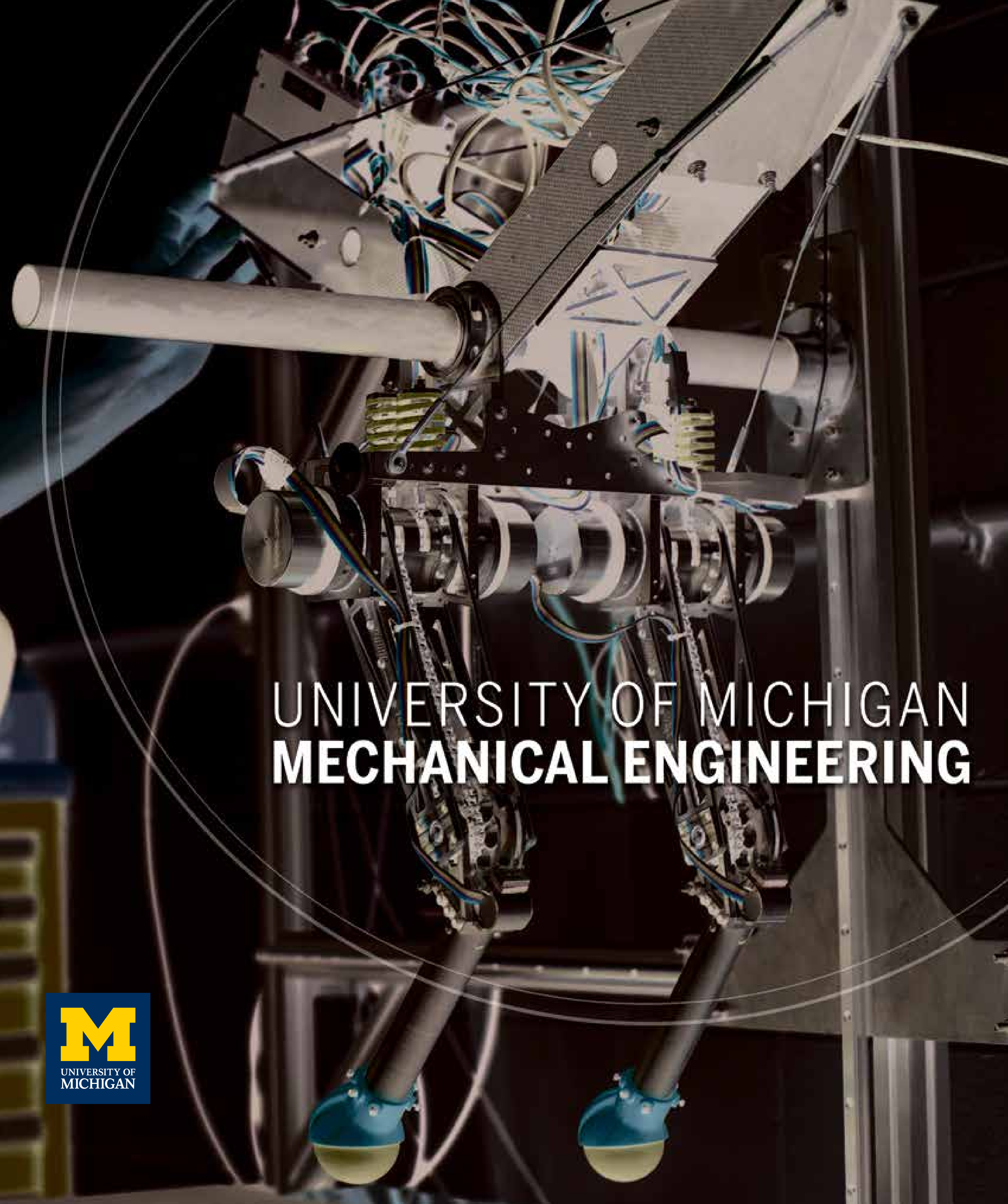


UNIVERSITY OF MICHIGAN

MECHANICAL ENGINEERING

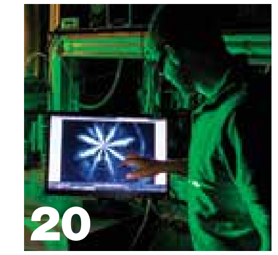
UNIVERSITY OF MICHIGAN

ANNUAL REPORT 2013–2014

Mechanical Engineering Annual Report 2013–2014

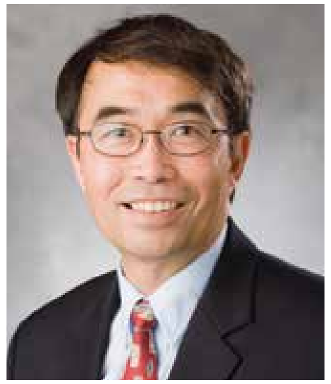
ON THE COVER AND INSIDE FRONT PAGE: RAMone, the new robot created by ME Assistant Professor David Remy's research group, is tested in the Robotics and Motion Laboratory (RAMLab) in the GG Brown building. See page 36 for the full story.

Photos: Joseph Xu, Michigan Engineering Communications & Marketing



Contents

Message from the Chair



[As one of the nation's top-ranked mechanical engineering programs, our research discoveries and educational efforts are making significant impacts in the technical community and on our society.]

It's my great pleasure to share our University of Michigan (U-M) Department of Mechanical Engineering (ME) 2013–14 annual report with you. As one of the nation's top-ranked mechanical engineering programs, our research discoveries and educational efforts are making significant impacts in the technical community and on our society.

Buttressing all that we do are major improvements in our facilities. Our new world-class research complex, a $46 million, 62,880-square-foot project, is complete. As you can imagine, the excitement is palpable since the new space enables truly transformative research that brings together core mechanical engineering and emerging areas, such as micro-, nano- and bio- systems.

We also have started the construction phase of a major renovation of the current GG Brown building, with completion expected in 2016. This $50 million effort will create innovative, student-centric instructional spaces. We are grateful to the State of Michigan for $30 million in support for the project.

As the GG Brown renovation wraps up in 2016, we will begin work on a much-anticipated interior renovation of the Lay Auto Lab. Improved lighting, display areas, floor and wall finishes and faculty and student offices will greatly enhance the space both for occupants and the many visitors who come from around the world to learn about the Auto Lab's programs.

Our faculty have been recognized nationally and internationally for their research advances and professional leadership. Our colleagues are playing major roles in national centers and initiatives, including two important new advanced manufacturing institutes: the American Lightweight Materials Manufacturing Innovation Institute and the Digital Manufacturing and Design Innovation Institute. A first-of-its-kind Mobility Transformation Center, a public-private research partnership, will lay the foundation for a commercially viable ecosystem of connected and automated vehicles. The faculty continue to make breakthroughs in fundamental and applied research across many fields, from energy to bio-systems, robotics, nanotechnology, computational mechanics and physics and advanced manufacturing.

Five of our junior faculty colleagues have garnered competitive National Science Foundation CAREER young investigator awards this past academic year. We welcome three new faculty members this year, and several additional new faculty searches also are underway.

Enhancing the educational opportunities and quality for our students remains a priority as we roll out new initiatives in both the undergrad and graduate programs. These include increased curricular flexibility, first of its kind RISE program, which puts an emphasis on undergraduate student independent projects, and a new two-year dual degree that combines a Master's of Science and Engineering in Mechanical Engineering with a Master's of Management from the Ross School of Business. Again this year our student teams have shown the breadth and depth of their engineering education through their many competitive activities.

Our alumni continue to inspire us through their diverse endeavors around the globe, and we are grateful for their enthusiastic support.

Thank you for your attention. Here's to a productive year ahead, filled with wonder and discovery.

Kon-Well Wang
Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor

Faculty Profile

4
NAE Members

76
Society Fellows

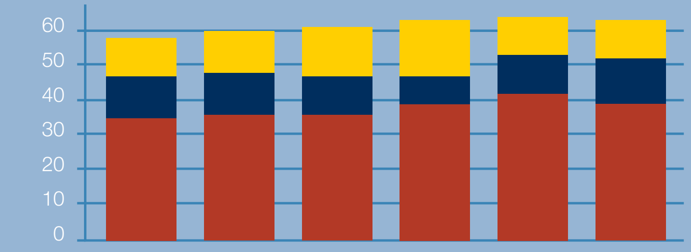
4
NSF PECASE or PFF Awards

35
NSF CAREER or PYI Awards

6
Current Journal Chief Editors

73
Current Journal Editorial Board or Assoc. Editor Appts.

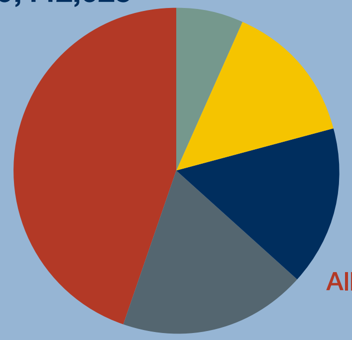
Faculty Trends: Tenured and Tenure-Track



	FA09	FA10	FA11	FA12	FA13	FA14
Assistant	11	12	14	16	11	11
Associate	12	12	11	8	11	13
Professor	35	36	36	39	42	39
Total	58	60	61	63	64	63

Annual Research Expenditures

TOTAL RESEARCH EXPENDITURES
$29,442,025

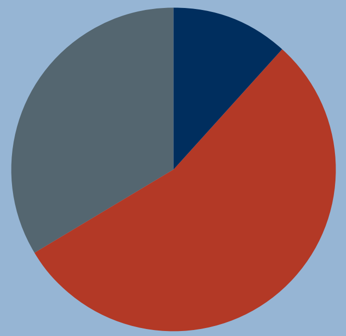


2013–14

NIH	2,119,796
NSF	4,430,451
DoE	4,926,596
DoD	5,842,707
All Other	12,122,475

Degrees Conferred

2012–13



BSE 220
MSE 134
PhD 47

New ME Research Complex Completed

The new 62,880-square-foot mechanical engineering research complex is now officially open.

The $46 million project, a three-story addition to the existing GG Brown Memorial Laboratories building, was partially supported by $9.5 million from the National Institute of Standards and Technology (NIST). It enables transformative and highly multidisciplinary research.

"The work that takes place in the new ME research complex will bring together core mechanical engineering disciplines and emerging areas such as micro-, nano- and bio-systems," said **Kon-Well Wang**, Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor. "It is providing our faculty a state-of-the-art facility to further advance their cutting-edge research at these new frontiers."

This world-class facility is dedicated to fostering collaborative research in several areas, including imaging and optics; biosystems; nanoengineering; micro-bioengineering; materials, mechanics and mechanical testing; microdynamics and nanostructures.

"The large and shared research facility consists of six major research labs, four core labs, and five large graduate student offices. The shared labs encourage our strong tradition of collaboration with researchers in our department as well as across our campus. In addition, the building features a gorgeous three-story galleria, an atrium/lounge, two conference rooms, and beautiful works of art. Whether conducting research in the labs or just pausing to study between classes, our students love these new and engaging spaces," said **Noel Perkins,** Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor.

At the core of the building, and resting on a separate and isolated foundation, lies the ultra-low vibration laboratory (ULVL) which includes eight separate testing chambers. In addition to providing vibration isolation, these chambers feature stringent control of temperature, humidity and shielding for acoustic, RF and magnetic interference. Collectively, the ULVL represents a facility like no other in the Department's history and it will enable our researchers to conduct experiments with unprecedented precision and accuracy down to the nanoscale. Their research discoveries will significantly impact many areas that are critical to society, including energy, manufacturing, health care and biotechnology.

[The work that takes place in the new ME research complex will bring together core mechanical engineering disciplines and emerging areas such as micro-, nano- and bio-systems.]

Realizing the Vision
Construction Started for GG Brown Major Renovation

The design phase for a major, $50 million renovation of the current GG Brown Memorial Laboratories building is now complete, and construction began summer 2014.

"Tremendous growth in the ME department is driving this project," said **Kon-Well Wang**, Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor. "The GG Brown renovation helps us realize our vision and goal of providing our students, faculty and staff with a truly world-class educational facility."

The renovation will create a central hub for the Department, directly connected to the new research complex addition (see related story on page 4).

Academic spaces will undergo state-of-the-art improvements to develop a student-centric environment. These include co-locating student advising, a learning center for faculty-student interaction, a large and flexible classroom and under-graduate instructional spaces for design, fabrication and laboratory work to foster further collaboration. The new, innovative spaces will support the "Design, Build, Test" pedagogic paradigm.

The renovation will also create more accessible and efficient administrative spaces, and infrastructure will be updated to greatly improve effectiveness and efficiency.

"The planning and design of the GG Brown renovation is an integrated effort involving faculty, staff and students," said Wang. "It's a very complex project, and I'm especially grateful to professors **Dawn Tilbury** and **Noel Perkins**, previous and current associate chairs for facilities and planning, and staff members **Merlis Nolan** and **Matt Navarre** for their outstanding leadership and efforts."

[The GG Brown renovation helps us realize our vision and goal of providing our students, faculty and staff with a truly world-class educational facility.]

"A renovation project on this scale and occurring in an owner-occupied building takes a massive team to plan and to complete. We are grateful for the wise counsel of our ME faculty, staff and students during the design phase, to the architectural firm of Integrated Design Solutions, and to the construction management team of Granger Construction and the University's Office of Architecture Engineering and Construction. We are also truly grateful for the strong commitment and support provided by our College of Engineering," said Perkins. The phased construction plan is expected to be completed in 2016.

The State of Michigan has provided $30 million for the renovation, with the College of Engineering and the U-M Office of the Provost funding the remaining cost.

TOP (LEFT TO RIGHT): Renderings of mechatronics and design innovation lab and a new classroom.

BOTTOM RIGHT: Rendering of new stairway connecting public spaces.

Lay Automotive Lab to Undergo Interior Renovation

With approval from the College of Engineering in winter 2013, the ME department recently completed the design phase of a much-anticipated interior renovation of the Walter E. Lay Automotive Laboratory building.

The Auto Lab is an invaluable asset to the Department. Its unique experimental facilities enable high-impact and internationally recognized research in transportation and many other fields, as well. The building serves some 140 occupants, including faculty, staff and over 100 research students and visitors. It is home to several major research centers, including the Automotive Research Center, the US-China Clean Energy Research Center and the GM/University of Michigan Engine Systems Collaborative Research Laboratory. Combined, Auto Lab annual research expenditures top $10 million.

"We're anticipating a very positive outcome that will allow the Auto Lab occupants to have a much better working environment and to showcase their outstanding research in befitting ways," said **Kon-Well Wang**, Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor. "This project will greatly enhance the work environment for, and productivity of, the faculty, students and staff and improve the experience for visitors, who come from around the world to learn about the Auto Lab's programs."

"The renovation includes updated corridors and staircases, improved lighting and display areas, a new lounge and conference rooms, in addition to updated restrooms and an added lactation room," said **Noel Perkins**, Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor. "Flooring and walls will receive new surface finishes, and faculty and student offices will be upgraded. The project also includes some HVAC and electrical upgrades, as well."

Phased construction will begin in 2016, as the GG Brown Memorial Laboratory building renovation (see related story on page 6) approaches completion.

The Auto Lab is an invaluable asset to the Department. Its unique experimental facilities enable high-impact and internationally recognized research in transportation and many other fields as well.

Renderings of the renovated second floor (above) and the new glass walls at the central stairway (right).

ME Welcomes New Faculty Members

JEFF SAKAMOTO

RAMANARAYAN VASUDEVAN

AMY HORTOP

The ME department is pleased to welcome **Jeff Sakamoto, Ramanarayan Vasudevan** and **Amy Hortop,** who will be joining the faculty as associate professor, assistant professor and lecturer, respectively.

JEFF SAKAMOTO

Sakamoto earned his PhD from UCLA and is currently a tenured associate professor at Michigan State University. An engineer with a strong interest in synthesis, processing and functionalization of ceramics and hydrogels, his research is highly interdisciplinary, guided by the fields of energy storage/conversion and biomedicine. Sakamoto has established independent and substantial research programs investigating superionic conducting ceramic electrolytes, solid electrolyte-electrode interfaces and highly ordered and hierarchical battery electrode architectures. Throughout his career, Sakamoto has demonstrated his ability to conduct cutting-edge research, publishing 51 peer-reviewed manuscripts and four book chapters and serving as a contributor to 13 patents.

RAMANARAYAN VASUDEVAN

Vasudevan received his PhD from UC Berkeley and is currently working as a postdoctoral associate at the Massachusetts Institute of Technology. His research focuses on the development of optimization, robotics and biomechanical modeling theory that takes advantage of data from cheap, ubiquitous sensing technologies to automate diagnostic and rehabilitative tasks. A primary application of Vasudevan's work has been the identification and analysis of dynamical models of human movement to construct personalized control strategies that can be used by robotic platforms to reduce the likelihood of falling. He will be collaborating with colleagues in the College of Engineering and the University of Michigan Transportation Research Institute on connected and autonomous vehicles research.

AMY HORTOP

Hortop earned her BS in Mechanical Engineering from Michigan Technological University and her MS in Mechanical Engineering from Rochester Institute of Technology. Her industry experience is primarily been in the automotive field. Her most recent experience includes over four years on the research staff at Technische Universität Braunschweig in Germany, where she was able to teach as well as work on industry projects. She will be coordinating and teaching ME 450 (capstone design) and teaching other ME and College of Engineering classes as well.

Five U-M Mechanical Engineering Faculty Win Early Career Awards in Academic Year 2013–14

Five ME faculty have won prestigious National Science Foundation Faculty Early Career Development (CAREER) Awards in academic year 2013–14. The NSF's CAREER program recognizes junior faculty teacher-scholars who successfully integrate innovative research with impactful educational and outreach initiatives.

KIRA BARTON

3D PRINTING AT THE MICRO-SCALE

Assistant Professor **Kira Barton** earned a CAREER award for her proposal, "Pushing the Boundaries: Advancing the Science of Micro-Additive Manufacturing." Although 3D printing can be a low-cost, flexible alternative for fabrication without a cleanroom environment, several barriers must be overcome, including a lack of standards for designing, modeling and controlling new processes.

Barton's research addresses these barriers through the characterization of key design criteria, process parameters and environmental conditions. Her work will provide a foundation for modeling and control laws to improve the performance of micro-scale 3D printing and will directly impact the way the United States manufactures functional electronics, biosensors and optics at the micro-scale.

Barton plans to develop interactive outreach activities and workshops tailored for families and K-12 students, integrate research findings into classroom modules for undergraduate and graduate courses and engage underrepresented students in her lab's research activities, all with an emphasis on the cross-disciplinary nature of advanced manufacturing.

ERIC JOHNSEN

SHOCK WAVES AND CAVITATION IN HUMAN TISSUE

Assistant Professor **Eric Johnsen's** CAREER proposal, "Shock Waves and Cavitation in Human Tissue," will explore these phenomena, which occur during therapeutic ultrasound as well as blast-induced traumatic brain injury. Researchers have developed a thorough understanding of how bubbles and shock waves behave in water, but the effects on human soft tissue are less well understood, hindering the timely and accurate assessment of tissue damage.

In collaboration with the U-M Museum of Natural History's Science for Tomorrow program, Johnsen and his researchers have set up an exhibit booth with an ultrasound device to help visiting middle school students visualize internal organs and functions.

ADAPTIVE FEED DRIVE SYSTEMS FOR SMART, SUSTAINABLE MANUFACTURING

Feed drives, or the motion delivery systems of manufacturing machines, currently are designed with fixed electromechanical structures, which leads to undesirable compromises in speed, accuracy and energy efficiency. Assistant Professor **Chinedum Okwudire** plans to change that with research based upon his winning CAREER award proposal, "Dynamically Adaptive Feed Drive Systems for Smart and Sustainable Manufacturing."

CHINEDUM OKWUDIRE

Okwudire envisions dynamically adaptive feed drives that can intelligently vary their electro-mechanical structure in real time to achieve high performance and energy efficiency as a function of the specific manufacturing operation being performed. The key challenge, though, is a design approach that maximizes synergy under fast switching, an obstacle no investigator has yet overcome. His work has the potential to enable significant improvements in the energy efficiency of a wide range of manufacturing machines without compromising quality or productivity.

The educational objective of Okwudire's proposal is to develop teaching resources and unconventional outreach efforts, all to foster synergistic thinking in engineering education to create a more diverse and capable workforce.

GABOR OROSZ

DATA-BASED DESIGN AND OPTIMIZATION OF CONNECTED VEHICLE SYSTEMS

Assistant Professor **Gabor Orosz's** CAREER proposal, "Heterogeneous Delayed Networks: Data-based Design and Optimization of Connected Vehicle Systems," will focus on the fact that the penetration of vehicles equipped with wireless communication is expected to grow significantly in the near future. This growth will in turn increase the demand for data-based models for heterogeneous connected vehicle systems, where heterogeneity originates from the differences in human behavior, vehicle properties and wireless communication across the network. This research is addressing a knowledge gap related to the decomposition of the dynamics of large, heterogeneous, infinite-dimensional networks and provides a systematic way to design and optimize such systems.

Modal equations that map the spatio-temporal complexity into the time domain will be used to optimize the system-level performance by designing the network structure and tuning the gains and delays for the communication links while satisfying driver constraints. The educational activities include the development of a new course on network dynamics and control design and the initiation of a problem-solving competition in high-school physics that will provide an opportunity for underrepresented minority students to increase their chances to enter and excel at the best universities in the nation.

DON SIEGEL

MODELING GAS EVOLUTION REACTIONS IN LITHIUM BATTERIES

Assistant Professor **Don Siegel** has received a CAREER award for his proposal, "First-Principles Modeling of Gas Evolution Reactions in Lithium Batteries." His primary research objective is to characterize the reaction mechanisms associated with electrolyte decomposition within the cathode of Li-air and Li-ion batteries. Such reactions have major implications for the safety, longevity and efficiency of these systems, yet they have received relatively little attention given the inherent complexity of the electrolyte/cathode interface where they occur.

Siegel will simulate the electrolyte/cathode interface at the atomic scale, under conditions similar to those found in a realistic battery. By revealing the elementary steps associated with these decomposition processes, he will facilitate the development of rational strategies to minimize their occurrence, leading to more efficient and safe batteries.

Siegel will translate his research outcomes into energy-themed educational activities for students. He will develop a weeklong focus group on "Materials for Energy" for the U-M Girls in Science and Engineering Summer Camp for middle school girls. For undergraduates, he will extend his existing course, "Atomistic Computer Modeling of Materials," by developing new lectures and laboratory exercises. For practicing automotive engineers, he will create a new module on battery safety for participants in his short course, "Introduction to Electrical Energy Storage."

ME Faculty Playing Key Roles in National Manufacturing Institutes

University of Michigan (U-M) Mechanical Engineering (ME) faculty are playing key roles in two new national manufacturing innovation institutes announced by President Obama in early 2014. The new institutes, part of the National Network for Manufacturing Innovation, will advance manufacturing technologies and help to boost U.S. competitiveness.

The U.S. Department of Defense selected a consortium of investigators, led by U-M, the Edison Welding Institute and Ohio State University, to head the new American Lightweight Materials Manufacturing Innovation Institute, or ALMMII. Many non-profit and industry partners will participate in the nearly $148 million effort, to be based outside Detroit, in Canton, Michigan.

Professor **Alan Taub** of Materials Science and Engineering is serving as the ALMMII chief technical officer. Mechanical Engineering Professor **S. Jack Hu,** currently also U-M's interim vice president for research, represents U-M on the ALMMII board of directors.

The ALMMII will support the U.S. manufacturing sector by developing and implementing innovative manufacturing technologies that enable cost-effective lightweighting of components used in ground-, water- and air-based transportation systems.

The institute's investigators will be undertaking research projects along the spectrum of manufacturing technology as it relates to lightweight materials, from the materials themselves to their integration into components and subsystems as well as workforce education and training.

"Detroit is the world capital of automotive manufacturing, and lightweighting in cars and trucks is of keen interest to auto manufacturers today," said Hu. "Couple that with the tremendous expertise and research base we have here at U-M and around the Midwest, and the location and timing are an excellent fit."

Professor Alan Taub (MSE), Michigan Senator Carl Levin and Professor Jack Hu (ME) at the White House.

A number of ME faculty will be involved with the ALMMII's technical projects, including Hu, **Albert Shih, Elijah Kannatey-Asibu, Steve Skerlos, Miki Banu, Jyotirmoy Mazumder** and **Jun Ni.**

ME Professor Jun Ni, the Shien-Ming (Sam) Wu Collegiate Professor of Manufacturing, also served as an ALMMII internal pillar leader and is leading U-M participation in a second manufacturing innovation institute, the Digital Manufacturing and Design Innovation Institute (DMDII). Led by the Chicago-based UI LABS, the $300 million DMDII includes almost two dozen institutions and more than 100 companies.

"Advanced digital modeling and simulation tools can greatly reduce the time from concept to market and optimize our design and manufacturing processes," explained Ni, who serves as U-M coordinator for the DMDII. "That extends to manufacturers' supply chains and sales and marketing networks. If we can improve all those business processes using technology, the U.S. can better compete globally."

Both institutes are expected to offer research and internship opportunities for U-M faculty and students. With a focus on technologies with a readiness level of between four and seven, the two MIIs will ensure that research projects move rapidly toward implementation and commercialization, thereby creating jobs and improving workforce preparedness.

University of Michigan ME roots run deep beneath the National Network for Manufacturing Innovation. ME Professor **Sridhar Kota,** the Herrick Professor of Engineering, served as assistant director for advanced manufacturing at the White House from 2009 to 2012. A major priority was to foster innovation and bridge the gap between basic research and manufacturing readiness. In 2011, Kota also helped create President Obama's Advanced Manufacturing Partnership (AMP). Hu and U-M President Emerita Mary Sue Coleman served on a working group of the AMP.

"To be able to help define a national agenda for manufacturing research and innovation and be a key participant on two winning manufacturing innovation institute proposals only underscores the strength of U-M's research and educational programs in manufacturing," said Hu.

Transformation in Transportation
Making Connected and Automated Vehicles Reality

Although connectivity and automation technologies have matured, the transportation field has yet to fully embrace their capabilities. A new collaborative, public-private research and development partnership among industry, government and the University of Michigan is about to change that through the U-M Mobility Transformation Center (MTC).

MOVING MULTIPLE METRICS

"We want to harness the potential of these technologies to improve the performance of transportation systems, safety in particular, by at least an order of magnitude," said ME Professor **Huei Peng,** the Center's associate director. "We also will address other critical issues, namely energy consumption and congestion; we want to have an impact on multiple metrics."

To realize the vision for the Center, one central goal is to develop and implement an advanced system of connected and automated vehicles in Ann Arbor by the year 2021. To that end, three research clusters will bring together vehicles, investigators and infrastructure to "test real breakthrough concepts in living laboratories," explained Peng.

Ann Arbor already boasts 2,800 connected vehicles, thanks to the U-M Safety Pilot Project, funded by the U.S. Department of Transportation (USDOT). The demonstration project was designed to test the potential and real-life performance of vehicle-to-vehicle and vehicle-to-infrastructure communications. The MTC's first research pillar will extend that initiative and involve tripling the number of connected vehicles on Ann Arbor roadways. A second research pillar will focus on expanding connected vehicles throughout southeastern Michigan. A third will focus on automated vehicle capabilities.

WORLD'S FIRST CONNECTED AND AUTOMATED VEHICLE PROVING GROUNDS

In July 2014, the MTC broke ground on a $6.5 million Mobility Transformation Facility, a state-of-the-art testing environment for connected and automated vehicles. The facility, funded in part by the Michigan Department of Transportation and slated for completion in spring 2015, is believed to be the first of its kind in the world.

Peng is enthusiastic about the MTC's accomplishments in its first year and the progress that can be made going forward. "The Safety Pilot Project gave us a very strong foundation to start with," he said. "Ann Arbor is very close to the heart of the U.S. automotive industry, where many connected and automated technologies are being developed. That, coupled with the university's strong tradition in automotive engineering, makes now the right time and U-M the right place."

+ more on the web

For more information on the Mobility Transformation Center, visit **umtri.umich.edu/who-we-are/research-groups/mobility-transformation-center.**

BELOW: Aerial view of the Mobility Transformation Center (MTC) site plan.

Automotive Research Center

Twenty Years Strong, Tradition of Excellence Carries On

Celebrating its 20-year anniversary in 2014, the University of Michigan Automotive Research Center (ARC) has a strong history to reflect upon—and a promising future to look forward to thanks to a $40 million, five-year contract renewal.

A U.S. Army Center of Excellence for advancing automotive technology for military and commercial vehicles, the ARC is supported by the United States Army Tank Automotive Research, Development and Engineering Center, or TARDEC. Since its inception, and in close collaboration with several academic, industrial and governmental partners, it has served as a hub for basic scientific research to support the modeling and simulation of ground vehicles.

"The renewal of our contract is a welcome acknowledgment of the quality of work the ARC has been doing since 1994 and that our work continues to be relevant and important for the Army as well as for industry," said ARC Director and ME Professor **Anna Stefanopoulou.**

The ARC has had both scholarly and commercial impact through its five research thrust areas: Dynamics and Control of Vehicles; Human Centered Modeling and Simulation; High Performance Structures and Materials; Advanced and Hybrid Powertrains; and Vehicle System Integration, Optimization and Robustness. The research findings across all five areas have helped ARC partners improve product development and make both commercial and military vehicles safer and more efficient.

Some of the ARC's accomplishments over the past two decades include:

- Virtual prototypes to support design and control of vehicles powered by alternative energy sources
- Full vehicle system simulations to reduce cost, energy, emissions and fatalities
- Demonstration of the value of modeling and simulation to TARDEC that led to its adoption of computational analysis in many of its processes

Each May, the ARC holds its Annual Program Review, which draws some 300 participants and a slate of renowned speakers. In 2014, invited speakers from the U.S. Department of Energy and Department of Defense and the Michigan Automotive Office highlighted the ARC's impact and the research needs that lay ahead. Also in May 2014, in celebration of the ARC's 20th anniversary, several U-M graduates returned to campus for the event to share their thoughts on how the ARC influenced their careers. Alumni included:

- Col. Scott Lathrop, Deputy Director of R&D, U.S. Cyber Command, Fort Meade
- Dr. Andreas Malikopoulos, Deputy Director, Urban Dynamics Institute, Oak Ridge National Laboratory
- Dr. Bin Wu, Manager, Electric Motor Core Control, Mercedes Benz Research & Development North America, Inc.
- Professor Denise McKahn, Assistant Professor, Smith College
- Professor Tim Jacobs, Associate Professor & Undergraduate Program Coordinator, Mechanical Engineering, Texas A&M University

"Hearing from alumni made this year's Annual Review an especially emotional and deeply gratifying event," said Stefanopoulou, who is enthusiastic about the coming years. "Since the ARC was founded, Army and automotive industry needs have changed dramatically and presented us with many and complex technical, environmental and economic challenges. With the ARC's strong past and productive collaborations, U-M's high caliber of students and TARDEC's renewed support, we're well positioned for a very promising future."

TOP LEFT: Dr. Jason Siegel (right), assistant research scientist in the Mechanical Engineering department, shows lab visitors a battery pack used to validate computational thermal models.

TOP RIGHT: Celebrating the 20th anniversary of the ARC with review attendees are Drs. Bodgan Epureanu (U-M), Zissimos Mourelatos (Oakland U.), André Boehman (U-M), Angela Violi (U-M), Panos Papalambros (U-M), Zoran Filipi (Clemson U.), David Gorsich (TARDEC), Mr. Mike Letherwood (TARDEC), Drs. Anna Stefanopoulou (U-M), Georges Fadel (Clemson U.), Naeim Henein (Wayne State U.).

ME Faculty Garner Media Attention

ME faculty are often featured in various media outlets for their expertise and research. Here are a few who were most recently highlighted.

KOTA QUOTED IN *CHICAGO TRIBUNE*

Sridhar Kota, Herrick Professor of Engineering, continues to be a part of the national conversation on manufacturing innovation and U.S. competitiveness. He has served as assistant director for advanced manufacturing at the White House and been a force behind the National Network of Manufacturing Innovation institutes spear-headed by President Obama.

Kota was quoted in a March 30, 2014 *Chicago Tribune* article entitled, "A model for innovation: Germany's research institutes provide lessons for Chicago as it plans $320 million digital manufacturing lab."

Kota's comment supported the need for a network of laboratories similar to that of Germany's Fraunhofer-Gesellschaft to "stop the bleeding of next-generation technologies and their manufacturing to other countries.… Otherwise we just continue to create knowledge but not wealth."

KOTA'S FLEXFOIL TECHNOLOGY ON CBS NEWS

Kota was also featured in an article by CBS News about novel shape-adapting technology that he developed for the aviation industry.

The airfoil technology, called FlexFoil, is more effective and efficient than the hinged wing flaps that traditionally have been used by aircraft designers. FlexFoil's structure is jointless, elastic and lightweight and optimizes control and performance of aircraft wings. The seamless technology leads to fuel savings of between three and 12 percent, and the improved control surface will reduce noise during take off and landing by up to 40 percent.

STEFANOPOULOU QUOTED IN *THE NEW YORK TIMES*

The June 18, 2014 edition of *The New York Times* featured an article, entitled "U.S. Opens Safety Review of Chryslers," focusing on the safety of ignition switches in vehicles. ME Professor and Director of the Automotive Research Center **Anna Stefanopoulou** commented on the idea that some of the problems carmakers face when it comes to ignition systems stem from having other features on the vehicle that need electric power, like power assist on the steering and deploying air bags.

"But these ignition systems have been so tried and true that automakers have not developed backup systems to provide power should the engine be accidentally turned off," said Stefanopoulou. "Such systems are very expensive and typically found only in the aerospace industry," she added.

WOOLDRIDGE QUOTED ON NPR

ME Professor **Margaret Wooldridge** was interviewed June 10, 2014 on NPR's "All Things Considered" about automakers' efforts to meet fuel-efficiency standards.

Wooldridge was quoted as saying, "If your only condition was, 'Build me a vehicle for 55 miles a gallon.' Two snaps we could have it done."

She went on to comment that with all the bells and whistles consumers are used to having on their cars, the harder the feat of manufacturing a more fuel-efficient vehicle has become.

OROSZ QUOTED IN BBC ARTICLE

ME Assistant Professor **Gabor Orosz** was quoted in the June 11, 2014 BBC story, "Can a city ever be traffic-jam-free?"

Orosz tapped into his expertise to comment on traffic jams and why they exist.

"Humans react to the motions of the vehicles immediately in front with a reaction time delay. The impact of this is that they often amplify the ripples created by other drivers tapping the brake. As the congestion wave cascades along the chain of vehicles, eventually it grinds traffic to a halt," said Orosz.

PERKINS' SWINGTRACKER TECHNOLOGY IN *SPORTS ILLUSTRATED*

The October 14, 2013 edition of *Sports Illustrated* ran an article, entitled "Precision Hitting," about new technology invented by ME Professor **Noel Perkins.** Perkins' SwingTracker system helps baseball players, and coaches, improve their game by analyzing their swing.

A wireless sensing unit attached to the bat captures information about the batter's rotation and acceleration and sends the data to SwingTracker software via wireless transceiver. The software instantaneously creates a dynamic visual of the batting movement, which players and coaches then can use to improve reaction time, speed and control.

FlexSys FlexFoil™ variable geometry control surface (eliminates conventional flaps)

Students Make Mentoring a FIRST Priority

Mechanical Engineering students and faculty have been helping shape the coming generation of engineers. This winter and spring, about a dozen ME students and **Mike Umbriac,** a lecturer in the department, donated several hours each week to share their engineering expertise with four local FIRST Robotics teams.

Umbriac met with the teams—from Huron, Skyline, Pioneer and Dexter high schools—at Maker Works in Ann Arbor and helped them find solutions to problems, such as determining the counterweight on a robot's arm and the spring forces on a catapult. Umbriac also conducted design reviews and lectured on basic mechanical components.

"It was amazing to have the U-M mentors help," said Matt Daida, a freshman at Huron High School. "They explained how systems like the pneumatic system should work in a way where they didn't tell us what to do but explained our goal and how we could get there. It allowed me to learn what to do by thinking ahead, then putting it into action as opposed to just trial and error."

"Our team benefited greatly from the synergy between the U-M volunteer mentors and our FIRST students, said Laura Earle, a parent and mentor along with her husband, Rich. "They took our students through critical thinking skills in engaging and empowering ways, while quickly adapting their own experiences to the parameters set by the FIRST Competition. They took a genuine interest in our team, even coming out to support us at competitions."

The U-M 3D Lab also helped the FIRST teams. The lab provided vouchers for 3D printing, and **Shawn O'Grady** and **Eric Maslowski** volunteered several hours of their time to assist participants.

One U-M volunteer, **Lauren Staszel,** who will graduate with a bachelor's degree in ME in December 2014, was a FIRST participant all four years of high school. "The experience really solidified my decision to go to engineering school and gave me a big head start over other students who did not have any hands-on or team experience," she said. "FIRST is a tremendous learning experience in itself, but having passionate mentors extends the realm of what you can learn."

Staszel shared the volunteer opportunity with other members of MHybrid Racing, for which she serves as business lead. "As members of an extracurricular project team, these students could connect with the FIRST teams well and had many skills to share. We hope to continue our partnership," she said.

Third-year U-M student **Alexandre Garrigo** also was a FIRST participant throughout high school and has volunteered as a drivetrain and chassis mentor for the past two years. The sense of accomplishment he felt from seeing his team win the world championship twice when he was in high school motivated him to volunteer.

"My mentors were some of the most influential people for me," Garrigo said. "They gave up a lot of their time, and I have no qualms about repeating that. I feel like I need to give back and give current students that same kind of experience."

Umbriac was proud of the dedication of the ME student-volunteers. He also was impressed by the degree of sophistication, cooperation, creativity and dedication of the FIRST team members.

"These high school students are going to be very prepared when they enter college," Umbriac said. "Because of this experience with FIRST, they're going to be a big step above their peers because they've already had the experience of designing, building and testing mechanical and electronic assemblies. They've used sensors, actuators, pneumatic systems….They're going to have a real advantage coming to college—and going into the workforce."

BOTTOM LEFT: Professor Albert Shih (second from left) with members of the Dexter High School "Dreadbots" FIRST Robotics team.

BOTTOM RIGHT: Members of the Huron High School FIRST Robotics team assemble their robot.

ME Plays Leadership Role in Engineering Conferences

In 2014, ME faculty and staff played vital roles in various conferences for Mechanical Engineering students and professionals. Here are three examples:

AMERICAN CONTROL CONFERENCE

U-M's ME professor **Dawn Tilbury** led and chaired the 2014 American Control Conference this past June in Portland, Oregon. The annual event, which welcomed more than 1,200 registrants from more than 40 countries, included a wide range of world-renowned engineering faculty, many of whom spoke at the event. ME Professor **Anna Stefanopoulou** was on hand to deliver one of the semi-plenary talks. She presented on the control of powertrain systems at the high efficiency limit, including internal combustion engines as well as batteries and fuel cells.

The ACC is internationally recognized as a premier scientific and engineering conference dedicated to the advancement of control, theory and practice. The conference brings together an international community of researchers and practitioners to discuss the latest findings in control research and practice. The 2014 ACC featured several kinds of presentations including contributed and invited papers, invited sessions, tutorial sessions, and special sessions along with workshops and exhibits.

MSEC/NAMRC/ICM&P CONFERENCES 2014

The U-M ME department played an integral role in the MSEC/NAMRC/ICM&P 2014 conference held June 9 -13 in Detroit. The annual event combined three separate conferences including the ASME International Manufacturing Science and Engineering Conference (MSEC 2014), the 42nd North American Manufacturing Research Conference (NAMRC 42) and the Japan Society of Mechanical Engineers International Conference on Materials and Processing (ICM&P 2014).

This was the second time these three conferences have been co-located, the fourth time that MSEC and NAMRC were co-located and the third time that MSEC and ICM&P have been co-located. University of Michigan ME professors **Albert Shih, Kira Barton,** and **Chinedum Okwudire,** and staff members **Patricia Mackmiller** and **Kathy Bishar** all worked to help bring the three conferences together this year with U-M as one of the hosting sites. Conference attendees had the opportunity to visit and tour U-M's Mechanical Engineering labs, including the 3D Lab, which features 3D printing, the Lurie Nanofabrication Facility, the S.M. Wu Manufacturing Research Center, the ERC for Reconfigurable Manufacturing Systems and the General Motors/U-M Collaborative Research Laboratory for Advanced Vehicle Manufacturing.

The conference schedule also included a wide range of keynote speakers and technical presentations, expert panels, student poster presentations, an exhibition of industry partners, an early career forum, industry tours, an awards banquet, luncheons and more.

The hope is that this conference helped foster new collaborations with industry and establish friendships with colleagues around the world, and that attendees had a memorable time in Detroit and Ann Arbor.

SEM MIDWEST GRADUATE STUDENT SYMPOSIUM ON EXPERIMENTAL MECHANICS

U-M's ME department and the College of Engineering (CoE) hosted the Society for Experimental Mechanics (SEM) Midwest Graduate Student Symposium on Experimental Mechanics this past May. This event allows students to present their research in a relaxed setting and rotates among schools in the Midwest.

The symposium has a more than 30-year history and owes its origins to Professor Charles E. Taylor. Students from Carnegie Mellon, Marquette, Michigan State, Northwestern, Ohio State, Penn State, Purdue, University of Pittsburgh, Wisconsin-Madison and the U-M gathered to present work on a variety of topics including the impact behavior of structural batteries, dynamic fracture phenomena and characterization, viscoelastic properties of hydrogels, vibration, adhesive fracture of biomaterial specimens, shape memory alloys, characterization and modeling of anterior cruciate ligament biomechanics, microscale material removal, aeroelastic performance evaluation of Aileron and strain evolution in MAX phases.

Professor **Samantha Daly** and her research group hosted a dinner party at a local lake on Saturday night. The forum allowed for casual social and professional interaction between faculty and students from midwestern universities. In all, there were 31 presentations and more than 40 participants. SEM, the U-M ME department and the U-M CoE sponsored the event.

BELOW: Conference attendees gather at the 50-yard line of The Big House after touring several ME facilities on the U-M campus during the 2014 MSEC/NAMRC/ICM&P.

Building a Better Battery

New technologies for sustainable transportation and energy storage

A dead battery isn't only frustrating for mobile phone, tablet and laptop users; energy storage also increasingly impacts transportation. Improved energy storage devices mean increased driving ranges for electric vehicles, which can ultimately reduce carbon dioxide emissions from the transportation sector by lessening its reliance on fossil fuels.

Energy storage for sustainable transportation is top of mind for Assistant Professor **Don Siegel,** who joined the ME faculty in 2009 after working in industry as a researcher at Ford Motor Company. Today, as head of the U-M Energy Storage and Materials Simulation Lab, Siegel is focusing on overcoming the myriad barriers to high-density energy storage using the tools of computational materials science and high-performance computing.

LOOKING TOWARD NEW AND SAFER BATTERY CHEMISTRIES

Through a number of collaborative initiatives, Siegel is looking at both the fundamental science and translational opportunities for new battery technologies. These include his participation in two centers funded by the U.S. Department of Energy: the U.S.-China Clean Energy Research Center-Clean Vehicles Consortium (CERC-CVC) and the Joint Center for Energy Storage Research (JCESR), a public-private energy innovation hub. Both centers are tasked with investigating critical technical questions on the way to developing new energy storage technologies.

The projects in Siegel's lab also are supported by the National Science Foundation—he is a recent CAREER Award winner; see related story on page 11—as well as industry leaders Bosch, Ford and Denso Corporation. "With these research partners, we look at everything from new battery chemistries to improving 'here and now' lithium-ion technologies," he explained.

As an example of the latter approach, Siegel's lab is exploring the chemical reactions underlying safety issues in Li-ion batteries. Specifically, he is investigating electrolyte decomposition at the liquid/solid interfaces between the electrolyte and cathode, a complex interface that has yet to be fully understood (see figure 1). What is known, however, is that electrolyte decomposition at this interface can lead to the accumulation of gases that, when vented to the atmosphere, release highly flammable vapor. Understanding the reaction pathways that precede these safety events will help Siegel and colleagues develop strategies to mitigate them.

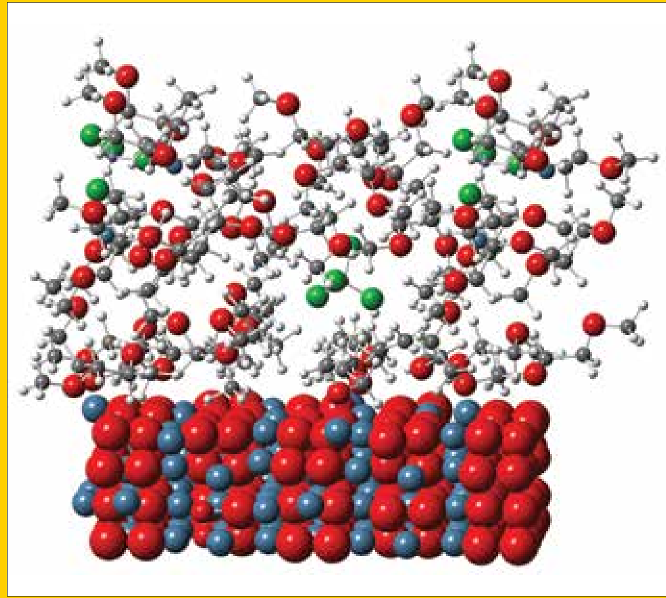


FIGURE 1: Quantum-mechanical simulation of an electrolyte/electrode interface in a Li-air battery.

IDENTIFYING MATERIALS FOR THE STORAGE AND CAPTURE OF GASES

While batteries store energy in the form of electrons, the chemical bonds of molecules also can store energy. In this regard, hydrogen and methane are attracting attention as alternative fuels. Hydrogen is being explored for use in fuel cell vehicles; methane is the primary component of natural gas, which, due to the emergence of hydraulic fracturing, has gained prominence as a low-cost domestic fuel.

However, just as in batteries, achieving high energy densities with either of these fuels is a challenge. Both are gases at standard conditions, and gases typically have very low densities. This results in the same type of "range anxiety" typical for battery electric vehicles.

To address the density problem, hydrogen and natural gas are usually stored on vehicles in compressed or liquefied form, but this approach comes at a cost. "Compression and liquefaction can be expensive and inefficient," explained Siegel, who is looking to develop new materials that could store these gases much more efficiently. "It's a materials discovery challenge to identify new compounds that can store these gases at high densities, and do so at lower pressures and costs."

Siegel's group uses a combination of data mining and high-throughput calculations to identify promising substances from more than half a million candidate compounds stored in the Cambridge Structure Database. By searching this database his team recently identified a handful of porous materials called metal-organic frameworks, or MOFs, that show promise for high-density storage of hydrogen and methane. The findings were published in *Chemistry of Materials* in 2013 (see figure 2).

The search is guided by geometric factors (such as surface area and density), composition and other parameters, but ultimately has to deal with missing or incomplete crystal structures. "Discovering these materials is akin to finding a needle in a haystack—with the important exception that sometimes the needle we find is broken," Siegel said.

While some of the data can be repaired, there remains more to do, both in terms of refining the search and improving the predictions of the amount of hydrogen and methane a given material can store. Nevertheless, the initial successes have attracted attention. "Now some of our experimental colleagues are attempting to synthesize these materials in hopes that they may realize the promise," he said.

CONNECTING RESEARCH TO SOCIETAL IMPACT

Outreach is a large part of Siegel's efforts. To illustrate the linkages between energy policy and the science of energy storage, Siegel developed a series of nine YouTube videos titled "Batteries of the Future." The videos, developed as part of the MconneX program, have been viewed more than 150,000 times and led to several speaking invitations and other connections (see figure 3).

"I believe the videos are helpful because they connect the research students are doing in the lab with their hoped-for consequences. I always encourage students to consider the bigger picture: Why is this work important, and how does one translate from the intended application to the properties that the active material must exhibit?" Siegel said.

For summer 2015, Siegel plans to further extend his outreach activities by developing a weeklong module on energy storage for the U-M Women in Science & Engineering-Girls in Science & Engineering (WISE-GISE) Summer Camp. He's also adding a segment on Battery Safety to a short course he developed for practicing engineers for the College of Engineering's Integrated Systems + Design Certificate in Emerging Automotive Technologies.

A highly sought-after speaker for lay and engineering audiences alike, Siegel was named one of four 2014 National Academy of Engineering Gilbreth Lecturers. He spoke on "Energy Storage for Sustainable Transportation" during the NAE National Meeting in February to an audience comprising both NAE members and high school students.

+ more on the web

View Siegel's "Batteries of the Future" video series at: **goo.gl/L1VVo**

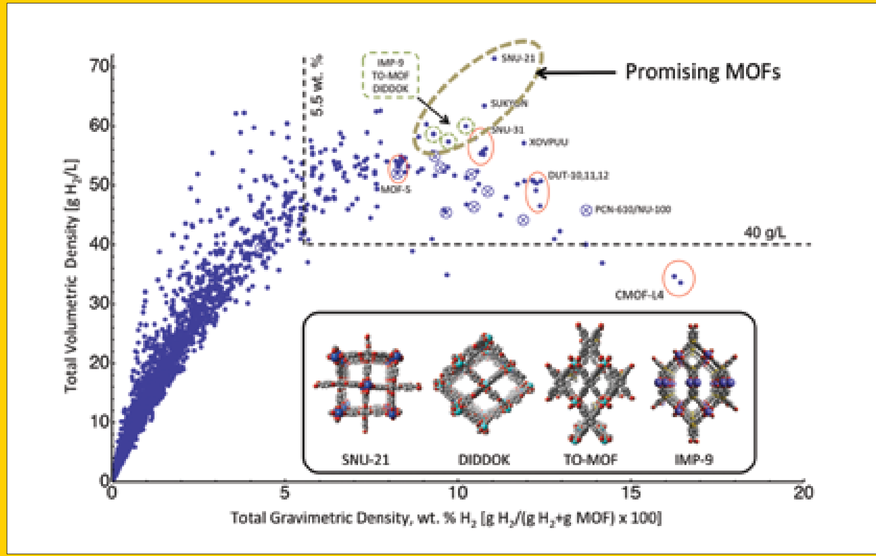


FIGURE 2: High-throughput computational screening of more than 4,000 candidate hydrogen storage materials identifies several "overlooked" MOFs having both high volumetric and gravimetric hydrogen densities. The DOE storage targets are indicated with a dotted line.

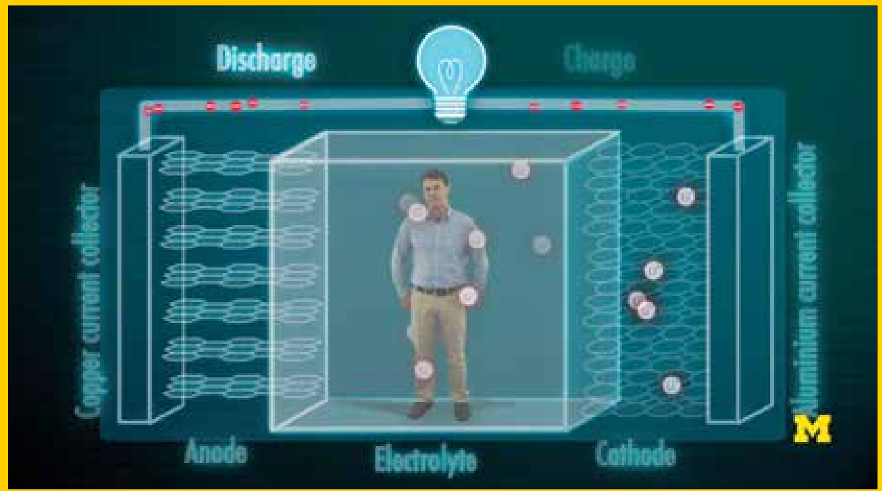


FIGURE 3: Screen-grab from Siegel's YouTube video series, "Batteries of the Future."

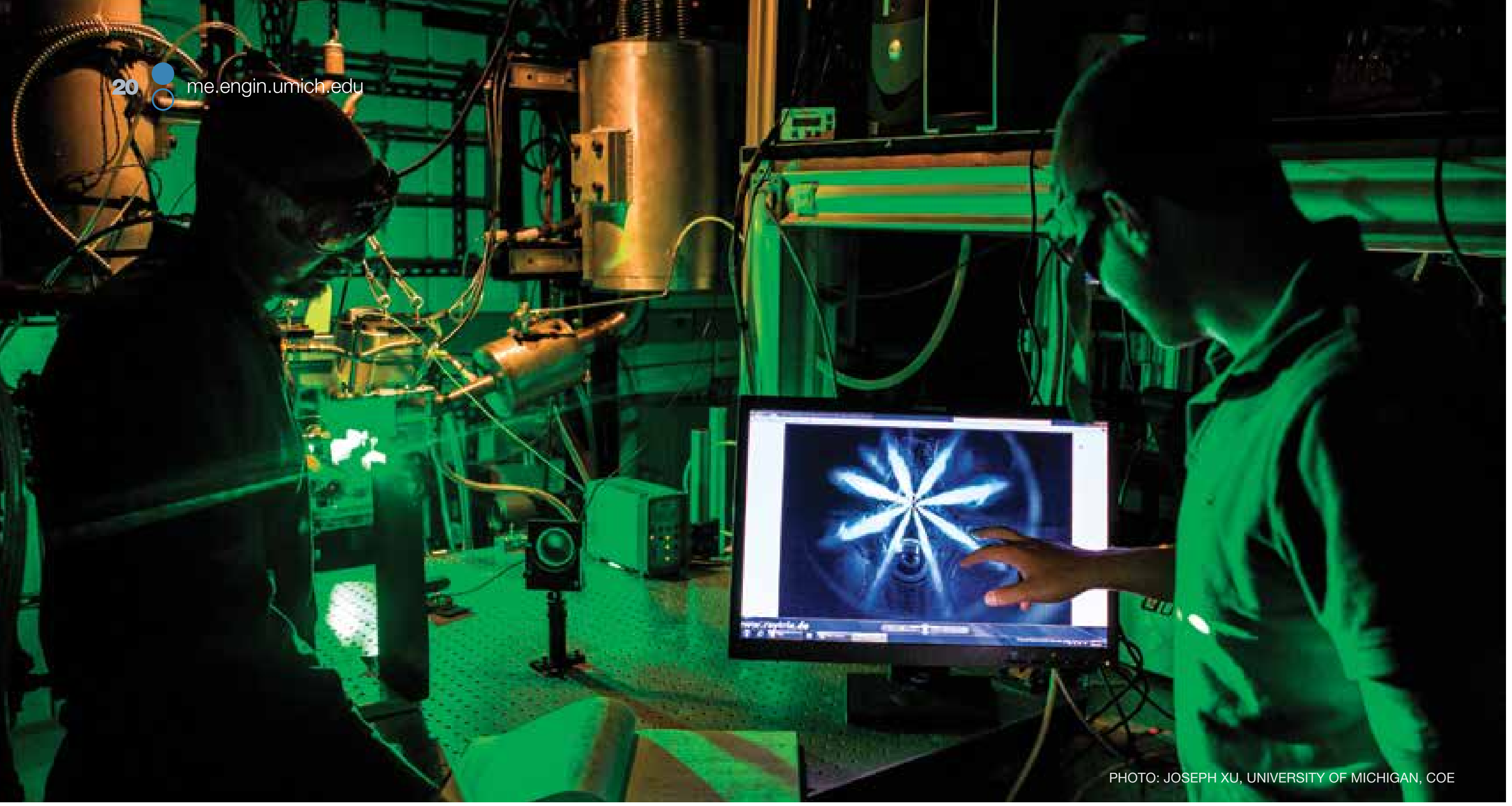


PHOTO: JOSEPH XU, UNIVERSITY OF MICHIGAN, COE

Translating Fundamental and Applied Research into Engineering Practice

Improving Engine Performance

Direct-injection internal combustion engines that run on lean stratified fuel-air mixtures can improve fuel economy, but combustion instabilities limit their broad introduction and use. Cycle-to-cycle fluctuations, or worse, misfires and partial burns, cause excessive emissions since fuel is not burned completely. Novel lean-burn compression-ignition engines can suffer from changes in heat transfer characteristics that also can cause combustion stability problems.

Scientists and engineers still lack a comprehensive understanding of the fundamental processes that lead to such combustion instabilities. Similarly, heat transfer under the transient conditions in engines is not well understood from first principles. As a result, no fully predictive simulation tools exist for engine design, which limits efforts toward ever more efficient and clean engines.

"A key reason for this shortcoming is the scarcity of experimental insights and discoveries, because we lacked the measurement tools needed to observe these fast and randomly occurring processes with the required high temporal and spatial resolution," said Professor **Volker Sick,** who heads the U-M Quantitative Laser Diagnostics Laboratory (QLDL).

Sick and the students and researchers in his lab develop new imaging diagnostics that have been instrumental in showing the underlying physics and chemistry of combustion instabilities. These new tools have enabled fundamental investigations, and the findings are already having a positive impact on engineering practice at General Motors.

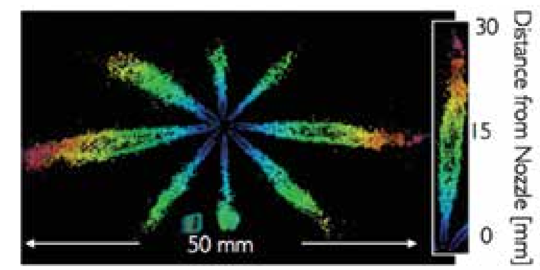
DEVELOPING NEW IMAGING TOOLS

In a joint project with the Fraunhofer USA Center for Laser Technology, Sick's research group developed a technique that allows measurements of the fully three-dimensional structure of the flow field in an operating engine using only a single camera. Initially, this single-camera tomographic particle tracking method was devised by Sick's group to observe flows near the spark plug in order to study misfires. Now, researchers in his lab will adapt the method to have a closer look at the flow near surfaces for heat transfer studies.

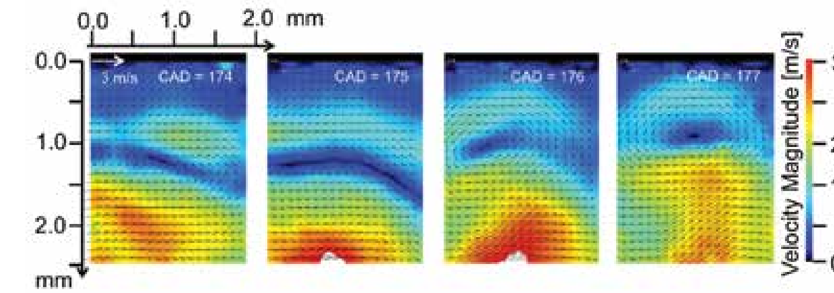
LIGHT FIELD IMAGING OF TRANSLUCENT OBJECTS

In a pilot program, Sick and several students recently demonstrated that plenoptic—also called light field—imaging shows promise for acquiring single-shot images of three-dimensional structures in flow and combustion processes. Plenoptic imaging has been used in the past for the three-dimensional imaging of objects with solid surfaces and is emerging in consumer camera applications. But the technology had not yet been used to image translucent objects, such as fuel sprays and flames for misfires studies, because the required reconstruction algorithms had not been developed.

Now, with funding from the National Science Foundation, Sick's QLDL has teamed up with Professor **Jeff Fessler's** group in U-M's Electrical Engineering and Computer Science department to explore novel algorithms for three dimensional imaging of translucent objects.



A unique new imaging technique to capture the fully three-dimensional structure of a fuel spray in a direct-injection engine.



Flow field at the cylinder head of an optical engine, capturing every crank angle degree, showing structured patterns that will significantly impact heat transfer. The colors show the velocity magnitude, the arrows the direction of the flow.

A FIRST LOOK AT MULTIDIMENSIONAL FLOWS

Using the diagnostic imaging tools developed in Sick's laboratory—and working globally and collaboratively with researchers at Stanford University, Western Michigan University and the Technical University in Darmstadt, Germany—Sick also is conducting fundamental investigations into energy and mass transfer in the transient boundary layers that form in internal combustion engines. This supports the development of heat transfer models for internal combustion engines. Sick's team adapted micro particle image velocimetry for high-speed use in engines, which has enabled a first look into, and early measurements of, the intricacies of the multi-dimensional flow and heat transfer near surfaces in an engine.

The combination of new imaging diagnostics and fundamental research has led Sick to work closely with industry to translate scientific findings into engineering practice. "Through this direct and strong coupling of fundamental research with an industrial application in the General Motors-U-M Automotive Collaborative Research Laboratory (CRL), we are able to swiftly translate basic science knowledge to direct use in industry," said Sick, who serves as CRL co-director.

ADVANCING PREDICTIVE AND 3D SIMULATION CAPABILITIES

A few years ago U-M, General Motors Research and Development and General Motors Powertrain, along with researchers at the University of Wisconsin-Madison and Penn State University, formed the Large-Eddy-Simulation Working Group to advance predictive simulation capability for internal combustion engines. The high-speed imaging techniques from the QLDL were instrumental in providing guidance in improving the group's simulations, and the data from measurements in several optical engines are used to evaluate simulation results.

The U-M 3D Lab in the College of Engineering has recently advanced their Virtual Reality CAVE facility to support the analysis of three-dimensional engine data from experiments and simulations, allowing researchers to literally walk through their data fields and explore and examine the complicated structures that can lead to combustion instabilities.

"Thanks to our strong collaborations and the groundwork laid in the QLDL, we finally are beginning to get a better handle on what causes unwanted cycle-to-cycle fluctuations in engine performance," Sick said.

Sick is leading additional efforts to bring University research in the transportation field to market as academic principal investigator in a new program, co-sponsored by U-M and the Michigan Economic Development Corporation. The Michigan Translational Research and Commercialization program (M-TRAC) works with an oversight committee of industry leaders and venture capitalists to help identify economically viable research and guide it toward start-ups or licensing maturity.

BELOW: Three-dimensional visualization of engine flow in U-M's 3D Lab Virtual Reality CAVE.

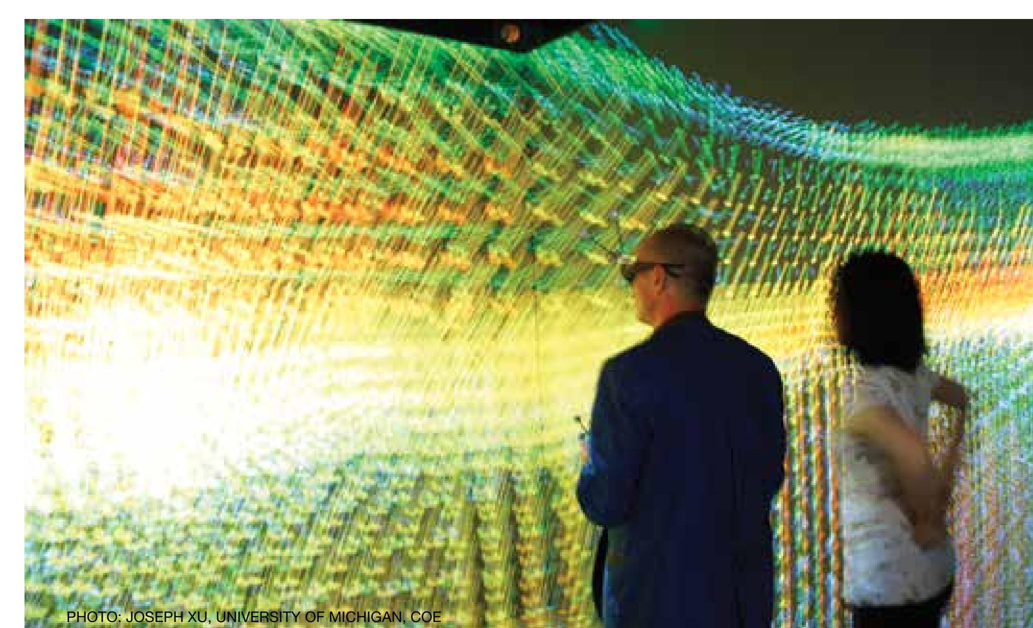


PHOTO: JOSEPH XU, UNIVERSITY OF MICHIGAN, COE

Predicting Materials Behavior Using *Ab-initio* Computations

Understanding and predicting the behavior of materials at both the macro- and nanoscale are critical to developing new materials with specific functional properties, such as lightweight materials with improved strength and fracture toughness.

Although the *ab-initio* (electronic structure) theories investigators use today, including the popular density functional theory, describe materials properties from a quantum mechanical perspective, their complexity makes computations restrictive and often applicable only to very small systems. And since most materials properties are strongly influenced by defects such as vacancies, dopants, dislocations and cracks, investigators must take into account both the electronic structure of the defect core as well as the elastic and electrostatic effects on the macro-scale to gain an accurate picture of material behavior.

"As a result, one longstanding challenge in materials science has been to bridge length scales from quantum mechanics to mechanics in a seamless way," said Associate Professor **Vikram Gavini.**

The research program headed by Gavini and his Computational Materials Physics Group focuses on developing computational and mathematical techniques to address materials behavior on varying length and time scales. His work connects quantum mechanical and mechanics descriptions of materials behavior and is yielding fundamental, predictive and transferable theories. Drawing on ideas from quantum mechanics and homogenization theories to create multi-scale models from fundamental principles, his group has succeeded in providing important insights into the complex behavior of materials.

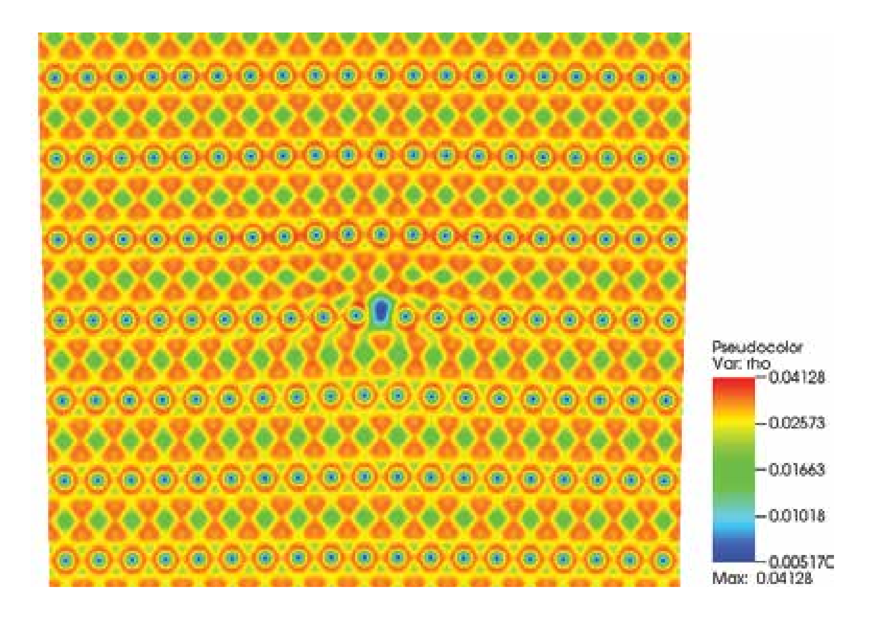
In fact, Gavini and his group have made an accurate quantum-mechanical description of defects possible by developing computational techniques for conducting electronic structure calculations using orbital-free density functional theory on macroscopic scales. This was realized due to their unique and combined use of a real-space formulation, finite-element discretization of the field equations and coarse-graining using adaptive numerical techniques.

Using these techniques, a recent study by the Gavini team on an edge-dislocation (a line defect that governs deformation and failure mechanisms in metals) in aluminum demonstrated, for the first time, strong interactions between the electronic structure of the defect-core at the quantum-mechanical length-scale and the macroscopic deformations on the continuum-scale.

This same study also revealed an additional force on the dislocation arising from quantum-mechanical interactions at the defect-core that can play a significant role in governing the behavior of dislocations in regions of inhomogeneous deformations, and, in turn, the overall macroscopic deformation and failure mechanisms.

Besides developing coarse-graining techniques for bridging length-scales from quantum-mechanics to mechanics, Gavini's group is focusing on developing efficient techniques for explicit large-scale electronic structure calculations. To this end, the group has developed real-space techniques for conducting both pseudopotential and all-electron density functional theory calculations based on the Kohn-Sham formalism. Using these techniques, the team has successfully computed the electronic structure on materials systems of up to 7,000 atoms.

> "One longstanding challenge in materials science has been to bridge length scales from quantum mechanics to mechanics in a seamless way." —VIKRAM GAVINI



Electronic structure of an edge dislocation in Aluminum.

The Gavini team also has demonstrated the scalability of its codes on parallel computing architectures, which makes it possible to leverage available high-performance computing resources to study larger and more complex materials systems.

In addition to using the techniques developed to conduct electronic structure studies on the energetics of defects in materials and their influence on macroscopic material properties, the research group simultaneously is looking at quantum transport in nanoscale systems.

The research efforts in Gavini's group have been advanced over the years by a number of students, including **Phani Motamarri**, **Sambit Das**, **Bikash Kanungo**, **Janakriraman Balachandran** (PhD 2014), **Mrinal Iyer** (PhD 2014), **Balachandran Radhakrishnan** (PhD 2014), **Rohit Jain** (MS 2013) and **Mike Nowak** (BS 2013).

The group's work has been recognized widely. In 2012, Gavini was awarded a prestigious Alexander von Humboldt Fellowship through 2014 and an Air Force Office of Scientific Research Young Investigator Award in 2013. His students, too, have garnered recognition for their contributions. In 2014, Motamarri won the Robert J. Melosh Medal and a Rackham Predoctoral Fellowship in 2013.

Multiphysics Phenomena

Seeking Common Answers to Varied Questions

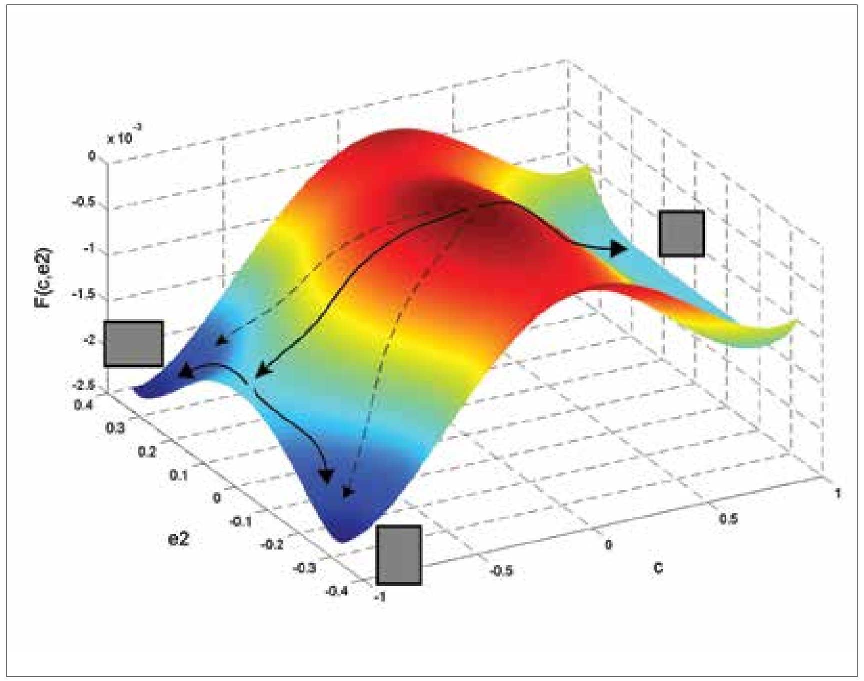
Questions such as how cancer cells proliferate and metastasize, how to improve the strength and durability of lightweight alloys or why an old cell phone battery may appear swollen if you lay it on a flat surface may at first seem unrelated. But the physics phenomena underlying these, and other, questions actually have a great deal in common.

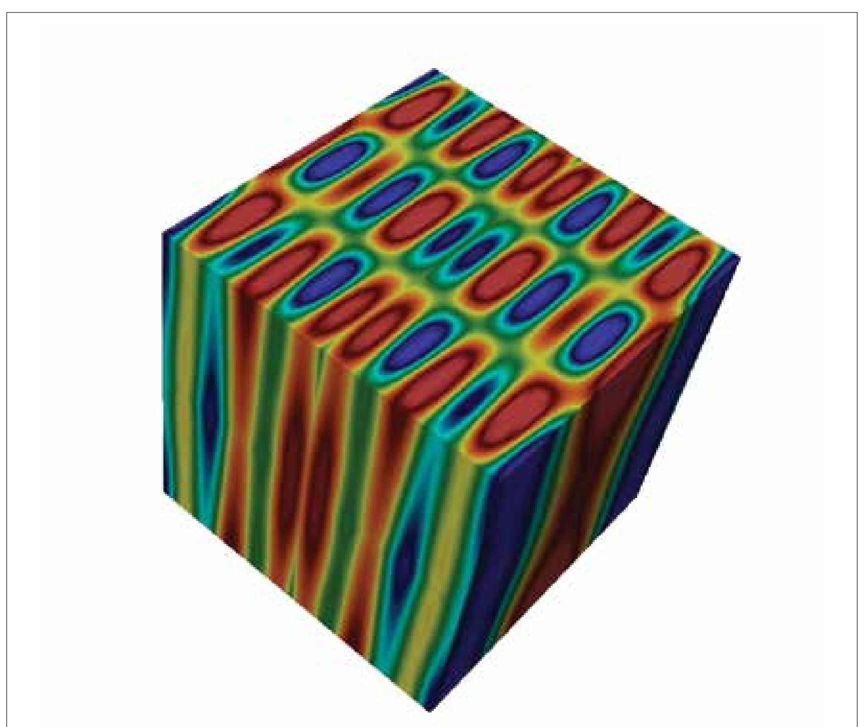
"Scientifically, many of the seemingly disparate questions we ask have similar answers at their root," said Professor **Krishna Garikipati,** who heads the Computational Physics Group at U-M. "The common language we speak is that of multiphysics phenomena."

The physics of biological and nonbiological materials comprise two key application areas for Garikipati's research group. The nonbiological materials his laboratory works with include battery materials and structural alloys used for vehicles, aircraft, buildings and ships as well as for the protective casing of commonly used electronic devices like mobile phones and laptop computers.

These materials are dominated chiefly by mechanical and chemical phenomena, some more well recognized and understood than others. In batteries, for instance, the electrochemical effects are well known, but what has gone underappreciated is the fact that battery electrodes also are subject to physical changes during the charge and discharge processes.

"It turns out that the way electrode materials swell and shrink affects how well a battery works," Garikipati explained. "This deformation happens on a small scale, but the successive changes to the materials lead to microscale mechanical defects like cracks and voids. Knowing that, it's not hard to imagine that these defects affect the efficiency with which a





battery develops voltage, stores a charge and how it recharges."

Garikipati's group explores the full range of physics underlying these phase transformations by developing mathematical models, i.e. the partial differential equations, that govern them. Not surprisingly the models are highly complex. "They can't be solved easily with paper and pencil; you have to solve them computationally." So Garikipati's group also develops the numerical methods required and writes—and shares—the computer code to solve them. "We are strong proponents of the open source movement," he added.

In fact, Garikipati is part of a large center funded by the U.S. Department of Energy to develop advanced open source computational methods and theoretical models to predict materials properties. The PRedictive Integrated Structural Materials Science (PRISMS) Center's investigators are focused specifically on new lightweight structural materials, including magnesium alloys that are strong and resist fracture and failure.

"Previously, the approach would have to have been trial and error, and that takes a very long time. That's why new materials take so long to come to market," said Garikipati. "Instead, we're developing predictive methods—including the models and the computational code—and there's a significant experimental component also. And while we're targeting magnesium alloys as a particular scientific problem, the methods and models are broadly applicable to other materials."

In a second project, funded by the Advanced Research Projects Agency-Energy, and in partnership with GE, Ford and three other College of Engineering faculty, Garikipati is developing models to predict battery performance. As with the PRISMS work, "our methods are more broadly applicable to predicting the mechano-chemo-electro response of other materials, too," he said.

Traditionally, researchers have approached phase transformations in materials from the standpoint of chemistry. "It turns out that mechanical transformation is just as important," said Garikipati, whose group has unveiled new methods that make possible the numerical solution of a class of hitherto unsolved mechano-chemical phase transformation problems. This work has appeared in *Computer Methods in Applied Mechanics and Engineering*, the leading journal in computational mechanics.

"We've been able to present the first general solutions to a class of problems that had been too complex to solve in the past," he said. The new methods will enable the solution of large-scale problems and are expected to lead to significant advances in current numerical approaches.

To underscore the broad applicability of his work across fields, Garikipati encourages his undergraduate and graduate students to work on multiple projects. "Students often share code and teach each other, no matter which application area they work in," he said. "Whether they're working on models and code for biological or non-biological materials, looking at problems from a broader perspective helps them understand them better, and that inevitably means the science is better."

> "We've been able to present the first general solutions to a class of problems that had been too complex to solve in the past."
> —KRISHNA GARIKIPATI

TOP LEFT: The free energy landscape (F(c,e2)) when viewed in composition (c) - strain (e2) space helps understand how certain materials assume specific crystal structures depending on their states. In this example, restricted to two dimensions for ease of visualization, the square crystal structure can transform into rectangular crystal structures of different orientations. Each crystal structure occupies a valley of the free energy landscape.

BOTTOM LEFT: Snapshot of the three-dimensional microstructure that develops as a phase transformation proceeds in a battery material. Each lamina, with yellow periphery/red core or green periphery/blue core, has a tetragonal crystal structure of differing orientations. These crystal structures have been simplified to rectangles in the free energy landscape of the top figure.

Exploring Multiscale Relationships in Advanced Materials

How a material behaves depends both on its macroscale and microscale properties as well as the interactions between them. Understanding those relationships is critical to predicting how structural materials like ceramics and metals will perform under stress.

Associate Professor **Samantha Daly** and the researchers in the U-M Advanced Materials and Mechanics Laboratory (AMML) explore such complex, multiscale relationships. Her research team focuses on functional materials, materials for demanding environments and developing novel methods to characterize materials at small scales.

"Just about any material you can think of is comprised of different structures at multiple length scales," Daly said. "To make accurate predictions about how materials will behave under varied conditions, such as high temperature or very high cycle fatigue, and ultimately to be able to control material behavior, we must understand the interactions between length scales."

A FOCUS ON FUNCTIONAL MATERIALS

Functional materials, in which the materials' mechanical behavior is coupled with outside influences—temperature or magnetic fields, for example—are used in a wide variety of applications. Materials such as shape memory alloys (SMAs) and piezoelectric and magnetostrictive materials are appealing given the distinct properties that arise from the coupling of their inherent mechanical properties with outside forces. Researchers in the Daly lab are working to provide a quantitative understanding of the heterogeneous nature of deformation and failure mechanisms in SMAs across several length scales.

"Connecting deformation mechanisms at different length scales—for example, the interactions between heterogeneous transformation at the microstructural length scale and the observed macroscopic behavior—will help us understand how we can manipulate this material, and others, for optimal use," Daly said.

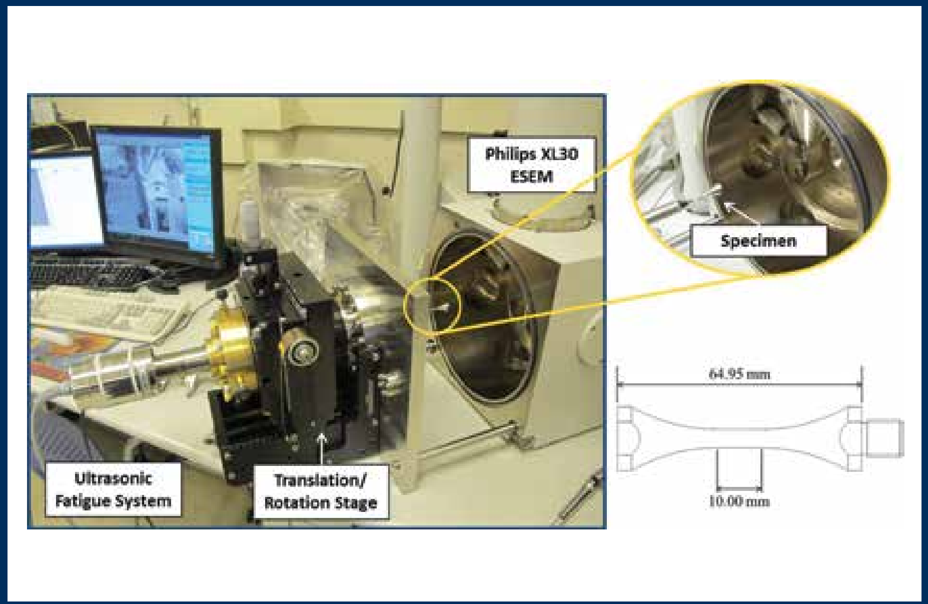
On the macroscale, Daly conducts experimental investigations and models SMAs under different structural modes, including bending, tension and torsion. Recently her group quantified a remarkable similarity in which grain clusters undergo phase transformation and accommodate strain during cyclic loading, among other findings. The paper describing this strain similarity was awarded the 2013 Hetènyi Award for best paper published in *Experimental Mechanics* in 2011. Daly also recently co-authored a paper describing the deformation of SMA cables, which won an award for the best paper published in *International Journal of Solids and Structures* in 2013.

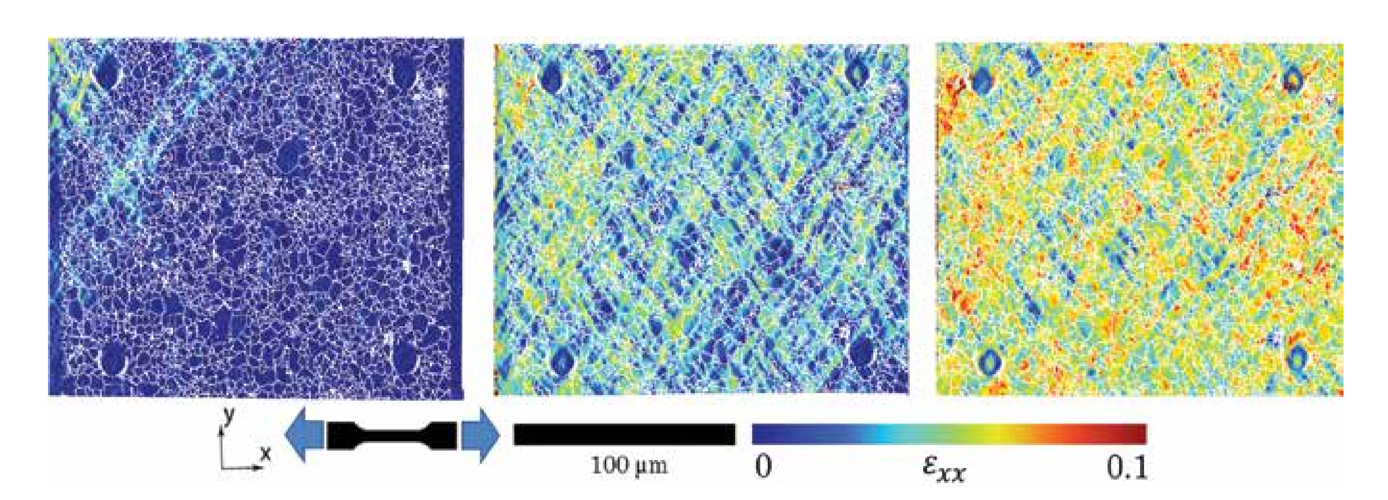
NOVEL IMAGING METHODOLOGIES

To enable the group's efforts to quantitatively map spatial measures of transformation at the microstructural length scale, Daly employs a combination of scanning electron microscopy and a deformation tracking methodology known as digital image correlation.

Building on her experience with these and other methodologies, and based on the initial work of a colleague at the University of Southern California, Daly developed an extremely accurate way to track deformation at the microscale. Carefully combined with in-situ electron backscatter diffraction, she has demonstrated the ability to map strains inside of grains and compare these strains, point-by-point, with the underlying crystallography—down to fields as small as tens of microns.

To achieve the necessary small-scale random tracking patterns, Daly chemically functionalized the surface and created, to the best of her group's knowledge, a pattern with unprecedented spatial resolution. Her technique, published in 2013 in *Experimental Mechanics,* is straightforward, inexpensive, substrate-independent and effective for curved and delicate test samples. She is now using the approach to look at deformation mechanisms in ultrafine-grained pure aluminum, and the work already has led to a number of new findings. **Adam Kammers**, a member of Daly's research team, recently won the Robert M. Caddell Memorial Award for Outstanding Research in Materials and Manufacturing for this work.





"Knowing which microstructural characteristics cause damage accumulation and premature failure of materials can directly lead to better processing approaches and more reliable, more efficient devices."—SAMANTHA DALY

MATERIALS FOR DEMANDING ENVIRONMENTS

Daly's lab is investigating interactions between crack nucleation and propagation and the structural characteristics of ceramic matrix composites at temperatures nearing 1,000 degrees Celsius. And, in a U.S. Air Force project funded through a Young Investigator Program Award received in 2012, her team is looking at the very high cycle fatigue (VHCF) behavior of titanium alloy Ti6242 at cycles on the order of 10^8.

"This is a particularly challenging and fun project, because it involves the creation and combination of several new experimental approaches in order to examine the impact of microstructure on the behavior of materials in the gigacycle fatigue regime," Daly said. "You can't use traditional means, because—as an example—it would take about a year to test one specimen at 50 Hz up to 10^9 cycles."

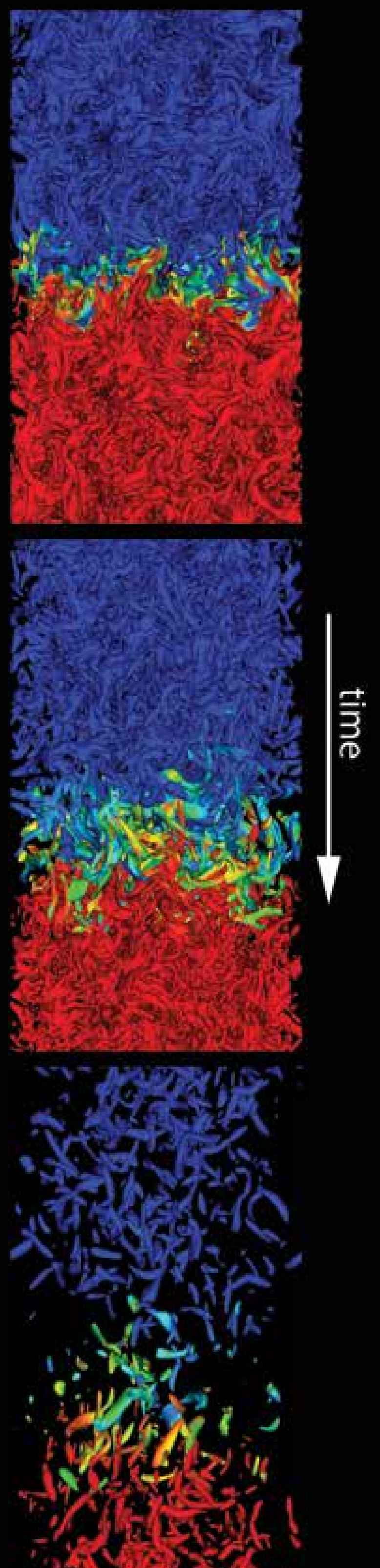
To speed the process and examine microstructural and environmental effects on VHCF crack propagation, Daly collaborated with Professor **J. Wayne Jones** at U-M and Chris Torbet at the University of California, Santa Barbara to create a device that enables ultrasonic fatigue inside a scanning electron microscope. Jason Geathers, a member of Daly's team, won the 2014 Society of Experimental Mechanics Student Competition and the 2014 Society of Engineering Science Student Competition for his work in this area.

Structural materials are used in critical applications ranging from heart stents to high temperature aircraft turbine blades. "Knowing which microstructural characteristics cause damage accumulation and premature failure of materials can directly lead to better processing approaches and more reliable, more efficient devices," Daly said.

TOP: Deformation color map depicting stress-induced phase transformation in Nickel-Titanium proceeding under a globally applied load, imaged at the microstructural length scale. The white lines are grain boundaries indicating regions of different crystal orientations. This analysis was achieved using self-assembled nanoparticles to track deformation during loading inside of a scanning electron microscope.

OPPOSITE: Custom ultrasonic fatigue scanning electron microscope ("UF-SEM") system combining ultrasonic fatigue at 20 kHz with the high resolution imaging capabilities of a scanning electron microscope. The Daly group is currently using this system to investigate the behavior of Titanium aerospace alloys up to 10^7 cycles and beyond.

Extreme Computations of Fluid Flows



LEFT: Isosurfaces of Q-criterion colored with mass fraction.

The work of Assistant Professor **Eric Johnsen** blends the traditional and the modern—core mechanical engineering disciplines of fluid dynamics and continuum mechanics with high-fidelity numerical simulations enabled by "extreme" computing technology. The combination allows him to investigate high-speed and high-energy-density phenomena in the U-M Computational Flow Physics Laboratory, which he directs. The fluid mechanics problems he looks at impact applications that span aeronautics to medicine, astrophysics to naval engineering.

A NEW PARADIGM IN EXTREME-SCALE COMPUTING

"A lot of problems we're interested in require us to develop our own algorithms and codes," said Johnsen. "Although we tend to focus on fundamental problems, no existing software produces results that we think are accurate enough to predict these complex multiscale, multi-physics flows."

To investigate such problems, Johnsen's research team uses high-performance computing, including performing parallel computations with tens of thousands of the "traditional workhorse," central processing units (CPUs). However, "the current paradigm of adding more and more CPUs to speed processing time is just not sustainable. At some point soon, we'll need a mini nuclear plant to power the computing cluster," Johnsen joked. "It's time for a new paradigm for extreme-scale computing, but the new technology means we must rethink how we integrate our algorithms to the hardware."

More recently, Johnsen has begun using graphics processing units (GPUs), processors akin to video cards, with each running about as fast as 100 CPUs. Now he and his group are working with many GPUs, which accelerates processing time tremendously but also poses new challenges—such as communicating information efficiently between GPUs—that his group is working to overcome.

SIMULATING TURBULENT FLOWS

Accurate numerical methods are critical to better understanding high-speed turbulent flows, yet simulating these phenomena is difficult because of the huge span in length and time scales.

"Let's say you're looking at turbulent flow over an aircraft," said Johnsen. "The scale spans tens of meters down to the sub-millimeter, maybe lower. It could be a five or six order-of-magnitude change, and the higher the speed, the larger that difference in scale becomes."

Addressing the challenges involves developing high-order accurate methods for compressible turbulence. His approaches include a variety of solution-adaptive discontinuity-capturing schemes and low-dissipation methods based on finite difference, finite volume and discontinuous finite element frameworks.

"Methods that scale well to extreme computing are especially interesting to us," Johnsen said. "By reducing discretization errors sufficiently, we can resolve all dynamical scales and conduct DNS, Direct Numerical Simulation. Under these circumstances, our simulations produce an 'exact' solution to the equations of motions—albeit numerical." For this reason DNS is an ideal tool to interrogate fundamental flow physics.

One particular application area of this work is mixing during combustion. Instabilities develop at interfaces between different fluids subjected to the accelerations that occur in combustion, ultimately leading to mixing. "We want to know how different fluids mix in these high-speed turbulent flows, since this directly impacts the combustion process and fuel efficiency," Johnsen said.

Direct numerical simulation is generally too computationally expensive for design purposes. More commonly, multiscale methods are used, such as large-eddy simulation (LES), in which large-scale features are resolved on the computational mesh, and the subgrid-scale dynamics are modeled.

Johnsen works with Ford Motor Company and colleagues in U-M's departments of Naval Architecture and Marine Engineering and Aerospace Engineering to improve fuel economy by reducing vehicle drag using LES. Vortex generators, placed in strategic locations, energize airflows over vehicles so the flow more closely follows the contours of the car. This reduces the low-pressure regions that cause drag. But what size and shape are optimal? How should they be arranged on the vehicle? Those are the questions Johnsen and his students are answering.

HARNESSING THE EFFECTS OF CAVITATION

Flows around underwater objects create regions of varying pressures. When pressure drops by a sufficient amount, cavitation bubbles form. Their rapid growth, to many times their original size, and collapse produce shock waves that interact with neighboring solid surfaces and cause erosion. Johnsen's group is looking at cavitation erosion of modern materials such as composites and polymeric coatings as part of his Young Investigator Award from the Office of Naval Research. He also has been trying to understand, and potentially make use of, its destructive aspects in therapeutic applications.

Ultrasound-induced cavitation is used in lithotripsy, to destroy kidney stones, and in histotripsy, a technique pioneered at U-M to destroy pathogenic tissue in conditions such as prostate cancer. Johnsen and colleagues in U-M's Radiology department are also looking at the potential for stabilized microbubbles to enhance contrast during cardiac imaging. And the dynamics of cavitation bubbles may play a role in traumatic brain injuries that result from blasts.

"The big hurdle in these applications is that we don't know how tissue behaves at the very fast rates of cavitation and shock waves. The knowledge we've acquired about cavitation in water does not directly translate to tissue," said Johnsen, who received a National Science Foundation CAREER Award in 2013 for his work in this area (see related story on page 10).

"At the end of the day, we're developing general theoretical and computational frameworks to study fundamental problems that have widespread applications in science and engineering," Johnsen said. Gaining insights and having an impact on society are important to him, and he finds working with such a talented group of student-researchers one of the most rewarding parts of his job.

"Students at U-M are outstanding: In many cases, all they need from me is a slight nudge to take the research to places I wouldn't have imagined. In addition to great graduate students, I work with fantastic undergraduate researchers, who regularly present and publish at conferences and in scientific journals. Getting to interact with such smart people on a day-to-day basis is a real privilege."

ABOVE: Shock-induced collapse of a bubble near a rigid surface. The incoming shock wave (moving right to left) in water interacts with a preexisting gas bubble and causes its collapse. High pressures and temperatures are achieved during this process, leading to potential structural damage to the neighboring solid (on the left side). This mechanism is thought to play a critical role in cavitation erosion to propellers, in high-intensity focused ultrasound and in certain traumatic brain injuries.

> "The current paradigm of adding more and more CPUs to speed processing time is just not sustainable. It's time for a new paradigm for extreme-scale computing, but the new technology means we must rethink how we integrate our algorithms to the hardware." —ERIC JOHNSEN

Discovering Opportunity, Advancing Manufacturing

As several recent national initiatives underscore, manufacturing innovation and competitiveness are key priorities for the United States. Professor **Jun Ni** conducts highly interdisciplinary research that advances important areas of manufacturing: process innovation, system design modeling and optimization and intelligent maintenance. Integral to his research are strong industry collaborations, which help ensure the findings from his group's work are translated into real improvements on manufacturers' factory floors.

"We continually pursue excellence in manufacturing," said Ni, who directs the S.M. Wu Manufacturing Research Center at U-M. "The three key goals are to produce higher quality products faster and with less cost. New materials, innovative product designs, new manufacturing processes—these can all improve quality while speeding production time and lowering cost."

FINDING HIDDEN OPPORTUNITIES

Equipment maintenance has been one longstanding bottleneck in the manufacturing industry and a source of expense and frustration. How to keep manufacturing systems running smoothly and productively with minimum down time is a critical question still facing manufacturers.

"Down time is very costly. Every minute machines sit idle can cost a company tens of thousands of dollars. Scheduling maintenance during non-production times is one option, but then that increases labor and overhead costs," said Ni, who develops intelligent maintenance and decision support tools to analyze system design and optimize production—both to sharply reduce down time and also to bring unrecognized opportunities to light.

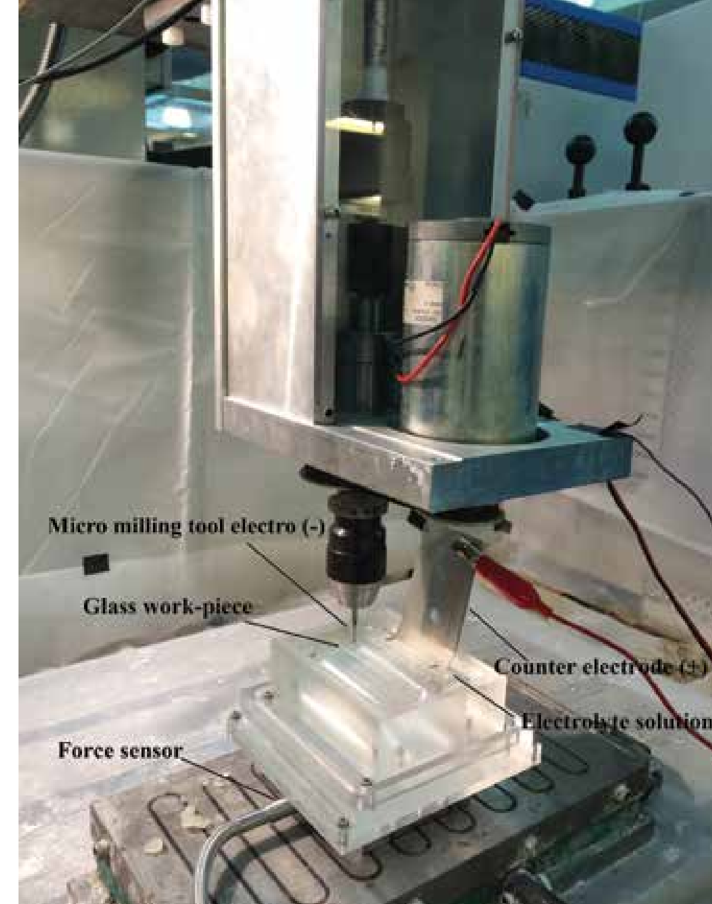
Ni and his research group have developed decision support systems—algorithms and software that monitor system performance in real time, predict machine degradation and proactively plan for maintenance without affecting production—for both GM and Ford Motor Company. Ni's work for GM earned his team a Kettering Boss Award, the company's highest recognition for innovation and technology implementation, in 2005, 2006 and again in 2008.

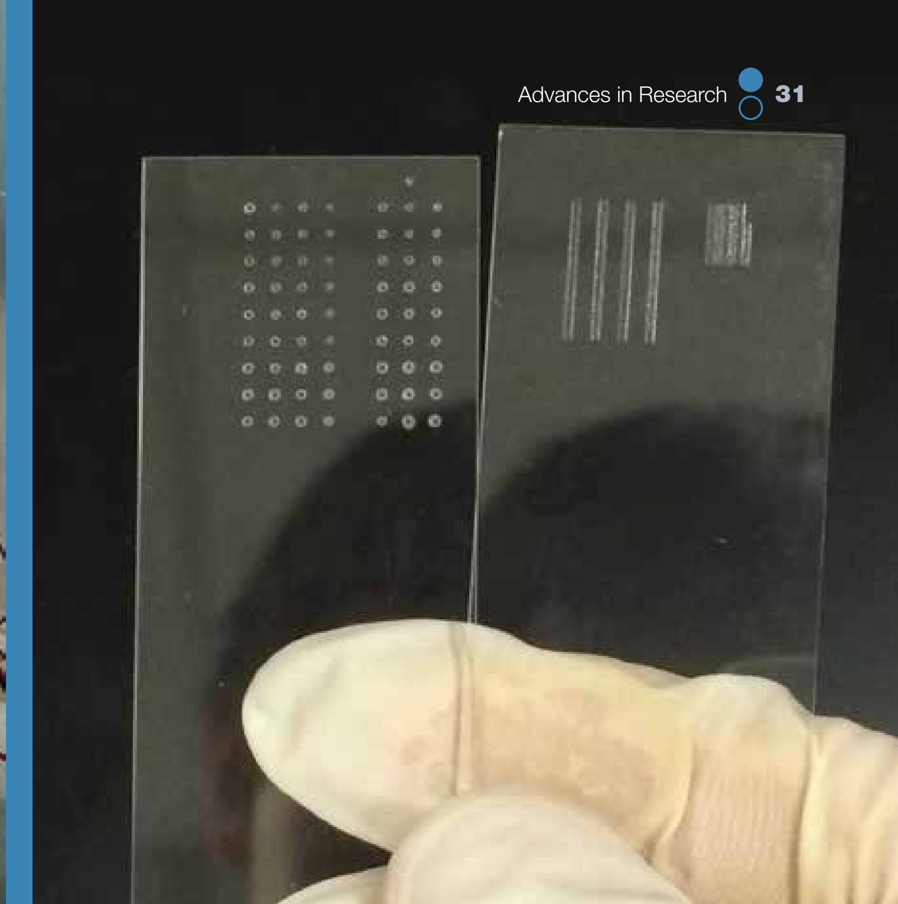
For Ford's Michigan Assembly Plant, Ni's intelligence maintenance work was incorporated into the Focus vehicle launch, and a decision support system he developed is used to analyze maintenance window opportunities and strategically identify times for work to be completed without affecting production. His contributions and their significant economic impact made this work a finalist for the company's Henry Ford Technology Award.

"If you don't have this kind of intelligence and equipment breaks down in the middle of production, your whole [assembly] line goes down. Just troubleshooting the problem can take a lot of time, and then parts might have to be ordered, which takes more time. It all costs money. But there is a lot of hidden opportunity, times where you can strategically shut down select processes at select times to carry out scheduled as well as unplanned maintenance without affecting throughput," he said.

LEFT: Experimental testbed for electrically assisted friction stir welding (FSW).

RIGHT: FSW welded specimen of Aluminum alloy Al6061 joined with advanced high strength steel: TRIP steel.





LEFT: Experimental set-up for elelctrochemical discharge assisted machining process.

RIGHT: Image of drilling/milling soda-lime glass workpiece samples.

Another area of Ni's research focuses on developing novel manufacturing processes and new ways of processing, cutting, joining and forming different materials, including lightweight metals. (Ni serves as a research pillar coordinator for novel processing of the new American Lightweight Materials Manufacturing Innovation Institute; see related story on page 12). Recently, in work published in *Materials & Design,* he demonstrated that a lightweight aluminum alloy could be joined with a type of advanced high-strength steel using friction stir welding to improve toughness, strength and tool life.

In another research effort Ni and his students are developing, and working closely with industry to implement, high definition metrology (HDM) systems to detect early changes in process conditions that manifest as abnormal variations on part surfaces. Data from HDM is invaluable, but current systems are inefficient and pose several challenges.

Ni's research team has developed algorithms and methods to detect and control surface variation as well as a framework for monitoring surface variation using HDM data. The results will help shift the paradigm of quality control based on dimensional variation to controlling surface shape variation. The algorithms are relevant to many high-precision manufacturing processes.

"We're working closely with industry to implement our system," Ni said. "As in a lot of the manufacturing work we do, collaboration and joint development are critical."

"We're working closely with industry to implement our system. As in a lot of the manufacturing work we do, collaboration and joint development are critical." —JUN NI

Biomedical Design and Manufacturing

Applying Advanced Manufacturing to Healthcare

"Healthcare is a new frontier of advanced manufacturing research," according to Professor **Albert Shih,** who is part of the Biomedical Design and Manufacturing Lab of the S.M. Wu Manufacturing Research Center (WuMRC) at U-M. "We want to help improve the safety, efficiency and dignity of healthcare for our future aging society."

It's a tall order: By 2030, individuals older than 65 will comprise one-fifth of the U.S. population. And a key challenge, Shih said, is to "innovate so that people can adopt assistive devices that help them to continue living independently and to maintain mobility."

3D PRINTING CUSTOM BRACES AND ORTHOSES

Due to a higher incidence of diabetes and stroke, as well as aging, the need for orthoses will reach 10 million by 2020, up from five million in 2011. The three most common types of orthoses—foot, ankle-foot and thoracolumbosacral—account for approximately 95 percent of all orthoses made at the U-M Orthotics and Prosthetics Center.

Custom orthotics far outweigh "off the shelf" devices in terms of quality, but they cost more, require labor-intensive fabrication and need multiple clinic visits to make them to fit individual patient geometries and gaits.

Using the additive manufacturing technique known as 3D printing, **Roland Chen,** a research fellow at the WuMRC, is working to improve the process. His objectives include reducing process time to one patient visit, enabling greater design flexibility and improving the quality of orthoses.

Chen and his colleagues have discovered faster 3D printing techniques for stronger orthoses and optimized design based on measured strain over the gait cycle. Although additive manufacturing is a "powerful tool," he said, "we also face many challenges."

Minimizing the support structure required during printing to reduce 3D printing time and cost and the need to use multiple software programs during the process are two obstacles Chen currently is addressing. He and Shih collaborate with Stratasys, Altair, the U-M Orthotics and Prosthetics Center and the VA Ann Arbor.

"Together, we're working to come up with a transformative manufacturing system that's efficient and user-friendly for clinicians and that gives patients a better, customized assistive device in one clinic visit," Chen said.

IMPROVING THE MANAGEMENT OF VENOUS RETURN

Advanced manufacturing process monitoring methods are readily applicable for noninvasive diagnosis in healthcare. Clinicians who work in critical care and emergency situations must make quick and accurate assessments of venous return—that is, how much blood flows back to the heart—in the vulnerable patients they care for. To manage low venous return, the standard of care is administration of intravenous fluids to increase central venous pressure. But too much intravenous fluid can also be dangerous, so careful management is crucial.

To gauge venous return, currently healthcare providers rely on the age-old physical exam, listening to the heart and lungs, or they use an invasive procedure whereby they can monitor central venous pressure from the superior vena cava or pulmonary artery. But the procedure requires much training and is not without high complication rates. And still, it doesn't provide a full and accurate picture of venous return. Recently, clinicians and physiologists have turned to real-time ultrasound to image the movement of the inferior vena cava wall during breathing to estimate venous return and guide treatment. But this, too, has limitations.

Now, **Barry Belmont,** a PhD student researcher in Shih's lab, is investigating the potential of using bioimpedance measurements of the arms and legs to ascertain venous return. The noninvasive technique relies upon changes in the fluid volume of blood vessels in the limbs in response to breathing. With dynamic respiratory impedance volume evaluation, or DRIVE, Belmont and his colleagues in the Department of Emergency Medicine have shown that the changes in limb impedance parallel changes in the inferior vena cava previously noted with ultrasound.

"The data show that with DRIVE, the extent of fluid deprivation can be accurately measured in critically ill patients," said Belmont, who envisions a portable, low-cost system for real-time and continuous patient monitoring of venous return.

"If a patient needs fluids to help with venous return, doctors would be able to diagnose not only the correct amount, but monitor how effective the treatment is as it happens," Belmont said.

TRANSLATION OF HOLE DRILLING IN AUTOMOTIVE TO ORTHOPAEDICS

In a two-part project, **Bruce Tai,** a WuMRC research investigator who will join Texas A&M University as an assistant professor, has worked with Ford Motor Company to reduce dimensional errors that result from heat generation during deep-hole drilling engine blocks.

Tai has developed an inverse heat transfer method and a drilling thermal model to calculate and localize heat generation during drilling and to visualize the temperature within and on the surface of parts. The method enables researchers to look at temperature distribution over time and from different drill designs and drilling processes in order to predict potential part distortion.

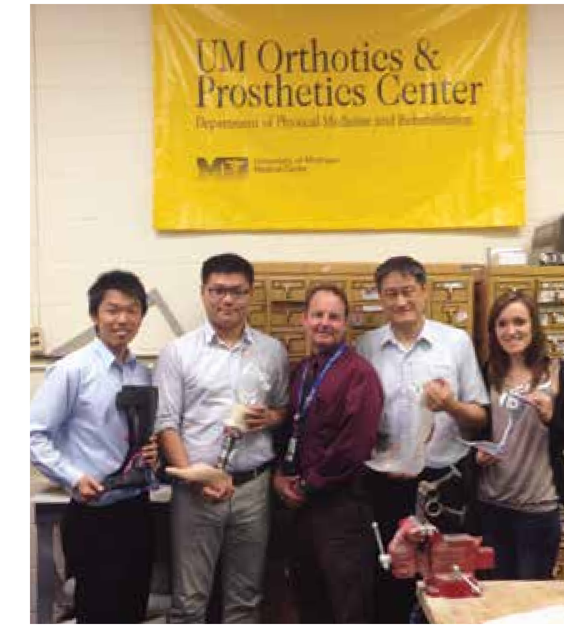
Now Tai is applying this work to bone drilling in orthopaedic surgery and neurosurgery. Skull-based brain tumors that were inoperable 20 years ago now can be treated endoscopically with high-speed drills. But the process creates a lot of heat, which increases the risk of stroke or permanent damage to neighboring neurovascular tissues.

In response, Tai has developed a cooling technique and specialized nozzle for surgical bone drilling. Experimental results show that the technique reduces temperature at the drilling site more effectively than conventional saline irrigation and improves the surgeon's view.

Tai and his colleagues also have created a novel bone drill for orthopaedic surgeons. With the optimized design, the new tip design reduces force and torque, helps evacuate bone debris and consequently lowers temperature at the surgical site.

Shih's group has made a number of other innovations: active and easy ingress and egress rehabilitation equipment in collaboration with NuStep; models and analyses to help reduce pressure ulcers in bed- or wheelchair-bound patients; clinical simulators for medical education; needles for newborns; high yield needle biopsy devices and many others.

"There are so many lessons to be learned from advanced manufacturing that we can apply to healthcare to improve the quality of life for patients and, at the same time, enable independent living and a high quality of care for our aging society," Shih said.



TOP: Roland Chen, Lei Chen, Jeff Wensman, Professor Albert Shih and Adrian Wolff with 3D printed orthoses.

BOTTOM: (from left) Professor Albert Shih, NuStep CEO Dick Sarns and Matt Weber, who points to a new design inspired by the collaboration with U-M to assist ingress and egress of the T4 rehabilitation device for people with disabilities.

OPPOSITE PAGE: (from left) Bruce Tai, Dr. Andrew Palmisano (orthopaedic surgery resident), Dr. James Holmes (orthopaedic surgery faculty) and Professor Albert Shih with the bone drilling test machine at the Biomedical Design and Manufacturing Lab.

Practicing Prevention

Understanding the Biomechanics of Injury

Prevention of unintentional injuries and their often-serious consequences is the vision guiding the work of **James A. Ashton-Miller,** the Albert Schultz Collegiate Research Professor and Distinguished Research Scientist. Ashton-Miller directs the Biomechanics Research Laboratory at U-M and works to understand the biomechanical mechanisms underlying injuries in order to better prevent them. His work applies to injury prevention in many areas, including injuries to the mother during childbirth, falls in the elderly and sports injuries.

RECOGNIZING THE LINK BETWEEN LIMITED HIP ROTATION AND KNEE INJURY

One of Ashton-Miller's doctoral students, Melanie Beaulieu, and the rest of his team recently won the prestigious American Orthopaedic Society for Sports Medicine Cabaud Memorial Award for their research into whether a maladaptation that limits internal hip rotation, a condition called femoro-acetabular impingement, increases strain on the knee's anterior cruciate ligament (ACL) during landing maneuvers, thereby upping the risk of injury.

"Good athletes need their full range of motion to be as quick and nimble as they are, but using an extreme range of motion in certain movements is not always without consequences," noted Ashton-Miller.

Upon learning of the high rate of restricted internal hip rotation among NFL Scouting Combine participants who had undergone ACL reconstruction, Ashton-Miller developed a hypothesis: Internal hip rotation restriction compared to a normal hip motion during a pivot landing can increase ACL strain at the knee.

Using a custom testing apparatus his team developed, Ashton-Miller, Beaulieu and orthopaedic colleagues, Drs. Edward Wojtys and Asheesh Bedi, simulated a series of pivot landings in 10 male and 10 female knee specimens. The results showed that for every 10-degree decrease in internal hip rotation, the knee's ACL strain increased 1.3 percent, representing a 20 percent increase in peak relative strain.

As a result, "screening athletes for limited internal hip rotation has the potential to prevent ACL injuries and become part of injury prevention programs, particularly in young people who play volleyball, football, basketball and soccer," Ashton-Miller said.

The paper describing the findings has been accepted for publication in the *American Journal of Sports Medicine*.

In related work, Ashton-Miller's lab is the first to show that the ACL can exhibit low-cycle fatigue failure, rupturing after fewer than 50 severe loading cycles of knee compression combined with flexion and internal tibial torques. Conventional thought has been that a single unusually large or awkward load is what causes the ligament to tear.

"Trainers, coaches, athletes and parents need to know the ACL has a limit; it can only tolerate so many severe loading cycles before it will fail, so athletes need to train and be trained wisely," said Ashton-Miller.

Additionally, the research shows that failure often occurs at the point where the ACL arises from the femur, so his group is working on understanding why.

"Magnetic resonance and other imaging doesn't yet have good enough resolution to reliably spot a ligament beginning to tear there, but our computer modeling points to that spot as being susceptible," said Ashton-Miller. "Eventually imaging will give us the images we need, but we are working on other ways to prevent ACL tears so as to head off the knee osteoarthritis they can cause later in life."

SEEKING INSIGHTS INTO HUMAN REACTION TIME

Human reaction time plays a key role in injury prevention. In collaboration with Drs. **James Eckner** and **James Richardson**, physical medicine and rehabilitation specialists at U-M, Ashton-Miller has invented, and U-M has patented, a simple clinical screening device to measure reaction time. They are using it to help determine whether student-athletes are ready to return to play following a concussion. A player who returns too soon and sustains a second concussion before the first has resolved can suffer permanent brain damage.

In a 2011 analysis of data from sprinters competing in the 2008 Olympic Games in Beijing, Ashton-Miller showed that what had long been believed to be a gender difference in reaction time between men and women was not likely the case after all.

The results, published in the open-access journal *PLOS ONE*, showed that men reacted in as little as 109 milliseconds, and women in as little as 121 seconds, to the starting gun. But the difference, Ashton-Miller and his student **David Lipps** proposed, may have been due to a systematic flaw in how the women's reaction time was measured.

Both men and women sprinters' reaction times were apparently being calculated using the same force threshold—the pressure athletes exert against the starting block as they start to run upon hearing the starting gun—despite women having 22 percent less muscle strength than men. If the force threshold were lowered for women by about 20 percent, he posited, reaction times would be similar.

Ashton-Miller and Lipps have subsequently conducted similar analyses using data from the 2012 London Olympics to determine whether this flaw has been corrected, and the findings are pending publication. The research also suggests to Ashton-Miller that applying the findings to automotive brake systems could be a smart application.

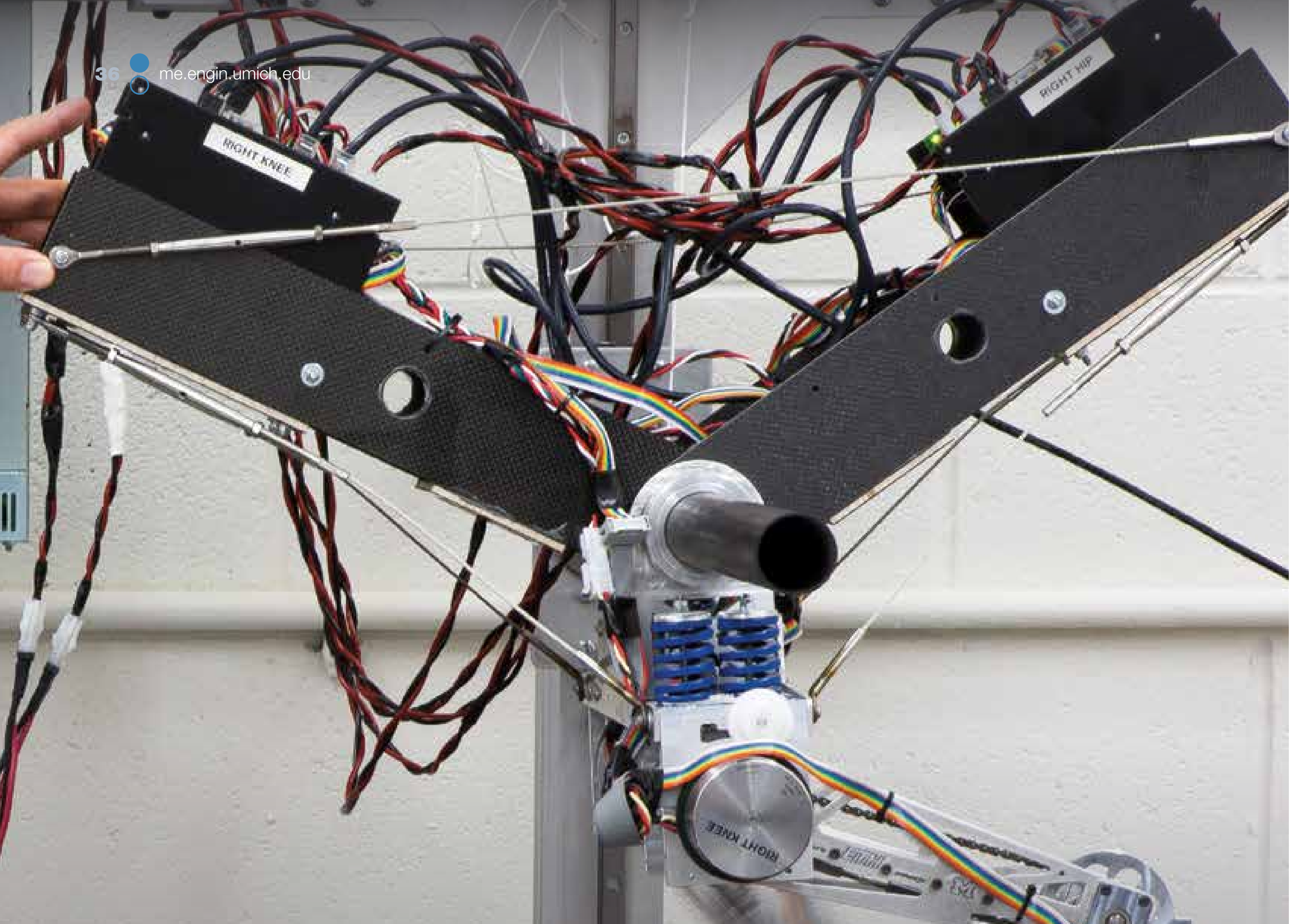
"If manufacturers reduced the requisite brake pedal force by 20 percent for women, this would allow women to minimize their reaction times and brake as quickly if not more quickly than men," he said.

> "Good athletes need their full range of motion to be as quick and nimble as they are, but using an extreme range of motion in certain movements is not always without consequences." —JAMES A. ASHTON-MILLER

A: The QuickStick clinical reaction time measurement device.

B: The tester, Dr. James T. Eckner (Physical Medicine and Rehabilitation), at left, preparing to test Dr. Ashton-Miller's recognition reaction time.

C: In this trial, the onboard light cue came on, so the testee has to respond by catching the falling QuickStick as quickly as he can. If the light cue did not come on, which happens randomly in 10 of these 20 trials, he would try to inhibit his response and allow the device to fall. This is easier said than done as one gets older, or in certain diseases and conditions, because of increasing difficulty with inhibiting motor actions. The device records the reaction times as well as the accuracy with which the testee correctly responds to the light cues. (Reprinted with permission from Psychological Assessment, 2012).



Natural Dynamics and Robotic Locomotion

Roboticist and Assistant Professor **David Remy** uses the description of a simple experiment to help illustrate a key concept underlying his work. "Let's say I have you climb onto a treadmill and walk while I use electromyography (EMG) to measure your muscle activity. You would expect to see a lot going on since your entire body is in constant motion—your legs are moving back and forth, your arms are swinging, your torso is twisting. You'd expect to see that your muscles are doing a lot of work."

But that is not the case.

"When looking at the EMG readings, we would see that your muscles aren't really doing much," explained Remy, who joined the U-M faculty in 2012 and directs the Robotics and Motion Laboratory.

That's due to the natural dynamics of the human body. Legs swing as if they were mechanical pendulums, driven by inertia and gravity. The arms follow. Muscles and tendons create elastic oscillations. In short, mechanical dynamics create most of the motion, allowing us to walk almost effortlessly.

"We're a system that's extremely well built for walking," said Remy, whose goal is to exploit these natural dynamics in legged robots and in rehabilitative devices for humans.

In a current project, Remy is conducting a simulation study to understand the role of different gaits in legged locomotion. In nature, using different gaits allows us to save energy. Think of a human walking faster and faster; at some point, it feels easier to break into a run.

"When you walk, your legs are like pendulums," Remy explained. "When you run, your knees are bent, and your legs act more like springs. Each creates a different set of natural dynamics and is better exploited at a different locomotion velocity."

A similar idea holds true in horses and other quadrupeds that have an even wider variety of gaits than bipeds. "Our hypothesis is that this is an effect of the natural dynamics," he said.

With the help of a numerical optimization algorithm, Remy and his students identified energy optimal gaits for computer models of bipedal and quadrupedal robots. That is, the computer automatically identified the best possible way in which the robots could move.

> "These differences are particularly interesting, since they tell us what we have to change when transferring nature's principles to robotics."
> —DAVID REMY

The team found that, just as in humans, it makes sense for a bipedal robot to switch gaits. "The optimization algorithm discovered that the robot should transit from walking to running at a particular velocity to minimize energy, just as a car switches gears," Remy said. In quadrupedal robots, the team found that, similar to horses, robots transitioned from walking to trotting to save energy.

Remy also found intriguing differences. In a bipedal robot, he noted an intermediate gait with the footfall pattern of walking but the elastic energy storage of running. In quadrupedal robots, unlike horses, his robotic models were more efficient when trotting rather than galloping, even as velocity continued to increase.

"These differences are particularly interesting, since they tell us what we have to change when transferring nature's principles to robotics," Remy said, "for example, to account for a robot's rigid main body as opposed to a horse's flexible spine."

In related work, Remy is now looking more closely at how gaits are generated. His research group simplified its models as much as possible while still producing realistic motions. The simplest model remaining consisted of four massless springs and a connecting rod.

"Even with this much-simplified model, we were still able to generate all the gaits you find in nature—walking, trotting, tölting [a gait used by small horses], bounding, pacing," Remy said. "This brings us another step closer to understanding what gaits are and how we can exploit them in robotics."

The next step is to move from simulations to studies in a real bipedal robot, RAMone, which has high-compliance elastic actuators that enable a wide range of natural dynamic motions.

A member of a Rehab-Robotics Cluster at U-M, Remy is also interested in human locomotion. He's currently exploring whether humans, too, can be "optimized." In a recent study, he asked research volunteers to walk on a treadmill to a metronome beat. While they walked, he and his team measured oxygen consumption and carbon dioxide production to determine how much energy subjects were using. The metronome beat varied from slow (long, less frequent steps) to fast (short, quick steps).

"When you look at energy consumption," said Remy, "you see a U-shaped curve—high energy consumption at low frequencies and high energy consumption at high frequencies but low in the middle, another consequence of the natural dynamics. If we turn off the metronome and let you walk at your normal pace, your steps would be dead on the minimum of that curve because you're trying to walk as efficiently as possible."

Remy's team then took real-time measures of human oxygen consumption and implemented an optimization algorithm in which a computer found the most efficient step frequency automatically. He compared that to subjects' own self-selected step frequency without the metronome. "We are very close," he said, "which demonstrates that we can optimize a parameter, in this case step frequency, to minimize energy consumption."

Remy's experiments mark the first time researchers have conducted such an optimization in real time.

Remy's work continues toward a longer-range vision. "Imagine someone wearing an exoskeleton, prosthesis or other assistive device. Imagine the device motor has a controller, and the controller has a set of parameters that the user has to tune. You could use the same method that we used to find optimal parameter values so the assistive devices could automatically adapt to a disabled user and provide optimal support."

OPPOSITE PAGE: Testing RAMone, the new robot created by Assistant Professor David Remy's research group, Robotics and Motion Laboratory (RAMLab).

RIGHT: Jeff Koller, Mechanical Engineering PhD student, demonstrates use of the exoskeleton project that is being constructed in the Robotics and Motion Laboratory headed by Assistant Professor David Remy.

Modeling and Improving Human-Robot Interactions

Teleoperated ground robots have the potential to save human lives both in military operations and in post-disaster search and rescue missions. They can spare soldiers and first responders from crawling around in cramped, dark and dangerous environments, and they can help locate survivors. But teleoperated robots, and their human operators, also have a number of limitations that hinder widespread use.

"When you have a human operator in the loop who has no visual contact with the robot, the operator has to rely on video feedback to make decisions about how to direct it next," said ME Professor **Dawn Tilbury,** who also chairs the steering committee for a new College of Engineering initiative in robotics. "Figuring out exactly where the robot is, what it's doing and how to control it is very hard to do when you can't see it."

Part of the problem is communications latency, or the time delay caused by the wireless link. Other hindrances include limitations of the robot's speed, inefficient human-robot interactions and human shortcomings related to decision-making, reaction time and control of a manipulator arm using a basic joystick.

To help more fully realize ground robots' potential, Tilbury works to increase the speed and efficiency of teleoperated robots. Toward this objective, she has developed a framework for characterizing, modeling and understanding the major factors that limit performance, defined as speed, accuracy and safety.

In one project, Tilbury developed and assessed novel interfaces, or input devices, for the human operator. Her research group conducted user studies—students teleoperated a mobile manipulator using a simple joystick or a master-slave manipulator arm—and analyzed the data. The findings showed that the master-slave manipulator arm helped novice users significantly more than it helped experienced users; in fact, experienced users were faster using the joystick. "This surprised us," she said. "We would have thought the master-slave manipulator arm would have helped all users."

From there, Tilbury's team began developing a user model to describe how people behave while teleoperating a mobile robot. "In the automotive industry, there are well-established driver models that describe how the driver responds to turns and obstacles in the road; similarly, we wanted to develop a model of the user teleoperating the robot."

Using a different set of user tests, Tilbury and her group created a simple transfer function model—likely the first-ever driver model for robotic teleoperation—that incorporates measures of performance time and accuracy. The model will be useful to understand how well a human-operated robot can perform certain tasks rather than having to conduct actual tests with humans, which costs significantly more and takes much longer.

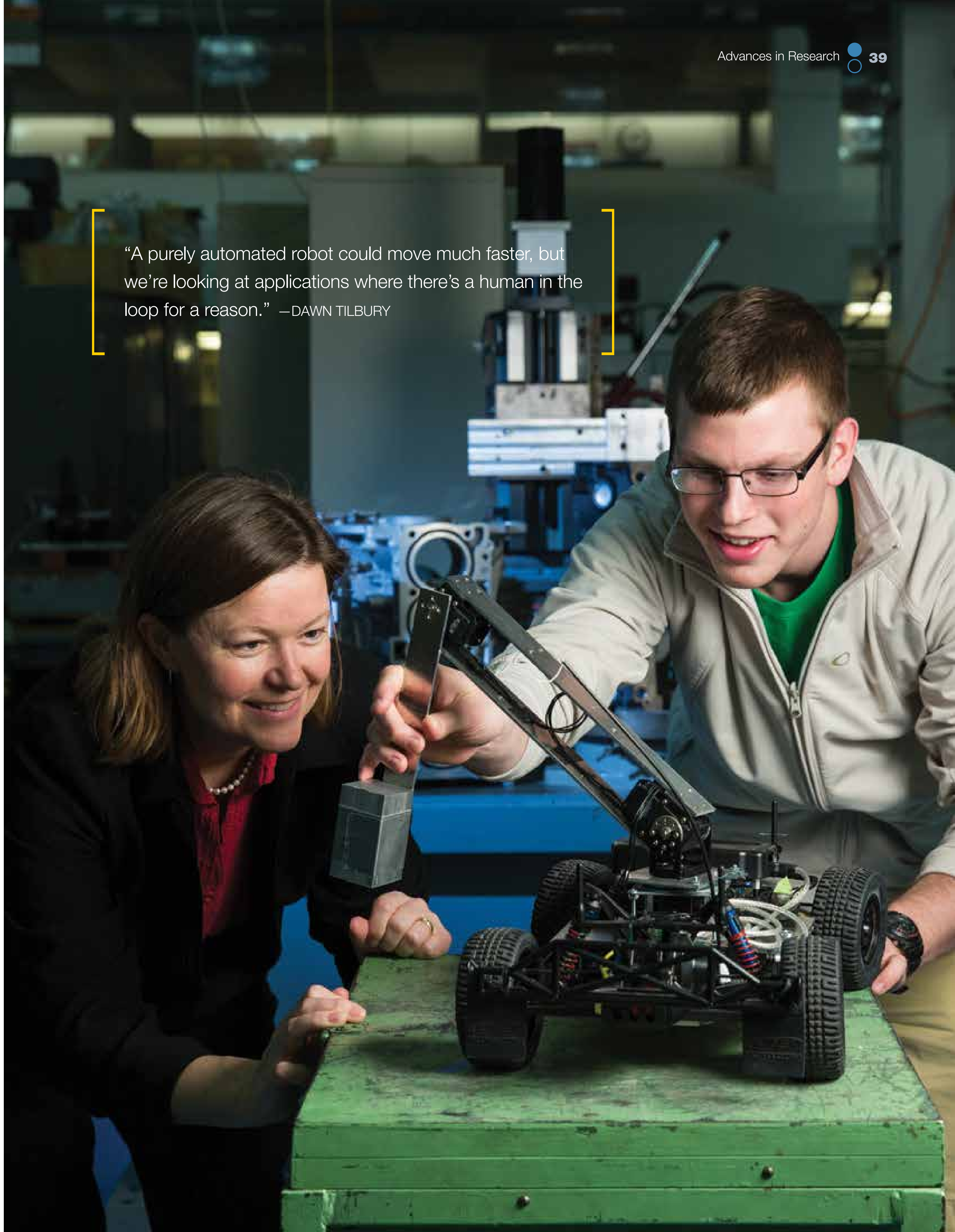
"A purely automated robot could move much faster, but we're looking at applications where there's a human in the loop for a reason," said Tilbury, such as to make decisions about how to search an area for survivors or explosive devices. "Maybe the operator notices a rock to look under or an area of terrain to explore further. Those highly variable and very specific situations are challenging to predict."

In addition, how do you combine models of human intention with autonomous robotic systems such as obstacle avoidance and stability control? In a related project Tilbury's group has developed a prototype manipulator arm (attached to the robot) to enhance performance. The arm is autonomously controlled when the robot is moving, but when it stops to perform a task, such as picking up a box, control transfers to the human operator.

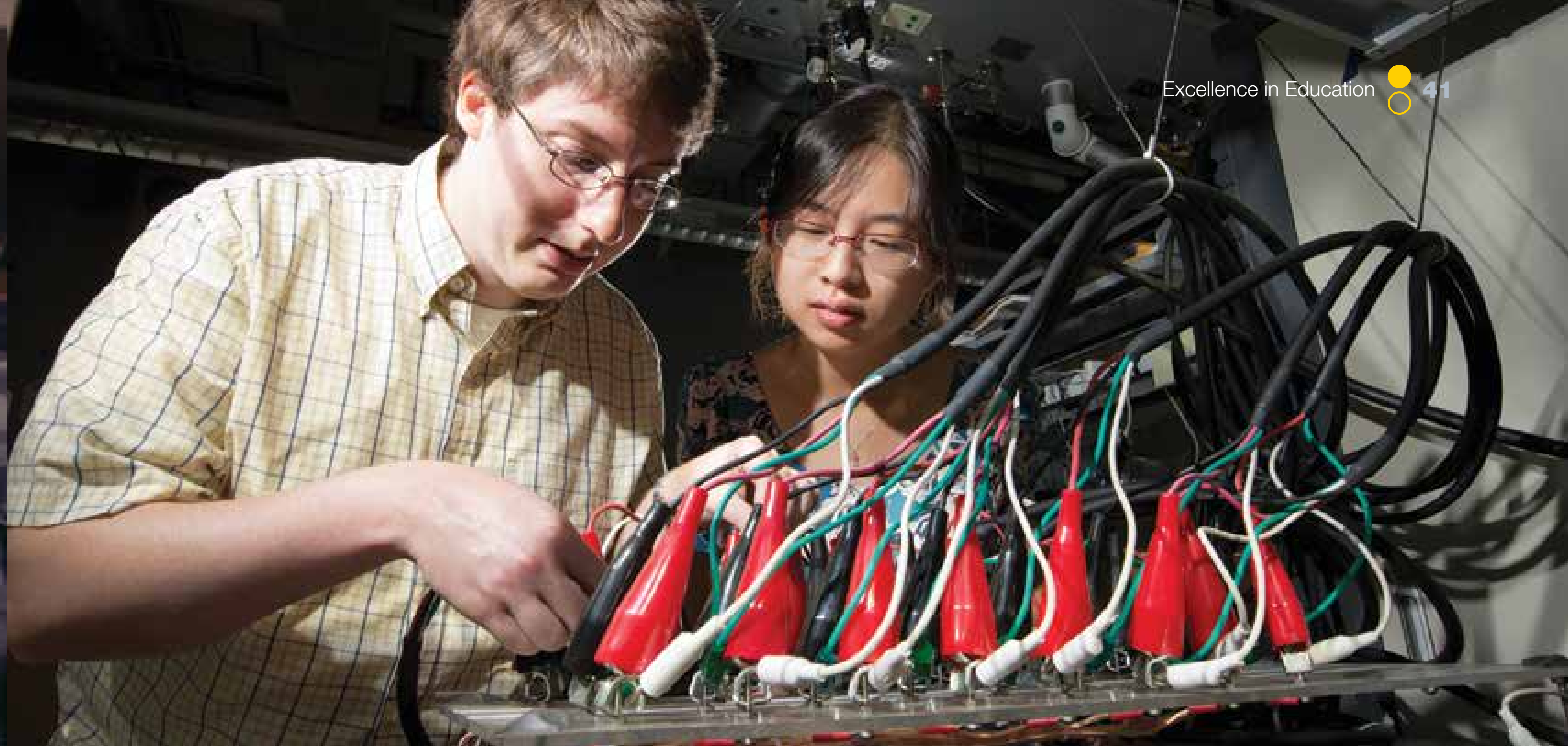
"We need to learn how to blend what the obstacle avoidance and other onboard controllers want to do with what the human operator wants to do, and communicate that seamlessly to the robot. It's partly a controls question, partly a human interface question," Tilbury said. "These are interesting controls challenges."

LEFT: Steve Vozar (right) explains to John Broderick the teleoperation task where users must operate a mobile manipulator to discover and pick up boxes in a controlled environment.

OPPOSITE PAGE: Professor Dawn Tilbury and graduate student Justin Storms examine an automatic weight-shifting mechanism that can increase stability of mobile robots at high speeds.



"A purely automated robot could move much faster, but we're looking at applications where there's a human in the loop for a reason." —DAWN TILBURY



Undergraduate Experience RISE-ing

The ME department has launched many new initiatives targeting the undergraduate experience to meet the societal demands of engineers in the 21st century. Increased curricular flexibility, new world-class instructional spaces and a novel effort called "RISE" are reshaping how undergrads are preparing to meet those demands.

RISE stands for Research, Innovation, Service and Entrepreneurship and emphasizes independent projects to show students how these important areas go hand in hand.

"This is more than simply a change in curriculum; it's a department-wide commitment, a synergistic leveraging all of our resources and cultural growth," said **Diann Brei**, ME professor and associate chair for undergraduate education.

RISE builds on ME's strong foundational curriculum that includes a rigorous core of key fundamental areas within mechanical engineering. A professional spine of design, build, test courses, including multidisciplinary and global product design, teaches students how to integrate knowledge and apply it in innovative ways in team-based environments. The flexibility initiative provides ME students the chance to further develop a broader vision through international, entrepreneurial and multidisciplinary design experiences across the University as well as by leveraging many of its "top 10" programs.

"It's important that our students be exposed to modes of thought and areas of human accomplishment beyond the purely technical," Brei said. "This breadth helps students understand the impact of engineering solutions in a global, economic, environmental and societal context." It also helps students uniquely customize their path to suit individual talents and strengths and to meet their career goals.

To support the many new undergraduate initiatives, the department is currently undergoing a $50 million dollar renovation of the GG Brown building. In addition to major infrastructure improvements, the project vision is to create a student-centric educational facility, adding and upgrading core experimental labs and other teaching facilities for subjects related to design and innovation, manufacturing and fabrication, mechatronics and technical communication through media and visualization.

Through the new initiatives, students at all levels work one on one with ME's world-renowned faculty on innovative projects at home and around the world. An inaugural undergraduate symposium in April 2015, to be held in the department's new research complex, will give students a forum to showcase their work.

> "It's important that our students be exposed to modes of thought and areas of human accomplishment beyond the purely technical."
> —DIANN BREI

Continuous Improvement

ME Graduate Program Pilots New Initiatives

"We have a very strong graduate program in ME, and our students have achieved much success," said Associate Chair for Graduate Education and ME Associate Professor **Kevin Pipe.** "To remain leaders, we continually look for innovative ways to improve our program."

Among several initiatives aimed at enhancing the program for industry-focused Master's students, in 2014–15 the graduate program is piloting a new, two-year, student-initiated dual degree that combines a Master's of Science and Engineering in Mechanical Engineering with a Master's of Management from the Ross School of Business.

"Ross' new Master of Management degree is ideal to pair with our ME master's degree to provide students an even stronger foundation from which to advance quickly in industry," said Pipe. "We want to give students a winning combination of technical and leadership skills as well as a strong understanding of finance, communications and other aspects of management that are critical for advancement within their first few years of joining a company."

Another initiative aims to supplement the coursework-based path for industry-focused Master's students with a rigorous project-based experience. The idea grew out of discussions with faculty, students and members of the department's External Advisory Board. "There was broad agreement on the benefits of a project-based experience," Pipe said. "The question was how best to implement it."

The College of Engineering's Multidisciplinary Design Program (MDP), which recently opened to Master's students, proved to be the best vehicle for piloting the proposed experiences; 12 students are currently assigned to project teams that include students from several degree disciplines through the MDP. "Given the program's organizational strengths and collaborations with industry, it has been a great fit so far for our industry-focused Master's students," Pipe said.

A number of other efforts are underway as well, including a pilot program with the Rackham Graduate School to increase the diversity of the ME PhD program. A new future-faculty group has also been formed. The group helps students and postdocs with the faculty application process by workshopping their CVs, research and teaching statements, giving feedback on practice interview talks and providing guidance from ME committee and departmental leaders on relevant topics, such as negotiating an offer.

"The future-faculty group has done a good job of improving outcomes for our students in tenure-track faculty job searches," Pipe said. Further initiatives include targeted assistance for students applying for fellowships as well as increased interactions with graduate student alumni.

"As with all of the new initiatives," Pipe added, "we want to make sure we're best preparing our students for their eventual goal, whether that's an academic position or a role within industry."

> "We want to give students a winning combination of technical and leadership skills as well as a strong understanding of finance, communications and other aspects of management...." —KEVIN PIPE

Meeting Global Health Challenges

It is important for engineers to understand the broader context of the design problems they work on, including cultural, economic and social factors. Students of Miller Faculty Scholar and Associate Professor **Kathleen Sienko** are learning this firsthand, through innovative design experiences in Ghana, China and Ethiopia.

Since 2008, Sienko has forged a number of collaborations to provide undergraduate and graduate students opportunities to solve challenges related to surgery and to maternal and infant health. To date, seven student cohorts have spent significant time in Ghana, observing medical teams at teaching hospitals in Accra and Kumasi and at district hospitals and rural clinics.

Students perform needs assessments using design ethnography techniques, including observations and interviews conducted during multi-month clinical immersion experiences. They then further collaborate with stakeholders in their host country and at U-M to select needs to pursue during their capstone design experience. In ME 450, students develop and evaluate prototypes; some students also complete a second semester of design coursework and refine their prototypes based on input from end users.

BLOOD PRESSURE SCREENING TO DETECT PREECLAMPSIA

In Summer 2013, a student team designed a blood pressure device for community health workers to use to screen for preeclampsia, a pregnancy-related hypertensive disorder. Complications from such disorders account for more than 30,000 maternal and 500,000 fetal deaths each year worldwide.

The team, including recent ME and BME graduates **Marcus Papadopoulos** (BSE ME '14), **Ben Schlanger** (BSE ME '13), **Elizabeth Sherzer** (BSE ME '13), and **Doga Kumusoglu** (BSE BME '14), were nominated and selected to present their design as a poster at the Capstone Design Conference, a national forum related to design-based capstone courses.

TRAINING SIMULATOR TO IMPROVE CERVICAL CANCER SCREENING

A second student team from the 2013 cohort developed a cervical cancer screening simulator to train midwives to perform the diagnostic technique. The device took second place in the 2014 Rice University Global Health Technologies Design Competition (see related story on following page).

COLLABORATION AND CO-CREATION

In Summer 2014, several students participated in a joint clinical immersion experience with undergraduate biomedical engineering students from the University of Ghana. Projects to be pursued during the Fall 2014 semester include a device to reduce blood loss in postpartum hemorrhage, a labor-to-delivery bed modifier, and a fetal heart monitoring system, all appropriate for low-resource settings.

Previous cohorts have worked on a portable gynecological examination table, an assisted delivery device, and a blood salvage device which led to the spinout company DIIME, Design Innovation for Infants and Mothers Everywhere.

ADVANCING MATERNAL HEALTH TECHNOLOGY IN ETHIOPIA

Sienko serves as faculty lead for the Maternal Health Technology Team and Biomedical Engineering Instructional Team of the newly launched Ethiopia-Michigan Platform for Advancing Collaborative Engagement, or EM-PACE. The effort is part of the U-M Third Century Initiative, for which she also serves as principal investigator of a grant to redefine the design process for global health technologies.

LEFT: Prototype demonstration and usability evaluation for a training tool for intrauterine contraceptive insertion device in St. Paul Hospital, Addis Ababa, Ethiopia.

OPPOSITE (TOP): Usability evaluation and end-user feedback elicitation with midwives and nurses for an underarm contraceptive implant insertion device in rural district hospital, Ethiopia.

OPPOSITE (BOTTOM): A training simulator for a cervical cancer screening method called visual inspection with acetic acid, or VIA, that was developed by ME students for use in low-income countries.

Through EM-PACE, ME PhD candidate **Ibrahim Mohedas** and Design Science PhD candidate **Amir Sabet Sarvestani** are studying the feasibility, design and implementation of a delivery system for subcutaneous contraceptive implants. Minimally trained and rural healthcare workers could use the device to assist women in rural areas seeking long-term contraception.

A NEW HOME FOR THE DESIGN OF HUMANITARIAN TECHNOLOGY

With ME Professor **Steven Skerlos,** Sienko will serve as co-director of U-M's new Institute for the Design of Humanitarian Technologies. The Institute will formalize and facilitate the design process for humanitarian technologies, defined as those that are created in collaboration with stakeholders and end users to improve human health and promote sustainable development.

"Our vision is to build an institute that teaches students to be global citizens, servant leaders and change agents who apply technology design principles in ways best suited to the needs of people and communities with limited resources," Sienko and Skerlos explained.

+ more on the web

Visit **sitemaker.umich.edu/specialization/Home** for more about the Multidisciplinary Design Minor Global Health Design Specialization.

Visit **thirdcentury.umich.edu/em-pace** for more about the EM-PACE project.

Students Take 2nd Place in Design Competition

Two members of a team working with Miller Faculty Scholar and Associate Professor **Kathleen Sienko** took second place in the National Undergraduate Global Health Technologies Design Competition at Rice University in March 2014. The challenge was ambitious: "Identify a challenge in delivering healthcare in the developing world and design a technology to solve the problem."

Julia Kramer (BSE ME '14) and **Maria Rose Young** (BSE BME '14) did just that, with a training simulator for a cervical cancer screening method called visual inspection with acetic acid, or VIA.

As part of the Multidisciplinary Design Program Specialization in Global Health Design, Kramer and Young traveled to Ghana in summer 2013 to perform clinical observations and interviews at two major teaching hospitals and a number of other healthcare facilities to identify maternal health needs. Among many observations, they noted a dearth of cervical cancer screening. The Pap smear, common in Western countries, is expensive and requires access to a cytology laboratory for analysis. The VIA method, by contrast, is effective and appropriate for low-income countries, but was not being widely used in Ghana due to limited training opportunities and simulators.

The two women set out to design a trainer that would simulate the procedure for midwives while complementing current VIA training techniques, which currently rely on flashcards developed by the nonprofit organization Jhpiego.

Working long-distance with Ghanaian midwives and clinicians in Ghana and the United States, Kramer and Young built a prototype in Design and Manufacturing III (ME 450) with teammates **Jeff Chu** (BSE ME '14) and **Jeff Hong** (BSE ME '14). Kramer and Young returned to Ghana over winter break to collect feedback from end users about their design. After returning to Ann Arbor, they made significant design changes to the user interface and the physical design of the device based on the Ghanaian feedback.

Both Kramer and Young were excited to be part of the Rice competition and have their work recognized. The judges were especially impressed by their needs assessment process and collection and incorporation of user feedback.

"The appreciation for ethnographic research in collaboration with engineering design processes was exciting for the future of global health design projects," Young said.

Lab Course Equips Students for New Engineering Challenges, Opportunities

It's not your grandparents' lab course. To further improve the relevancy of Laboratory II (ME495) to students' ME education—and career success—ME495 instructors are emphasizing new themes and adding new experiments to the curriculum.

Thanks to significant support from the ME department and the College of Engineering, students have the opportunity to explore phenomena and conduct experiments at the tiniest scales using atomic force microscopy (AFM). Now they can visualize what happens at the nanoscale and use the insights to better understand a range of processes in applications that span manufacturing to biology.

For most students, ME495 marks their first exposure to the nanoscale world. In one lab activity, students are asked to visualize microtubules—filaments inside cells that measure a few micrometers in length by 25 nanometers in diameter—and deduce their mechanical properties to answer such questions as how much force is required to bend the filament.

"Students are used to working with things they can see and touch," said Professor **Edgar Meyhofer,** who has been teaching ME495 for four years. "But part of our brave new world is the need to engineer things that are so small you can't see or touch them. And the modern tools we need to extract necessary information require skills and practice. You don't just turn on a switch and get your data."

ME495 students also will learn to take calorimetric measurements of alternative transportation fuels using oxygen bomb calorimeters. The experiment, conceived of by Professor **Andre Boehman,** grew out of his idea to have students compare the energy content of different alternative and blended fuels.

"Taking the measurements will be interesting for students in and of itself, but through those measurements students will have to begin thinking about fuel properties as well as broader issues of sustainable transportation and the environment," said Boehman, who will teach ME495 in winter 2015.

Through the new experiments, "students in the course are faced with more complex and open-ended problems that push them to think in new ways," Meyhofer said. "They're no longer just using a lab instrument to get a number; they must figure out how to solve a real problem in a way that distinguishes the engineer from the technician."

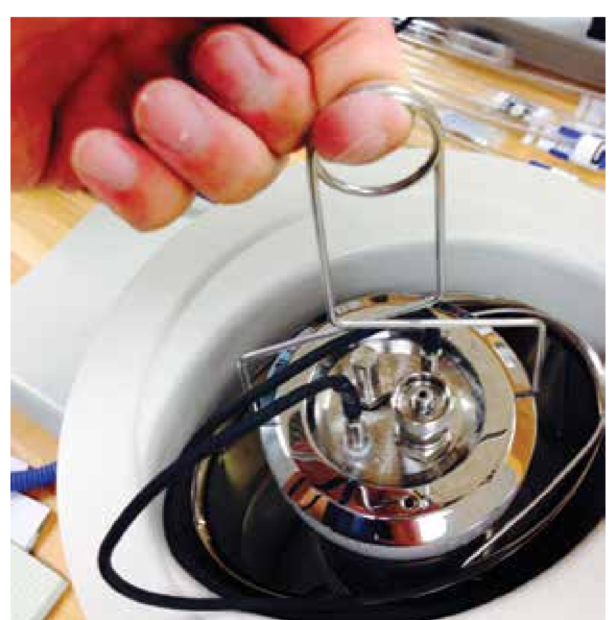
"The key challenge in the course is to look at real world systems—that sometimes cross disciplines—and create mathematical models of such systems," explained Associate Professor **Pramod Sangi Reddy,** who has taught the course for two years. "To do that, students have to identify aspects of a problem that are essential and exclude factors that are unimportant. This process can be hard to grapple with."

Students work in teams, in a different configuration for each of the three to four experiments they must conduct during the semester. They present their work in various formats: oral presentations, posters, technical papers and/or reports. In addition to instructor assessments, peer evaluations contribute to the final course grade.

"This is not the same course experience it was just a few years ago," said Boehman. "As instructors, we're updating the experiments and introducing advanced instrumentation and technologies in a way that raises topical issues, new concepts and problems in society that mechanical engineers now face everyday."

BELOW LEFT: ME 495 students Sean Fortnam (left), Chuming Zhao (GSI, in the middle), Maher Abubakr (right) and Trevor Trudell (back) work together on a project in the lab.

BELOW RIGHT: Students use oxygen bomb calorimeters to take calorimetric measurements of alternate transportation fuels.



Learning Comes to Life in X50 Design Series

The ME department's core design curriculum has been recognized nationwide for its breadth, depth and innovation—on the part of both instructors and students. In Design and Manufacturing I, II and III (ME250, 350 and 450 respectively), students turn concepts into real, working engineered systems and manufacturable products.

In ME250, lecture material and hands-on experience introduce students to systems and design thinking as well as cascading objectives and requirements, a routine part of professional engineering projects in industry. The course project culminates in an "M-Ball" competition, conceived of by Professor **Panos Papalambros**. In M-Ball, each student team must design and build a remote-controlled robot, collaborate with four other teams and work together as a squad, with each robot serving a role much like players on a football or soccer team to score points.

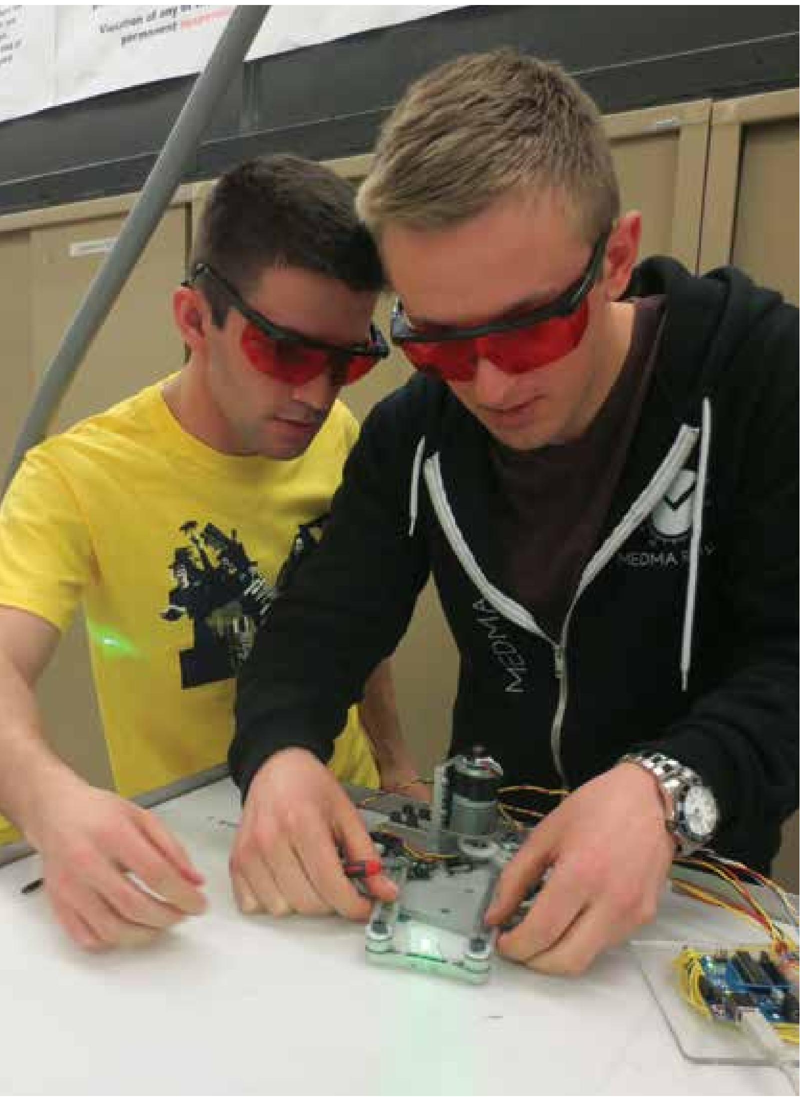
"Teams had to put their creativity and engineering skills to work building extended linkages and other mechanisms to earn points—or to prevent other teams from earning points," explained **Mike Umbriac,** ME lecturer and course instructor.

Students were required to model and analyze their plans before building prototypes to encourage considerable thinking about the specific components and materials required to achieve desired results. Students gained additional experience drawing free body diagrams and writing equations of equilibrium to describe their mechanical systems.

"Analysis before designing and building, that was a strong message we wanted to impart to students," said Professor **Kazu Saitou,** course instructor, "because that's what they'll need to do in industry—think it through thoroughly before they build."

In ME350, the emphasis is on modeling-based system design. Projects change frequently to add new challenges and stress new topics. This past academic year, students analyzed, designed, built and tested a mechatronic device to rapidly position a mirror to reflect four laser beams onto a photoresistor target. To heighten the challenge, the source laser changed position every few seconds. Instructors measured each team's number of target hits and their time on target.

To control the fast dynamic responses, students gained hands-on experience working with closed-loop controllers. The mechatronic systems each team designed included a four-bar linkage system to position the mirror and incorporated an electric motor with integrated encoder to track linkage position. Teams also designed a transmission for the linkage and limit switches to discern when it reached the end of travel. An infrared sensing mechanism stopped motion in case of an obstruction.



ME350 students Eljon Elezi and Robert Self make adjustments to their laser reflection project.

"Students really like the controls component," said **C. David Remy,** ME assistant professor and course instructor. "They take theoretical controls classes and so they appreciate the practical aspects—they see what those numbers and parameters look like in application as well as the challenges that arise in real life rather than in a textbook problem."

The final course of the series, ME450, builds on previous learning and further challenges students with problems from university and industry sponsors such as Coherix, Johnson Controls and ROUSH CleanTech.

"These projects let students interact with professional engineers and their companies," said **Dan Johnson,** PhD, 2013–14 interim course coordinator for ME450. "Students are also very drawn to these projects because they provide exposure to potential employers."

Students addressed a variety of complex engineering design challenges over the past year, including a gas strut valve and surrounding ecosystem for vehicle hatches to make closing easier for users, a cooling system for a laser-based metrology system that measures three-dimensional surfaces and an automotive seatback spinal support system.

Other students developed medical devices, including a blood pressure monitoring device, a training tool to aid in diagnosing cervical cancer, a low-cost spinal orthosis for treating conditions such as scoliosis and spinal trauma and a low-cost prosthetic foot for amputees.

Students participated in seven design reviews over the course of the semester, up from five in previous years. As a result, student teams completed their prototypes earlier. This afforded the opportunity to more thoroughly validate prototypes against design specifications prior to the College of Engineering Design Expo, where students showcased their inventions.

Throughout the course, students maintained online portfolios with their design documentation and shared their findings in a mock journal article.

"Tweaks will be implemented to improve the course structure moving forward, but we were thrilled by the results we saw with these changes," Johnson said.

U-M - SJTU Joint Institute
Focused on Future Innovation

With the strong foundation laid over the past eight years, the University of Michigan - Shanghai Jiao Tong University Joint Institute (JI) is poised for growth and change as it continues to fulfill its mission: to create a global partnership and world-class institute for engineering education in Shanghai.

Toward its overarching goal, the JI has made strides on several fronts, including education, research and governance.

"On the educational front, we continue to grow tremendously and improve our undergraduate program," said JI Dean **Jun Ni,** the Shien-Ming (Sam) Wu Collegiate Professor of Manufacturing at U-M. The JI is about to go through the ABET accreditation process, the first Chinese institution to do so. And the JI's curriculum now includes many new laboratory and additional course offerings.

Recruitment efforts continue for faculty. Currently 28 tenured and tenure-track faculty and 18 full-time instructors work closely with the JI's 1,200 students.

Research is an integral part of the JI experience. When the Institute was founded in 2006, each university contributed $3 million as research seed funding for five years. Last year, given the success of the joint research program, both U-M and SJTU agreed to commit an additional $2 million each to promote and continue joint projects and programs.

The collaborative research programs have centered on two technical areas, renewable energy and biomedical engineering. A third technical area, focused on nanoscience and technology, will further expand research opportunities for faculty and their students.

During 2013–14, several workshops and a joint research exchange were held for faculty to identify future research partners and collaborative projects. Currently, administrators are working to ensure the sustainability of the research efforts underway and to facilitate new partnerships through a Joint Research Laboratories initiative, funded equally by each university.

The effort would include joint leadership, shared lab facilities as well as co-supervision of graduate students. Laboratory focus areas would initially include multimodality medical imaging and cognitive science and engineering. A third proposed lab would be in the field of dark matter physics. Shanghai Jiao Tong University is home to a unique underground dark matter facility.

In August 2014, **Peisen Huang,** JI deputy dean for academic affairs, will assume the position of JI dean as Ni steps down after serving two terms and co-founding the JI. Huang has ties to both universities; he completed his undergraduate studies at SJTU and earned his PhD at U-M. He has served in a number of capacities at the JI related to undergrad education, research and administration since its inception.

"I know I'm leaving the JI in good hands," said Ni. "With Dean Huang's experience and focus on innovation, internationalization and quality, it's exciting to think about the future of the JI, with so many new opportunities and new ideas."

BELOW: A UM-SJTU Joint Institute student presents JI Dean Jun Ni with a portrait as a token of appreciation for his leadership of the Institute.

Community members in Samox San Lucas, Guatemala, test the solar light designs and provide feedback to Sa Nimá members on components of the light that meet their needs and areas for improvement.

BLUELab:
Designing Sustainable Solutions

On the heels of its 10th anniversary last year, the popular, student-led organization Better Living Using Engineering Laboratory, better known as BLUElab, "is becoming even more like an incubator for sustainability ideas that students co-develop with end users," said **Steve Skerlos,** ME professor and BLUElab faculty advisor.

A major focus over the past year has been to formalize the learning process for designing new technologies.

"It all starts with understanding and engaging the community of end users," Skerlos explained, "and includes identifying and quantifying needs in terms of applications all the way through validation, reflection after implementation and embedding with the community."

To reinforce that mindset, project teams undergo a series of design reviews to ensure that each team has followed a thorough human-centered sustainable design process. "That means a much higher probability of high-quality outcomes," Skerlos said.

Each BLUElab team works directly with a partner organization and community to address local needs. Projects span the globe and issues, including areas such as water accessibility, solar technology, resource management in homes, waste-to-energy, engineering education and wind-powered technology.

LIGHTING HOMES IN GUATEMALA

The Sa Nimá Group of BLUElab is furthering its efforts in Samox San Lucas, Guatemala, to co-design advanced lighting systems with community leaders. The project team is working to promote, distribute and provide a financing mechanism for the solar-powered lanterns, based on technology Sa Nimá developed. The lanterns would make it possible for the community to reduce its use of candles, which are expensive and pose health and safety risks to local families.

IMPROVING QUALITY OF LIFE IN INDIA

Launched in 2013, the BLUElab India Project is carrying out a broad needs assessment for appropriate technologies to improve quality of life for residents in the state of Gujarat. Working in collaboration with the Setco Foundation, the project team—led by ME Junior Erica Dombro—spent a month in Gujarat in May 2014. The team returned to Ann Arbor with ideas for a number of projects, including stoves, drainage, electricity, toilet systems and ventilation. The team plans to travel back to Gujarat in summer 2015 to begin to implement co-created technologies.

CATCHING RAINWATER FOR CROP IRRIGATION IN NICARAGUA

In Leon, Nicaragua, BLUElab project team NicarAGUA is working with the nonprofit Aqua Clara International to implement a rain-water catchment and drip irrigation system at a farm and ecolodge. If successful, the team plans to modify the current design for other crop types and other regions in order to promote sustainable water technology solutions globally. Previously, the team implemented water filtration systems at two schools in the country.

PROMOTING SUSTAINABLE SOLUTIONS AT HOME

Back on campus, BLUElab members run a well-attended annual sustainability lecture series and job fair, develop sustainability education content for local K-12 and U-M students and collaborate across campus to minimize energy use and solid waste.

+ more on the web

For more information on BLUElab projects and events, visit **bluelab.engin.umich.edu**

MRacing Innovation Paves the Way for Future Successes

Ranked 24th among 500 Formula SAE teams in the world, U-M's MRacing members spent the 2013-14 year with an eye toward innovation.

Senior driver John Logan displays the car's lateral acceleration capabilities during the endurance event at Michigan International Speedway this past May.

The team added a new aerodynamics package to its vehicle, MR-14. After much simulation work, results showed that the largest components that would still meet Formula SAE rules would be the most advantageous. At the car's unveiling in March 2014, jaws dropped at the size of the bottom and top wings, which create a differential in pressure that helps improve vehicle traction.

One of the biggest challenges with the new package was its added weight, about 40 more pounds, almost 10 percent of the vehicle's overall weight. That led the team to painstakingly look for opportunities to reduce weight, both within the package and elsewhere on the car. The exercise also led the team to a new sponsor, Oxeon, and a high-performance material it developed, TeXtreme. Woven with carbon fiber, it met the teams strength and stiffness requirements yet weighs half as much as the carbon fiber composite used on earlier MRacing vehicles.

"The company is really on the cutting edge of motor sports," said MRacing Team Captain **Joe Martin** (ME '15). "It was a great experience for us as students to work with a new technology that's quickly making its way into the industry."

And designing with new materials in turn led the team to work with Altair's composite modeling software, another opportunity for MRacing engineers to gain valuable industry experience and push the envelope.

"The aero package was a big step for us," Martin said. "It gave us a big advantage both in design and dynamically. We had, according to our judges, the best and most efficient aerodynamic package at competition."

MRacing finished in the top five in the skidpad event at FSAE Michigan, held at Michigan International Speedway in May. It finished first in the FSAE Lincoln competition in Nebraska in June. Overall, MRacing finished 8th of 120 teams at MIS and 9th of 80 teams at Lincoln.

At the Formula Student Germany race in August, a disappointing fuel pump short during the endurance event led to a 37th place finish among the 75 competing teams. But that didn't dampen the team's experience, which included testing at Opel's facilities in Dudenhofen (the company is a team sponsor), spending time with alumnus **Mike Abelson** (BSE ME '82) and other ME grads and taking a day trip to Luxembourg.

"That trip was about much more than the race itself," said Martin, who will graduate in May 2015 with a bachelor's degree in Mechanical Engineering, a minor in German and a minor in Multidisciplinary Design. As he makes post-graduation plans, which include landing a job in the automotive industry, he's confident in the team's performance down the road.

"Having the experience of implementing the aero package and working with sponsors, including EOS on 3D printing titanium parts, taught newer members a lot about innovation and gave them a taste for some of the possibilities for future improvements. I think the team's results over the next few years are going to be very strong."

U-M Solar Car Shines

Winning Fifth American Solar Challenge

The U-M Solar Car Team continued its streak, winning the American Solar Challenge for the fifth consecutive time, a run of nearly a decade. The team took first place in each of the five stages of the July 2014 competition, which spans eight days, 1,700 miles and seven states, from Texas to Minnesota.

The winning streak is motivating, if not intimidating. “It does add some pressure,” said **Arnold Kadiu** (ME ’15), the team’s engineering director. “You don’t want to be the team that drops the ball, so to speak.”

For the first time in the team’s history it raced an older vehicle, *Quantum*, built and first raced in 2011.

“None of the members who raced [in 2014] had experience with that car, so there was a pretty steep learning curve,” Kadiu said.

Changes were made to the lighting and braking systems and to improve driver safety by adding additional protective foam. The team also spent plenty of time on the test track training a new generation of drivers so they would grow comfortable and confident.

On the first day of the race, however, an overheating motor brought the team to the side of the road for diagnosis and repair. Within about 45 minutes, *Quantum* was off again and humming.

Looking back over the 2013–14 season, Kadiu says that no one particular moment stands out as the group’s proudest accomplishment. Rather it was the experience of working closely with each other day in and day out for months and learning to deal with differences that brought about a cohesive, winning team.

“It’s as much a technical challenge as it is a growing up and learning challenge,” said Kadiu. “It’s one of the greatest rewards of being on the team—that members look back and say, ‘I really grew from that experience, as a person and as an engineer.’”

Alumni who mentor the team, including alumnus **Charles (Chuck) Hutchins** (BSE MEAM ’57) who has been with the team at every American Solar Challenge since 1993, echo those sentiments.

“Alumni tell us that the technical knowledge is all well and good, but it’s the communication skills that have made the most difference in their careers,” Kadiu noted.

Sponsors, too, give the team immeasurable support. “We learn so much from the experts in the field—Ford, GM, Siemens, Roush and all of our other sponsors,” Kadiu said. “They help us implement new concepts and new technologies so we can build the car well and make it reliable and safe.”

Currently, the team is in development mode for a new vehicle that will compete in the World Solar Challenge in October 2015. For the 3,000-kilometer race across Australia, the team has made good headway on a car that will be capable of racing two to three hours faster than the 2013 vehicle, *Generation,* thanks to significant changes to the aerodynamics and the solar cells.

When the team isn’t working on the vehicle, it’s busy with outreach and recruiting. Its goal is to develop members who are ready to build the world’s best vehicle, and that demands “a golden team,” said Kadiu.

“We’d like to use more advanced manufacturing techniques, such as 3D printing of titanium parts, and more advanced composite techniques,” he added. “And those require an army of people qualified, trained and committed to developing a winning vehicle that way.”

Rocking Off Road:

Baja Racing Design Changes Pay Off in Competition

Key design changes and critical testing time turned out to be a winning combination for U-M’s Society of Automotive Engineers Baja Racing team, which finished fourth, second and fourth respectively in the season’s three competitions.

“We focused mainly on the transmission and suspension to improve efficiency, handling and performance of the vehicle, and the changes all had big payoffs,” said **Jason Willig** (ME ’16), team captain.

The team completely redesigned the car’s continuously variable transmission to improve its efficiency and devoted two weeks to testing, data collection and refinement prior to the first race.

Lowering the weight to a lean 288 pounds also improved efficiency and made the vehicle the lightest in team history by 20 pounds. “We carefully designed and analyzed all the components to take weight out wherever we didn’t believe it was necessary,” Willig noted.

In competition, the team aced the acceleration events, coming in first, second and first place, respectively. During the season’s first event, U-M Baja won by three-tenths of a second, “a large margin in Baja competitions,” Willig said.

Changes to the vehicle’s suspension tightened the turning radius and improved maneuverability and acceleration through corners, complementing the experience and expertise of driver **Brandon Amat** (BSE ME ’14). The team made the design finals in two of the three competitions and, in the third competition, U-M Baja took third place, the highest in the team’s recent history.

A number of other experiences made it a memorable season. At the April 2014 competition in El Paso, TX, a dust storm kicked up, and several team members got lost in the desert on foot while walking the endurance course prior to the race. The dust picked up again during competition.

“It was hard to see the cars in front of you so we tried to take the outside routes and go around the others on the straightaways,” Willig said. “It was the harshest Baja course we’ve seen.”

At the May competition in Pittsburg, KS, the team attended the Baja Car Show with live music and enthusiastic residents filling downtown streets to support visiting teams. Pittsburg State University broadcast the event.

“There was a live feed online so our families and friends could watch the race,” said Willig. “It was really cool that people who hadn’t seen events like that could get a taste of it over the internet.”

The team’s greatest accomplishment, according to Willig, is having set high-level goals at the start of the season and meeting them. It wasn’t easy. Completing the car early, to ensure time for testing, meant some members gave up their spring break and several nights’ sleep to meet the deadline.

This year, the team plans to focus on improving the durability of the car and improving stability with a few more suspension tweaks. It also plans to pair new members with a mentor on the team to more quickly engage new recruits and encourage them to return year after year, since experience is so valuable.

That’s true both for experience that resides with team members and with sponsors and alumni. This year the team’s title sponsor, GKN, helped with testing and analysis of the suspension links. Last summer the company helped with the analysis of the drive shafts.

“GKN has gone many extra miles to help us understand the testing process and to be able to do it ourselves so we learn in the process,” Willig said. “Experience really is one of the greatest advantages with this team.”

Bayazitoglu Honored with 2013 ME Alumni Merit Award

YILDIZ BAYAZITOGLU

Mechanical Engineering alumna **Yildiz Bayazitoglu** (MS ME '69; PhD '74) was selected to receive the 2013 ME Alumni Merit Award.

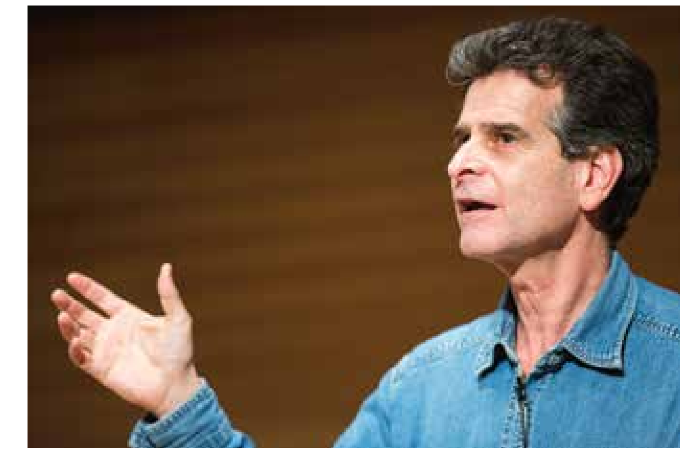
Bayazitoglu joined Rice University in 1977 and has served as the Harry S. Cameron chair Professor of Mechanical Engineering since 1996. Previously, she was assistant professor at the Middle East Technical University in Turkey and a visiting assistant professor at the University of Houston. She earned her bachelor's degree in mechanical engineering at Middle East Technical University in Ankara, Turkey.

Bayazitoglu has made significant contributions to thermo-physical property determination and containerless processing of materials, radiation and convective heat transfer, phase-change heat transfer, oil reservoir fluid flow heat transfer, cryogenic tank thermal analysis, hydrogen-oxygen fuel cells, solar collector analysis, micro- and nanoscale heat transfer and thermal modeling of the human head and optimization of hypothermic therapies. Her work has been published in professional journals and high-caliber proceedings, and she has more than 200 publications in technical journals and conference proceedings. She also has co-authored two undergraduate textbooks, *Elements of Heat Transfer* and *Textbook for Heat Transfer Fundamentals.* She currently serves as the editor-in-chief of the *International Journal of Thermal Sciences*.

Bayazitoglu has amassed a long list of honors, including the Society of Women Engineers (SWE) Distinguished Educator Award, many awards from Rice University and, from the American Society of Mechanical Engineers (ASME), the Heat Transfer Memorial Award. She is a fellow of the ASME and the American Association for the Advancement of Science.

In 2012, Bayazitoglu was made an honorary member of the ASME, and she received the SWE's Achievement Award, the highest award given by the organization.

Korybalski Lectureships Bring Dean Kamen and Arun Majumdar to Campus



TOP: Inventor and entrepreneur Dean Kamen presents to the crowd at the 2013 Korybalski Lecture.

BOTTOM: (From left) ME Chair Kon-Well Wang, Dr. Arun Majumdar and ME Alumnus Michael Korybalski at the 2014 Korybalski Lecture.

Dean Kamen, inventor, entrepreneur and timeless advocate for science and technology, gave the sixth annual Korybalski Lecture in Mechanical Engineering on October 18, 2013. The address, which was titled "Pushing Boundaries, Addressing World Challenges," discussed Kamen's work at DEKA and how his education nonprofit, FIRST (For Inspiration and Recognition of Science and Technology), teaches students ages 6 to 18 hands-on robotics programming and encourages them to continually question how they can contribute to the world.

The subject fit Kamen's expertise as he has created a wide range of products that have significantly improved countless lives, including essential medical products, the Segway Human Transporter, iBOT and Luke…. for wounded warriors as well as working to bring clean water and energy to developing nations. Kamen is known to continually push boundaries to create products.

Kamen holds more than 440 U.S. and foreign patents and has received many awards for his efforts. Notably, he was awarded the National Medal of Technology in 2000 and was inducted into the National Inventors Hall of Fame in May 2005. He has been a member of the National Academy of Engineering since 1997.

Dr. **Arun Majumdar,** vice president for energy at Google, delivered the seventh annual Korybalski Distinguished Lecture in Mechanical Engineering on May 16, 2014. His lecture, titled "Energy and the Industrial Revolution: Past, Present & Future," expanded on a variety of research opportunities and challenges in stationary power and transportation systems that could enable the transition of our energy economy to a sustainable one.

At Google, Majumdar is driving energy initiatives and advising the company on its broader energy strategy.

Majumdar was nominated by President Obama and confirmed by the Senate to become the Founding Director of the Advanced Research Projects Agency (ARPA-E) from October 2009, through June 2012. He also served as the Acting Under Secretary of Energy and a Senior Advisor to the Secretary of Energy between March 2011 and June 2012.

Prior to joining the Department of Energy, Majumdar was the Almy and Agnes Maynard Chair Professor of Mechanical Engineering and Materials Science and Engineering at the University of California, Berkeley, and the Associate Laboratory Director for Energy and Environment at Lawrence Berkeley National Laboratory. His research career includes the science and engineering of nanoscale materials and devices as well as large engineered systems. Majumdar is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. He received his bachelor's degree in Mechanical Engineering at the Indian Institute of Technology, Bombay, in 1985 and his PhD from the University of California, Berkeley, in 1989.

Both Kamen's and Majumdar's talks were part of the annual lectureship endowed by one of our distinguished alumni, Michael Korybalski, chair of the ME External Advisory Board and former chief executive officer of Mechanical Dynamics. Each year, the lectureship brings prominent speakers to U-M as a means to engage engineers across disciplines and inspire them to think about their role in solving societal problems.

Thouless Granted Arthur F. Thurnau Professorship

ME Professor **Michael Thouless** has been named an Arthur F. Thurnau Professor in recognition of his exceptional contributions to undergraduate education. Thouless joined the Mechanical Engineering department in 1995. He will be joining six other professors from the Department who have been appointed in the past.

The Thurnau Professorship is awarded according to a faculty member's influence on the intellectual development and lives of students. Each year, five University professors are selected and will retain the professorship throughout their career. Each recipient also receives a $20,000 grant, which they may use to enhance their teaching.

In addition to teaching ME courses, Thouless is also a professor of materials science and engineering. In 2013, he won the CoE award for Education Excellence. The year prior, the Senate Advisory Committee on University Affairs selected Thouless to receive the Distinguished Faculty Governance Award, which is given to a select few faculty members who have demonstrated university-wide service.

His research interests include micromechanics modeling of materials, interfacial fracture mechanics and adhesion, mechanical properties of thin films and coatings, toughening mechanisms in polymers and mechanical properties of structural adhesives.


MICHAEL THOULESS

Kathleen Sienko Selected as Miller Faculty Scholar

Kathleen Sienko, Associate Professor of Mechanical and Biomedical Engineering was selected as a Miller Faculty Scholar, earning both honorary recognition and funding for current and future research projects.

Sienko currently heads the Sensory Augmentation and Rehabilitation Lab (SARL) and the Lab for Innovation in Global Health Technology (LIGHT). SARL focuses on the design and assessment of wearable balance aids for older adults and individuals with vestibular disorders, while LIGHT focuses on the design of medical devices for low-income settings. The award will allot Sienko $15,000 per year for the next three years to fund research projects of her choice. She plans to use the funds to further the balance studies performed in SARL as well as support the expansion of the Global Health Design Program. "The funds enable me to pursue a few high-risk studies and generate pilot results for inclusion in external grant proposals," says Sienko.

In 2011, Sienko gave a TEDxUM talk on the challenges of designing global health technologies and the need to co-create solutions with communities. In 2012, she received an Undergraduate Teaching Award from the University, along with the Provost's Teaching Innovation Prize.

The Miller Faculty Award is given by U-M CoE alumnus Larry Miller, who supports research in medicine and human health.


KATHLEEN SIENKO

ME Faculty Take Leadership Positions


S. JACK HU


GREG HULBERT


DAWN TILBURY

Three ME faculty members have been appointed to leadership positions across campus.

JACK HU NAMED U-M INTERIM VICE PRESIDENT FOR RESEARCH

The University of Michigan Board of Regents approved the appointment of ME Professor **S. Jack Hu**, the J. Reid and Polly Anderson Professor of Manufacturing Technology, as the interim vice president for research for a two-year term, effective this past January 1.

In his new role, Hu has the overall responsibility for nurturing the excellence and integrity of research across the entire campus. He is currently overseeing the U-M Office of Research, which encourages interdisciplinary research, oversees research policy, provides central administrative services in support of faculty research, scholarship and economic outreach and manages activities related to compliance and the responsible conduct of research. Hu continues to hold the titles of Professor of Mechanical Engineering, Professor of Industrial and Operations Engineering and the J. Reid and Polly Anderson Professor of Manufacturing Technology.

Hu succeeds Stephen R. Forrest, who announced in September that he would step down as vice president for research in January to return to research and teaching in the CoE.

GREG HULBERT NAMED U-M FACULTY ADVISOR FOR INTERNATIONAL PROGRAMS IN ENGINEERING

Mechanical Engineering Professor **Greg Hulbert** has been named faculty advisor for International Programs in Engineering. His research interest focuses on computational mechanics, with particular emphasis on time-dependent phenomena, including structural dynamics, vehicle dynamics, finite element methods and more recently the design and analysis of novel materials and structures for dynamics applications. He teaches courses in dynamics and vibrations, finite element methods, capstone design and applied mathematics.

Hulbert joined the University of Michigan in 1989. He earned his BS from Virginia Tech, his MS from the University of Wisconsin-Madison and his PhD from Stanford University, all in mechanical engineering. Prior to Stanford, he worked for Westinghouse Electric Corporation on nuclear power plant piping design.

DAWN TILBURY APPOINTED COE ASSOCIATE DEAN FOR RESEARCH

The College of Engineering Executive Committee has appointed Professor **Dawn Tilbury** as the next Associate Dean for Research and Graduate Education (ADRGE).

Tilbury, a professor of both Mechanical Engineering and Electrical Engineering and Computer Science, began her term as ADRGE in January 2014. She succeeds Alec Gallimore, who has recently accepted the position of Associate Dean for Academic Affairs.

The ADRGE is primarily responsible for overseeing the CoE's research efforts. The ADRGE office organizes and supports the CoE's research community by notifying both students and faculty of new research opportunities, encouraging collaborations in research projects and by helping to partner University members with external collaborators and corporations that may facilitate corresponding goals.

The office's concentration lies with graduate students and research fellows, as it remains in charge of 19 graduate programs and works toward preparing each student for a successful career in the field.

Robert J. Vlasic Dean of Engineering David C. Munson, Jr. has made the decision to split the ADRGE office into two sections, which mirrors its past arrangement. Starting Fall 2014, the office was split between that of the Associate Dean for Research and that of the Associate Dean for Graduate Education. Tilbury assumed the role of Associate Dean for Research, while Professor Jennifer Linderman became Associate Dean for Graduate Education.

Professor Richard Scott Retires

RICHARD SCOTT

Richard A. Scott, PhD, professor of applied mechanics and engineering science in the College of Engineering retired this past December.

Scott received his BS and MS degrees from the National University of Ireland, University College Cork in 1957 and 1959, respectively. He received his PhD from the California Institute of Technology in 1964 and joined the University of Michigan faculty as an assistant professor in 1967. He was promoted to associate professor in 1971, and professor in 1977.

Scott is a leading authority in the fields of dynamics of flexible mechanisms, dynamics of rotating composite shafts, optimization of damping treatments and finite elements methods in solid mechanics and vibration. He authored and co-authored numerous publications in leading engineering journals and was actively involved in the University of Michigan Chapter of Sigma Xi, the American Academy of Mechanical Engineers, the Society for Industrial and Applied Mathematics, and the American Society of Engineering Education. From 1984–92, Scott served as associate chair of the Department of Mechanical Engineering and Applied Mechanics. A dedicated teacher and mentor, he taught a generation of students and received numerous honors including the Outstanding Teaching in Engineering Award, the Excellence in Service Award and three Pi Tau Sigma Faculty of the Semester awards.

Professor Yoram Koren Retires

YORAM KOREN

Yoram Koren, James J. Duderstadt Distinguished University Professor of Manufacturing, Paul G. Goebel Professor of Engineering and Professor of Mechanical Engineering in the College of Engineering, retired this past May.

A world-renowned researcher and pioneer in manufacturing, Professor Koren is regarded as the originator of reconfigurable manufacturing systems (RMS). He has a notable history of successfully securing research funding and has published over 270 articles in leading scholarly journals and popular textbooks; he also is the holder of 14 U.S. patents. Professor Koren provided visionary leadership as the founding director of the Engineering Research Center for Reconfigurable Manufacturing Systems. A gifted teacher and dedicated mentor, he played an instrumental role in developing a world-class manufacturing curriculum and furthering the University's reputation as a leader in advanced manufacturing research.

Koren advised over 30 doctoral students throughout his tenure, many who have gone on to successful careers in academia and industry. He was the recipient of numerous honors including the American Society of Mechanical Engineers' William T. Ennor Manufacturing Technology Award (1999), the Society of Manufacturing Engineers' Gold Medal (2008) and election to the National Academy of Engineering (2004).

Professor Alan Wineman Celebrates 50 Years at U-M

In his 50-year career as a U-M professor, **Alan Wineman** has been honored with multiple awards and demonstrated many outstanding achievements.

Over the past five decades, Wineman's research has been in developing and applying mathematical models for the mechanical response of polymeric solid and fluid materials. He has used continuum mechanics to make important contributions to a wide range of technically significant problems. In work that has touched nearly every aspect of mechanics, Wineman has made significant contributions to elasticity, viscoelasticity, mixture theory, non-Newtonian fluid mechanics and mechanics of field-dependent materials. He has published more than 120 papers in the top-ranked journals and has earned international recognition as a highly creative and innovative researcher.

As both a professor and mentor to undergraduate and graduate students, Wineman has gained a reputation as a caring, committed teacher. Pi Tau Sigma, the Mechanical Engineering Honor Society, has named him Professor of the Term four times. In addition, he twice has received the CoE Teaching Excellence Award, an unprecedented achievement. Over the years he has earned the Tau Beta Pi Outstanding Teaching Award, the College of Engineering Teaching Excellence Award twice, the Arthur F. Thurnau Professorship, the Society of Engineering Science Prager Medal and, most recently, the Rubber Division of the American Chemical Society George Stafford Whitby Award for Distinguished Teaching and Research, to name just a few.

ALAN WINEMAN

Wineman's extensive career and overall contributions are an inspiring model for his juniors and contemporaries in the field of mechanics. He combines creativity, insight and dedication with great concern for the welfare of students and colleagues alike.

Remembering Chuck Vest, A Pioneer in Engineering Education

Charles "Chuck" Vest, former University of Michigan provost, Engineering dean, Mechanical Engineering professor and a U-M ME alumnus, passed away last year at the age of 72.

Vest remained a dear friend and honored alumnus after leaving the University to become the 15th president of the Massachusetts Institute of Technology, a post he held from 1990 until 2004, and its president emeritus since 2005. He was also the president of the National Academy of Engineering from 2007 until earlier this year.

Vest received his bachelor's degree in mechanical engineering from West Virginia University before arriving in Ann Arbor, where he earned a master's degree and a doctoral degree in mechanical engineering in 1964 and 1967 respectively. He later received an honorary doctorate from the U-M College of Engineering.

Among his many publications were two highly acclaimed books: *The American Research University from World War II to World Wide Web: Governments, the Private Sector, and the Emerging Meta-University* and *Pursuing the Endless Frontier: Essays on MIT and the Role of Research Universities*.

Vest served as dean of engineering at U-M from 1986 until 1989 and U-M provost and vice president for academic affairs from 1989 to1990.

He is survived by his wife, Rebecca; daughter and son-in-law, Kemper Vest Gay and John Gay; son and daughter-in-law, John and Christina Vest; and grandchildren Mary and Robert Gay and Ameri and Charles Vest.

CHUCK VEST

Excellence in Staff Service
Jacob Hayward Wins 2014 Award

JACOB HAYWARD

Jacob Hayward, web applications developer for the ME department, was honored with a 2014 Excellence in Staff Service Award. The College of Engineering recognized Hayward for the many database systems he developed that have transformed departmental processes and enhanced the experiences of faculty, staff and current and prospective students.

Since joining the department in 2009, Hayward has undertaken several major projects, including development of the Graduate Applicant System (known as UGRAB), the Graduate Student Information Center and the Undergraduate Student Information Center. All have helped the department, and other departments within the College, replace cumbersome paper processes and streamline workflows while improving service.

"These systems allow administrative faculty and staff to do their jobs more efficiently and more effectively; they can also be used across multiple departments without much setup time," Hayward said when asked of which accomplishments he was most proud.

Recently, Hayward finished migrating ME's old graduate student database to a new database design that allows for better cross-department compatibility and removes previous limitations. He also is about to start on a new awards system to minimize redundancy and create one place where staff and students can manage all awards.

Colleagues and clients praise Hayward, who earned a bachelor's degree in Computer Science from U-M, for his willingness to collaborate, his listening skills and the ingenuity of the tools he created that faculty, staff and students now use on a daily basis. The department congratulates him on this well-deserved award.

Faculty Awards & Recognition

EXTERNAL AWARDS

JAMES ASHTON-MILLER
Cabaud Memorial Award, American Orthopaedic Society for Sports Medicine, 2014

SHORYA AWTAR
R & D 100 Award, 2013

ASME IDETC Best Paper Award Compliant Mechanisms, 2013

ASME IDETC Best Paper Award Micro and Nano Systems, 2013

KIRA BARTON
NSF CAREER Award, 2014

DIANN BREI
ASME Best Paper Award Structures and Structural Dynamics, 2013

STEVE CECCIO
ASME Freeman Scholar Award, 2013

SAMANTHA DALY
IJSS Best Paper of the Year, 2013

SEM Young Investigator Lecturer, 2013

NSF CAREER Award, 2013

JACK HU
NAMRI/SME S.M. Wu Research Implementation Award, 2014

ERIC JOHNSEN
NSF CAREER Award, 2013

ALLEN LIU
Young Innovator in Cellular and Molecular Bioengineering, BMES Conference, 2014

WEI LU
ASME Gustus L. Larson Memorial Award, 2014

JUN NI
International Science and Technology Cooperation Award, People's Republic of China, 2013

Shanghai Science and Technology Int'l Cooperation Award, 2013

SME Gold Medal, 2013

CHINEDUM OKWUDIRE
NSF CAREER Award, 2014

GABOR OROSZ
NSF CAREER Award, 2014

JWO PAN
SAE Arch T. Colwell Merit Paper Award, 2014

PANOS PAPALAMBROS
ASME Robert E. Abbott Award, 2014

ASEE Ralph Coats Roe Award, 2014

NOEL PERKINS
ASME Best Paper Award Biomedical and Biotechnology Engineering, 2013

KEVIN PIPE
ASPLOS Best Paper Award Architectural Support for Programming Languages and Operating Systems, 2013

ALBERT SHIH
The Milton C. Shaw Manufacturing Research Medal, 2014

DONALD SIEGEL
NSF CAREER Award, 2013

NAE Gilbreth Lecturer, 2013

SAE Ralph R. Teetor Educational Award, 2013

DAWN TILBURY
ASME Michael J. Rabins Leadership Award, 2014

GALIP ULSOY
ASME Charles Russ Richards Memorial Award, 2013

Hideo Hanafusa Award, 2014

ALAN WINEMAN
George Stafford Whitby Award for Distinguished Teaching and Research, American Chemical Society, 2014

MARGARET WOOLDRIDGE
Department of Energy E. O. Lawrence Award, 2013

NEW FELLOWS

JOHN HOARD
SAE Fellow, 2014

HUEI PENG
SAE Fellow, 2013

KAZU SAITOU
ASME Fellow, 2013

GALIP ULSOY
IEEE Fellow, 2013

U-M AWARDS

ELLEN ARRUDA
CoE Service Excellence Award, 2014

Distinguished Faculty Achievement Award, 2014

SHORYA AWTAR
CoE 1938E Award, 2013

SAMANTHA DALY
Robert Caddell Memorial Faculty/Student Achievement Award, 2013

ME Department Achievement Award, 2014

CoE 1938E Award, 2014

JIANPING FU
ME Department Achievement Award, 2014

Robert Caddell Memorial Faculty/Student Achievement Award, 2014

BRENT GILLESPIE
Provost's Teaching Innovation Prize (TIP), 2013

ERIC JOHNSEN
CoE Ted Kennedy Family Team Excellence Award with AOSS, 2014

SRIDHAR KOTA
Regents' Award for Distinguished Public Service, 2014

Herrick Professorship in Engineering, 2013

KATSUO KURABAYASHI
ME Department Achievement Award, 2013

WEI LU
ME Department Achievement Award, 2013

JONATHAN LUNTZ
CoE Kenneth M. Reese Outstanding Research Scientist Award, 2013

PANOS PAPALAMBROS
Distinguished University Professor, 2013

HUEI PENG
CoE Research Excellence Award, 2014

VOLKER SICK
Arthur J. Thurnau Professorship, 2013

KATHLEEN SIENKO
Miller Faculty Scholar, 2014

MICHAEL THOULESS
CoE Education Excellence Award, 2013

Arthur J. Thurnau Professorship, 2014

DAWN TILBURY
CoE Education Excellence Award, 2014

ANGELA VIOLI
Faculty Recognition Award, 2013

PROMOTIONS

SAMANTHA DALY
to Associate Professor with tenure

MICHAEL UMBRIAC
to Lecturer IV

Student Awards

GRADUATE STUDENT AWARDS

SHIMA ABADI
Acoustical Society of America Best Student Paper Award in Animal Bioacoustics, 2014

JORDAN EASTER
NSF Graduate Research Fellowship, 2014

ANTHONY FIORINO
NSF Graduate Research Fellowship, 2014

JESSANDRA HOUGH
NSF Graduate Research Fellowship, 2013

ASME Bioengineering Division Best Paper Award, 2014

ADAM KAMMERS
Caddell Team Award for Research (Samantha Daly faculty), 2013

PETER LILLO
NSF Graduate Research Fellowship, 2013

RYAN MCGINNIS
ASME Bioengineering Division Best Paper Award, 2014

ADALEENA MOOKERJEE
Acoustical Society of America Second Place Best Student Paper Award in Acoustical Oceanography, 2014

POOYA MOVAHED
Azarkhin Scholarship, 2013

PHANI MOTAMARRI
Robert Melosh Medal, 2014

Rackham Predoctoral Fellowship, 2014

JOSHUA NOVACHECK
Dow Sustainability Fellow, 2014

HAESUN PARK
William Mirsky Memorial Fellowship, 2014

BRANDON PATTERSON
NSF Graduate Research Fellowship, 2014

BRADLEY PERRY
NSF Graduate Research Fellowship, 2013

DANVIR SETHI
William Mirsky Memorial Fellowship, 2013

YUE SHAO
Azarkhin Scholarship, 2014

YUBING SUN
Caddell Team Award for Research (Jianping Fu faculty), 2014

DAKOTAH THOMPSON
NSF Graduate Research Fellowship, 2014

UNDERGRADUATE STUDENT AWARDS

BRANDON AMAT
R&B Tool Scholarship, 2014

MICHELLE BAKKER
ASME Foundation/ASME Auxiliary FIRST Clarke Scholarship, 2014

WILLIAM CHEN
Caddell Memorial Scholarship, 2013

LEVON CIMONIAN
Caddell Memorial Scholarship, 2014

SCOTT COOPER
J. A. Bursley Mechanical Engineering Award, 2014

CHRISTOPHER COYNE
R&B Tool Scholarship, 2013

DUANE GARDNER
Caddell Memorial Scholarship, 2014

ZACHARY GRIFKA
R&B Tool Scholarship, 2014

ZACHARY HWANG
ME Spirit Award, 2013

BRIAN KEYT
R&B Tool Scholarship, 2013

CAMERON MCBRIDE
Lloyd H. Donnell Scholarship, 2014

STEPHANIE SINGER
ME Spirit Award, 2014

NICHOLAS MONTES
Caddell Memorial Scholarship, 2013

MAX OLENDER
Lloyd H. Donnell Scholarship, 2013

CHENGHAO WANG
R&B Tool Scholarship, 2014

FANGZHOU XIA
R&B Tool Scholarship, 2014

HAIPEI ZHU
R&B Tool Scholarship, 2013

ZIQI ZHU
R&B Tool Scholarship, 2013

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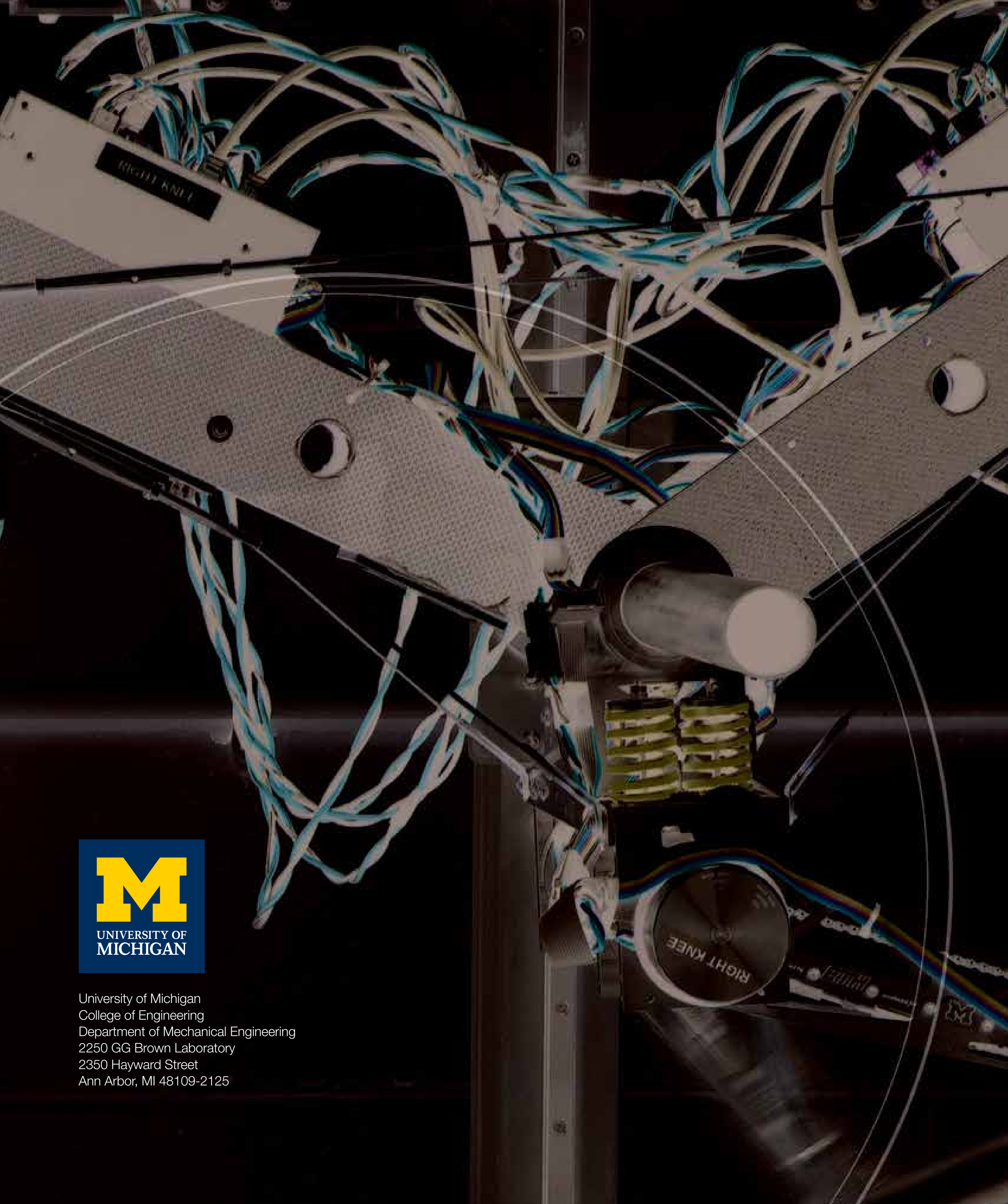
MC 140204

The completed new ME Research Complex. See page 4 for details.
PHOTO: Joseph Xu, Michigan Engineering Communications & Marketing



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