

The U-M ME doctoral program has received exceptional marks from the National Research Council in its latest assessment of U.S. PhD programs, with composite rankings among the highest in mechanical engineering nationwide.

In April 2011, the Mechanical Engineering faculty and staff were joined by government officials and U-M academic leaders to break ground on a new, 62,880-square-foot, world-class research complex. This is an exciting milestone for the ME department: the facility will enable transformative research activities where core mechanical engineering intersects with emerging technologies.

Faculty members have played important leadership roles vis-à-vis the national agenda with many examples highlighted in this report. Our colleagues have been selected to lead a Clean Vehicles Consortium under the U.S.-China Clean Energy Research Center, invited to speak about transportation electrification on Capitol Hill, and have led National Science Foundation (NSF) and National Academy of Engineering workshops on the future of manufacturing, the future of mechanical engineering education and on junior female faculty mentoring. Faculty also have led the promotion of advanced manufacturing at the White House Office of Science and Technology Policy, which paved the way for President Obama's recent call for action through an Advanced Manufacturing Partnership.

Our junior faculty, as always, are recognized for their early-career successes with highly competitive young investigator awards from various agencies, such as the NSF and the Department of Defense. This coming year we are welcoming two new assistant professors to our faculty: Drs. Allen Liu and Xiaogan Liang. Each brings valuable expertise to the departmental and university communities. We will be conducting several new faculty searches in the coming year as well.

Our research efforts continue to have strong impacts on the scientific community as well as society at large. In the pages ahead, we share just a few of the breakthroughs in both fundamental and applied research: robotics, energy, automotive, micro-/nano- systems, global health, cell mechanics, structural dynamics, computational physics, design science, complex system synthesis, and more.

We also continue to spearhead new education initiatives and opportunities for students. Examples highlighted in this report include our comprehensive curriculum in design, build, test, show and tell, and our many international programs in Germany, China, Ghana and Korea, among others. Our student teams and organizations, from BLUElab to MRacing and the Solar Car Team, also had an outstanding year.

Our fantastic alumni continue to support the Department in countless ways, generously devoting time and effort. We have highlighted several examples in this year's report.

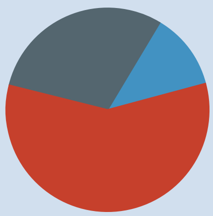
We hope you, too, have had a productive and successful year. Thank you for reading and for your interest.

Kon-Well Wang

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

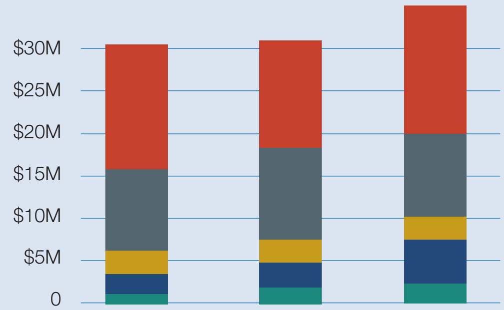
TRENDS & STATISTICS

ME DEGREES CONFERRED 2009–2010



BSE 242
MSE 105
PhD 39

ANNUAL RESEARCH EXPENDITURES



	08–09	09–10	10-11
NIH	1,403,643	1,996,237	2,168,238
DoE	1,773,858	2,390,860	5,407,039
NSF	2,460,177	2,701,330	3,104,779
DoD	10,195,017	10,992,316	9,796,979
All Other	14,608,221	13,792,756	14,092,339
Total	**$30,440,916**	**$31,873,498**	**$34,569,374**

FACULTY PROFILE

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

63
# of Society Fellows

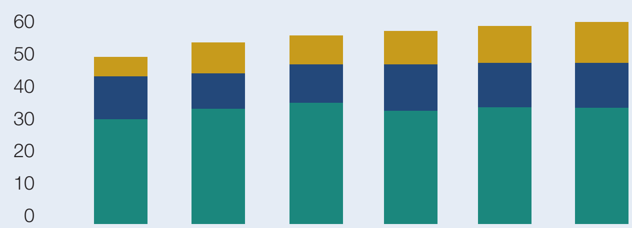
4
# of NSF PECASE or PFF Awards

28
# of NSF CAREER or PYI Awards

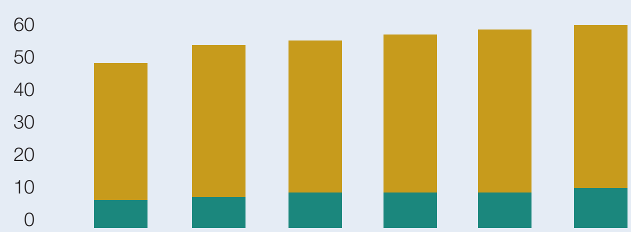
5
# of Current Journal Chief Editors

68
# of Current Journal Editorial Board or Associate Editor Appointments

TENURED AND TENURE-TRACK FACULTY TRENDS



	FA06	FA07	FA08	FA09	FA10	FA11
Assistant	6	9	10	11	12	14
Associate	13	12	11	12	12	11
Professor	31	34	36	35	36	37
Total Faculty	50	55	57	58	60	62



	FA06	FA07	FA08	FA09	FA10	FA11
Male	42	46	47	48	50	51
Female	8	9	10	10	10	11
Total Faculty	50	55	57	58	60	62

IN THE NEWS

NEW MECHANICAL ENGINEERING RESEARCH COMPLEX UNDERWAY

In April 2011, the University of Michigan (U-M) Mechanical Engineering (ME) faculty and staff were joined by government officials and U-M academic leaders to break ground on a new, world-class research complex. This is an important milestone for U-M ME: The new facility will support the Department's role in actively defining and shaping the future of mechanical engineering.

The 62,880-square-foot addition to the existing G.G. Brown Laboratories will enable transformative research activities where core mechanical engineering intersects with emerging technologies.

The $46 million project is supported in part by $9.5 million from the National Institute of Standards and Technology (NIST).

The new three-story building will contain lab modules as well as offices for professors, research staff and students. A below-grade level will house special ultra-low vibration (ULV) laboratories, including eight specialized lab chambers designed to meet NIST vibration specifications, with stringent temperature and humidity control and air filtration. In addition to the ULV labs, the facility will have laboratories dedicated to imaging and

CLOCKWISE FROM TOP: Mechanical Engineering faculty and staff gather to break ground for the new research complex; NIST Director Patrick Gallagher speaking at the ground breaking ceremony. To his left are College of Engineering Dean David Munson and U-M President Mary Sue Coleman; Michigan Governor Rick Snyder (left) and U-M President Mary Sue Coleman (middle) talking with other guests attending the ceremony. PHOTOS: SCOTT SODERBERG, U-M PHOTO SERVICES

OPPOSITE PAGE, LEFT: GG Brown expansion: View looking southeast. ARCHITECTURAL RENDERING: PERKINS + WILL AND INTEGRATED DESIGN SOLUTIONS, LLC

optics; biosystems; nanoengineering; micro-bioengineering; materials, mechanics and mechanical testing; microdynamics and nanostructures.

The state-of-the-art laboratories will allow investigators to conduct cutting-edge research at unprecedented levels of precision and accuracy. Such activities include nanoscale metrology, single-molecule bioengineering, nanoscale energy conversion, nanomanufacturing and nano/micro electromechanical systems (NEMS/MEMS) for medical research and diagnostics. The research outcomes will be critical to future advancements in energy, manufacturing, health care and bio-technologies.

The new facility is designed to encourage collaboration through space and equipment sharing. This arrangement will further solidify the many multidisciplinary projects that already are underway within the ME department—and undoubtedly spark new ones.

The new building is expected to be completed in academic year 2013–14.

NATIONAL RESEARCH COUNCIL RANKINGS—U-M ME EARNS STELLAR MARKS

The U-M ME doctoral program has received exceptional marks from the National Research Council (NRC) in its latest assessment of U.S. PhD programs. The U-M ME program's composite NRC rankings are among the highest in mechanical engineering nationwide. The Department has also earned an overall #2 ranking from the independent website PhDs.org, based on its default weightings of the NRC data for large institutions: http://graduate-school.phds.org/rankings/mechanical-engineering/rank/larger.

The NRC's evaluation includes data on more than 5,000 PhD programs in 62 fields overall. Over 200 American universities were included in the study. In the field of Mechanical Engineering, over 120 programs were evaluated.

The NRC's rankings are based on quantitative data, including characteristics such as faculty publications, grants and awards; graduate student financial support, employment outcomes and time to degree; as well as measures of faculty and student diversity. The NRC uses two methods for calculating its composite rankings: regression-based or R rankings and survey-based or S rankings. Both assess quality based on the characteristics that are important to a high-quality doctoral program. Each method yields a different set of weights, which subsequently result in the two distinct sets of rankings. The ME program at U-M ranked among the top in both rankings.

The NRC's methodologies are designed to take variability and individual user priorities into account. The assessment is meant to help prospective students with their search for a doctoral program and to help universities improve their programs. The NRC's data also are used by PhDs.org in its Graduate School Guide. The website, which is not affiliated with the NRC, allows users to compare programs by selecting the characteristics that are most important to them.

+ more on the web

More information about the assessment can be found at http://www.nap.edu/rdp

http://graduate-school.phds.org/rankings/mechanical-engineering/rank/larger

U-M NAMED MEMBER OF U.S. ADVANCED MANUFACTURING PARTNERSHIP BY PRESIDENT OBAMA

President Obama recently named U-M as one of six universities that will represent higher education in a new Advanced Manufacturing Partnership (AMP). Mechanical Engineering Professor **S. Jack Hu**, the G. Lawton and Louise G. Johnson Professor of Engineering, will help lead U-M in the collaborative effort.

The AMP will help the United States to improve its economic competitiveness by fostering the development and deployment of new technologies. Other universities in the partnership include Massachusetts Institute of Technology, Carnegie Mellon University, Georgia Institute of Technology, Stanford University and University of California, Berkeley.

"The University of Michigan brings to the table an excellent record in manufacturing research, education and in partnering with industry," said Hu, who also is a professor of Industrial and Operations Engineering.

The six universities will share educational materials as well as best practices related to advanced manufacturing research, education, innovation and industry partnerships. The effort may include such activities as an "open-source" concept for advanced manufacturing courses; creating K-12 outreach materials about advanced manufacturing; collaborating with community colleges on curriculum development and implementing competitions that promote advanced manufacturing awareness.

A key part of the AMP also will include facilitating conversations among industry partners and government agencies to create a roadmap for advanced manufacturing research, as well as recommendations for common infrastructure to support research and technology transfer.

The University already has programs that could serve as a starting point, including several manufacturing master's programs available via web-based technologies, a top-notch design and manufacturing sequence and a multidisciplinary design minor as well as many long-standing industry partnerships.

"Equipped with our strong reputation in manufacturing research and education, U-M now is ready to further its work on the national level," said Hu.

ME PROFESSOR KOTA SPARKS ADVANCED MANUFACTURING MOMENTUM IN WASHINGTON

Professor **Sridhar Kota** has brought his extensive product development expertise to bear in Washington, D.C. For the past two years Kota has been serving the White House Office of Science and Technology Policy as assistant director for advanced manufacturing. In addition to coordinating advanced manufacturing research and development and devising policy recommendations and strategies to enhance U.S. competitiveness, Kota has been instrumental in shaping a number of initiatives. One of those efforts is the Advanced Manufacturing Partnership (AMP), which President Obama announced at Carnegie Mellon University in June 2011 (see related story on page 6).

Advanced manufacturing refers to the use of information technology or other new technologies in the manufacture of new or emerging products as well as the use of advanced processes during the manufacture of existing products.

In fall 2009, when the President's Council of Advisors on Science and Technology, or PCAST, began working on a report on American leadership in advanced manufacturing, Kota responded to the Council's many and varied questions about challenges and opportunities. He prepared background information and case studies that addressed topics such as trade imbalances and the need for public-private partnerships to mature emerging technologies and ensure manufacturing readiness.

Kota made the case for a strong innovation policy to strengthen our country's manufacturing base. "The 'invent it here, manufacture it there' approach to innovation that we've seen in past decades simply is not economically sustainable," he said. Using examples from the past three decades, he conveyed how failing to manufacture today's advanced technology products puts our ability to innovate next-generation products at tremendous risk.

Government has traditionally invested in basic research, and it must continue to do so in order to feed our innovation pipeline with new scientific discoveries, Kota explained. But while discovery is vital, it is not sufficient to compete in today's global economy.

Kota's work laid the foundation for a key recommendation from the PCAST: to launch an advanced manufacturing initiative to support innovation through applied and translational research programs for promising new technologies and public-private partnerships around broadly-applicable and pre-competitive technologies—all to close the gap between research and manufacturing. Several new initiatives including the AMP were born.

“The Advanced Manufacturing Initiative is a direct outgrowth of the intellectual leadership Professor Kota provided to the PCAST. The nation owes him a debt of gratitude for his dedication and hard work,” said Professor Rosina Bierbaum, a PCAST member and dean of the U-M School of Natural Resources and Environment.

President Obama personally thanks Sridhar Kota for his contributions.

“Professor Kota has brought clear vision around advanced manufacturing and played a key role in shaping the nation’s program to revitalize this critical sector of our economy,” added Dr. Eric Lander, PCAST co-chair. “He’s been a great asset and resource.”

Dr. Shirley Ann Jackson, PCAST member and president of Rensselaer Polytechnic Institute, agrees. “Sridhar played a key role in PCAST’s development of the Advanced Manufacturing report by researching key issues as well as identifying technological opportunities and different ways to weigh the importance to the United States of advanced manufacturing tied to R&D.”

In announcing the AMP, President Obama said, “If we want a robust, growing economy, we need a robust, growing manufacturing sector.” The President also announced a National Robotics Initiative, a multi-agency initiative that Kota helped orchestrate, and other initiatives including an Open Manufacturing Initiative from the Defense Advanced Research Projects Agency and an Innovative Manufacturing Initiative from the U.S. Department of Energy. And that’s good news, he says. “Between invention and manufacturing, you have innovation through translational research and engineering. Support for those is what we need to take our ideas and turn them into home-grown products.”

Momentum has been building for other federal advanced manufacturing initiatives as well, and Kota will continue his involvement in a number of related efforts in the Detroit area in order to leverage the region’s unique manufacturing resources.

ME PROFESSOR STEIN BRINGS CAPITOL HILL UP TO SPEED ON ELECTRIC VEHICLES

Electric vehicles can reduce the use of petroleum and lower levels of greenhouse gas emissions, but they also can help the U.S. electric grid system operate more efficiently. Professor **Jeffrey Stein** explained this and other less commonly known benefits of electric vehicles to a group of congressional staff in Washington, D.C., in March 2011.

The event, entitled "The Promise and Challenges of Vehicle Electrification," was sponsored by the National Science Foundation (NSF), *Discover* magazine, the American Society of Mechanical Engineers and the Institute of Electrical and Electronics Engineers.

Stein had a lot of insight to share on Capitol Hill. For the past several years he and colleagues have been investigating the potential synergies that occur when electric vehicles (EVs) are connected to the grid. "Combining the two systems improves the grid and the vehicle in terms of our efforts to provide both transportation and power, and to provide both in a sustainable and resilient way," he said.

One of the greatest advantages to EVs, Stein explained to those in attendance, stems from the fact that their demands on the grid are deferrable. Unlike turning on a light, which consumers require instantly, there often is some leeway when it comes to charging EVs. As long as the car is charged by the time the driver next needs it, electric companies can delay the increased load on the grid until overall demand is lower.

"Deferrable loads provide electric companies with a huge advantage, specifically a lot of flexibility about how to distribute the power they're generating. This helps them keep loads more consistent and to avoid the need to bring on ancillary generation services—which are more expensive and dirtier—to meet increased demands," he said.

At U-M, Stein is leading a multidisciplinary effort supported by the NSF on infrastructure systems coupled by hybrid electric and electric vehicles: "A Multi-Scale Design and Control Framework for Dynamically Coupled Sustainable and Resilient Infrastructures, with Application to Vehicle-to-Grid Integration."

As part of the NSF effort, he and colleagues have been conducting simulations and life-cycle analyses to determine the net effect of EVs on the grid in terms of pollution. Although EVs increase the amount of power electric companies must generate, their load deferability actually leads to lower levels of greenhouse gas emissions because ancillary generation methods are required less often.

Other associated projects include studies of battery health and longevity, creating an engineering design framework that maximizes battery life and efficiency, plug-in charging strategies and using intermittent power sources such as wind and solar in the context of plug-in EVs.

"We're looking at a lot of different aspects," Stein said, "but we're not solving all the problems. The solutions we're investigating are by no means trivial to implement, and no one is a silver bullet for our energy challenges. Still, they're powerful ideas that are important for identifying additional research needs."

Jeffrey Stein on Capitol Hill. PHOTO: MIKE WARING

> "Combining the two systems improves the grid and the vehicle in terms of our efforts to provide both transportation and power, and to provide both in a sustainable and resilient way." —JEFFREY STEIN

ME FACULTY LEAD U.S.-CHINA CLEAN VEHICLE CONSORTIUM

When it comes to energy, the United States and China have a great deal in common: The two nations are the world's largest energy producers, consumers and greenhouse-gas emitters. Likewise, both countries have rapidly growing clean energy sectors, and new clean energy technologies will help both nations meet future energy needs and climate challenges alike.

Now the United States and China are addressing these needs and challenges together, through the U-M-led Clean Vehicle Consortium (CVC), which is one of three U.S.-China Clean Energy Research Centers (CERC) established in 2010.

Dennis Assanis, ME professor and the Jon R. and Beverly S. Holt Professor of Engineering, has served as director of the U.S. CVC. Dr. Minggao Ouyang from Tsinghua University is leading the Chinese consortium.

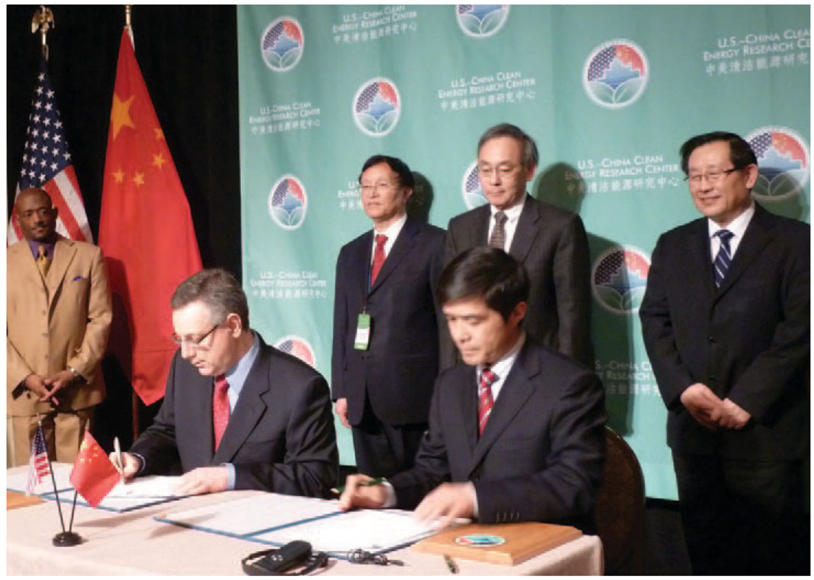
The announcement that U-M would lead the U.S. consortium was made in September 2010 by U.S. Energy Secretary Steven Chu. Chu also announced last fall that West Virginia University would head a U.S. consortium for Advanced Coal Technology, and Lawrence Berkeley National Laboratory, a consortium for Energy Efficient Buildings.

"Our goal with the CVC is to contribute to dramatic, rather than incremental, improvements in technologies that have the potential to reduce vehicle dependence on oil and to improve fuel efficiency," explained Assanis.

To that end, joint research projects will focus on the following areas: energy systems analysis, technology roadmaps and policies, vehicle-grid interaction, vehicle electrification, advanced batteries and energy conversion, advanced biofuels and clean combustion, and advanced lightweight materials and structures (see related story on page 42).

Grants from the CERC and matching funds from U-M and Tsinghua University will support at least $50 million in research projects over five years.

The CVC also includes other universities, industry partners and national laboratories, such as Ohio State University, Massachusetts Institute of Technology, Sandia National Laboratory, Joint BioEnergy Institute, Oak Ridge National Laboratory as well as General Motors, Ford Motor Company, Cummins, Delphi and Toyota Motor Company, among many others.



Professor Dennis Assanis, founding director for the United States Clean Venicle Concortium, and Professor Minggao Ouyang, founding director for the People's Republic of China, are signing the Joint Work Plan under the U.S.-China Clean Energy Research Center. Witnessing the signing are (standing from center to right) Director of China National Energy Administration Zhang Guobao, U.S. Department of Energy Secretary Steven Chu, and Minister of China Science and Technology Wan Gang.

During a visit to the United States by Chinese President Hu Jintao in January 2011, U.S. and Chinese CVC members signed Joint Work Plans that spell out the shared goals and objectives.

In October 2011, Assanis joined The State University of New York at Stony Brook as provost, senior vice president for academic affairs and vice president for Brookhaven affairs. Professor **Huei Peng**, who has served as the deputy director of the CVC, was appointed as the new CVC director.

+ more on the web

For more information on the CERC or CVC, visit **http://www.us-china-cerc.org/**

NSF WORKSHOP AND NAE SYMPOSIUM—STRATEGIZING TO REVITALIZE U.S. MANUFACTURING

More than two dozen leaders in manufacturing research convened in Ann Arbor in May 2010 to attend a workshop hosted by U-M and sponsored by the National Science Foundation (NSF). Participants in "Innovations and Operations of Manufacturing Systems" represented academia, government and industry.

"The NSF workshop was motivated by the challenges the manufacturing industry in the U.S. has been facing: declining contributions to gross domestic product and increasing unemployment," said ME Professor **S. Jack Hu**, who co-organized the event with ME Professor **Yoram Koren** and Don Chaffin, professor emeritus of Industrial and Operations Engineering.

The workshop was held in conjunction with a one-day symposium of the National Academy of Engineering on improving manufacturing operations.

"The trends are disturbing, and they have made manufacturing a less attractive career choice for young people," Hu added.

The purpose of the NSF workshop was to develop practical recommendations for new areas of research and education in manufacturing systems innovation and operations that policymakers could understand. Participants clearly voiced pressing concerns that high-level manufacturing infrastructure support, including coordinated federal policies and support for research and development, is urgently needed in order to revitalize the sector.

By the end of the workshop, participants had made 14 recommendations, including:

- creation of a bipartisan blue ribbon panel to examine government policies for a more effective manufacturing infrastructure
- establishment of a network of regional manufacturing innovation centers
- development of "K to Gray" manufacturing education programs for all ages
- support for research on open architecture products to spur innovation and value-creation for small business

"The United States has enormous opportunities to revitalize manufacturing and create new employment opportunities," said Koren. "Workshop participants agreed that the price of inaction is high: irreversible consequences for our manufacturing and innovation capability, for our future economy and for national security. The recommendations need immediate attention from the highest levels of government."

"The United States has enormous opportunities to revitalize manufacturing and create new employment opportunities."

—YORAM KOREN

Workshop participants tour the Engineering Research Center for Reconfigurable Manufacturing Systems.

CONVERGENCE: DESIGN SYMPOSIUM MARKS PROGRESS AND DEFINES AGENDA

In May, some 80 invited design professionals from academia and industry, including many former U-M design students, came to North Campus for the first *Design Frontiers: Crossing Boundaries, Creating Disciplines* symposium.

The event followed several recent national design research and education initiatives, including a series of National Science Foundation-sponsored workshops. **Panos Papalambros**, the Donald C. Graham Professor of Engineering and head of the Optimal Design (ODE) Laboratory at U-M, chaired the symposium.

Papalambros has a lot to celebrate this year. Not only has he been an active leader in design-related efforts worldwide; he helped spearhead U-M's now five-year-old Design Science doctoral program, and his ODE lab marked its 30th anniversary. He also celebrated his 60th birthday.

"All of these things converged and, since it's also an academic tradition in Europe to celebrate professors' 60th birthdays, my students persuaded me to mark the occasion with a symposium," he said.

The two-day event included presentations, posters and panel discussions centered on the theme of "Uniting behind a common cause: Design and the national agenda." Small groups addressed such questions and issues as the driving needs behind a "design agenda"; who benefits and universities' role in creating design-oriented minds for industry and society.

At the end of the symposium, participants presented their ideas for taking action and sustaining design movement momentum. More events and follow-up actions are planned.

TOP: Design Frontiers symposium participants at the historic Michigan Union entrance steps on May 19, 2011.

LEFT: Professors Diann Brei and Panos Papalambros at the Design Frontiers symposium.

Small groups addressed such questions and issues as the driving needs behind a "design agenda"; who benefits and universities' role in creating design-oriented minds for industry and society.

more on the web

Information on the symposium and subsequent activities can be found at http://sitemaker.umich.edu/designfrontierssymposium/home

ME FACULTY CREATE BIG 10 WOMEN'S WORKSHOP

In spite of rising numbers of female engineering faculty, few opportunities exist for women in the early stages of their career to network with other women faculty and find mentors. The lack of professional interaction and role models contributes to the under-representation of women in academic engineering departments, and this can discourage other women from pursuing engineering degrees and careers.

In response, U-M ME professors **Ellen Arruda** and **Dawn Tilbury**, together with colleagues from University of Wisconsin (Naomi Chesler) and Ohio State University (Mary Juhas), created the Big 10 Women's Workshop, a three-day networking and mentoring event for junior women faculty at Big 10 universities. Some 40 junior and 20 senior faculty attended the inaugural event, held in Milwaukee in April 2010. Six Big 10 deans also attended. The National Science Foundation, Rockwell Automation and the Big 10 deans sponsored the workshop.

Inspired by the Women's International Research Engineering Summit in 2008, the organizers wanted to develop something similar in the upper midwest, building upon the collaborative culture that already exists among Big 10 engineering programs.

"We set out to do three things," explained Arruda. "We wanted to provide an opportunity for junior women engineering faculty to network with each other, cultivate peer collaborations and mentoring relationships and interact with senior engineering faculty role models. Unfortunately there haven't been a lot of opportunities for junior women to do these things, even though they're critically important to their success as faculty members."

U-M and Michigan State University faculty on the way home from the Big Ten Women's Workshop.

Over the course of the workshop, invited participants attended poster presentations, panel discussions and problem-solving sessions. Topics ran the gamut: advice from the deans on the tenure process and defining career pathways to identifying funding opportunities and interacting with graduate students. Professor Linda Katehi, former professor and associate dean for research and graduate education at U-M, and now chancellor at the University of California, Davis, gave a keynote address on academic leadership.

The women in attendance found the workshop both practical and inspiring. Evaluations garnered extremely positive results. About half of the participants reported having identified potential collaborators, and ten women received travel grants to further develop joint research projects. All who attended agreed the workshop should be offered again in 2012. Arruda and Tilbury are thinking beyond that, hoping to make it a biannual event.

"Our long-term goal is to support junior female faculty and increase their visibility so that they, in turn, can serve as role models and mentors for undergraduate and graduate students at their home universities," said Tilbury. "These faculty interact with thousands of engineering students, so they really can have an impact on women who choose academic and professional engineering careers."

+ more on the web

Visit **http://www.umich.edu/~tilbury/btww** for more information

LEADING NSF WORKSHOP TO REDEFINE ME EDUCATION

Change is underfoot in mechanical engineering education, and ME faculty are leading the transformation. ME Professor **Galip Ulsoy** and Department Chair **Kon-Well Wang** have been working with the National Science Foundation (NSF) and other U.S. universities to redefine mechanical engineering curricula nationwide. Their efforts address a critical challenge facing U.S. engineering programs: how to educate mechanical engineers who provide five times the value—"5XME"—of their global competitors.

The science-based mechanical engineering curriculum taught in the United States is available to students the world over, including those in low-wage markets. Today, global companies can employ world-class engineering talent in those markets, often at a significantly lower cost than in the United States. As a result, global firms are moving their manufacturing, research and design activities to these locales, which directly impacts U.S. competitiveness and economic growth.

The 5XME initiative has been underway since late 2007, when Ulsoy led a NSF-sponsored workshop, "Transforming Mechanical Engineering Education and Research in the United States." Participants developed several recommendations, and a follow-up NSF workshop in 2009 focused on their implementation.

The transformation, says Ulsoy, "must embrace our society's priorities and present exciting leadership opportunities for diverse and talented students." Implementation will require new infrastructure and methods of educational delivery to ensure graduates possess

- a broad grounding in science and technology fundamentals as well their societal context
- flexibility and agility to pursue topics based upon students' interests and unique abilities
- creativity to identify problems and the ability to work on project-based teams to solve them
- a sense of engineering as a learned profession, comparable in rigor, prestige and opportunity to medicine and law

Several academic institutions are now pursuing pilot programs to demonstrate and assess changes to their mechanical engineering curricula.

+ more on the web

Additional information can be found at
http://umich.edu/~ulsoy/5XME.htm

THREE ME PROFESSORS KEYNOTE AT ASME CONFERENCE (IDETC)


Perkins


Kota


Peng

Mechanical Engineering professors **Noel Perkins**, **Sridhar Kota** and **Huei Peng** all presented keynote addresses at the American Society of Mechanical Engineers (ASME) 2011 International Design Engineering and Technical Conference (IDETC).

Perkins' keynote address, *"Computing the Twisted Mechanics of Your DNA,"* gave an overview of a computational rod model that simulates the twisting and bending dynamics of DNA during large, conformational changes. He highlighted these effects in a series of example systems that include the looping of DNA by a gene-regulatory protein.

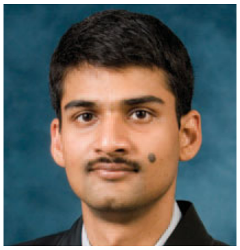
At U-M, Perkins' research focuses on dynamics, including vibration and stability, nonlinear dynamics and experiment methods. He is a fellow of the ASME.

Kota's keynote, *"Innovation and US-based Manufacturing,"* dealt with how innovation and manufacturing are intricately linked, and how advanced manufacturing and systems engineering can serve to ensure economic, energy and national security. Kota's research at U-M includes the synthesis of bio-inspired engineering systems, shape-adapted compliant structures and electromechanical systems design.

Peng, also an ASME fellow, addressed current development trends and efforts related to electrified vehicles (EVs) in his keynote, *"Design and Control of Electrified Vehicles for Improved Fuel Economy."* He covered the application of modern modeling, design and control techniques on EV design and EV integration with future transportation and energy grid solutions. Peng's current research at U-M focuses on design and control of hybrid EVs and vehicle active safety systems.

The IDETC, held in August 2011 in Washington, DC, is the flagship international meeting for design engineering.

FACULTY WIN EARLY CAREER AWARDS



Assistant Professor **Vikram Gavini** has received a 2011 **National Science Foundation (NSF) CAREER award**, the organization's most prestigious award for early-career faculty.

Gavini was selected by the NSF Division of Civil, Mechanical and Manufacturing Innovation for his proposal, "Bridging Quantum-Mechanics with Mechanics: Towards Predictive Computations of Materials Behavior."

With the award, Gavini will develop a seamless multi-scale computational technique to study defects in crystalline solids. Defects directly influence materials properties and behavior, and even small concentrations of defects can produce significant macroscopic effects. Multiple interacting length scales must be resolved in order to accurately describe the energetics of defects, and this has remained a long-standing challenge in the field of multi-scale modeling.

Gavini's novel approach will resolve all relevant length-scales governing the defect behavior—from quantum-mechanical interactions at the sub-Angstrom length-scale to the elastic fields on the continuum scale. By virtue of using a quantum-mechanical theory as the sole physics input, his method is expected to be transferable and will enable predictive simulations of deformation and failure mechanisms in solids.

In conjunction with his research, Gavini plans to develop a core nanoscience curriculum for graduate and undergraduate students at U-M. He also plans to create educational modules that include simulations of materials behavior as part of his outreach efforts, which will demonstrate to high school students the importance of computations in science and technology.

Assistant Professor **John Hart** has won an **Air Force Office of Scientific Research Young Investigator Research Program award**. He was granted the highly competitive award to explore the fabrication and properties of novel "morphing" carbon nanotube (CNT) microstructures.

Inspired by nature—specifically the design and responsiveness of plant tissues that swell or contract in response to a stimulus—the proposed CNT microstructures will change their shape in response to the swelling of an active material. This shape change, combined with the mechanical and electrical characteristics of the CNTs, potentially could enable intrinsic actuation and sensing in new structural materials and engineered surfaces.

Hart's research program builds on the "capillary forming" method that he and his students pioneered, wherein passive three-dimensional CNT microstructures are fabricated by capillary densification of lithographically patterned, vertically aligned CNT templates. His team plans to demonstrate morphing CNT microstructures that move radially, laterally and vertically upon actuation. The team will measure the actuation performance and use the data to create predictive models of shape transformations.

For the first application of these novel microstructures, Hart plans to build CNT "bridge" sensors on micropatterned electrodes, which will have high force resistance sensitivity. In a second application, large arrays of morphing CNT structures will change their shape in response to temperature, demonstrating a prototype for an environmentally responsive surface.

Hart proposes that, over time, morphing CNT structures could be designed with prescribed force, stroke and directional outputs, and therefore the response behavior of a CNT microactuator could be "programmed" into the fabrication process.

MEET NEW FACULTY

ALLEN LIU

Liu earned his doctoral degree from the University of California-Berkeley. He continued as a postdoctoral fellow in cell biology at The Scripps Research Institute in San Diego.

Liu's research lies at the interface of engineering and biology. He is fascinated by cellular dynamics, particularly cell migration and clathrin-mediated endocytosis, which are topics of his doctoral and post-doctoral research, respectively. The protein clathrin plays a major role in coating the vesicles that cells use to internalize external molecules. Liu's latest work involves high resolution live cell imaging and computational analysis of clathrin-coated pit dynamics.

At U-M, Liu plans to work on the role of chemokine receptor endocytosis during cell migration. He also will reconstitute biological processes based on encapsulation of biological molecules inside lipid bilayer vesicles. The two research directions represent an integration of biology and engineering with a focus on the mechanics of biological systems.

"I am excited to join U-M and explore many opportunities for collaboration with the ME faculty and to apply engineering principles to biology," he said.

Liu also looks forward to interacting with ME students and to helping open their eyes to the wonders of mechanobiology.

XIAOGAN LIANG

Liang earned his PhD from Princeton University. He comes to U-M from the Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL), where he conducted post-doctoral research and then worked as a staff scientist.

At LBNL, Liang invented a new scheme for producing high-quality graphene nano/microstructures in functional arrays over large areas. His research at Princeton focused on nanoimprint lithography (NIL) and its applications in nanofluidics and nanoelectronics. Specifically, he developed an experimental approach to investigate bubble formation during NIL in order to reduce air bubble defects and pave the way for the mass production of functional nanodevices. Liang also invented an integrated nanofluidic sensor, capable of DNA analysis.

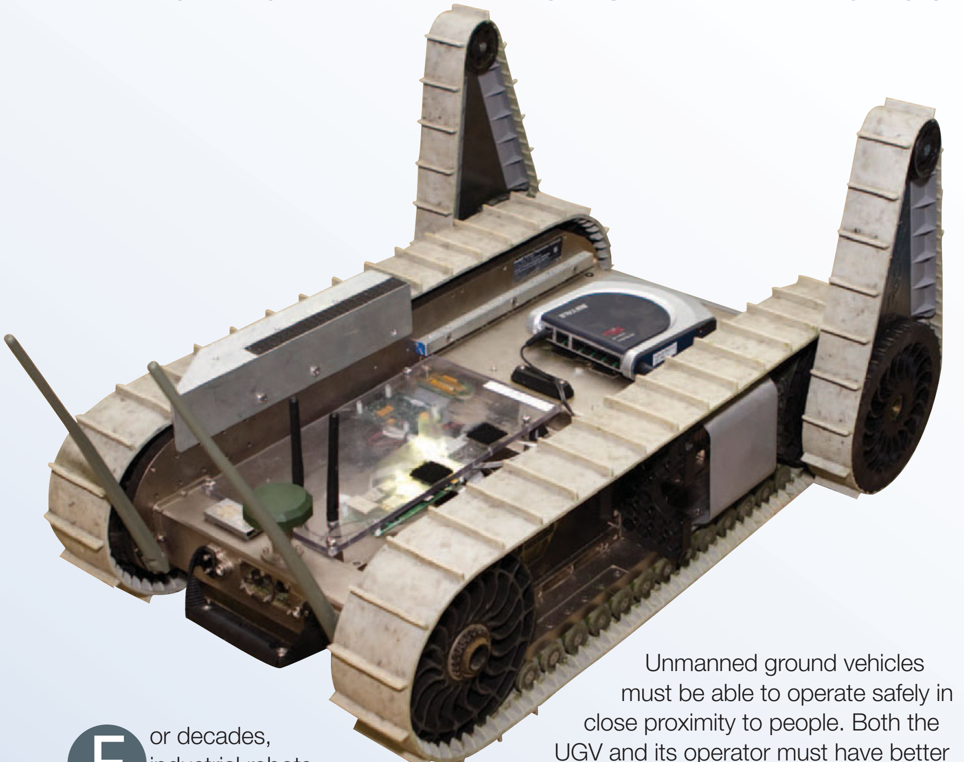
Liang will continue his work on advanced nanofabrication techniques at U-M. "The ME department has strong programs related to advanced manufacturing as well as fundamental nanoscience, and I'm excited for my research and teaching to bridge these two fields and to facilitate the conversion of nanoscience and technology into new products," he said.

+ more on the web

NEW FACULTY SEARCHES IN 2011–12

The U-M ME department seeks candidates for multiple full-time tenured or tenure-track faculty positions in 2011–12. To learn more, visit our website at: www.me.engin.umich.edu

IMPROVING RELIABILITY OF UNMANNED GROUND VEHICLES



For decades, industrial robots have been efficiently performing tasks such as spray painting, welding and assembly in manufacturing plants. Such robots can be pre-programmed to perform routine tasks reliably and precisely in their stable and structured environments. A new generation of robots, unmanned ground vehicles, or UGVs, are taking those capabilities a step beyond, performing complex tasks in diverse operating environments, often with human or robotic partners.

Autonomous robots are being used today for a range of commercial and military purposes. Unmanned ground vehicles can explore deep oil well pipes, assist with rescue missions after earthquakes and collect samples from the surface of Mars. They can detect hidden bombs, disarm explosive devices and carry heavy loads for soldiers. Not surprisingly, though, the increasing capabilities of UGVs bring with them new obstacles, which the U-M Ground Robotics Reliability Center (GRRC) and several ME faculty are working to surmount.

Unmanned ground vehicles must be able to operate safely in close proximity to people. Both the UGV and its operator must have better situational awareness of environments through on-board sensors and sensor processing. Robots must be able to avoid obstacles—or detection—while exploring unfamiliar environments. Batteries must last long enough for missions to be completed. And, finally, both the design and manufacturing processes must improve in order to achieve a consistently high level of reliability.

INTEGRATED POWER SYSTEMS

Energy and power are critical to UGV reliability. Autonomous robots require total power levels of several hundred watts to several kilowatts—and must fit in casing not much larger than a backpack. Professor **Huei Peng** and researchers in the GRRC's Power and Mobility thrust area are developing a systematic process for the design and control of energy systems for UGVs that will increase battery life and enable longer and more reliable missions (see related story on page 20).

MOVING OBSTACLE AVOIDANCE

Professor **Galip Ulsoy** is working with colleagues to improve the moving-obstacle avoidance capabilities of autonomous UGVs in the face of uncertain sensor data. The team's approach divides a laser range finder-generated image of the robot's environment into a grid of individual cells, each corresponding to a velocity of the mobile robot. For each moving obstacle, a "velocity obstacle" is the set of robot velocities that will lead to a collision. The velocity occupancy space combines the velocity obstacles, including sensor noise, and the goal position of the robot in a weighted average for each velocity grid cell.

Different types of obstacles, for example pedestrians or cars, have different weights. At each point in time, the robot selects the reachable velocity with the largest combined cost. Using hand-tuned weights for the positive (attractive) potential of the goal and the negative (repulsive) potential of the obstacles, Ulsoy's team has achieved good simulation results. The group currently is integrating sensors onto a UGV in order to validate the results experimentally.

INDOOR POSITION TRACKING

It can be difficult for operators to keep track of indoor UGVs' whereabouts when tele-operating them remotely from outside. Global Positioning Systems typically don't operate indoors and information from the robots' on-board sensors can be limited. Operators quickly can become disoriented when remotely controlling UGVs—even in familiar buildings.

To address this, Professor **Johann Borenstein** is developing an Indoor Position Tracking (IPT) system that produces accurate real-time trajectories of the robot on the operator's screen. If the robot becomes incapacitated or if communication breaks down, the last known position of the robot immediately is evident from the trajectory plot, which allows for the quick extraction of the robot with minimal risk exposure for the rescuers.

The IPT system is based on low-cost gyros and inertial measurement units, which are used for dead reckoning. Traditionally, the drift inherent in these sensors has rendered the measurements useless after a short time, but Borenstein and his team have developed a heuristic method to eliminate drift. Applications of this and related technology include leader-follower scenarios and navigation assistance for UGV operators. The team demonstrated these technologies at the U.S. Army's Robotics Rodeo in Fort Benning, Georgia, in October 2010.

A UNIVERSAL ROBOTICS TESTBED

The GRRC also has developed a robotics testbed that includes a Packbot—a type of robot currently used by the military—and several other small robots. The robots are equipped with multiple sensors and with standard interface software, known as the University Research Controller (URC). The URC allows multiple research teams to test and validate their results using a common interface, regardless of differences in individual UGV hardware and software.

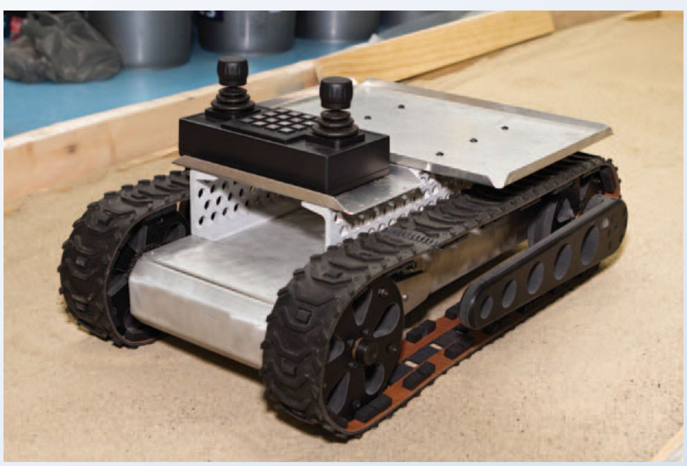
The URC not only allows investigators to implement the results of their research on a variety of platforms; it also protects the proprietary nature of many commercial UGV platforms in the testbed. In this way, the URC supports technology transfer and commercialization of the Center's research.

Numerous other research efforts are underway at the GRRC to improve reliable operations of UGVs, including instruction-based programming, map-building, energy management for hybrid powertrains, enhanced reliability through design optimization, control reconfiguration and augmented reality user interfaces.

+ more on the web

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

The team's approach divides a laser range finder-generated image of the robot's environment into a grid of individual cells, each corresponding to a velocity of the mobile robot.



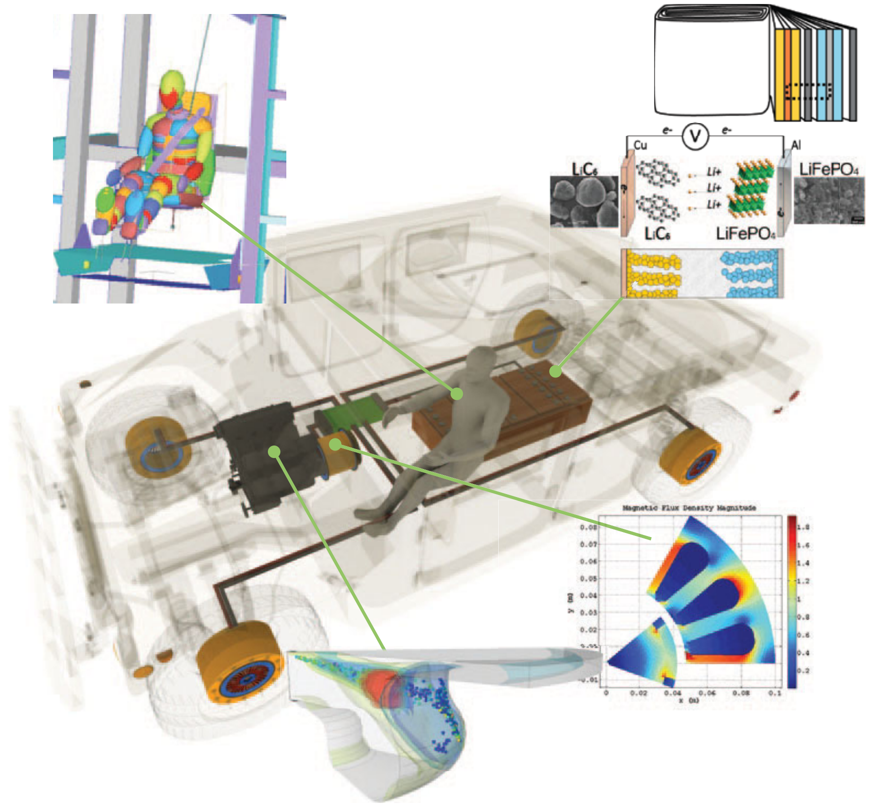
ABOVE, LEFT: The tracked Superdroid LTF is almost as versatile as the iRobot Packbot used by the U.S. military. At less than 1/10th of the cost of a Packbot, it is an ideal research platform for technologies to be ported to the Packbot. ABOVE, RIGHT: Specialized visual tracking tags enable an augmented reality video feed that can improve a teleoperator's situational awareness during mobile manipulation tasks. OPPOSITE PAGE: This Packbot was donated to U-M by its manufacturer, iRobot. Thousands of these robots are on active duty in Iraq and Afghanistan and have saved tens or even hundreds of lives of U.S. warfighters. Thanks to the availability of the Packbot, U-M researchers get to test their work with the most relevant hardware available.

POWERING FUTURE MOBILITY: ARC RENEWS FUNDING AND SHARES RESEARCH

The U-M-led Automotive Research Center, or ARC, was awarded renewal funding of $20 million over the next three years from the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC).

A U.S. Army Center of Excellence for the modeling and simulation of ground vehicles, the ARC was established in 1994 and includes Oakland University, Wayne State University, The University of Iowa, Clemson University and Virginia Tech. The Center focuses on improving the fuel economy of ground vehicles, enhancing survivability of complete vehicle systems including human operators, and extending mobility of ground vehicle technologies.

"These are complex cross-disciplinary challenges that require far more than model stitching since the solution space is so over-constrained and pushes the boundaries in every technological direction," said Professor and Center Director **Anna Stefanopoulou.**



Multidisciplinary and fundamental research results from the ARC come together to solve large system-of-system level problems, such as hybridizing powertrains and microgrid infrastructures.

The new funding will support development of models for on-board prognostics of critical systems with an emphasis on vehicle power and energy challenges. Although the focus is on mathematical models of novel components and numerical synthesis of systems, the Center also conducts experiments and simulations using state-of-the-art facilities. Such synergistic activities that share resources and yield solutions applicable to both the military and industry were highlighted by U.S. Senator Carl Levin at the 17th Annual ARC Conference, held in May 2011. Levin delivered opening remarks at the event.

Prompted by the conference theme, "Powering Future Mobility," Major General Nick Justice, Commanding General for the U.S. Army Research Development and Engineering Command, asked for an innovation roadmap to reduce the cost of fuel in military expeditions, both combat and humanitarian relief. The total cost to the Army of transporting fuel in these situations can run as high as $800 per gallon; high fuel prices for civilians also hinder our nation's economic recovery. Although military and civilian vehicle needs and applications vary significantly, the need to improve the fuel economy remains a constant driving force for innovation.

Jeffrey Singleton, director for basic research with the Office of the Assistant Secretary of the Army (Acquisition, Logistics & Technology), presented the conference's plenary lecture. Singleton highlighted the Center's unique capability to excel in studying fundamental issues, yet still address complex automotive problems. Indeed the Center presented three case studies involving system-of-systems solutions that improve fuel efficiency and weave together dozens of multidisciplinary ARC research projects.

The ARC is tackling the issue of fuel efficiency in several ways: by hybridizing the powertrain, reducing weight and by enabling the use of on-site renewable power generation in a microgrid configuration. These strategies still present several challenges, including how to manage the power and thermal loads of an electrified powertrain, reduce weight without compromising survivability, and how to integrate vehicle-to-grid and microgrid topologies.

Batteries, a critical component in any hybrid or electric vehicle platform, make it even more difficult to manage vehicle thermal and power loads in extreme environments such as desert heat and Arctic cold. The challenges are further amplified in armor-protected vehicles or robots with limited real estate for housing on-board cooling systems. The ARC has demonstrated a simple yet predictive model of the coupled thermal and electrochemical behavior of lithium iron phosphate batteries to prevent harmful operation under real driving conditions.

Detailed measurements of the *in situ* lithium concentration and spatio-temporal patterns across battery electrodes in pouch cells to validate the electrochemical models were taken by Dr. Jason Siegel, postdoctoral fellow at the National Institute of Standards and Technology Center of Neutron Research.

Such models were necessary for managing the battery load and for sizing the cooling system of a mine-resistant, all-terrain vehicle platform in a case study by **Zoran Filipi**, the ARC's deputy director, and his team. The integrated vehicle power and cooling system simulation was instrumental in assessing real fuel economy, while simultaneously ensuring safe battery operation by avoiding excessive discharge rates.

Fuel economy improvement of up to 40% was originally reported when a vehicle powertrain is hybridized. The fidelity of models enabled additional thermal analysis completed in collaboration with Dohoy Jung, assistant professor at U-M Dearborn, to capture the impact of so-called parasitic losses associated with battery cooling. The actual improvement, after taking into account losses from compressors, pumps, fans and other cooling auxiliaries, was closer to 33%.

Built-in adaptation and on-board parameterization of the battery models by **Michael Kokkolaras**, associate research scientist, and his team addressed the demanding conditions of military missions and unavoidable aging.

Fuel transportation to and from military bases and combat zones not only incurs significant costs but poses tremendous risk. In another case study, ARC researchers and ME professors **Panos Papalambros** and **Jeff Stein** presented work on renewable power sources and vehicle-to-grid and microgrid technologies, which can reduce costs and risks and improve reliability of power supplies on autonomously operating military bases.

The successful implementation of such a paradigm-shifting technology requires an integrated approach to design and control at different time scales, said ME Professor **Huei Peng**. In fact, Abigail Mechtenberg, assistant research scientist with the Applied Physics department, showed how her team modeled the long time-scale predictions of stochastic operating conditions.

Together with Diane Peters, a post-doctoral scholar, the team used these predictions in calculations of optimal configurations, component sizes and dispatch strategies to ensure a reliable electricity supply while minimizing cost.

Focusing on the short time-scale, Peng and Ian Hiskens, professor of Electrical Engineering and Computer Science, co-directed the team that developed controllers for regulating grid voltage and frequency to maximize stability under unpredictable disturbances.

+ more on the web

The annual conference also included poster sessions and two symposia with three parallel tracks of oral presentations. For more information, visit http://arc.engin.umich.edu/events/conf/index.html

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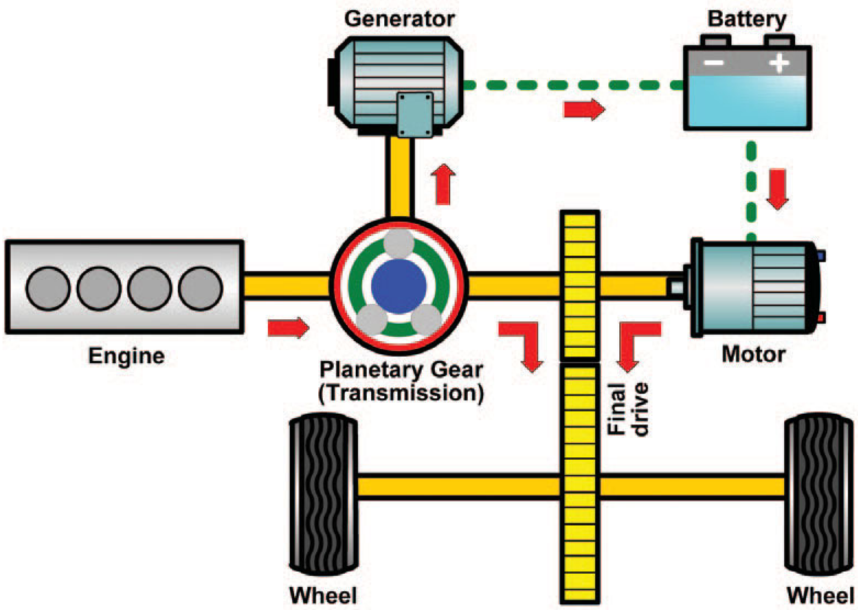


OPTIMAL CONTROL STRATEGIES: EMPOWERING HYBRID ELECTRIC VEHICLES

Adoption of hybrid electric vehicles, or HEVs, has been increasing in recent years, in large part due to the appealing benefits they offer—and potential they still represent—including improved fuel economy and reduced emissions.

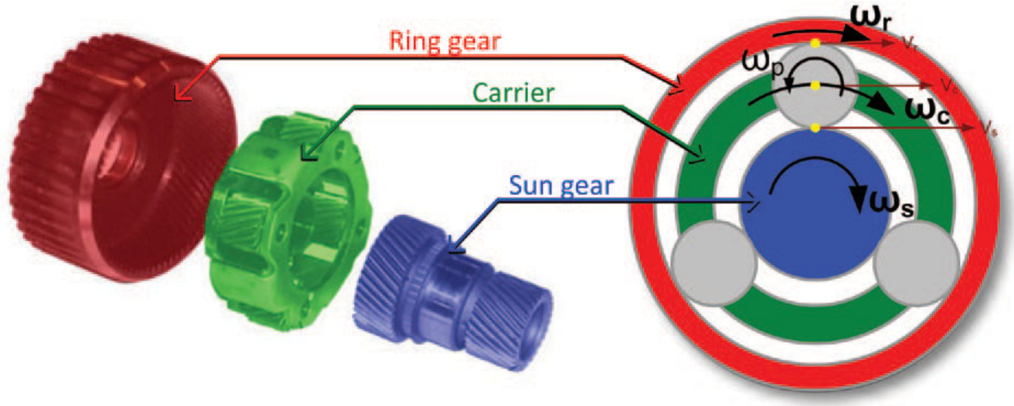
But in order to turn that potential into reality, engineers must develop new and optimal power management and control strategies. Compared with internal combustion powertrains, HEVs require more complex control methodologies in order to account for their dual on-board power sources, multiple modes of operation and many possible ways to connect all sub-systems together. Finding the right balance among fuel economy, emissions and component reliability constraints therefore presents an indeterminate problem; a potentially infinite number of possible solutions exists.

For the past decade Professor **Huei Peng** has been improving the control of HEVs. His research group was among the first in the world to develop software that generates optimization models not only of planetary gear configuration but battery sizing and control as well. Until Peng's breakthrough, engineers developed control strategies based on a small number of driving cycles, along with intuition and heuristics.

"When you take a piecemeal approach—'here's a model for configuration,' 'here's a model for sizing,' 'here's a model for control'—you only find one of many possible solutions. It may work fine, but it's not going to lead you to the best possible design you can have."

Peng's approach is based on dynamic programming, or DP, a valuable methodology for solving general dynamic optimization problems. His is one of the first groups worldwide to apply the DP concept to HEVs. Dynamic programming can address multiple factors, objectives and constraints, such as fuel economy and nitric oxide or particulate matter emissions. Investigators find optimal control actions by using DP and, by analyzing those actions, then can identify implementable rules.

Peng and his team have developed and verified their strategies using advanced vehicle models or a hybrid vehicle



Peng's research group was among the first in the world to develop software that generates optimization models not only of planetary gear configuration but battery sizing and control as well.

"engine-in-the-loop" experimental setup developed at the U-M Automotive Research Center. His results are frequently cited and have been implemented on several prototype vehicles, including a commercial delivery truck designed by Eaton Corporation for FedEx.

The reliable and robust algorithms Peng developed have led to near-optimization and showed a 45% improvement in fuel economy in one study, compared with a non-hybrid control vehicle. The algorithm also performed better than a conventional rule-based method, which achieved a 33% lower improvement in fuel economy on the same hybrid vehicle. Eaton has since gone on to extend the DP concept to its electric bus line of business.

Now Peng is applying his HEV work to mobile robots. In contrast to common fixed-arm robots frequently used in automotive manufacturing plants for such tasks as painting and welding, mobile robots potentially can carry out a range of complicated missions, from searching rubble for survivors to detonating explosives to keep soldiers out of harm's way.

Mobile robots are similar to HEVs in that they require on-board energy. And that's been the bottleneck to widespread adoption: energy storage. "The problem is that batteries used in mobile robots typically last only an hour, which limits the robots' usefulness," noted Peng. "The operator has to be mindful of how much energy is left, which can distract from carrying out the mission."

Peng's long-range vision is a mobile robot energy system that lasts four or even eight hours, perhaps using a hybrid powertrain similar to those on advanced passenger vehicles. Toward that goal, his students currently are working to understand the propulsion needs of mobile robots as they interact with various types of terrain, including mud, rocks and sand. "The situations where ground robots usually are deployed are not exactly your typical on-road driving scenarios," he said.

Since mobile robots are much smaller than HEVs, factors that are negligible in HEVs—for example, internal friction losses or auxiliary loads—can have a greater effect in mobile robots. Peng sees that not as a drawback but as an opportunity. "If we pay close attention to the robots' energy usage, I think in the near-term we can easily double their 'fuel economy,'" he said. "Many mobile robots have been designed to showcase their artificial intelligence capabilities, with inadequate attention on energy efficiency. We think leveraging our HEV knowledge can bear a lot of fruit and help to elevate the design and analysis of energy systems for mobile robots."

Peng's robotics research has been sponsored by the U-M Ground Robotics Reliability Center (see related story on page 16). His HEV work has been supported by the U.S. Department of Defense, Eaton, GM and Chrysler.

ABOVE: Understanding the kinematic relations of the sun, carrier and ring gears is key to designing efficient control algorithms for power-split hybrid vehicles.

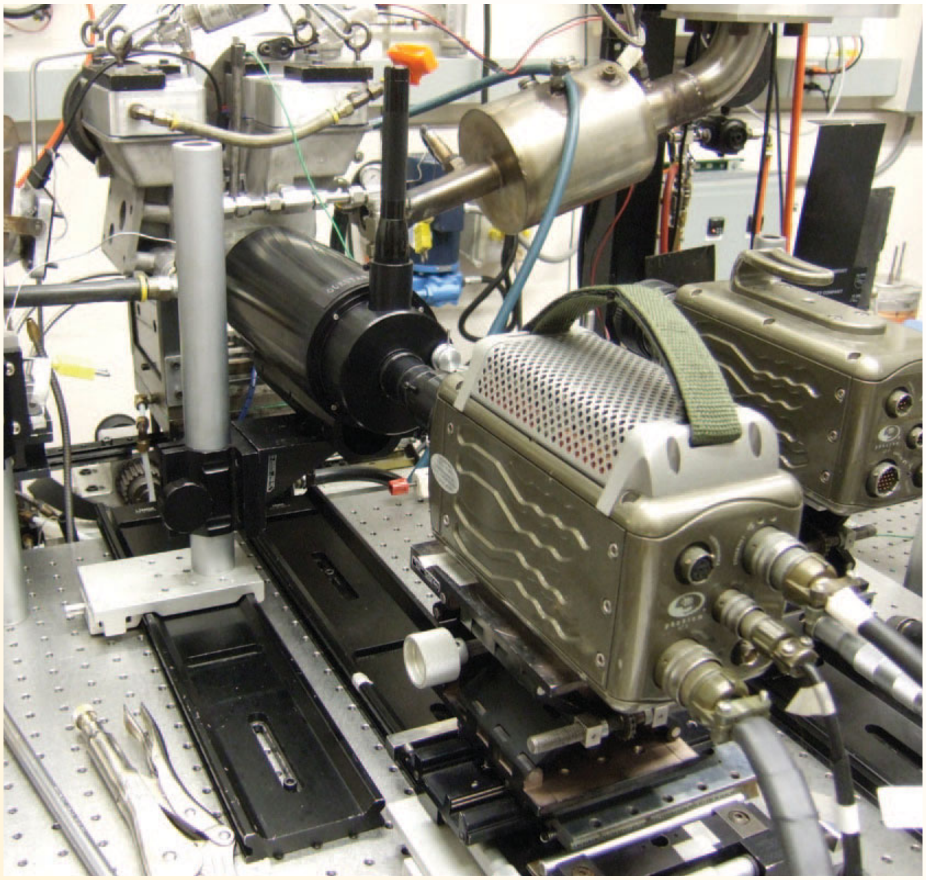
OPPOSITE PAGE: A power-split hybrid vehicle uses planetary gear(s) to integrate an internal combustion engine and two electric machines to power the vehicle.

LASER LIGHT: THE FASTEST YARDSTICK FOR NEXT-GENERATION ENGINE DESIGN

Game-changing advances in internal combustion engines can only be realized through novel combustion modes, such as spray-guided direct-injection and pre-mixed charge compression ignition combustion strategies. But these potential solutions also present their own set of challenges to overcome: combustion instabilities, super knock and pollution formation, among others.

Scientists and engineers rely upon optical diagnostic tools in order to understand the physical and chemical phenomena controlling these new combustion modes, but existing tools currently don't go far enough to capture the fine-scale details of ignition processes, combustion instabilities and the randomness of in-cylinder engine flows. Visualizing such phenomena is particularly difficult in mechanically restricted and vibrating environments.

To address the pressing need for novel optical diagnostic methodologies, Professor **Volker Sick** and the students in his Quantitative Laser Diagnostics Laboratory (QLDL) are inventing new laser-based imaging tools that enable more complex and higher resolution measurements. The resulting devices, methodologies and software they have developed find application well beyond internal combustion engines, including materials processing, quality control and laser development as well.



A long-distance microscope on a high-speed camera enables flow measurements in boundary layers in an optical engine. Thousands of images per second are captured in order to help develop better heat transfer models.

"Using light as a measurement tool allows us to discover and characterize fundamental processes in constrained environments and at microscopic levels—these processes occur at too small a scale and much too quickly to be investigated otherwise," said Sick.

"Major advances in optical flow and reaction diagnostics will have to include four-dimensional imaging capability to enable measuring how temperature, species concentrations and the flow change in time and space," he added. "This is critical for understanding the intricate non-linear coupling between these quantities."

Working in collaboration with Fraunhofer USA's Center for Laser Technology, the QLDL has developed such a four-dimensional imaging methodology. The new single camera tomographic particle tracking velocimetry approach enables four-dimensional flow measurements at thousands of frames per second. The images then can be used to identify the flow anomalies that might cause misfires in engines, thereby enabling the development and validation of physics-based predictive simulation tools for engine design.

A unique aspect of this approach is that it does not require a specialized camera. The project is part of the Alternative Energy Technology for Transportation program, an international collaboration between U-M and Fraunhofer.

In work supported by the National Science Foundation (NSF), Sick and his team are using high-speed laser imaging to study mass and energy transport in turbulent and near-wall flows under high pressure and high temperature conditions. The group has developed novel micro-particle imaging velocimetry and laser-induced fluorescence methods to investigate microscopic transport processes near surfaces, for example, at the cylinder head of an engine.

"Our goal is to support the development of much-needed predictive models for transient heat transfer processes," said Sick. "We have to better control these processes not only to improve efficiency but also to counteract the potentially negative impact of heat transfer on ignition and combustion phasing in future engine concepts."

For more than a decade Sick and the QLDL have been part of the first General Motors/University of Michigan Collaborative Research Laboratory (GM/UM CRL). In 2011 Sick was named U-M co-director to lead the GM/UM CRL on Engine Systems Research with GM Co-Director Dr. Todd Fansler.

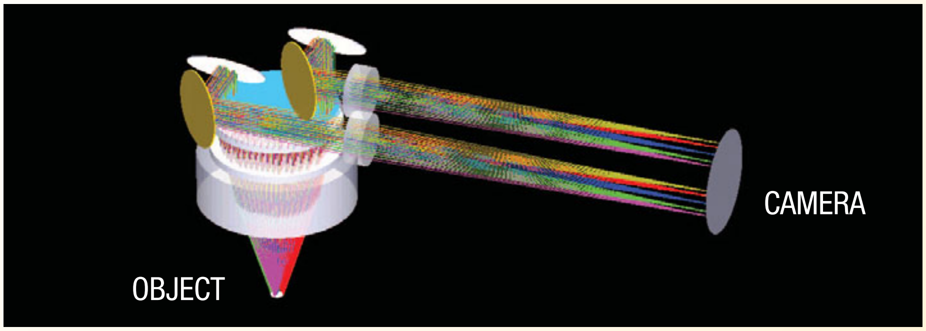
Extending the work of the CRL, Sick has co-founded the Large Eddy Simulation (LES) Working Group. The LES group develops predictive simulation tools for engine design using experimental benchmarking data from several optical engines in use at U-M. The LES effort includes researchers from GM, Sandia National Laboratories, University of Wisconsin–Madison and Pennsylvania State University.

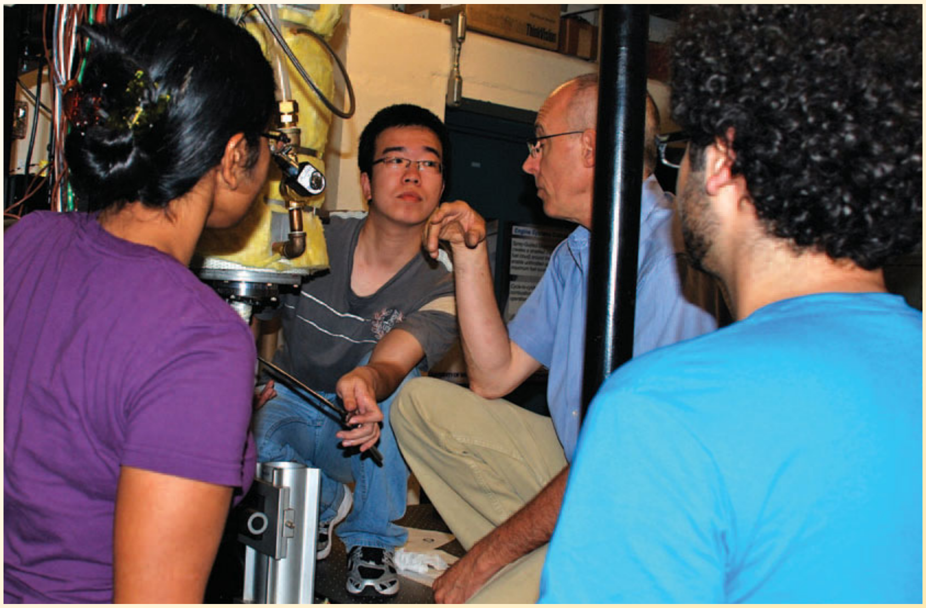
Joint research projects have been underway between Sick's QLDL and both Shanghai Jiao Tong University in China and TU Darmstadt in Germany. Graduate students in the QLDL spend time at both institutions; likewise, graduate students based abroad frequently pursue research at U-M in the QLDL.

"While I teach Engineering Across Cultures (ENGR 490), a required course for the International Minor for Engineers, it is of course imperative that our students experience other cultures firsthand by going abroad," said Sick. "Being a graduate student in the QLDL provides this opportunity through collaborative research partnerships." Sick also serves as the College of Engineering faculty advisor to International Programs.

+ more on the web

More details can be found at http://sitemaker.umich.edu/vsick/home





TOP: Ray-tracing design of the single-camera 3D flow imaging device. COURTESY BORIS REGAARD, FRAUNHOFER USA

BOTTOM: Visiting Research Scientist David Reuss (third from left) discusses the design of the LES Working Group engine with graduate students. From left to right: Preeti Abraham, Hao Chen (visiting from Shanghai Jiao Tong University, Professor Min Xu), David Reuss, Omar Almagri.

MATERIALS DISCOVERY FOR BETTER ENERGY STORAGE

Most of us have experienced the frustration of having our laptop battery die at an inconvenient time. The problem is one of energy storage, and it's a focus of Assistant Professor **Don Siegel**, who joined the ME faculty in 2009.

"Energy storage not only impacts portable and personal electronics, it impacts the transportation sector and the adoption of intermittent renewable power sources such as wind and solar," said Siegel.

Better energy storage devices have the potential to reduce carbon dioxide emissions, increase efficiency and lessen our reliance on fossil fuels. However, the improvements needed will require breakthroughs in performance, most likely through new materials development. "That's where we come in," said Siegel. "Our goal is to accelerate the discovery process by using computation." The computational tools used by Siegel's research group are largely drawn from condensed matter physics.

In his Energy Storage and Materials Simulation Laboratory, Siegel's team traces performance limitations to materials phenomena, and then makes recommendations for how materials scientists can rectify them.

Before joining U-M, Siegel worked as a researcher at Ford Motor Company. At U-M, Siegel's research interests have expanded to include the storage of electrical, thermal and chemical energy, as well as the discovery of materials for carbon capture and lightweight automotive alloys.

BEYOND LI-ION BATTERIES

Siegel is looking toward the future by exploring a highly speculative—but potentially transformative—energy storage technology called lithium-air batteries. While the lithium-ion (Li-ion) batteries currently in use today can discharge energy quickly, their capacity is less than optimal.

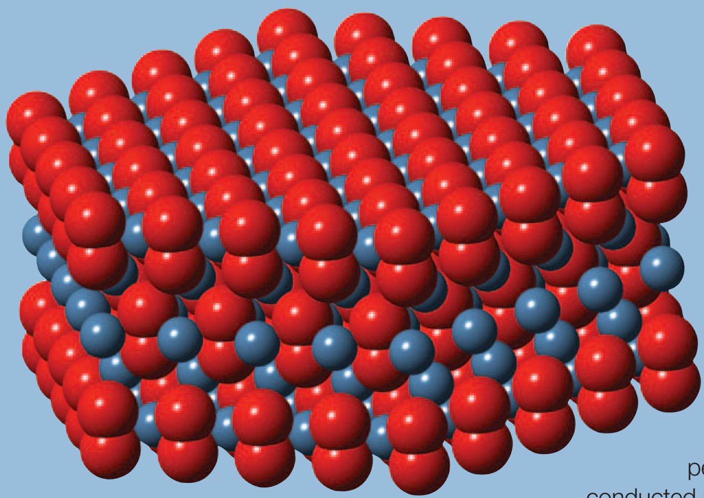
"The 'holy grail' of transportation is an electric vehicle that can go 300 to 400 miles between charging," said Siegel. "That's going to be hard to achieve with current Li-ion technology." By contrast, lithium-air batteries, which "breathe in" oxygen rather than carry it onboard, have potentially enormous capacities per unit of mass. But they present their own set of problems, which have prevented their commercialization, including poor power density, low efficiency and limited cycle life.

Working with experimental collaborators in the U.S.–China Clean Energy Research Center (see related story on page 9) and at Shanghai Jiao Tong University, Siegel has been using first principles modeling to understand the complex phenomena at work in lithium-air batteries. The goal of these efforts is to identify limiting mechanisms in order to improve performance. "Theoretically, a lithium-air battery could cost one tenth of a Li-ion battery while achieving ten times the energy density," said Siegel.

CHEMICAL ENERGY STORAGE AND CARBON CAPTURE

While batteries store energy in the form of electrons, energy also can be stored in the chemical bonds of molecules such as hydrogen and methane. Hydrogen makes for an attractive energy carrier because it can be produced renewably from non-fossil feedstocks. On the other hand, hydrogen is a low-density gas, and the viability of futuristic technologies like hydrogen fuel cell vehicles hinges on finding an efficient technique for storing hydrogen under ambient conditions.

One promising approach is to adsorb hydrogen onto a new class of nanoporous materials called metal-organic frameworks (MOFs). As a partner in the U.S.



Surfaces control rechargeability: the surfaces of Li_2O_2 particles (shown) are metallic, whereas those of Li_2O are insulating. This difference explains why Li-air batteries that discharge to Li_2O_2 are rechargeable, whereas those that form Li_2O are not. (Red spheres = oxygen, blue spheres = lithium.)

Department of Energy's Hydrogen Storage Engineering Center of Excellence, Siegel is leading an effort to establish the relationships among structure, processing and properties for MOFs, and to engineer a prototype system around them.

Siegel also is collaborating with Ford Motor Company and BASF to improve the capacity and thermal conductivity of these materials without degrading their desirable properties. The team recently demonstrated simultaneous improvements of 400% in volumetric capacity and 600% in conductivity through a combination of processing and composition modification.

Now Siegel's team is taking the work a step further and looking at MOFs at the system level. They've created a specialized vessel to hold MOF pellets and recently conducted neutron imaging studies at the National Institute of Standards and Technology.

"Neutrons allow us to image the dynamics of hydrogen storage in a non-destructive fashion. It's a great way to characterize the performance of these systems and to develop high-fidelity models," he said.

Building on his experience with hydrogen, Siegel also is exploring whether MOFs can be used to capture carbon dioxide from coal-fired power plants. This is a crucial technology for reducing the carbon intensity of power generation. In collaboration with colleagues in the departments of Chemistry and Computer Science, Siegel is developing a "materials informatics" approach to accelerate the discovery of optimized MOFs for carbon dioxide capture.

There are literally thousands of MOFs, but only a small fraction have been tested to see if they would make for a good carbon dioxide adsorbent. By combining database mining, experiments and detailed atomistic calculations, the team hopes to replicate *in silico* the approach used by the pharmaceutical industry to quickly screen large numbers of potentially therapeutic agents.

"At the end of the day, we hope to pinpoint a small number of compounds that should have outstanding properties," said Siegel. "This will allow our colleagues to focus their experimental efforts on the most promising materials."

AN UNPRECEDENTED LOOK AT SOOT FORMATION IN FLAMES

Engineers and scientists have long known that soot and particulate emissions are a hazard to the environment and to human health. A significant amount of particulate matter in the atmosphere is generated from the burning of hydrocarbon fuels, but precisely when and how these fine particles form during the combustion process is not yet completely understood. Due to the complexities of the associated physical and chemical characteristics, developing high-fidelity computational models to accurately predict soot formation remains a tremendous challenge.

Professor **Hong G. Im** plans to change that. In collaboration with colleagues around the United States, Im is heading an effort to develop software that will capture the fine-scale physics and chemistry of turbulent sooting flames at an unprecedented level of detail and realism. Until now, scientists have been using empirical and heuristic models to describe these sub-grid-scale events, but this approach relies on extrapolation from larger-scale information and limits the accuracy and usefulness of the models.

“At least for a while, the majority of power-generating methods for transportation worldwide is going to rely on combustion, including the burning of new, alternative fuels,” said Im, who serves as principal investigator of the effort. “So we need to better understand the combustion characteristics of these new players.”

The resulting software, namely direct numerical simulation (DNS), will provide a new level of detail about the soot development process—under what conditions, exactly how, and in what particle-size distributions it forms. Such models, and their predictive capabilities, have been impossible in the past, in part because of the computing power required. Im and his team will use peta-scale supercomputers—capable of processing 10^{15}, or one quadrillion, floating point operations per second—for their simulations.

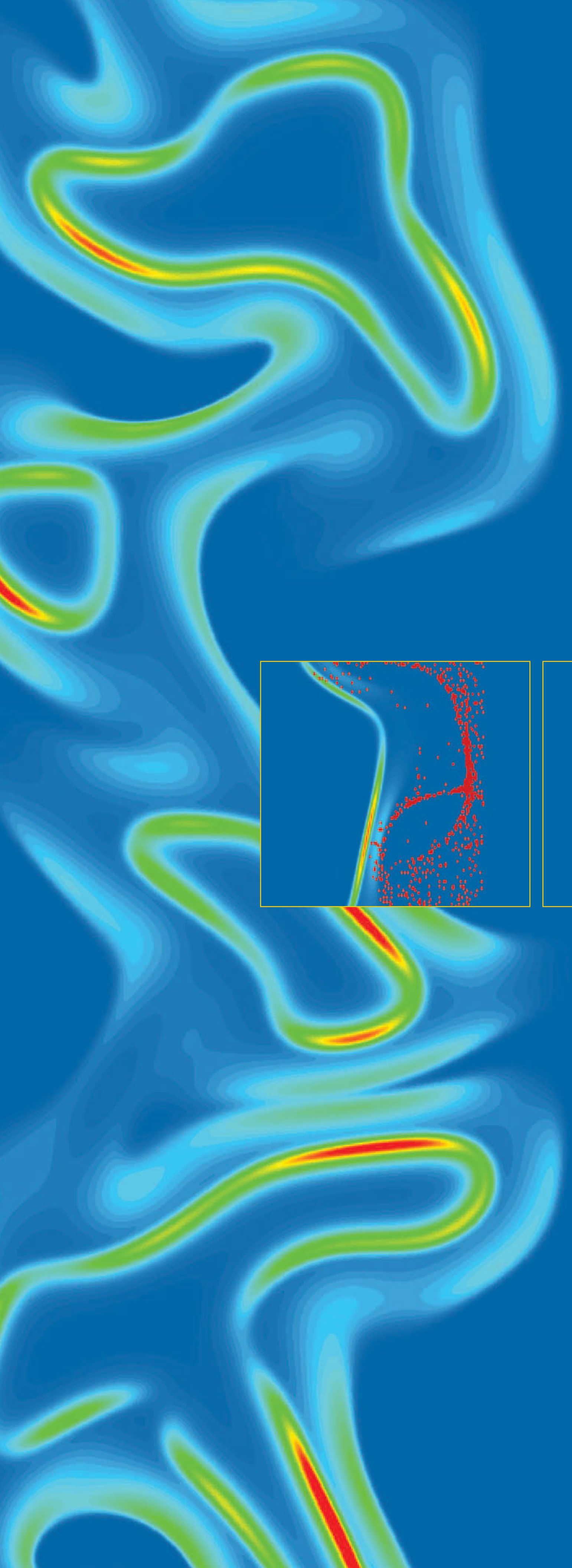
“Creating these three-dimensional simulations is similar to making a movie,” Im said. The team will capture high-resolution data, digitize them and apply mathematical equations pixel by pixel, with a grid resolution of about 10 microns. “To expand up to the size of a laboratory-scale flame, we need over 100 million grid points.”

The project builds off earlier work by Im and colleagues on tera-flop code for the DNS of turbulent combustion. It enhances the fidelity in the physics sub-models as well as the computational efficiency optimized on modern parallel computing architecture.

The comprehensive software package under development also will enable *in situ* visualization and the ability to track particular features of limit phenomena, such as ignition and extinction in sooting flames. The work will advance the fundamental understanding of many key scientific questions related to energy conversion and pollution control.

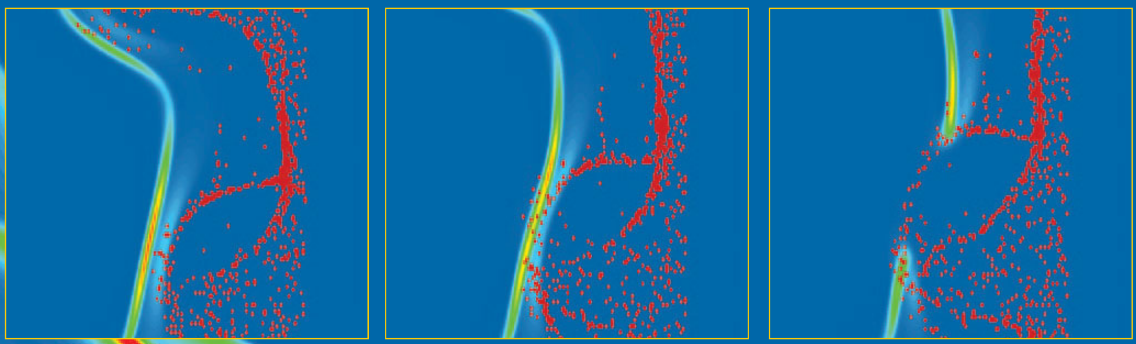
“Combustion-generated soot affects energy efficiency, the environment and our health,” said Im. “Understanding and controlling it is a major concern, both from a technological and societal standpoint, and we’re getting closer and closer to being able to do that.”

The project is supported by the National Science Foundation and includes faculty from the University of Maryland; Pennsylvania State University; University of Connecticut; University of California, Davis; and Oak Ridge National Laboratory.



"The majority of power-generating methods for transportation worldwide is going to rely on combustion, including the burning of new, alternative fuels. We need to better understand the combustion characteristics of these new players."

—HONG G. IM



A sequence of images shows an extinction event of turbulent flames (colors represent the burning intensity) induced by water spray (red dots). Direct numerical simulation captures the moment of local flame quenching as a result of water droplet evaporation.

LIFE ON MARS? NEW MEMS-BASED DEVICE MAY PROVIDE AN ANSWER

In order to uncover signs of life forms in space, astrobiologists often turn to gas chromatography, a technique to analyze the composition of gases. A more recent variation, comprehensive two-dimensional gas chromatography (GCxGC), can provide improved sensitivity and selectivity, but not surprisingly, GCxGC also poses significant challenges.

Associate Professor **Katsuo Kurabayashi** and researchers in his Laboratory for Microsystems Technology and Science are addressing, and surmounting, those challenges using novel microelectromechanical systems (MEMS) based technologies. The group's contributions may soon be incorporated into existing gas chromatography systems—and potentially discover life in the atmosphere of Mars.

Two-dimensional gas chromatography uses two separation columns, or small channels, with different chemical coatings inside their inner walls. The complementary separation processes in these columns enable the system to detect a much larger number of compounds than conventional methods. In order to regulate the flow of gas within the device, GCxGC systems also require a thermal modulator. Existing modulators are extremely large, however, and must cycle between -40 degrees and 300 degrees Celsius within just three to four seconds. To do so, they require coolant as well as about 1,000 kilowatts of power.

"Current thermal modulators require a lot of coolant and dump a great deal of heat," said Kurabayashi. "Energetically, they're extremely wasteful." Particularly in light of the space and power constraints aboard spacecraft, GCxGC systems haven't been a viable option for missions to detect and analyze volatile organic compounds on Mars.

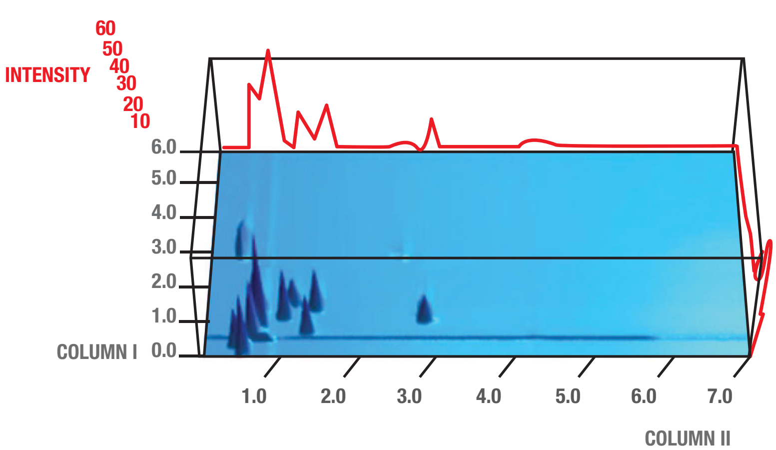
Kurabayashi and his team, including colleagues with the U-M Wireless Integrated Microsystems Engineering Research Center, are the first in the world to have designed, fabricated and tested a MEMS-based thermal modulator for GCxGC. Their modulator, microfabricated in conjunction with the U-M Lurie Nanofabrication Facility, is comprised of two microchannels that cryogenically trap analytes in the sample from the first-dimension column and thermally deliver them to the second-dimension column in a rapid, predictable and programmable way.

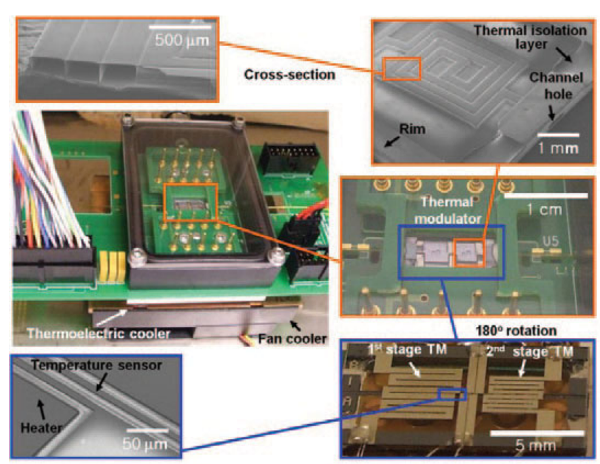
The device not only improves selectivity and sensitivity. It is capable of cycling between -40 and 300 degrees Celsius within 100 microseconds. The on-chip, solid-state micro-cooling unit does not need coolant, and the entire modulator requires just 10 watts of power, two orders of magnitude less than conventional thermal modulators.

The project builds off of Kurabayashi's earlier work to develop microsystems that analyze large numbers of chemical components in the atmosphere. His work on the microscale thermal modulator was initially funded by NASA. More recent support has been provided by Agilent Technologies, which has expressed interest in incorporating the device into its future GCxGC gas chromatography products.

Since the novel thermal modulator enables *in situ* samples to be analyzed with minimal temperature constraints, it makes on-site detection of complex gas mixtures possible. The applications extend far beyond space and Mars' atmosphere to homeland security and environmental air quality monitoring at industrial plants, airports, hospitals and other locales.

The device was featured on the cover of the July 7, 2010, issue of the journal *Lab on a Chip.*





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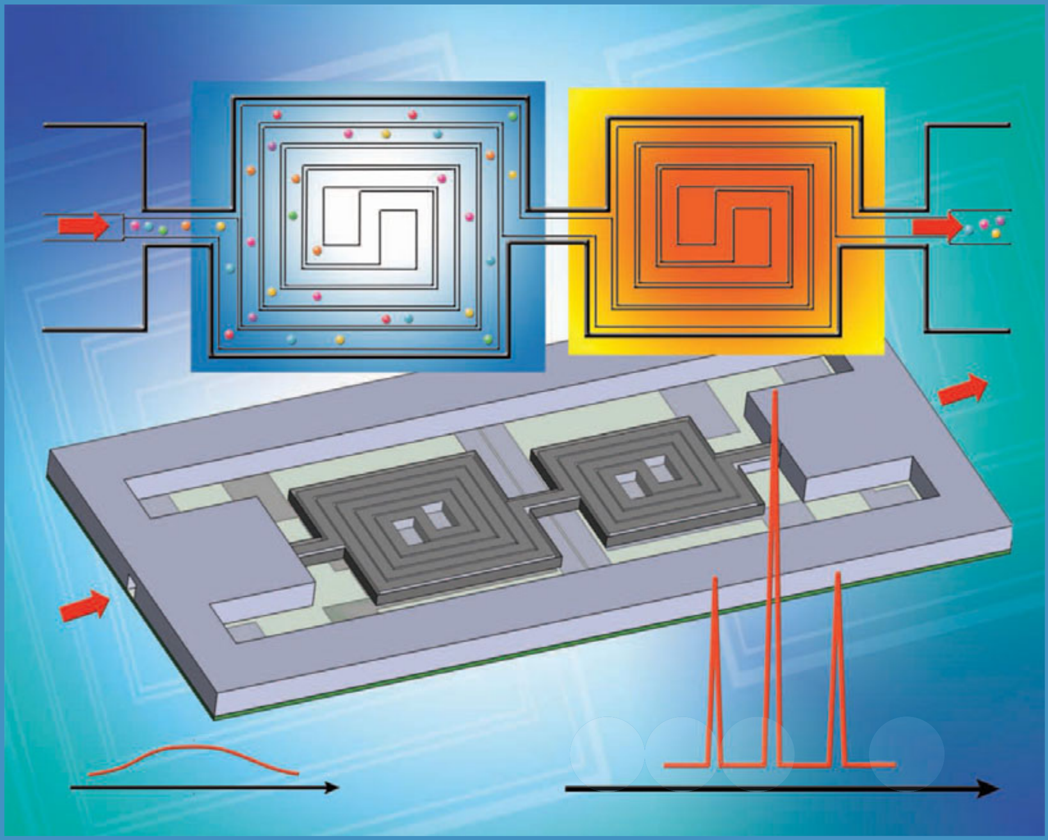


ABOVE: The MEMS device is integrated with microfabricated GC columns and generates heating and cooling cycles between -50°C and 250°C over short timescales for rapid on-chip trapping and re-injecting of volatile organic compounds. Significant technological advances are being explored to reduce space, mass and power resources required for the organic vapor separation process with the MEMS-based thermal modulator device. The system incorporating the thermal modulator provides the opportunity to conduct complex *in situ* sample analysis with minimal temperature control requirements.

OPPOSITE PAGE, LEFT: 2D chromatogram showing separation of 10 alkane compounds

OPPOSITE PAGE, RIGHT: Microfabricated thermal modulator and packaging assembly

IMPROVING GLOBAL HEALTH: A NON-INVASIVE TOOL TO DIAGNOSE MALARIA

More than one million people die each year from malaria, and between 350 and 500 million new cases are reported annually, predominantly in developing nations. A top global public health priority, malaria is transmitted by mosquitoes carrying the *Plasmodium* parasite. The parasite infects red blood cells, where it uses the oxygen-carrying protein hemoglobin as a source of nutrition. Malaria is treatable if diagnosed quickly, otherwise infected individuals may soon develop life-threatening complications, including severe anemia and organ failure.

The new approach and diagnostic tool pave the way for simple, rapid, low-cost screening and diagnosis and can be implemented easily and widely in developing countries, where the burden of malaria is highest.

Malaria currently is diagnosed through microscopic examination of Giemsa-stained blood smears, but this method requires trained health workers, blood to be drawn from patients and a complex logistics system to process samples.

"A diagnostic method that is low cost and easy to use is crucial to fighting malaria," said Associate Professor **Wei Lu**, who is developing an innovative and noninvasive system to diagnose the infectious disease.

Lu's system uses light scattering to differentiate healthy red blood cells from those that are infected with *Plasmodium falciparum*, the most common and most dangerous species of malarial parasite. Affected red blood cells have significantly different characteristics when illuminated by light.

When a particle is illuminated and subsequently scatters light, the spatial distribution of the scattered light forms a complex and distinct spatial pattern based upon numerous factors: particle size, shape refraction index, density and morphology. The resulting "fingerprint" can be used to identify and distinguish different types of cells or different cell states.

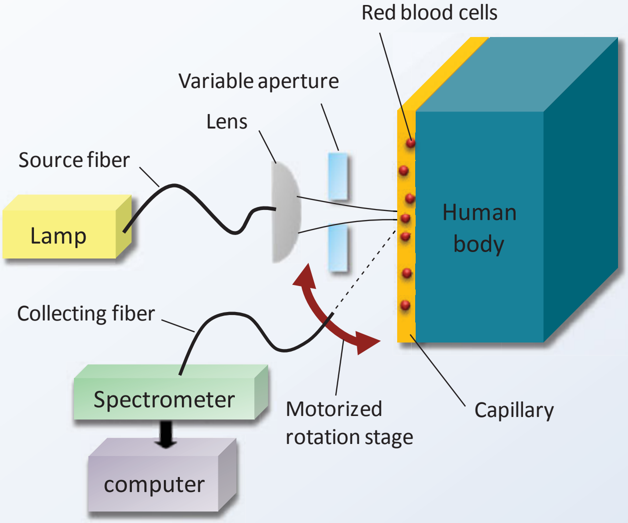
"We've identified the common signature of *Plasmodium falciparum*," said Lu. "If you apply this method to healthy and malaria-infected red blood cells, you can clearly see a difference." One of the reasons why, Lu believes, is the presence of hemozoin crystals, a waste product that results from the parasite's metabolism of hemoglobin. Only malarial parasites generate hemozoin, making Lu's technique highly specific for detecting the disease.

The backward scattering system Lu has devised also can enable malaria detection noninvasively, that is, through capillaries near the surface of the skin or the iris rather than a blood sample. He has achieved this by configuring the system so that the light source and spectrometer are situated on the same side of the sample.

The new approach and diagnostic tool pave the way for simple, rapid, low-cost screening and diagnosis and can be implemented easily and widely in developing countries, where the burden of malaria is highest. Lu's system also has the potential to detect other diseases that affect red blood cells.

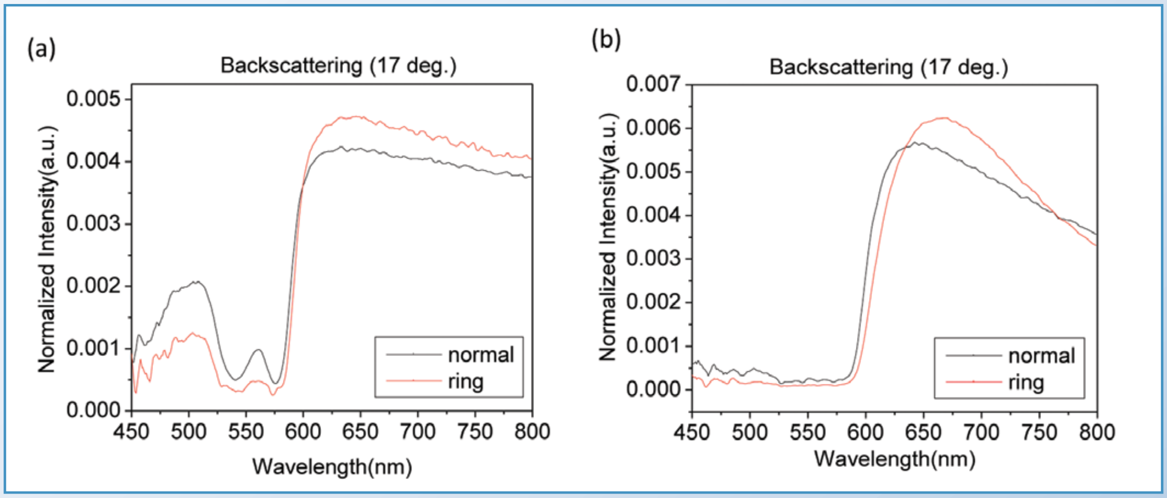
The project has been funded by the Bill & Melinda Gates Foundation through its Grand Challenges Explorations program. Lu's work was one of 76 investigations selected for funding from among more than 3,000 proposals.

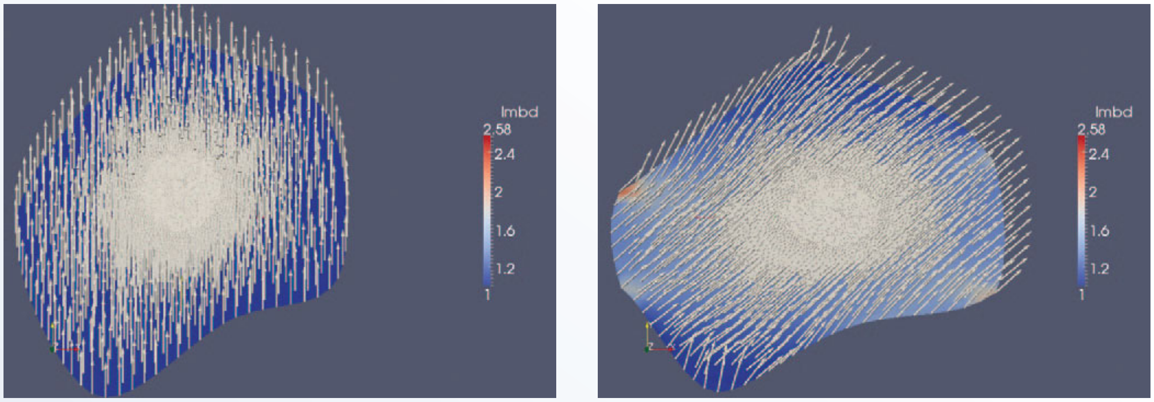
Lu's interest in diagnostic tools for malaria grew out of his research program and interest in the modeling and simulation of nano/microstructures and the mechanics of nano/micro systems. He is developing computational tools to speed the development of advanced batteries for vehicle electrification through the U-M Advanced Battery Coalition for Drivetrains, and he also works with the U.S. Department of Energy's first energy innovation hub, the Consortium for Advanced Simulation of Light Water Reactors (CASL). As part of the $120 million CASL effort, Lu will develop advanced mechanics and predictive simulation approaches to reduce grid-to-rod fretting, a dangerous type of wear. His work ultimately will help improve the performance and reliability of pressurized water reactors.



ABOVE: Schematic of the optical setup for light scattering measurement

BELOW: Backward scattering shows a clear spectrum difference between samples with healthy blood cells and samples with 2% ring stage *P.falciparum* (a) diluted with PBS. (b) no dilution.





CELL MECHANICS OFFERS INSIGHTS INTO CANCER'S SPREAD

Understanding how cancer cells multiply and move has been a perennial goal of biologists the world over. That's because metastasis, or the spread of cancerous cells to other areas of the body, is responsible for the majority of mortality caused by the all-too-common disease.

How cancer cells move involves several mechanical and chemical interactions within and among cells. "The mechanical aspect of this process isn't unlike making your way through a rainforest, at times hacking at the dense vines and creepers, and at other times actually using the vines, tree trunks and roots to pull yourself along," said **Krishna Garikipati**, associate professor. Garikipati develops computational models to predict certain behaviors of cancer cells in order to better understand tumor growth and cancer metastasis.

Cancer cells mimic these hacking and pulling processes by secreting enzymes called proteases that break down the protein fibers they encounter in the extracellular matrix, or ECM. And, by attaching themselves to and hauling themselves along the extracellular matrix, cancer cells are able to migrate to the deepest layer of tissue, known as the basement membrane. They burrow through, and from there can reach the blood stream or lymphatic system and spread to other parts of the body. Once they do, cancer is considered invasive—and is much harder to treat.

To travel along the ECM, cells rely on focal adhesions, which function like "sticky feet," explained Garikipati. The dynamics of how cells create and manipulate focal adhesions are strongly dependent on mechanics. "We're increasingly realizing that many of the critical processes cancer cells carry out are mechanical in nature. The mechanical life of cells, particularly cancer cells, is very significant," he added.

In collaboration with cancer biologists at the U-M Medical School, Garikipati is investigating how changes in cells' cytoskeletons affect their ability to move—since motion, after all, is governed by mechanics. By comparing control and genetically modified cells, researchers are learning more about the dynamic changes of the cytoskeleton that lead to or hinder locomotion, and therefore metastasis. By linking these changes to specific proteins, investigators may help uncover new targets for anti-cancer drugs.

Garikipati's fundamental work characterizing the mechanics of cells and their motion reflects a natural progression of scientific questioning that stems from an earlier interest in how biological tissue grows, that is, how it adds—or, in the case of negative

"We're increasingly realizing that many of the critical processes cancer cells carry out are mechanical in nature. The mechanical life of cells, particularly cancer cells, is very significant." —KRISHNA GARIKIPATI

growth, loses—mass as well as how tissue remodels itself.

"In both instances, growth and remodeling, one can ask questions of the energetics—how is this tissue using the energy available to it? Physicists and mathematicians have worked this out for nonliving materials such as metals and plastics, but not for biological tissue," he said.

In an international and interdisciplinary collaboration with the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, Garikipati and colleagues are exploring the rates of change in free energy in a growing tumor in relation to such functions as cell proliferation, ECM production, oxygen and glucose consumption and cell migration. Although these biological, chemical and mechanical processes are physically distinct, their respective free energy rates of change represent one of the few, if not only, rigorous ways to compare them.

As part of the project, investigators are culturing two cancer cell lines and using them to seed *in vitro* models of early-stage tumors. The tumors will be analyzed to learn the rates at which their cells multiply, produce the ECM, consume nutrients and move, as well as their mechanical properties. Garikipati will use the resulting data to devise physically accurate computations of free energy rates.

The effort is believed to be the first to study tumor progression in the context of free energy. "Looking at the change in free energy rates may hold clues that lead us to a better understanding of the switch that cells undergo between rapid proliferation and rapid motion, which is what distinguishes invasive cancer from non-invasive disease. Making connections between mechanisms and their free energy rates also may help identify potential therapeutic pathways," said Garikipati.

Both projects, on cell mechanics and motion, as well as the energetics of growing tumors, fit under a broader University-wide effort to discover new ways to understand the biology and mechanics of cells.

In an initiative spearheaded by Garikipati, the Medical School departments of Microbiology & Immunology and Cell & Developmental Biology as well as the departments of Biomedical Engineering, Chemical Engineering and Mechanical Engineering are hiring several junior faculty. Three of these exceptional faculty already are establishing their laboratories in the Medical School: Irina Grigorova in Microbiology & Immunology and Ajit Joglekar and Shiv Sivaramakrishnan in Cell & Developmental Biology. The third, **Allen Liu**, will join Mechanical Engineering in January 2012 (see related story on page 15). Two more will be recruited in Biomedical Engineering and Chemical Engineering.

The shared vision is to enable the investigation and characterization of cell biology from a quantitative standpoint. "As this corps of new faculty comes together and works with more senior faculty," said Garikipati, "physicists, engineers, mathematicians, chemists and biologists will work hand in hand to explain the physical life and mechanics of cells. It's a campus-wide effort that truly distinguishes U-M."

OPPOSITE PAGE, TOP: Reorientation kinetics drive the fibers (arrows) to locally orient toward an equilibrium direction for which the strain energy of the cell-extracellular matrix system is minimized. Simultaneously, active contractility of the cytoskeleton causes cell polarization in this direction. Color contours show the maximum stretch at each point in the cell.

ENCOURAGING AND PREDICTING THE GROWTH OF STEM CELLS

Stem cells have the unique ability to differentiate into numerous types of cells. Mesenchymal stem cells, or MSCs, for example, can grow into fat, cartilage or bone cells. Scientists have long known that cells' behavior, including differentiation, is influenced by the microenvironment around them, and biologists today have the ability to induce differentiation into desired cell types using genetic and biochemical methods. But very few researchers have looked at the use of mechanical means to influence the behavior of MSCs.

"Increasingly over the last few years, biologists and engineering researchers alike have been realizing how important mechanics are in regulating cell functions," said Assistant Professor **Jianping Fu**, who studies how the mechanical and physical signals in cell microenvironments affect cell behaviors.

"We know that cell functions are regulated mainly by extracellular stimuli, and recent evidence suggests that the mechanical properties of the scaffolding that surrounds a cell—the extracellular matrix—and particularly the rigidity of the matrix, can influence a number of cellular functions," he added.

In work published in the journal *Nature Methods,* Fu recently invented, fabricated and demonstrated an array of microstructures that can encourage MSCs down different differentiation pathways. Using micromolding and microfabrication techniques used in the semiconductor industry, Fu fabricated an array of post-like microstructures out of a type of silicone. By changing the height of the tiny structures, he is able to control their rigidity.

Fu has shown that MSCs placed on top of the more rigid (shorter) posts prefer to differentiate toward bone cells, while MSCs in the same chemical microenvironment but placed on top of the more flexible substrate (the longer posts) show a tendency toward fat cells. "All other factors being equal, the mechanical environment is critical," he said.

As the cells attach to the micropost substrate, they exert force, which bends the tops of the posts. Because the mechanical properties of the post are known, investigators can calculate the traction force the cell is exerting. "In that way we can use the posts as sensors to monitor one of the mechanical traits of the cell," said Fu.

In addition, Fu has found that the traction force of a cell also can be used as a nondestructive predictor of MSC differentiation. Stem cells that commit toward bone cells, or osteoblasts, show much higher contractility at the earliest stages than cells that will become fat cells, he and his team found. By contrast, undifferentiated MSCs that are treated with chemical growth factors—the conventional way of encouraging differentiation *in vitro*—typically have a heterogeneous response.

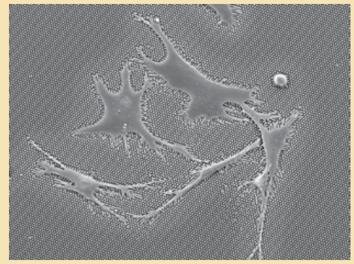
"Some cells go down one path, some go down another, and some show no response at all—and there's no way to predict their behavior," he said.

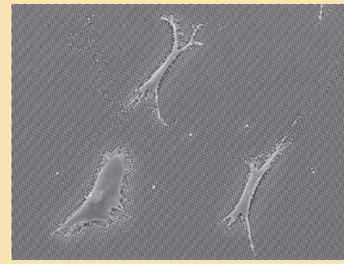
When conventionally cultured cells differentiate, it can take days if not weeks for scientists to learn what type of cell they will become. In Fu's system, however, cells show a differential contractility response within 24 hours. His findings have tremendous implications for developing novel high-throughput drug screening platforms to test molecules related to the encouragement or inhibition of differentiation into different cell types. The platform also can serve as an efficient testbed to explore other rigidity-dependent stem cell functions.

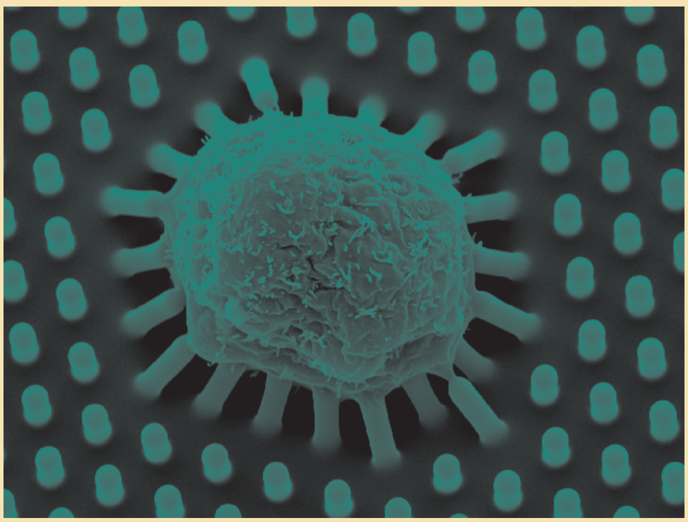
While the current substrate system is passive, the research team also is exploring active environments, such as adding a stretching force where the cell membrane adheres to the post. Stretching the membrane in effect stretches the cell, introducing an active force control.

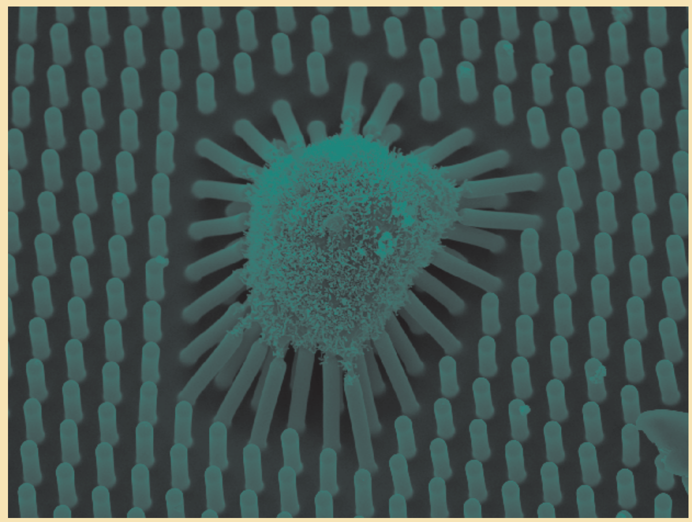
"Now we can modulate two independent controls," explained Fu, who plans to use both passive and active techniques to improve the survival rate of embryonic stem cells. Currently about 99% of human embryonic stem cells die in culture if they are plated as single cells, significantly hampering research progress. Scientists add chemicals to improve their survival, but that only raises the rate to between 20 and 30%. "The chemicals aren't ideal for cells," said Fu, "and we're hoping our mechanical cure can replace them one day soon."

Using micromolding and microfabrication techniques used in the semiconductor industry, Fu fabricated an array of post-like microstructures out of a type of silicone. By changing the height of the tiny structures, he is able to control their rigidity.

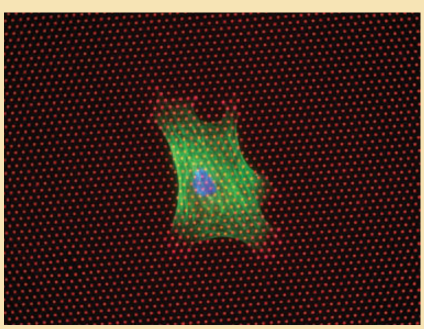


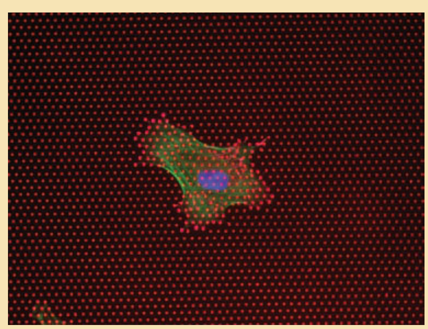






Representative immunofluorescence image of human mesenchymal stem cells (hMSCs) plated on the PDMS micropost arrays. hMSCs were stained with fluorophore-labelled phalloidin, anti-vinculin and DAPI to visualize actin filaments, focal adhesions and the nuclei, respectively.





INNOVATIVE MODELS REVEAL THE HEALTH OF HIGH PERFORMANCE STRUCTURES

Military and commercial aircraft manufacturers are placing ever-higher demands on the operational capabilities of their aircraft, including improved performance, safety and reliability. Among the most critical systems for modern fleets are turbine engines, since many types of jets rely on a single engine that must meet high thrust-to-weight and durability targets over a wide range of operating conditions.

"Creating powerful tools to enhance performance and avoid disasters involves multidisciplinary knowledge to capture essential complex dynamic interactions," said **Bogdan Epureanu**, associate professor. Epureanu's work investigating structural dynamics applies to a range of technologies, from aircraft engines and military vehicles to microscale imaging and mass sensors. "Innovative computational models and unique damage detection techniques are needed," he added.

Aircraft safety and reliability is improved when the bladed disks used inside engines are lighter, stronger and free from defects. Bladed disks, also called "blisks," are manufactured as one part using advanced materials and technologies. Blisks offer several advantages over conventional hub-and-blade rotors: improved propulsion efficiency, increased durability and a reduction in the number of components that can potentially fail.

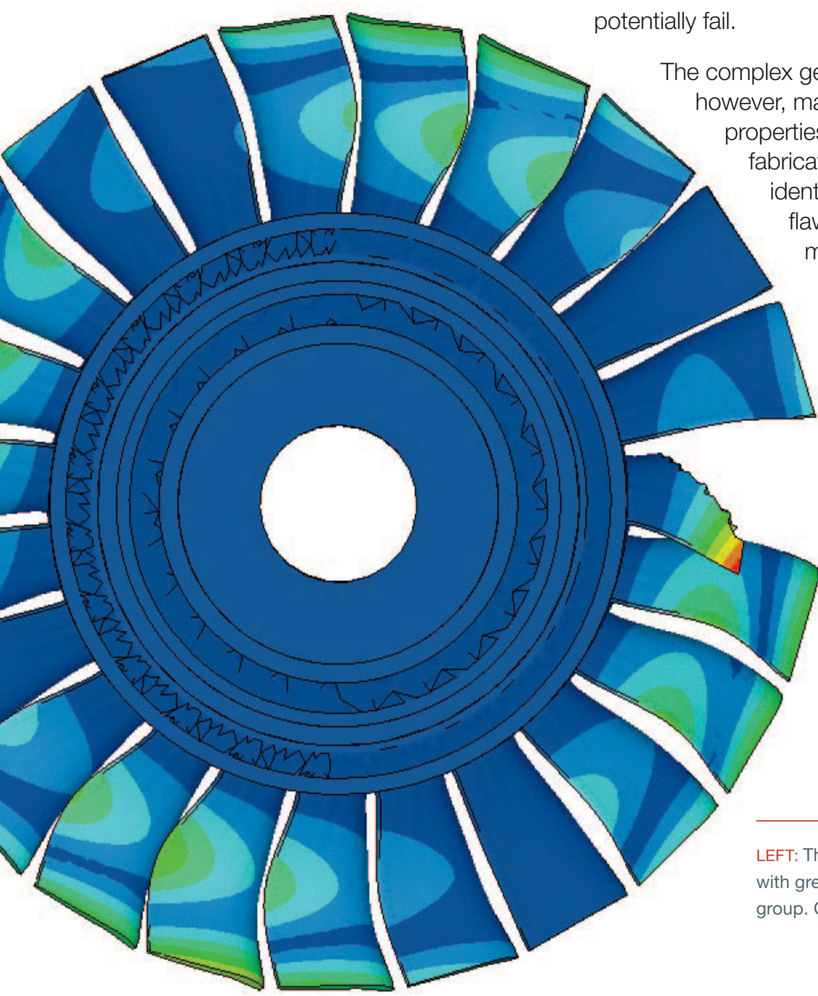
The complex geometry of blisks, however, makes controlling their properties more difficult during fabrication. The ability to identify properties, detect flaws and take detailed measurements therefore has become even more important. Epureanu's group tackles this challenge by devising both experimental and computational techniques to obtain highly efficient yet higher fidelity predictions of nonlinear vibration responses of cracked structures such as blisks. This technology enables a quantum leap toward detecting damage and estimating fracture propagation and fatigue life in complex structural and fluid-structural systems.

The research performed in Epureanu's group has led to a critical collection of advanced modeling techniques for turbine engine rotors. These techniques provide an unprecedented opportunity to develop substantially new predictive technologies that will have important applications to design, online structural health monitoring and system prognosis of turbine engines.

"The modeling methodologies we develop capture nonlinear, aeroelastic, multi-stage and localization phenomena, and have strong potential to impact Air Force and civilian technology," said Epureanu.

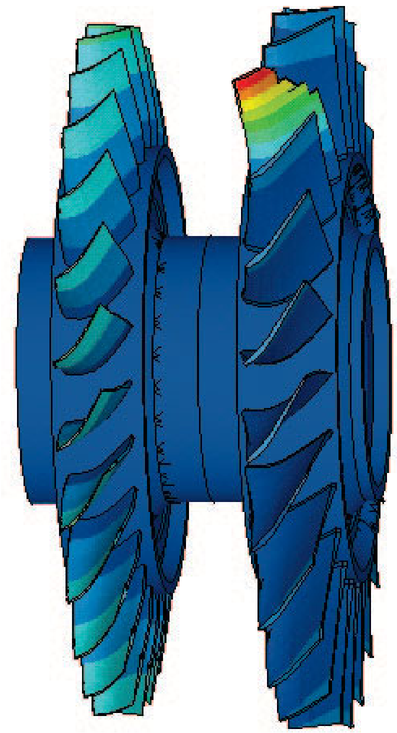
In a project for the U.S. Air Force, Epureanu has created an integrated solution to model and detect flaws in aircraft engines while in operation. The paradigm uses onboard sensors to relay critical information to the pilot. The approach is a departure from conventional time-based maintenance practices and a move toward condition-based maintenance, which allows the military to operate more efficiently by improving asset management and readiness.

The approach involves sensors mounted in the casing of the engine to capture the time elapsed between each blade passing. From that information, central processing units, or "reasoners," can interpret sensor data by using the models developed in Epureanu's group to identify the location and severity of flaws. The system also aims to provide prognostic information about how much longer the pilot safely can fly.



LEFT: The vibration of complex bladed disks with small and large damages can be predicted with great computational speed by using the innovative methods developed in Epureanu's group. One of the vibration modes of a full blisk is shown.

> "The modeling methodologies we develop capture nonlinear, aeroelastic, multi-stage and localization phenomena, and have strong potential to impact Air Force and civilian technology."
>
> —BOGDAN EPUREANU



This effort was spearheaded by the Defense Advanced Research Projects Agency and Pratt & Whitney, and is expected to open the door to realistic and practical structural health assessments for both onboard monitoring and offline maintenance inspections.

In a collaborative project with GE Aviation entering its sixth year, Epureanu is leading an effort to model and identify the structural properties of blisks so that accurate predictions can be obtained computationally. The key is to identify structural properties of blisks after they have been manufactured and after they have been in use.

"If there's a bird strike or other problem that leads to a structural change in the engine, we want to know the consequences for the overall engine, including how long the repaired blisk will last and how it will affect the vibration of the other components of the engine," Epureanu explained.

Minute differences in properties can lead to a large increase in vibration of one or a few blades, which increases failure risk. But blades can't be measured individually; instead, system-level measurements are required to determine the properties of each blade. Epureanu's research group is providing system-level, predictive computational tools that GE Aviation can incorporate into its design process to reduce experimentation. He also is working on developing new experimental devices to measure the dynamics of blisks.

In a project for the U.S. Army, Epureanu's group is helping ensure the safety of soldiers. His team has been developing key modeling capabilities and computational tools to evaluate the structural integrity and reliability of ground vehicles exposed to impact, blast and wear and tear.

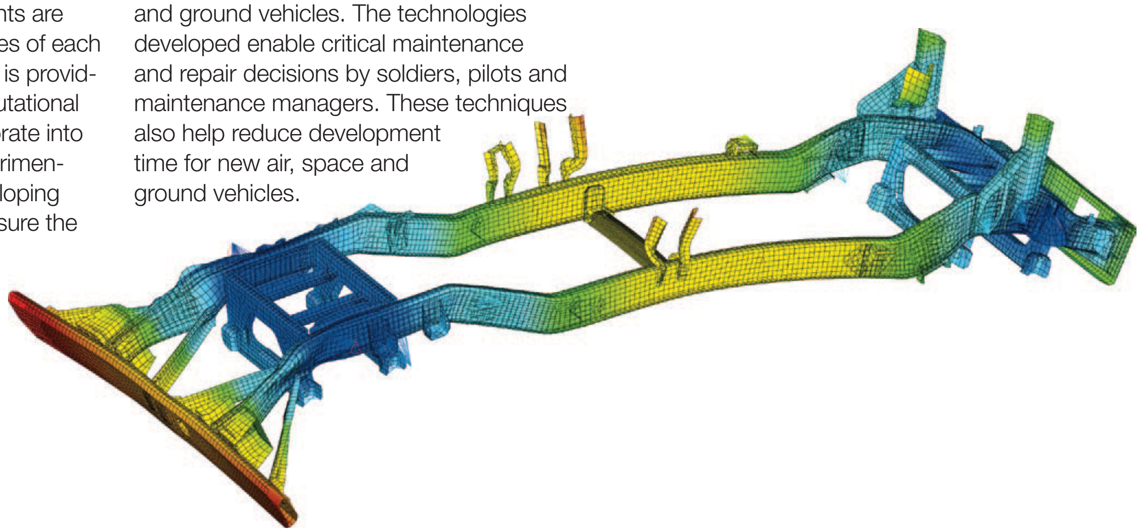
"We approach the problem in an integrated fashion, with a soldier-centric perspective," he said. The original technologies developed by Epureanu's group are designed to pinpoint the best locations on vehicles to place sensors that detect defects and to identify optimal joining locations where armor should be attached.

"We're developing a computational aid that helps designers identify the weakest, most vulnerable points of a vehicle," Epureanu said. "We're also helping the Army understand how attaching armor in those areas will affect vehicle weight and performance. This way, designers can evaluate the consequences of different configurations before vehicles are produced."

The research conducted in Epureanu's lab directly supports both established and emerging practices in design, modeling and damage assessment of aerospace and ground vehicles. The technologies developed enable critical maintenance and repair decisions by soldiers, pilots and maintenance managers. These techniques also help reduce development time for new air, space and ground vehicles.

ABOVE: Although damage is located on one stage, all (coupled) stages of an engine will be affected. By using the novel models developed in Epureanu's group, system-level consequences can be predicted. Shown is a mode of vibration of a multi-stage system.

BELOW: The dynamics of the frame of a vehicle play an important role on reliability and performance. The techniques used in Epureanu's group focus on detecting failures and predicting vibrations. A vibration response of the frame of a military high mobility vehicle is shown.



EXPLORING SHOCK WAVES AND BUBBLE DYNAMICS: FROM MEDICAL ULTRASOUND TO STAR FORMATION

ABOVE: Vortices visualized using the Q-criterion for the decay of compressible isotropic turbulence with eddy shocklets. The vortices represent turbulent structures and span a wide range of scales. Because of the high compressibility and turbulence intensity, the fluctuating fields of the turbulent eddies lead to the formation of "eddy shocklets". This phenomenon plays an important role in high-speed combustion and astrophysics.

When it comes to understanding and modeling complex systems and problems, such as the erosion caused by turbulent cavitating flows on propellers, the explosion of a supernova or the ablation of human tissue by shock waves, researchers can't possibly represent every detail accurately.

"That's just not a realistic goal," said Assistant Professor **Eric Johnsen**. Instead, investigators such as Johnsen often look at smaller-scale, idealized sub-problems to understand the fundamental physics at play. "Our motivation is the actual application," Johnsen added, "and, by putting the pieces back together, we can paint an accurate picture of the full problem at hand."

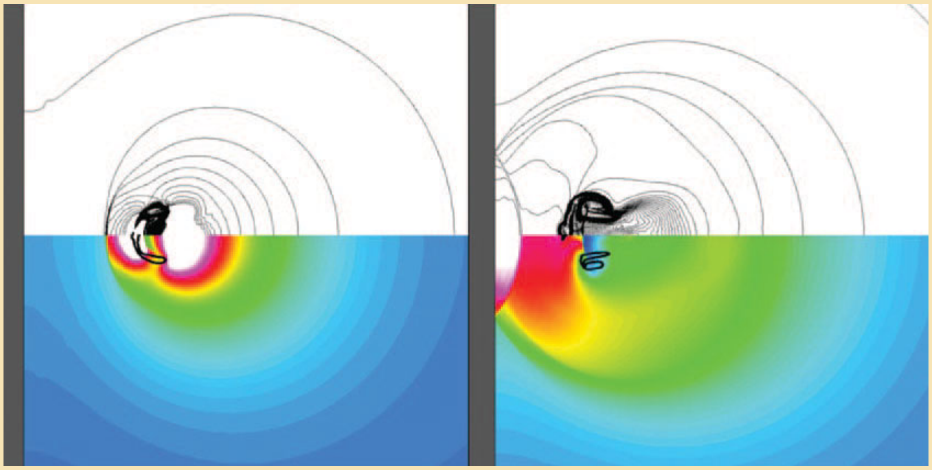
Johnsen heads the Computational Flow Physics Laboratory at U-M, and his work investigating high-speed and high-energy-density phenomena blends traditional mechanical engineering disciplines—fluid dynamics, continuum mechanics—with modern techniques such as multiscale modeling and high-performance computing. The applications of these problems span biomedical engineering to astrophysics.

Johnsen and the researchers in his lab investigate compressible multiphase flows, including the interactions of shock waves with interfaces that separate different fluids and materials. His team uses and develops high-fidelity numerical methods in order to describe the physics of such flows. Due to the complexity, numerical methods to study many of these problems over a wide range of scales and energies don't yet exist.

When density gradients within materials accelerate, for example due to the passage of a shock wave or flow in a converging geometry, small imperfections along the interface separating the different materials lead to hydrodynamic instabilities and, subsequently, to the mixing of these materials.

"In some problems, such as combustion, mixing is desirable," explained Johnsen. "But in other applications, mixing must be prevented." Such is the case with inertial confinement fusion (ICF), in which nuclear fusion—potentially one of the cleanest and safest energy sources—is initiated by compressing a fuel target, he explained. If mixing takes place, the conditions for fusion won't be achieved.

Although the early-time behavior of many types of instabilities is well-understood, the late-time, turbulent, multi-material mixing characteristics are less well-understood. This is especially true for high-energy-density applications where extremely strong shocks and high pressures are achieved, and magnetic fields play important roles. These conditions often exist in ICF and



ABOVE: Last stages in the collapse of an air bubble in water near a rigid wall on the left. Density lines (top) and pressure contours (bottom) are shown. Left frame: shock emission upon collapse; right frame: shock reflection off the wall. The bubble collapses in a non-spherical fashion: a re-entrant jet is created and impacts the distal side, thus creating a strong water-hammer shock. This phenomenon plays an important role in cavitation erosion of propellers and in shock wave lithotripsy.

many astrophysics flows, such as star formation and supernova explosion.

“Computationally, these compressible and turbulent processes have not been explored in great detail because of shortcomings of current methods,” said Johnsen. His work to develop numerical methods and better understand this flow regime is part of a large University-wide collaboration, the Center for Radiative Shock Hydrodynamics, funded by the U.S. Department of Energy and the National Nuclear Security Administration.

Johnsen also applies the study of shock waves and the mixing of multiple fluids and phases to cavitation, or the formation and implosion of vapor bubbles in a liquid in response to a drop in pressure. Cavitation can occur in a variety of settings and, whether deliberately induced or unintended, understanding bubble dynamics has important implications across many applications.

“Although historically cavitation had been considered detrimental, researchers are starting to take advantage of its destructive power in the medical field, particularly in therapeutic ultrasound,” he said.

In shock-wave lithotripsy, the most common treatment for kidney stones in the United States, clinicians focus shock waves on the stone to break it up. Cavitation occurs because the stones typically are immersed in liquid—urine or blood—but precisely why the stones break apart remains unclear.

Johnsen’s research team has developed methods to study bubble dynamics during lithotripsy. His group has found that the shock-induced collapse of a bubble may generate pressures higher than those of the incoming shock and that the presence of a bubble will locally amplify the pressure of the incoming pulse. He also found that cavitation bubble collapse and the resulting shock waves both erode the kidney stone surface and cause structural damage within the stone. His findings are the first to show the coupling between these two damage mechanisms.

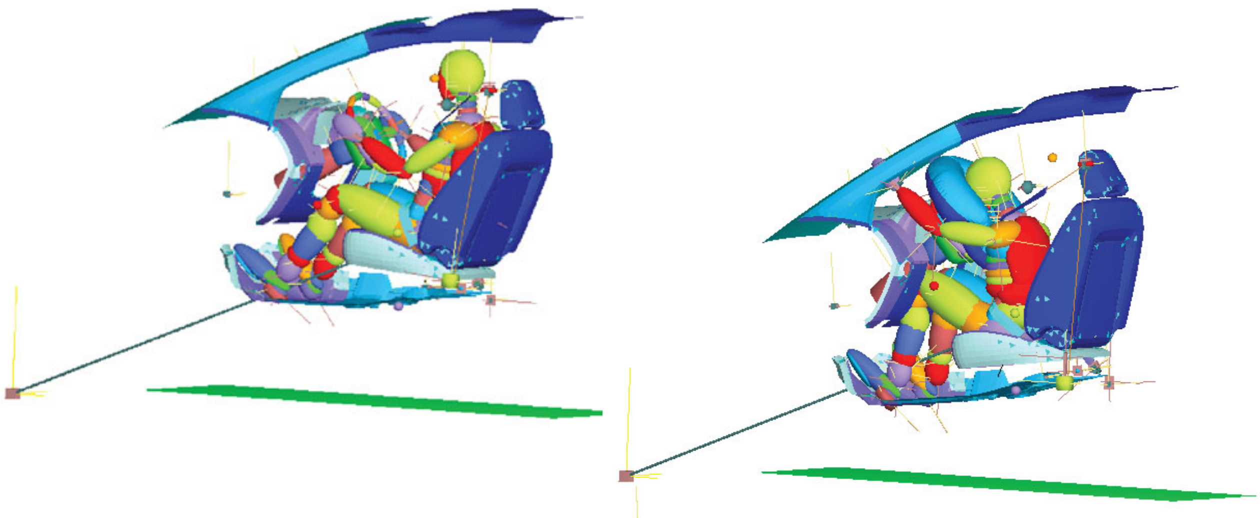
In collaboration with colleagues in Biomedical Engineering and Radiology, Johnsen is looking at similar mechanisms in histotripsy, which uses high-amplitude ultrasound to destroy pathogenic tissue. The ultrasound waves are thought to cause cavitation, the subsequent bubble collapse to destroy cells and fragment the targeted tissue.

One of the main challenges, however, is to model the effects of shock waves and cavitation on human tissue. The mechanical properties of tissue are not well established at the high strains and strain rates that occur in histotripsy. In addition, tissue behaves like an elastic solid under certain types of forcing and more like a fluid under other forcing. One of Johnsen’s students has found that, due to nonlinear coupling, the elasticity of tissue causes cavitation bubbles to behave differently than in typical compressible and viscous media.

With a Ralph E. Powe Junior Faculty Enhancement Award from the Oak Ridge Associated Universities consortium, Johnsen is simulating bubble dynamics and shock waves in mercury. Liquid mercury contained in a stainless steel vessel is a key part of Oak Ridge National Laboratories’ Spallation Neutron Source (SNS) facility.

Shock waves form and propagate within the SNS when mercury interacts with a proton beam, and the shock waves can place high stresses on the steel vessel. Cavitation bubbles that form in the heated mercury also can cause damage. Johnsen’s work will help assess the effectiveness of, and further develop, mitigation techniques.

“Our long-term goal with all of these research efforts is to develop a comprehensive numerical framework for compressible multiphase flows in order to study shock waves, cavitation and multi-material mixing; predict the occurrence of these phenomena; and ultimately control them,” he said.



DESIGN: LINKING ENGINEERING WITH HUMAN AND SOCIAL DECISION MAKING

Design plays an important, yet sometimes subtle, role in how engineering decisions affect human and social decisions, including those related to vehicle safety, optimal product designs and even behavior. In Professor **Panos Papalambros**' Optimal Design (ODE) Laboratory, researchers are working to develop quantitative and qualitative design analysis capabilities, strongly influenced by the paradigm of design as a decision-making process.

VEHICLE DESIGN FOR SAFETY AND SUSTAINABILITY

Developed countries have seen their rates of *per capita* automobile-related injuries and fatalities decline in recent decades. The improvements are likely due to several factors, including new safety technologies and better vehicle designs. In the United States, many safety technologies, such as seat belts, air bags and energy-absorbing front frame rails, have been implemented in response to federal mandates and widely available crash test ratings.

"And yet it's not enough for automotive manufacturers to just include these features," said Steven Hoffenson, a doctoral student working in the ODE lab. "Safety technologies must be optimized for each vehicle as well as for specific crash scenarios."

Since crash tests impact consumer purchasing decisions, manufacturers often optimize their designs to perform well in the tests, which don't necessarily reflect the full range of real-world crash scenarios. For instance, the tests don't address the risks during side impacts when the intrusion occurs near occupants' heads, or when vehicles with high front ends, such as SUVs and pickup trucks, strike a conventional passenger vehicle.

Hoffenson and Papalambros used computational modeling and simulation to analyze the impact of changing test speed, measurement of injury severity and the test rating scale for the National Highway Traffic Safety Administration (NHTSA) New Car Assessment Program (NCAP) frontal crash test. "We set out to learn what test specifications would optimize overall road safety," explained Hoffenson.

Taking variables such as vehicle mass, frontal stiffness, seatbelt stiffness and airbag inflation rates into account, Hoffenson and Papalambros discovered that in order to optimize safety against injury, crash test standards should represent the scenarios that occur most frequently under real driving conditions, such as crashes at lower speeds and with lower injury severity. They found that lowering the NCAP test speed to 30 miles per hour from 35 predicted a 24% reduction in serious injuries, and that changing the NCAP rating system to a more precise 100-point scale could reduce serious to fatal injuries by 10%.

Next steps include looking at the impact of additional parameters, including occupant seating position and occupant body size in order to make recommendations to the NHTSA for improved NCAP testing.

CAPTURING CONSUMER PREFERENCES ONLINE

Consumer preferences inform the product design process, but effectively capturing and integrating those preferences into the design optimization process is challenging for designers and manufacturers. Preference models with small numbers of variables can be used to bridge consumer choices with optimal designs, but when it comes to complex three-dimensional geometries, such as vehicle shape, models require a large number of variables.

"Capturing the right design variables for a qualitative or holistic design problem like vehicle styling is hard to do using market or consumer survey data," said Max Yi Ren, another doctoral candidate in the ODE lab. "It's difficult to represent a shape verbally, and people may not be aware of their preference in the first place. Alternate sampling techniques exist, but they haven't entirely solved these challenges."

Instead, Ren has proposed an interactive human-computer method to solicit and capture preferences directly from users. His web-based application, "Matchbox 3D," uses WebGL to dynamically create three-dimensional models on a web page, AJAX to enable interaction, and Google Datastore to save user submissions.

Ren's statistical learning approach collects individuals' preferences using binary comparison data. The application displays nine designs, and users pick any number that they prefer over the rest. Using effective global optimization (EGO) and active learning algorithms, the application "learns" from the feedback and delivers more relevant designs with each iteration.

Ren has demonstrated that this method can successfully elicit user preferences and most preferred designs using an appealing interactive experience. He plans to further develop the application by exploring the collection of preference data from multiple individuals in order to create preference models for groups of users or market segments.

To date, Ren has collected more than 600 user interactions. To try the application, visit: www.yirenumich.appspot.com. It works best with Google Chrome 10 or higher.

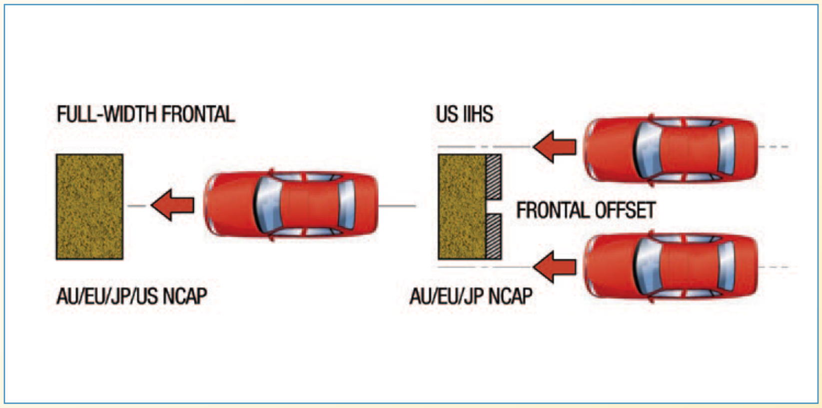
ENCOURAGING BEHAVIOR THROUGH DESIGN

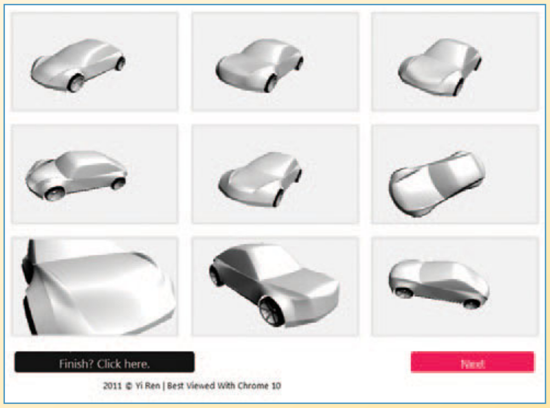
Can the design of a recycling bin motivate people to recycle more? That's the question Design Science doctoral candidate and ODE lab member Soodeh Montazeri plans to answer with a study she recently has undertaken. Montazeri is co-advised by Richard Gonzalez, professor of Psychology.

If the appearance of a recycling bin attracts attention, Montazeri hypothesizes it will remind individuals to recycle, in effect acting as a situational cue. "We argue that if a recycling bin is more visible—either through high-arousal colors such as red, orange and yellow or situated so that it contrasts sharply with its background—it is more likely to be used," she said.

Psychologists have known that arousal is a source of behavioral change, but how this concept can become a useful design instrument is an open question. Montazeri's early study showed that color does have impact on recycling bin use but contrast does not. She is working with U-M staff in charge of campus recycling to expand her study to several campus sites. Isolating the many variables that can affect human behavior in any given context is her biggest challenge.

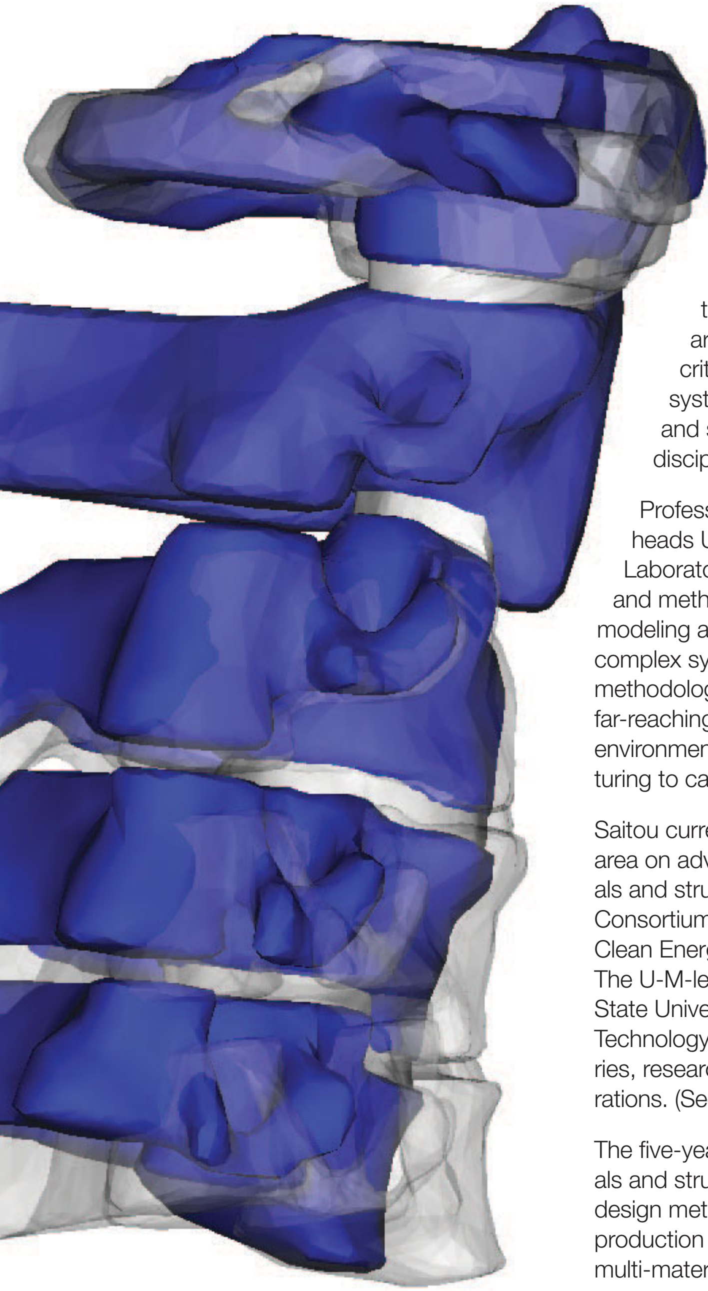
Montazeri presented her work at the Persuasive Technology Conference in June 2011.





ABOVE, LEFT: Frontal crash test procedures for New Car Assessment Programs (NCAPs). ABOVE, RIGHT: Creating your very own most-preferred vehicle shape through a web-based human-computer interaction application (yirenumich.appspot.com). This is just one of the many design projects in the Optimal Design Laboratory. COURTESY OF MAX YI REN OPPOSITE PAGE: Multibody dynamics simulation of an occupant restraint system, before (left) and after (right) a crash.

MODELING AND SYNTHESIS OF COMPLEX SYSTEMS



A finite element model of cervical spine motion that realistically shows the deformation that occurs over the course of treatments in image guided radiation therapy (IGRT). Such models have the potential to dramatically improve the accuracy of image registration during treatment.

The system-level modeling, abstraction and algorithmic synthesis of mechanical, industrial and biomedical systems are becoming increasingly critical since these human-made systems are growing more complex and spanning multiple academic disciplines.

Professor **Kazuhiro Saitou**, who heads U-M's Algorithmic Synthesis Laboratory (ASL), explores new theories and methods for the computational modeling and synthesis of many types of complex systems. The techniques and methodologies he devises soon may have far-reaching impact in many areas, from environmental sustainability and manufacturing to cancer detection and treatment.

Saitou currently leads the research thrust area on advanced lightweight materials and structures for the Clean Vehicle Consortium, part of the new U.S.-China Clean Energy Research Center (CERC). The U-M-led consortium also includes Ohio State University, Massachusetts Institute of Technology and several national laboratories, research institutes and private corporations. (See related story on page 9.)

The five-year goal of the lightweight materials and structures thrust area is to develop design methodologies and optimize production processes for ultra-lightweight, multi-material vehicle body structures.

"We're looking toward ultra-lightweight structures that weigh, potentially, half as much as vehicle bodies currently on the market—with comparable price and safety," explained Saitou.

Saitou is up to the challenge, which builds on his earlier work in many aspects of vehicle structure design. "The vehicles we're envisioning may very well be electric, but we're focused less on the powertrain right now and more on integrating lightweight materials and components in vehicle bodies as affordably as possible without compromising on safety," he said.

FLEXIBLE DEFENSE MANUFACTURING

Sponsored by the Defense Advanced Research Projects Agency, Saitou is part of a team led by Carnegie Mellon University that is transforming defense manufacturing for ground combat vehicles. The Instant Foundry Adaptive through Bits, or iFAB, initiative is leading the way from the conventional—and time-intensive—design-build-test-redesign cycle common in the defense industry to a more flexible, foundry-style approach. The latter concept has been used successfully for several years now in the production of integrated circuits.

"Our vision is that multiple defense contractors could share a manufacturing facility or networked supply chain as 'factory America' that can adapt itself to multiple designs from multiple contractors," Saitou noted.

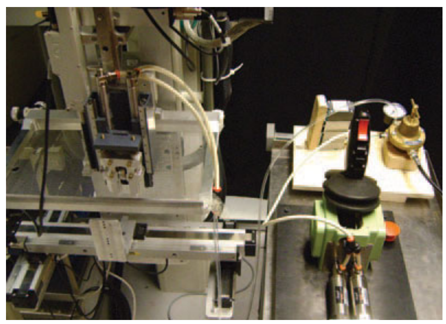
To optimize efficiency, and to protect proprietary and mission-critical component design information, design specs would be standardized using a metalanguage. Saitou's charge is to develop the fundamental theory and underlying methodology for an interface between the metalanguage and iFAB; that is, to translate the design specs into a format that can be assessed for manufacturability and assigned to the supply chain's facilities for eventual production. The initial phase of the project will serve as a proof of concept.

“We’re looking toward ultra-lightweight structures that weigh, potentially, half as much as vehicle bodies currently on the market—with comparable price and safety.” —KAZUHIRO SAITOU

AN EYE TOWARD BIOMEDICAL APPLICATIONS

Saitou is applying many of the computational modeling theories and techniques from mechanical and manufacturing systems to biomedicine. With colleagues in the U-M Department of Pharmaceutical Sciences, he and his research group have created ChemReader, an automated system that uses a machine vision-based classifier to recognize chemical structure diagrams in research articles and annotate and link them with database entries. By annotating each molecule in the database with relevant links to scientific literature, the database allows biochemical scientists to more readily and easily share information.

Applying his work to the detection and treatment of cancer, Saitou is collaborating on a project on automated ultrasound imaging, a promising breast screening technology particularly for dense breast tissue. He is designing and testing an automated system for locally compressed scanning, which is capable of delivering images in the same geometry as conventional and three-dimensional mammography. Until now, automated ultrasound has proven inferior because of increased shadowing when compared to hand-controlled imaging. Recently Saitou and his collaborators in the U-M Department of Radiology

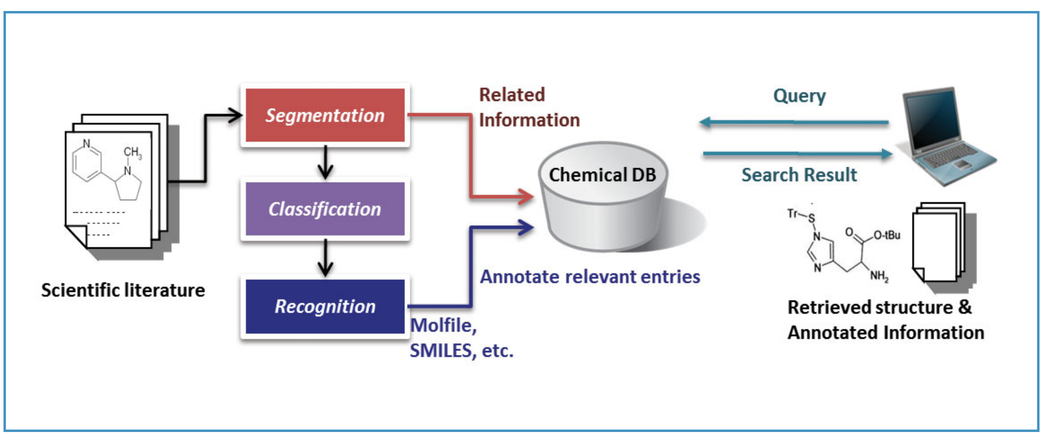


have overcome this obstacle by using light mammographic compression with flexible mesh and localized compression of the breast while the transducer is scanned.

For cancer treatment, image-guided intensity-modulated radiation therapy (IGRT) is widely used against several types of cancers, but uncertainties such as patient set-up errors, changes in volume and shape of tumors and tissue, and patient motion during treatment all affect the accuracy of guiding images. Realistic image registration is critical to effective treatment and to detecting how tumors and normal tissues respond. With colleagues in the U-M Department of Radiation Oncology, Saitou is working to improve the accuracy of B-spline image registration by devising biomechanical penalty algorithms in order to create more realistic deformation maps in both bone and soft tissue.

“I like to keep pushing the boundary of mechanical engineering and working in areas that are important to society,” Saitou said.

Funding for Saitou’s work has been provided by federal agencies such as the National Science Foundation, National Institutes of Health, the departments of Energy, Defense, and Agriculture as well as industry.



ABOVE: Locally-compressed automated ultrasound scanning system installed on a mammography machine, which allows an operator to control vertical compression force on an ultrasound transducer array during horizontal scanning.

LEFT: ChemReader system recognizes chemical structure diagrams in research articles and links them with relevant entries in the database.

ALL HANDS-ON DESIGN

Recognized internationally for its core design and manufacturing undergraduate curriculum, the U-M ME department presents senior students with the opportunity to apply their engineering knowledge to practical, real-world problems. In particular, the senior capstone design course, ME450, lets students solve applied problems posed by sponsors, who closely work with student teams throughout the semester.

"Students learn to synthesize novel ideas and design, manufacture and test a physical prototype they develop to validate the concept—all within three months and a pre-set budget," explained Professor **Albert Shih**, who serves as course leader. "Sponsors benefit from creative ideas, a working prototype and the opportunity to get to know, and potentially recruit, outstanding students." At the end of the semester, student teams present their work at the College of Engineering's Design Expo, a half-day event open to the public and the media.

"The amount of growth students go through from the beginning of the course to the end is incredible," noted **Gordon Krauss**, a research investigator and lecturer in the Department and ME450 course coordinator. "The experience challenges them in many ways."

Former ME450 student, Kristin Cermak, now a manufacturing engineer with General Motors (GM), took the course in 2006. "To this day, I can recall the moment our team learned our project assignment," she said, "which was to develop a thermal management system for monopolar electrosurgery. We spent many hours researching electrosurgery and understanding what we were to deliver, and then we got down to work."

The experience helped shape her approach to the engineering projects she works on today. "The course teaches two critical elements for engineers in any field: teamwork and how to deliver a quality product to your customer," she said.

Students gain confidence throughout the course and apply their creativity. "We see students go from 'How in the world are we going to do this?' to coming up with a solution that surprises and delights the sponsor," Krauss said. "Student teams often surpass the original project specs. We frequently hear from sponsors that the students' work went well beyond their expectations."

Course projects, initiated by industry, alumni and faculty sponsors, are grouped by thematic areas. While some of the thematic areas change from year to year, many remain constant. All are supervised by a faculty member who is knowledgeable and passionate about each particular theme.

LEFT: During one ME450 class lecture, students take part in a "crash-course" exercise in design. In a single lecture period, they must design and fabricate a wallet that meets certain specifications.

RIGHT: In the undergraduate machine shop, students receive hands-on training that they put to immediate use fabricating their final prototypes in time for the Design Expo. Here, a student applies rivets to a reconfigurable labor and delivery bed.

AGING GRACEFULLY

Working closely with the Department of Physical Medicine and Rehabilitation and U-M Hospitals, Shih recently was awarded a National Science Foundation grant and leads a continuing thematic area focused on geriatric assistive devices and systems. The goal is to design reconfigurable and personalized assistive devices to help individuals remain active as they age and to help society at large prepare for upcoming demographic shifts.

"In the next twenty years, the number of Americans over 65 will have doubled," Shih said. "Engineers are in a position to improve the lives of many, many people."

Shih's student teams are working closely with clinicians, social scientists and local industry. Students have developed a walker that fits over a toilet, giving patients more independence and privacy; a canopy that shields users from the weather while getting in and out of a car; a mechanism for adjusting the seat on recumbent exercise machines; and a seat cooling system for exercise equipment for patients with multiple sclerosis, who can have difficulty regulating their body temperatures. These projects were sponsored by NuStep, an Ann Arbor company that designs fitness equipment for all ages and ability levels.

To meet a challenge posed by Johnson Controls, Inc., students devised an innovative—and discreet—solution to enhance stability as individuals get into and out of an automobile. "If the assistive device is too obvious, people are less likely to use it," Shih explained. "The students considered the social and psychological aspects and incorporated what they learned into their design."

IMPROVING AUTOMOTIVE DESIGN AND ENGINEERING

Course leaders and faculty also have long-term, ongoing relationships with many automotive manufacturers and suppliers, and automotive design and engineering is another continuing thematic area for ME450.

In a project sponsored by Ann Arbor-based Coherix Corporation, which develops defect detection and surface metrology equipment for precision automotive and semiconductor parts, students designed an enhancement to the company's disk thickness variation measurement system. The system is used to measure rotor thickness as it passes through brake shoes. Accurate measurements are critical since variations in thickness cause unwanted brake pulsation.

> "The amount of growth students go through from the beginning of the course to the end is incredible."
>
> —GORDON KRAUSS

Working with GM, students expanded the capabilities of a thermal predictive analysis tool for testing different external vehicle lighting configurations, sizes and styles. The enhanced tool allows vehicle designers and engineers to minimize the distances between bulbs and outer lenses.

Projects related to the automotive industry hold special appeal in the greater Detroit area. The course has been fortunate in recent years to have a broad range of projects sponsored by major automotive suppliers such as Bosch and Freudenberg-NOK, in addition to manufacturers Toyota and Honda. Some projects have focused on manufacturing technology or vehicle safety, while others have involved mechatronics or surface measurement and characterization. "Such breadth provides a rich opportunity for students," said Krauss.

STRONG HISTORY OF LEADERSHIP

Shih attributes the success of the course experience to several factors, including a long and strong tradition of leadership. Many dedicated ME faculty course leaders have contributed, and transformed, the course in the two decades it has been offered. In addition, students continually bring an abundance of enthusiasm and dedication to meeting project sponsors' needs. Sponsors contribute in many ways, too, including funding and—more importantly—time and guidance. Department leadership over the years has recognized the course's importance to the curriculum and provided support in the form of staff, equipment and space.

"The whole ME450 design experience is a true win-win," explained Shih. "Students have a hands-on experience that coalesces their four years' of learning, and sponsors benefit from an energetic, creative approach to their idea or product."

+ more on the web

For more information, contact Krauss at gkrauss@umich.edu

EXPANDING HORIZONS: ME STUDENTS AND FACULTY FORGE RELATIONSHIPS WORLDWIDE

Through a range of international programs, ME students are gaining invaluable experience overseas—experience that broadens their engineering education, exposes them to different cultures and, ultimately, helps them better solve some of the world's most pressing problems.

GLOBAL HEALTH DESIGN

Pursuing a long-time interest in global health, **Rajen Kumar** enrolled during his senior year in *Design for Global Health: Sustainable Technologies for the Developing World*, a course taught by Assistant Professor **Kathleen Sienko**.

Throughout the semester, Kumar and his classmates explored current global health challenges and assessed best and worst practices regarding technology design principles that address these problems. The class developed case studies for technologies targeting the top ten causes of death in low- and middle-income countries. A subset of the case studies generated was published in a recent report by the World Health Organization.

Students also participated in a clinical immersion experience in Nicaragua during spring break. There, Kumar and classmates observed clinicians at rural, district and urban hospitals to gain an understanding of the challenges specific to these settings.

Kumar also traveled to Ghana last August while participating in one of Sienko's co-creative design programs that provides students an opportunity to complete a design project scoping exercise in the summer preceding their senior year. Students gain global learning experiences that emphasize co-creative design principles by engaging end users throughout the entire design process. The program is part of the College's Minor in Multidisciplinary Design: Specialization in Global Health Design, developed by Sienko and Aileen Huang-Saad of Biomedical Engineering.

“The global health technologies that work the best usually come out of brainstorming at field sites and collaborative design with end users.”

—RAJEN KUMAR

ABOVE, LEFT: U-M GIEU (2009) students working on recycling bins to set up a plastics recycling program at Senya Beraku, a small town in Ghana. ABOVE, RIGHT: U-M GIEU (2005) students with staff of *Suame Magazine* manufacturing enterprise in Kumasi, Ghana, working on a project for modernizing the facilities. OPPOSITE PAGE: Specialization in Global Health Design 2011 cohort, Komfo Anokye Teaching Hospital, Kumasi, Ghana, August 2010.

Kumar joined a group of 12 multidisciplinary students conducting observations in the Department of Obstetrics and Gynecology at the Komfo Anokye Teaching Hospital in Kumasi, Ghana. As a result of their month-long immersion experience, Kumar and his team identified the need for a blood salvage device that is appropriate for resource-limited settings and that can be operated by a health care provider to collect, filter and transfuse blood in the event of life-threatening bleeding. Such a technology would address the current lack of donated blood and improve patient outcomes, particularly in the case of ruptured ectopic pregnancies. Kumar's team developed an entirely mechanical and reusable device that salvages and filters a patient's blood for reinfusion.

Students spent two semesters at U-M designing a prototype, and Kumar's team returned to Ghana over winter break to obtain feedback from local health professionals and conduct basic validation studies. The students incorporated this feedback into a new design and have formed a company to further pursue the device as a commercial product.

“The global health technologies that work the best usually come out of brainstorming at field sites and collaborative design with end users,” said Kumar, who will graduate in December 2011 with a master's degree in ME. He plans to pursue a career in medical devices with a focus on global health. “This,” he said, “is where I can make an impact.”

FOSTERING COLLABORATION IN AFRICA

Professor **Elijah Kannatey-Asibu, Jr.**, has been working with colleagues at Kwame Nkrumah University of Science and Technology (KNUST) and other institutions to increase collaboration and joint research activities.

Kannatey-Asibu spent part of his sabbatical in fall 2010 at KNUST, initiating a collaborative research project on natural fiber composites, and also taught a course on manufacturing processes. Together with Assistant Professor Kathleen Sienko and Professor Herbert Winful of Electrical Engineering and Computer Science, he co-organized an African Studies Center (ASC) Science Technology Engineering and Mathematics-Africa Initiative Launch Conference at U-M in May 2010. The ASC supports the exchange of scholars, faculty, knowledge and resources between U-M and partnering educational institutions in Africa. Kannatey-Asibu chaired a panel on “Engineering Solutions in Africa.”

In May 2011, the ASC sponsored Kannatey-Asibu's participation in a regional curriculum workshop for the launch of the Pan African University Institute of Science, Technology and Innovation in Nairobi, Kenya.

Through the Global Intercultural Experience for Undergraduates program, Kannatey-Asibu has taken several student groups to Ghana for community education and implementation of pilot plastics recycling programs in different parts of the country. In Accra, U-M students outfitted the University of Ghana's largest residence hall and a local high school with recycling bins. At KNUST, in Kumasi, they set up recycling and trash bins in several locations on and near campus. In Senya Beraku, a small fishing town, the team worked with local youth groups to implement a sustainable recycling program. The benefit to U-M students is direct exposure to other cultures, as well as identification of opportunities for investment and helping solve global problems.

Kannatey-Asibu, Sienko and ME Assistant Professor **Nikos Chronis** recently received a Rackham Global Engagement of Doctoral Education grant to help the ME department develop an initiative in collaborative graduate education with the Kwame Nkrumah University of Science and Technology and the University of Ghana.

U-M President Mary Sue Coleman meets with several JI students after attending the JI's Board of Directors meeting in Shanghai

"The JI is turning out to be an excellent pipeline of talented students for U-M's graduate programs."

—JUN NI

JOINT INSTITUTE CONTINUES TO EXPAND

Alumna and former state representative Pamela Byrnes, who holds a bachelor's degree in Far Eastern Studies from U-M, was named executive director of the U-M - Shanghai Jiao Tong University (SJTU) Joint Institute (JI) in April 2011. Byrnes will oversee personnel management, training, budgeting and planning, policy and operations, and fundraising. She will be based in Shanghai.

On the research front, six ongoing collaborative projects—three in renewable/clean energy and three in biomechanics—are being co-led by principal investigators from each university. Both U-M and SJTU committed $3 million over five years for the first phase of the program. It has proven so productive that both institutions agreed to fund another round. This year, many joint proposals were submitted by ME faculty.

Students, too, interact closely. Nearly 30 U-M students are taking a full summer semester at SJTU. Michigan faculty, including several from ME, are teaching courses at SJTU as well. Likewise, over 200 SJTU students are studying in Ann Arbor, both within and outside the College of Engineering.

The JI completed its first internal review in January 2011. The review committee, comprised of faculty and administrators from both institutions, met for two days to assess every aspect of the program, from curriculum and faculty hiring to governance and staff support.

"The committee felt that the JI has accomplished an amazing amount and developed into a high-quality program in a short period of time," said ME Professor **Jun Ni**, who is serving a second term as JI dean and who was instrumental in launching the Institute in 2006.

Indeed the JI's first year of graduate placement data is impressive: Of 165 graduates, over 76% are pursuing graduate study, and more than 95% of those coming to the United States have been admitted into top 10 programs. U-M has made offers to 85 for admission into dual-degree graduate programs. "The JI is turning out to be an excellent pipeline of talented students for U-M's graduate programs," said Ni.

The JI will hold an external review, as well as a board of directors' meeting, in October 2011.

JUNIOR FACULTY MAP RESEARCH DIRECTIONS WITH KAIST

The U-M - Korea Advanced Institute of Science and Technology (KAIST) program held its sixth Joint Workshop, entitled "Frontiers in Mechanical Engineering Education and Research," in St. Helena,

U-M-SJTU joint research workshop at SJTU. L to R: Dennis Assanis (Director of MMPEI), Doug Noll (Chair of BME), Steve Forrest (VP for Research), Jun Ni (Dean of U-M-SJTU JI), Albert Shih (ME faculty), James Geiger (Director of Medical Innovation Center), and a post-doctoral fellow from U-M.

California, from December 16 through 18, 2010. The majority of the participants were junior faculty members from both institutions.

“We wanted to create a venue to allow newer faculty to get to know each other and to spark future research collaborations,” said program co-chair and ME Professor **Hong Im**. Those in attendance discussed their research through individual presentations and group discussions about immediate and achievable joint activities. As a result, several faculty have begun collaborating, and Im expects to hold follow-up workshops specific to particular disciplines.

“We had such a broad range of interests represented, and we think these sub-meetings will serve to enrich existing and future collaborations,” Im noted.

SUMMER PROGRAM IN GERMANY AND INTERNATIONAL MINOR REACH MILESTONES

Professor **Volker Sick** once again is co-teaching the International Engineering Summer School (IESS) at Technische Universität Berlin, or TU Berlin. Sick co-founded the six-week program with TU Berlin Professor Frank Behrendt in 2006.

Open to all College of Engineering (CoE) undergraduates, the IESS includes an intense German language and culture component for which the students earn credit. Students also choose from a selection of laboratory projects and spend four weeks with German doctoral students investigating topics such as alternative energy concepts, digital processor programming and internal combustion engine performance.

Enrollment in 2011 marks a new record for the IESS: 28 students are participating, up from 10 in 2006. The IESS was the largest study-abroad program in the College in 2011. Generous support has been provided by IAV Inc. and IAV GmbH, enabling more students to participate regardless of financial constraints.

As faculty advisor to International Programs since 2007, Sick has worked diligently to increase the number of students who study, work and volunteer abroad. Participation in international activities is now at almost 20% of graduating CoE undergraduate classes. “We’re pleased that the upward trend is continuing toward our goal of 50%,” said Sick.

Together with Amy Conger, director of the College’s International Programs in Engineering office, Sick developed and established the International Minor for Engineers in 2008. This was the first minor offered within the College of Engineering in its more than 150-year history and, by fall 2010, the minor had become the most popular in the College.

Sick is engaged in many other international activities, including co-teaching *Engineering across Cultures* (ENGR490) and serving on the executive committee of the U-M - SJTU Joint Institute. Sick also spoke on behalf of U-M at the Institute’s first commencement, which took place in Shanghai in 2010.

ABOVE, LEFT: ME student Michael Fortin drives an electric test vehicle during a visit to IAV in Berlin. ABOVE, RIGHT: During the Welcome Reception to the Summer School, traditionally held on a boat crusing the many rivers and canals of Berlin, CoE students Sam Kapor, Avi Wolf, and Eric Hung (from left) marvel at the diesel engine that has powered the boat for more than 100 years.


WISE orp
WOMEN in SCIENCE and ENGINEERING
residence program

ENGINEERING FOR THE GREATER GOOD: BLUELAB PROJECTS MAKE LASTING IMPACT

Student members of BLUElab, Better Living Using Engineering, are on a mission: to conceive, develop and lead projects that address real-world problems and have a lasting impact—locally, nationally and around the globe.

"As an organization, we try to create avenues for students to explore their passions in sustainability," said **Steve Skerlos**, co-founder and faculty advisor.

WOVEN WIND TURBINE GENERATES POWER

In spring 2011, a BLUElab team traveled to Nueva Santa Catarina Ixtahuacan, a town of about 4,000 in the mountains of Guatemala, where electricity is limited and expensive. The students set out to build a prototype small wind turbine made entirely of affordable and locally-sourced materials, including woven fabric for the turbine blades, handmade by local women. Not only will the turbines generate a low-cost source of power; they will provide a source of revenue for the weavers. The students plan to return in 2012 to continue their work.

OPEN SOURCE TREADLE PUMP REAPS BENEFITS TO FARMERS

Another BLUElab team has been working on an open-source treadle pump in Guatemala in collaboration with Ann Arbor nonprofit Appropriate Technology Collaborative. The pump was designed so that farmers can grow crops during the dry as well as rainy seasons. In the past, farmers had to carry buckets of water over long distances to irrigate their fields since their diesel pumps were prohibitively expensive to run.

The treadle pump was initially designed by a team from the ME senior capstone design course, ME450, and subsequently modified by BLUElab during site visits. Once the team built its prototype, it made the straightforward documentation available online. Many non-governmental organizations have downloaded the plans, and entrepreneurs in developing countries have manufactured and sold more than 1.4 million pumps for about $20 each.

COOKING UP SUSTAINABLE FUEL

BLUElab students also have been working on a prototype biodigester, which takes animal waste and food scraps and—with the help of anaerobic bacteria in the waste—turns the mixture into biogas for cooking, heating water and odorless fertilizer. The team is working in a rural area of Nicaragua, where wood often is used for cooking. But biogas is more sustainable than wood and healthier, too. Fine particulate matter formed when wood burns can lead to health problems among women who spend long hours cooking and preparing food.

The biogas, comprised of about 60% to 70% methane, is created when the waste mixture and water combine in the biodigester's tank, and the bacteria break it down. Biodigesters are not a new concept in Nicaragua, but the BLUElab team has been studying existing designs and making improvements that enhance both user-friendliness and yield.

FROM GLOBAL TO LOCAL

Other BLUElab efforts address problems much closer to students' own backyards. A team is designing and building an underground rainwater storage and irrigation system for the greenhouse of a nonprofit community garden organization in Ypsilanti, as well as a rain garden to capture runoff from the parking lot.

On campus, BLUElab has contributed to the development of courses and course modules on sustainability. The group also organizes a popular lecture series and job fair.

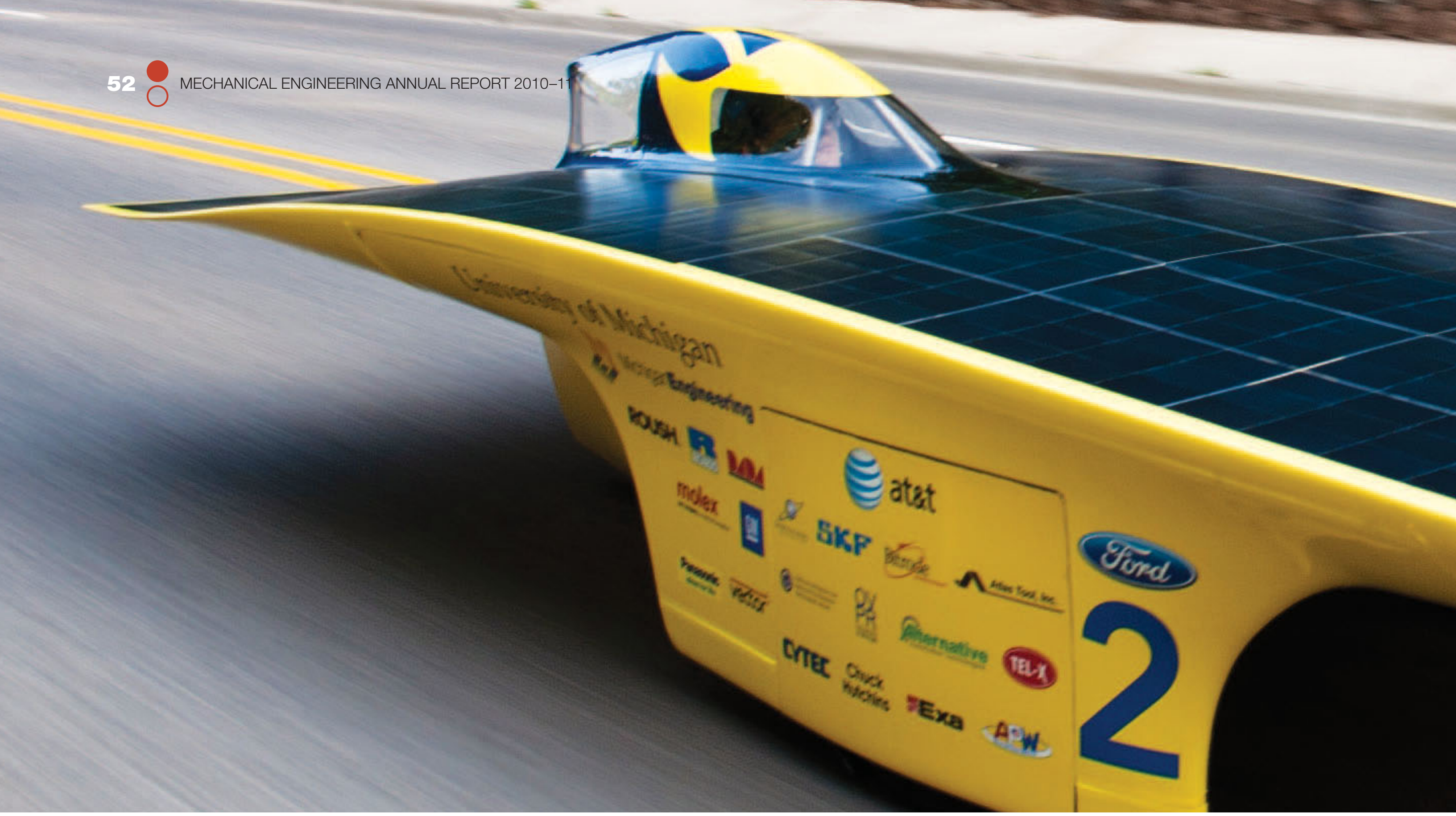
"Students come up with a diverse set of projects that have tremendous potential impact on real social and environmental issues," said Skerlos.

+ more on the web

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

ABOVE, RIGHT AND OPPOSITE PAGE: Students travel to Nueva Santa Catarina Ixtahuacan, Guatemala, to build windmills from local materials and cloth woven by local women. PHOTO: MARCIN SZCZEPANSKI, MULTIMEDIA CONTENT PRODUCER/COLLEGE OF ENGINEERING

BELOW, RIGHT: BLUElab students on their way to another day of work in Hagley Gap, Jamaica.



DRIVEN TO WIN

Since the U-M Solar Car Team's formation in 1989, the team has won six national championships, the most recent in 2010. While rewarding, those achievements have only heightened the team's desire to reach a persistent goal: to win the World Solar Challenge, an 1,800-mile race through the Australian outback, from Darwin to Adelaide.

"The team's new car, Quantum, specifically was built to win the World Solar Challenge," said **Kazu Saitou**, ME professor and faculty advisor to the team. "This year we took a whole different approach to designing a new vehicle."

Quantum is 200 pounds lighter than the 2009 car, Infinium. Quantum also is more aerodynamic and has more efficient tires and battery cells, according to **Gerald Chang**, crew chief and first-year ME graduate student.

In another departure from previous years, the team finished building Quantum a full six months before the World Solar Challenge. "I think not having enough time to test the car may have been one of the reasons for the team not reaching its goal in the past," said Saitou. "This year we pushed back the schedule aggressively so that there would be more time to refine."

In July 2011 the team embarked on a four-day, 1,000-mile mock race around Michigan's lower peninsula. The event gave the team a chance to practice on open roads and get used to working with the caravan's multiple support vehicles.

"Mock Race was priceless, because it taught us many things about Quantum," said Chang. As a result, the team identified needed design changes to the fender, debugged problems with the battery protection system and improved the warning system for debris and road hazards.

Quantum now is poised to compete in the grueling conditions of the Australian outback, and the team has undertaken an ambitious campaign to raise funds for additional refinements that will lead to an estimated 25% further improvement in performance.

"I'm quite hopeful," said Saitou. "As faculty advisor, this was the first car I've been involved with from the very beginning, and I'm excited to see how Quantum will perform in Australia in October."

Many other members of the ME department are part of the Solar Car Team, including **Cole Witte**, mechanical engineer and navigator; **Troy Halm**, mechanical engineer and solar car driver; **Karl Nagengast**, mechanical engineer and chase vehicle driver; **Ethan Lardner**, head of operations; **Alex Trublowski**, strategist; and **Andrew Huang**, interim engineering director.

+ more on the web

For more information, visit http://solarcar.engin.umich.edu/ or follow @umsolarcarteam on Twitter.

LEFT: Nightly maintenance is key to racing a reliable car. Every night all engineers make sure the car is ready to drive the next day.

RIGHT: Last day at Formula Sun Grand Prix 2011. The experience in this event helped the team prepare for the world race.

FORMULA SAE: MRACING TO A TOP 10 INTERNATIONAL FINISH

The University of Michigan Formula SAE® team, MRacing, recently returned, smiling, from Formula Student Germany 2011. The team finished eighth, its sixth consecutive top 10 finish.

"It was amazing to have such a successful year with such a young team," said **Nathan Lusk**, 2011 captain, who will graduate with a bachelor's degree in ME at the end of the year. Almost half of the core team members graduated last spring.

In Germany, RheinMain University in Russelsheim invited MRacing to use half its shop space to prepare the car. Auto manufacturer Opel allowed the team to use two of its test facilities exclusively for several days to get the drivers and vehicle ready for competition at the Hockenheimring.

The event wasn't without challenges. The first few days went well, but then a broken laptop computer prevented the team from presenting data it had recorded from the car and its electrical systems. A delayed start to the team's autocross run meant it had to compete in the rain. The pressure was on to recover and perform well during the endurance event the next day.

"We knew we had one of the most reliable and well-tested vehicles in the competition, which gave us the confidence to push through the prior day's troubles," said Lusk. "We were proud not only to finish the endurance race, which was a feat in itself, but to place fourth in this final event. Even some teams ranked in the top 10 didn't finish endurance."

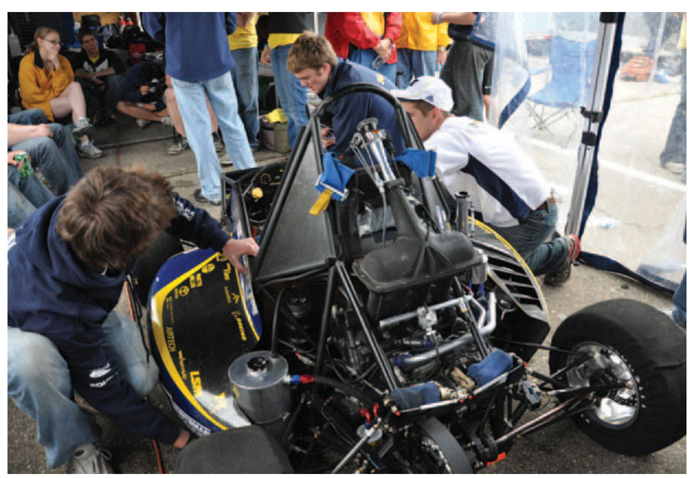
The August race came on the heels of the May 2011 Formula SAE race, held at the Michigan International Speedway (MIS). There, the team placed sixth overall, third in acceleration, fourth in endurance and seventh in design.

Lusk believes the team's strong year is due to a great deal of hard work and dedication among team members and the vital help of the College and its staff and faculty as well as devoted alumni and long-time sponsors, including Bosch Engineering and title sponsor BorgWarner.

A number of other team members also hail from the ME department. Participating on MRacing and other student teams, Lusk believes, is a key part of any engineer's education. "Being part of a team like MRacing can make student life more complicated but it teaches you an incredible amount, from engineering design to marketing, sales and management. I don't think any of us would have it any other way," he said.

+ more on the web

For more information visit the chapter website at http://mracing.engin.umich.edu/home.htm



LEFT: Team members showing the car at the GG Brown expansion groundbreaking. RIGHT: Preparing the car for the endurance race at competition. OPPOSITE PAGE: Freshman driver Reed Sullivan waiting to enter the track at the endurance race. Sullivan, along with fellow freshman John Logan, were the fourth fastest set of drivers in both Michigan and Germany.


BELL
MICHIGAN
BOSCH
2
ROUSH
Ford
ALCOA
OPEL
SAE

A YEAR OF CHANGE FOR MICHIGAN BAJA RACING

Change was a constant for the 2010–11 Society of Automotive Engineers (SAE) Michigan Baja Racing team. With five senior members graduating, the team lost more than two decades of experience. Only two members of the remaining team had participated for more than a year; only one member had experience as a system design lead. Yet the losses also meant opportunity, said **Nick Ridenour**, program manager and a ME senior. "They forced us to learn and to develop a whole new perspective," he said.

The focus for the season centered on a new drivetrain design, with a double synchronous carbon belt design and heavy use of aluminum to eliminate the steel hubs from prior seasons, which lowered the weight of the drivetrain. The team also made changes that dropped almost four pounds from the rear suspension and increased adjustability of the driver interface in order to fit more types of drivers more comfortably. Improved suspension articulation and tunability enabled better handling. Vinyl wrapping for the body panels have given the vehicle a more professional look.

Michigan Baja competed in three races during the year, in Alabama, Kansas and Illinois. Overall the team finished fifth, eighth and eleventh in cost; fourth and fifteenth in hill climb, eighth in rock crawl and eleventh

and sixteenth in design. In spite of multiple parts failures during the races, "we had several successes, and we learned a lot as a team," said Ridenour.

The team is taking that learning and already applying it to the coming year's vehicle. In the works are a lighter, more adjustable and dynamic rear suspension for improved cornering and a rear differential rather than a spool in order to improve maneuverability. Ridenour says he and his teammates are excited to pursue new sponsors, recruit new students and move up the design and build cycles to complete the new car faster.

ABOVE: The car launches off a jump during the Illinois Endurance race. OPPOSITE PAGE, TOP RIGHT: The Baja Team repairs a breakage in their gearbox during the Alabama Competition. OPPOSITE PAGE, BOTTOM: The Michigan Baja Racing Team at Illinois.

TIMOTHY MANGANELLO: CARVING OUT TIME FOR MECHANICAL ENGINEERING

Despite a packed schedule and a high-pressure job, alumnus **Tim Manganello** (BSE ME '72, MSE ME '75, PDM [Dearborn] '81) is a regular and welcome visitor to the ME department and the College of Engineering.

Since 2003 Managanello has served as chairman and chief executive officer of BorgWarner, Inc., in Auburn Hills, Michigan, which designs and produces advanced powertrain systems. Yet Manganello makes time to visit campus regularly to talk with undergraduate ME students about design in industry.

Manganello also serves as an advisor to the College as a member of the Engineering Advisory Council. Thanks in part to his passionate involvement with the ME department, BorgWarner gave $400,000 to name the BorgWarner Galleria in the new mechanical engineering building addition. (See related story on page 4.)

Prior to joining BorgWarner in 1989, Manganello held product engineering and sales management positions in the automotive industry. Once he joined BorgWarner, he held positions of increasing responsibility and scope, including president and general manager of BorgWarner Torq Transfer Systems and vice president of operations for the company's Muncie, Indiana, facility.

Manganello serves on the board of directors of the Bemis Company, Inc., the executive committee of the Manufacturers Alliance/MAPI and on the Governor's Board of the World Economic Forum.

He credits his ME education for preparing him well for the breadth of positions he has held in his career. "When it comes to my education as a mechanical engineer, the analytical thought process, the approaches and tools I learned while at the College have remained priceless."

Manganello earned a 2005 Alumni Society Merit Award from the Department for outstanding professional achievement.

"When it comes to my education as a mechanical engineer, the analytical thought process, the approaches and tools I learned while at the College have remained priceless." —TIM MANGANELLO

MAKING CONNECTIONS: BRUCE WANTA (BSME '79)

Bruce Wanta with scholarship students. (Back row, L to R): Matthew Tetlow, Bruce Wanta, Noah Judson. (Front row, L to R): Charlotte Sawyer, Ingrid Robaidek

Bruce Wanta, who grew up in Washington State, initially was drawn to U-M ME by its excellent reputation. During his time at the University, he had the opportunity to study a range of engineering subjects and explore his interests. "The combination of rigorous class study and diverse lab courses was a great way to gain both the analytical and practical experience required in mechanical engineering," he said.

By the time Wanta graduated in 1979 with a bachelor's of science in ME, the seeds connecting U-M and the Pacific Northwest had been planted. Once he earned his degree, Wanta returned to Washington and worked as a field sales engineer for the Square D Company and as a systems division manager for Stusser Electric. In 1983 Wanta founded Spectrum Controls Inc., a Bellevue firm that designs, manufactures and sells industrial automation controls to a global market.

"The purpose of the scholarship is to allow students from Washington to go to Michigan in the hope that they will come back to our state and use their degree locally."

—BRUCE WANTA

As a successful entrepreneur, Wanta recognized the value of his U-M experience and wanted to create an enduring link to the University from his home state. In the fall of 2004, Wanta and his wife Peggy created the Bruce M. Wanta Scholarship to support engineering students from the State of Washington studying at U-M.

"The purpose of the scholarship is to allow students from Washington to go to Michigan in the hope that they will come back to our state and use their degree locally," said Wanta, who currently supports four scholarships through his endowments.

Besides leading the executive team at Spectrum Controls, Wanta is an avid supporter of the arts. He is a member of the board for the Village Theatre in Issaquah and is a long time donor to a number of art and education institutions. He is a founding member and ongoing benefactor of Bellevue's annual Jazz Gala Auction project at Newport High School.

Wanta's long-time personal goal of "supporting excellence" was nurtured during his time at U-M and now is evident in both his U-M endowments and the many art and education programs to which he is dedicated.

KORYBALSKI LECTURESHIP BRINGS MARSHALL JONES TO CAMPUS

ABOVE: Marshall Jones giving the 2011 Korybalski Distinguished Lecture.

BELOW: Michael Korybalski congratulating Marshall Jones after the Korybalski Distinguished Lecture.

Alumnus **Marshall Jones** (BS ME '65), a renowned researcher in laser technology, delivered the fourth annual Korybalski Distinguished Lecture in Mechanical Engineering in May 2011. His address, *"Never Give Up: The Marshall Jones Story,"* chronicled Jones' journey from Long Island, New York, where he grew up on a duck ranch, to his current position as principal engineer and a Coolidge Fellow with GE Global Research.

During his presentation, Jones highlighted some of the challenges he overcame during his youth, his path to U-M ME, where he earned his bachelor's degree, and a few of his many research contributions to the field of laser technology.

After receiving his ME degree from U-M, Jones went on to earn a master's and doctorate from the University of Massachusetts. He joined GE Global research in 1974 as a mechanical engineer. Since then he has performed research and development work for all of the industrial business segments of GE. He has spent most of his GE career addressing laser material processing, laser device development and fiber optics.

In addition to having been named a Coolidge Fellow, Jones is a member of the National Academy of Engineering (NAE) and a fellow of the American Society of Mechanical Engineers and the Laser Institute of America (LIA). He has served on a number of local and national boards, and he has a strong interest in inspiring young people to consider science, technology, engineering and mathematics careers.

Jones has received a number of awards and professional honors, including the GE Phillippe Award and the 2007 Arthur Schawlow Award, the LIA's highest technical achievement award.

Jones' 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. Previous Korybalski lecturers have included Charles Vest, president of the NAE and president emeritus of the Massachusetts Institute of Technology; Roger McCarthy, chairman emeritus and retired chief executive of Exponent, Inc.; and Larry Burns, retired vice president of research and development and planning for General Motors.

RONALD MOLITOR WINS 2010 ALUMNI SOCIETY MERIT AWARD

Ronald A. Molitor (BSE ME ’70, MSE ’71) has won the 2010 Alumni Society Merit Award. The awards are bestowed annually to recognize an alumnus/a in each engineering department who has demonstrated sustained and outstanding professional accomplishments.

Molitor is actively involved with the College of Engineering through the Engineering Advisory Council. At the University level, he is a member of the U-M Presidential Societies and a lifetime member of the U-M Alumni Association and Victors Club. He and his family are avid U-M Athletics supporters and devoted fans of several student teams.

A highly respected and successful entrepreneur, Molitor has built and led several companies in the precision mold-making and plastic injection molding industry. He is the co-founder and president of Mol-Son, LLC, which specializes in building close-tolerance precision tooling, and he was a founding member of Engineering Plastic Services, Western Diversified Plastics, Plastic Management Consultants, and Engineering Plastic Components, Inc.

A lifelong resident of Kalamazoo, Michigan, Molitor is a founding director of Keystone Community Bank, serving as a board member since 2004. He also has been engaged in numerous other civic and community activities, including as founding director of the Portage Public Schools Education Foundation Board, board president of the Southwest Michigan High School Hockey League, a member of the Western Michigan University Foundation Board, director of the Kalamazoo Valley Community College Foundation Board and chair of the Kalamazoo Valley Community College Advisory Board to establish a Plastics Technology program among many other contributions. The ME department congratulates Molitor on winning the well-deserved Alumni Society Merit Award.

College of Engineering Dean David Munson, Ronald Molitor and ME Department Chair Kon-Well Wang at the 2010 Alumni Award Event.

KOREN NAMED DISTINGUISHED UNIVERSITY PROFESSOR

Professor **Yoram Koren** has been named James J. Duderstadt Distinguished University Professor of Manufacturing. Koren is the second Distinguished University Professor in the ME department, and one of only seven in the College of Engineering.

Distinguished University Professorships recognize exceptional scholarly and creative achievements, international reputation and superior teaching skills. The professorship is one of the highest honors the University bestows upon faculty.

Professor Duderstadt served as dean of the College of Engineering from 1981 until 1986 and as University president from 1988 until 1996. As dean, he created the Center for Robotics and Integrated Manufacturing in 1981, and appointed Koren director of its Integrated Design and Manufacturing Division. The two worked together to establish the University as a leading manufacturing research institution.

Koren went on to found the National Science Foundation-sponsored Engineering Research Center (ERC) for Reconfigurable Manufacturing Systems (RMS) in 1996, and currently serves as its director. The Center has graduated 270

Professor Yoram Koren and U-M President Mary Sue Coleman at award ceremony.

master's students and 80 PhD students, many of whom now work at U.S. companies, national laboratories and as professors at universities.

A member of the National Academy of Engineering, Koren is known as the creator of the reconfigurable manufacturing paradigm and for establishing flexible automation and computer numerical control as a research field and educational discipline. He holds 14 patents on reconfiguration, automation and robotics technologies. More than 9,000 papers have cited his publications in these areas. He is the author of four books, including *The Global Manufacturing Revolution: Product-Process-Business Integration & Reconfigurable Manufacturing* (Wiley, 2010).

Koren is a strong proponent of U.S. manufacturing, of which RMS is a cornerstone. "As a Distinguished University Professor, I hope to build on all that we've accomplished in reconfigurable manufacturing and take the next step toward sustainability and personalized domestic production that can generate manufacturing jobs in this country," he explained. "My goal is to create a competitive manufacturing paradigm for the 21st century that will benefit U.S. society, our economy and the environment."

"My goal is to create a competitive manufacturing paradigm for the 21st century that will benefit U.S. society, our economy and the environment." —YORAM KOREN

MICHELE MAHLER WINS EXCELLENCE IN STAFF SERVICE AWARD

ME Graduate Program Associate **Michele Mahler** has been awarded the 2011 College of Engineering Excellence in Staff Service Award.

This highly competitive award is given annually to staff members who have made significant contributions and possess rare qualities and attributes. Michele was recognized specifically for exhibiting dependability, patience and commitment. She also has shown creativity in solving challenging problems in the Academic Services Office, particularly related to recruiting. Michele has fostered collaboration and cooperation among colleagues and has always gone out of her way to help the ME community when called upon.

In the words of one of her colleagues, "Michele is a creative problem solver who greets students with a smile and handles faculty and staff colleagues with grace and competence. She is, in addition, a delight to work with and someone who can be depended on to handle new situations with a positive attitude."

FACULTY AWARDS & RECOGNITIONS

EXTERNAL AWARDS

JAMES ASHTON-MILLER
Best Paper Award Cabaud Memorial Award, 2011

DENNIS ASSANIS
ASEE Ralph Coats Roe Award, 2011

SHORYA AWTAR
SME Outstanding Young Manufacturing Engineer Award, 2011
ASME Freudenstein/General Motors Young Investigator Award, 2011
ASME Leonardo da Vinci Award, 2011

JAMES BARBER
ASEE Archie Higdon Distinguished Educator Award, 2010

SAM DALY
DoE Early Career Research Program Award, 2010

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

ZORAN FILIPI
Best Paper Award Donald Julius Groen Award, 2011

VIKRAM GAVINI
NSF Faculty Early Career Development Award, 2011

JOHN HART
SME Outstanding Young Manufacturing Engineer Award, 2010
AFOSR Young Investigator Research Program Award, 2011

JACK HU
Best Paper Award, International Conference on Frontiers of Design & Manufacturing, 2010

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

MASSOUD KAVIANY
ASME James Harry Potter Gold Medal, 2010

NOBORU KIKUCHI
USACM Computational Structural Mechanics Award, 2011

SRIDHAR KOTA
ASME Ruth & Joel Spira Outstanding Design Educator Award, 2010

GRANT KRUGER
Best Paper Award, International Conference on Engineering and Meta-Engineering, 2010

TAE-KYUNG LEE
Donald Julius Groen Award - Institution of Mechanical Engineers, 2011

JYOTI MAZUMDER
ASME Thomas A. Edison Patent Award, 2010

JAMES MOYNE
Semiconductor Equip and Materials Int'l (SEMI) Outstanding Achievement Award, 2010

KENN OLDHAM
NSF Faculty Early Career Development Award, 2010

JUN NI
Outstanding Achievement Award, Oversea Chinese Office, State Council, China, 2010
Distinguished Service Award, Chinese Institute of Engineers, 2010
Magnolia Gold Medal, Shanghai Municipal Government, 2010
Best Paper Award Int'l Conference on Frontiers of Design and Manufacturing, 2010

JWO PAN
Arch T. Colwell Merit Award for SAE Paper, 2010

HUEI PENG
Best Paper Award, International Symposium on Advanced Vehicle Controls, 2010
Visiting Chang-Jiang Scholar at Tsinghua University, 2010

NOEL PERKINS
ASME N. O. Myklestad Award, 2011

ANN MARIE SASTRY
CNN Money.com's Innovators in Detroit List, 2010
ASME Frank Kreith Energy Award, 2011

ALBERT SHIH
Best Paper Award, International Conference on Engineering and Meta-Engineering, 2010

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

JEFF STEIN
ASME Dedicated Service Award, 2010

MICHAEL THOULESS
Overseas Fellow, Churchill College, Cambridge, 2011

ANGELA VIOLI
Monroe–Brown Foundation Education Excellence Award, 2010

KON-WELL WANG
SPIE Smart Structures & Materials Lifetime Achievement Award, 2011

MARGARET WOOLDRIDGE
ASME George Westinghouse Silver Medal, 2011

NEW FELLOWS

ELLEN ARRUDA
Fellow, The American Academy of Mechanics, 2010

DIANN BREI
Fellow, American Society of Mechanical Engineers, 2011

DAVE DOWLING
Fellow, American Society of Mechanical Engineers, 2010

BOGDAN EPUREANU
Associate Fellow, American Institute of Aeronautics & Astronautics, 2010

KARL GROSH
Fellow, Acoustical Society of America, 2010

ZHENG-DONG MA
Fellow, American Society of Mechanical Engineers, 2010

GALIP ULSOY
Fellow, International Federation of Automatic Control, 2010

KON-WELL WANG
Fellow, American Association for the Advancement of Science, 2010

FACULTY AWARDS & RECOGNITIONS (CONTINUED)

U-M AWARDS

DENNIS ASSANIS
CoE Stephen S. Attwood Award, 2011

SHORYA AWTAR
ME Department Achievement Award, 2011

JOHANN BORENSTEIN
Research Faculty Recognition Award, 2011

DIANN BREI
CoE Ted Kennedy Family Team Excellence Award, 2011

NIKOS CHRONIS
ME Department Achievement Award, 2011

ZORAN FILIPI
Research Faculty Achievement Award, 2010

JOHN HART
ME Department Achievement Award, 2010

Robert Caddell Memorial Faculty/Student Achievement Award, 2011

ELIJAH KANNATEY-ASIBU
CoE Raymond J. & Monica E. Schultz 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

JONATHAN LUNTZ
CoE Ted Kennedy Family Team Excellence Award, 2011

ALBERT SHIH
Rackham Faculty Recognition Award, 2010

CoE George J. Huebner, Jr. Research Excellence Award, 2011

KATHLEEN SIENKO
CoE Raymond J. & Monica E. Schultz Outreach & Diversity Award, 2011

STEVE SKERLOS
CoE Neil Van Eenam Memorial Undergraduate Teaching Award, 2011

MICHAEL THOULESS
ME Department Achievement Award, 2010

CoE Trudy Huebner Service Excellence Award, 2011

ANGELA VIOLI
CoE Education Excellence Award, 2010

ALAN WINEMAN
CoE Research Excellence Award, 2010

FACULTY PROMOTIONS

HONG IM
to Professor

STUDENT AWARDS

UNDERGRADUATE AWARDS

ANDREW DOSS
Lloyd H. Donnell Scholarship, 2010

SHANE LARKIN
Caddell, 2010

BRENNAN MACDONALD
J.A. Bursley Prize, 2011

MEREDITH MILLER
Caddell, 2010

ANIRUDDHA RAINA
R&B Tool Scholarship, 2010

JUSTIN RAJABIAN
R&B Tool Scholarship, 2010

BRYAN SKULSKY
R&B Tool Scholarship, MESLB Impact Award, 2010

CRAIG TENBUSSCHEN
Cooley Writing Prize – Fiction, 2011

EDWARD WAGNER
R&B Tool Scholarship, 2010

EDWARD ZINGER
Graebel Top Scholar Award, 2010

GRADUATE AWARDS

MICHAEL ALEXANDER
MLK Spirit Award, 2010

JUSTIN BEROZ
NSF Fellowship, 2011

JOSHUA BISHOP-MOSER
NSF Fellowship, 2010

JEREMY BROWN
NSF Fellowship, 2010

MATHIEU DAVIS
NSF Fellowship, 2010

Young Investigator Award – International Society of Biomechanics, 2011

JESSICA DENEWETH
National Defense Science & Engineering Graduate Fellowship, 2010

TERESA FRANKLLIN
NSF Fellowship, 2010

DAN JOHNSON
Outstanding Graduate Student Instructor Award, 2010

BRIAN JUSTUSSON
1st Place in Army Research Laboratory Summer Student Research Symposium, 2011

JEREMY KOEHLER
NSF Fellowship, 2010

BENJAMIN LAWLER
NSF Fellowship, 2010

YOON KOO LEE
Graduate Distinguished Achievement Award, 2011

PAI-CHEN LIN
SAE Colwell Award, 2010

DAVID LIPPS
Cabaud Memorial Award for Excellence in Research, 2011

RYAN MCGINNIS
NSF Fellowship, 2010

YOU KEUN OH
Young Investigator Gold Award, 2010

Cabaud Memorial Award for Excellence in Research, 2011

GAURAV PARMAR
NIST-ARRA Graduate Fellowship, 2011

MEGAN ROBERTS
NSF Fellowship, 2010

SOOD SIDDHARTH
NIST-ARRA Graduate Fellowship, 2011

WILLIAM SMITH
SMART Scholarship, 2010

JOHNNY TSAI
Outstanding Student Instructor Award, 2011

STEVEN VOZAR
Distinguished Leadership Graduate Award, 2011

ETHAN WAMPLER
U-M International Institute Fellowship, 2011

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