COLLEGE OF ENGINEERING

MECHANICAL ENGINEERING

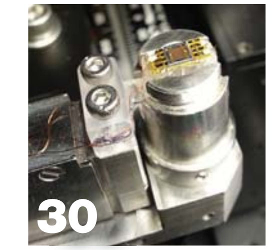
UNIVERSITY OF MICHIGAN

ANNUAL REPORT **2014–2015**

Mechanical Engineering Annual Report 2014–2015

ON THE COVER AND INSIDE FRONT PAGE: New Mechanical Engineering Research Complex at dawn, depicting the sidewall exterior display showing the electronic structure around a vacancy in aluminum (Courtesy: ME faculty Vikram Gavini). Inside front cover features the entryway and stairwell.

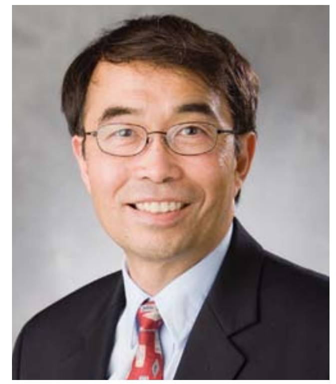
Photos: Michigan Photography



Contents

Message from the Chair

As a top-ranked engineering program, our research work is advancing many fields, from the basic mechanical engineering core to emerging new areas. Our educational programs are shaping an impressive cadre of engineers who will have a significant impact on society.



It is with great pleasure that I share our 2014–15 University of Michigan (U-M) Mechanical Engineering (ME) annual report with you. As a top-ranked engineering program, our research work is advancing many fields, from the basic mechanical engineering core to emerging new areas. Our educational programs are shaping an impressive cadre of engineers who will have a significant impact on society.

Perhaps most exciting is the opening of our new $46 million research complex, a truly unique facility for a university mechanical engineering department. The three-story, 62,880-square-foot addition to the GG Brown Laboratories building opened in October 2014. This new space enables transformative research at the intersection of traditional mechanical engineering and emerging areas, such as micro-, nano- and bio-systems.

In addition, we have started a major $50 million renovation of the current GG Brown building to create innovative, student-centric instructional spaces and greatly improve the existing infrastructure. We anticipate completion next year, and we are grateful to the State of Michigan for $30 million in support of the project.

We also will begin an interior renovation of the Lay Auto Lab next year. Improved lighting, display areas, floor and wall finishes and faculty and student offices will greatly enhance the space, both for occupants and for the Auto Lab's many visitors.

Our faculty have been recognized nationally and internationally with major awards for their research/education advances and professional leadership. Among them, Jack Hu has been elected to the National Academy of Engineering. Two of our junior faculty colleagues, assistant professors Xiaogan Liang and C. David Remy, have earned competitive National Science Foundation CAREER young investigator awards in 2015. Joining the Department are two new faculty, Jesse Austin-Breneman and Shanna Daly.

Faculty also play major roles in national research centers and initiatives. The U-M Automotive Research Center has recently renewed its contract with the U.S. Army Tank Automotive Research Development and Engineering Center for $40 million over five years. Other recent research achievements are highlighted in this report, in areas that span mechanics, dynamics and thermal/fluids to energy, robotics, sensing and control, bio-systems, nanotechnology and design and manufacturing.

In education, our new Research, Innovation, Service and Entrepreneurship (RISE) program gives undergraduate students more opportunities to work on various high-impact projects with our faculty and showcase them at the ME Undergraduate Symposium (MEUS). RISE helps students synthesize their work—in courses, in co-curricular activities and in the community—to make a lasting difference. Through our international programs, students have been gaining invaluable engineering experience globally. In addition, our student teams have showcased the breadth and depth of their engineering education through their many competitive activities.

The Department has over 16,000 living alumni, one of the largest mechanical engineering alumni networks in the nation. Our graduates continue to inspire through their contributions and innovations worldwide. We so appreciate their generous and enthusiastic support.

Thank you for reading. Here's to a productive year ahead, filled with curiosity and discovery.

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

Faculty Profile

5 NAE Members

77 Society Fellows

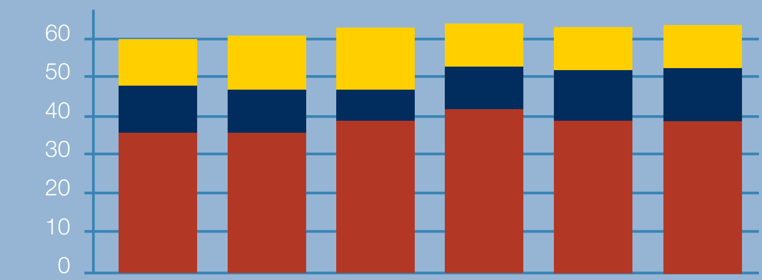
4 NSF PECASE or PFF Awards

37 NSF CAREER or PYI Awards

6 Current Journal Chief Editors

68 Current Journal Editorial Board or Assoc. Editor Appts.

Faculty Trends: Tenured and Tenure-Track

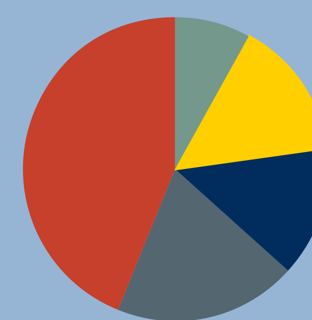


	FA10	FA11	FA12	FA13	FA14	FA15
Assistant	12	14	16	11	11	11
Associate	12	11	8	11	13	14
Professor	36	36	39	42	39	39
Total	60	61	63	64	63	64

Annual Research Expenditures

TOTAL RESEARCH EXPENDITURES
$28,856,808

2014–15

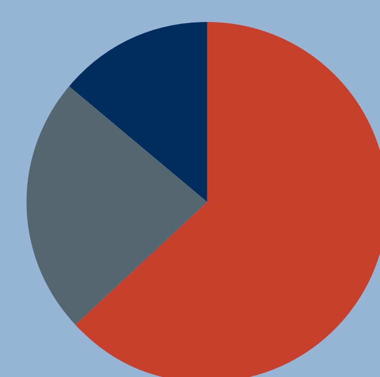


NIH	2,232,617
NSF	4,109,982
DoE	3,897,349
DoD	5,410,782
All Other	13,206,078

Degrees Conferred

2013–14

BSE 260
MSE 95
PhD 56



ME Professor Jack Hu Elected to the National Academy of Engineering

S. **Jack Hu**, a University of Michigan Mechanical Engineering professor noted for leadership in the field, has been elected to the National Academy of Engineering (NAE). Election to the NAE is among the highest professional distinctions accorded an engineer.

S. JACK HU

Hu, professor of mechanical engineering and J. Reid and Polly Anderson Professor of Manufacturing at the U-M, is currently the interim Vice President for Research. He also has a joint appointment as professor of industrial and operations engineering. Hu received both his masters and PhD degrees from U-M.

A world-renowned scholar and leader in manufacturing engineering, Hu's technical interests include manufacturing systems design and operations, assembly modeling and statistical quality methods. He has made a mark with his seminal contributions in developing methods for predicting and diagnosing root causes of product quality variation in multistage assembly systems, which have tremendously impacted the automotive industry.

> Hu has made a mark with his seminal contributions in developing methods for predicting and diagnosing root causes of product quality variation in multistage assembly systems.

Hu has received numerous awards for his accomplishments, including the SME Outstanding Young Manufacturing Engineer Award, National Science Foundation CAREER Award, the ASME William T. Ennor Manufacturing Technology Award, the SME/NAMRI S. M. Wu Research Implementation Award, the College of Engineering Research Excellence Award and several best paper awards.

From 2002–06, Hu served as the director of the Program in Manufacturing and executive director of Michigan Interdisciplinary and Professional Engineering at U-M. He also served as the associate dean for research and graduate education from 2007–09, and associate dean for academic affairs from 2009–13, both in the College of Engineering. Recently, he has worked with the U-M President's Office on President Obama's Advanced Manufacturing Partnership, a working group advising the federal government on how to bolster American manufacturing.

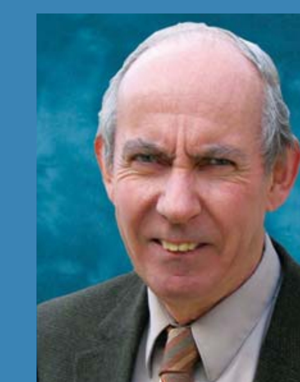
Hu is a fellow of the American Society of Mechanical Engineers and a fellow of the International Academy for Production Engineering. He served as the editor-in-chief of the *Journal of Manufacturing Systems* from 2008–13.

ME Faculty Recognized for Prestigious Awards

The research and educational efforts conducted by ME faculty have a far reach, and the advances and contributions made by many of them are widely and frequently recognized by professional societies with prestigious awards. Over the past few years, ME faculty have been honored with highly coveted awards for the depth, breadth and forward thinking of their work. Several of these very recent honors are highlighted below (more awards listed on page 55).

YORAM KOREN

SME Honorary Membership: The SME Honorary Membership is conferred upon an individual of recognized ability and stature who has, by voluntary action, contributed substantial skills and talent to accomplish the goals of SME. This award is one of the most prestigious honors presented by SME and is reserved for those exhibiting professional eminence among manufacturing engineers. Koren was chosen for his leadership, innovation and implementation of manufacturing technologies, particularly related to automation and reconfigurable manufacturing systems.



MARGARET WOOLDRIDGE

E.O. Lawrence Award: This award is the U.S. Department of Energy's highest honor for mid-career scientists. Created in 1959, the award celebrates contributions in research and development that support the Energy Department's science, energy and national security missions.

Wooldridge's award acknowledges "her work advancing energy science and innovation." Her research group focuses on combustion, that powerful release of energy from fossil fuels that powers much of modern life—at great environmental cost. Her work explores combustion's possibilities in both traditional and new energy supplies, in the context of the growing need to mitigate climate change and plan for an ecologically sustainable and secure energy future.

JIM BARBER

ASME Ted Belytschko Applied Mechanics Award: The Applied Mechanics Award was established in 1988 and renamed the Ted Belytschko Applied Mechanics Award in 2008. The award is given to an outstanding individual for significant contributions in the practice of engineering mechanics; contributions may result from innovation, research, design, leadership or education. Barber's research interests are in solid mechanics with particular reference to thermoelasticity, contact mechanics and tribology.

ME Faculty Recognized
for Prestigious Awards (cont.)

JAMES ASHTON-MILLER

ASME H. R. Lissner Medal: The H.R. Lissner Medal was established by the Bioengineering Division of ASME and recognizes outstanding achievements in the field of bioengineering. This award recognized Ashton-Miller for his vast contributions in bioengineering.

The Bioengineering Division of ASME established the H. R. Lissner Award as a divisional award in 1977. It was upgraded to a society award in 1987, made possible by a donation from Wayne State University, and is named in honor of Professor H. R. Lissner of Wayne State University for his pioneering work in biomechanics that began in 1939.

VOLKER SICK

ASME Internal Combustion Engine Award: The ASME Internal Combustion Engine Award recognizes eminent achievement or distinguished contribution over a substantial period of time, which may result from research, innovation or education in advancing the art of engineering in the field of internal combustion engines; or in directing the efforts and accomplishments of those engaged in engineering practice in the design, development, application and operation of internal combustion engines. Sick is also the Associate Vice President for Research of Natural Sciences and Engineering and serves as the Director of the W.E. Lay Automotive Laboratory.

ELIJAH KANNATEY-ASIBU

ASME William T. Ennor Manufacturing Technology Award and SME Education Award: The William T. Ennor Manufacturing Technology Award is presented to an individual or team of individuals for developing or contributing significantly to an innovative manufacturing technology, the implementation of which has resulted in substantial economic and/or societal benefits. Kannatey-Asibu's research focuses on the multi-sensor monitoring of processes, specifically for machining, welding, laser processing and multiple-beam laser processing. Kannatey-Asibu also received the SME Education Award. This award honors the educator most respected for the development of manufacturing-related curricula, fostering sound training methods or inspiring students to enter the profession of manufacturing.

MICHAEL THOULESS

ASEE Mechanics Division Archie Higdon Distinguished Educator Award: This award recognizes distinguished and outstanding contributions to engineering mechanics education. Thouless' technical 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.

NOEL PERKINS

ASME Leonardo da Vinci Award: The ASME Leonardo da Vinci Award recognizes eminent achievement in the design or invention of a product that is universally recognized as an important advance in machine design.

Perkins is recognized for his eminent achievement in the invention, design and commercialization of the inertial measurement unit (IMU), which is now universally recognized as an important novel product for the precise monitoring of human body movements. This path-breaking technology has broad applications to many fields spanning the health, sport and defense industries.

ANGELA VIOLI

ASME George Westinghouse Silver Medal: The George Westinghouse Medals were established to recognize eminent achievement or distinguished service in the power field of mechanical engineering. The Silver Medal is bestowed upon one who is not yet 45 on June 30 of the year in which the medal is awarded. Considering power in the broad sense, the basis of the awards shall include contributions of utilization, application, design, development, research, and the organization of such activities in the power field.

Violi is also a Professor of Chemical Engineering, Biomedical Engineering, Macromolecular Science and Engineering, Applied Physics, and Biophysics. Her lab, the Violi Group, focuses on multiscale processes occurring in reactive systems, with applications crosscutting combustion, nanoscience and biology.

NEIL DASGUPTA

ASME Pi Tau Sigma Gold Medal Award: The Pi Tau Sigma Gold Medal is awarded to an engineering graduate who has demonstrated outstanding achievement in mechanical engineering within ten years following receipt of the baccalaureate degree. This award recognized Dasgupta for his exceptional contributions in nanotechnology, energy science and manufacturing.

KIRA BARTON

SME Outstanding Young Manufacturing Engineer Award: Since 1980 the SME Outstanding Young Manufacturing Engineer Award has recognized manufacturing engineers, age 35 or younger, who have made exceptional contributions and accomplishments in the manufacturing industry. Barton is a 2014 NSF CAREER awardee and her research interests include control theory and applications, high precision motion control, iterative learning control, high performance nano-scale printing for electrical and biomedical applications, micro/nano-manufacturing, control for manufacturing, cooperative control and control for autonomous vehicles.

KAZU SAITOU

ASME Kos Ishii-Toshiba Award: The Kos Ishii-Toshiba Award is given by ASME Design for Manufacturing and the Life Cycle (DFMLC) Committee. The award honors Kosuke "Kos" Ishii, a professor of mechanical engineering at Stanford University and the director of the Manufacturing Modeling Laboratory there. Saitou's research interests include algorithmic and computational synthesis of mechanical, industrial and biomedical systems, utilizing techniques such as finite element analysis, geometric and kinematic reasoning, image and pattern recognition and planning and optimization.

VIKRAM GAVINI

USACM Gallagher Young Investigator Award: This award recognizes outstanding accomplishments, particularly outstanding published papers, by researchers of 40 years of age or younger. It is presented in honor of Richard H. Gallagher, co-founder of the *International Journal for Numerical Methods in Engineering*.

This award recognized Gavini for his pioneering work toward developing multiscale methods for density-functional theory calculations at continuum scales, electronic structure studies on defects in materials and quantum transport in materials.

Dedication of the New Mechanical Engineering Research Complex

BY NICOLE CASAL MOORE

PICTURED FROM LEFT: U-M ME Doctoral Students, Will LePage and Kaitlyn Mallett, U-M Tim Maganello/BorgWarner Department Chair of Mechanical Engineering Kon-Well Wang, U-M Robert J. Vlasic Dean of Engineering David C. Munson, Jr., State of Michigan Governor Richard D. Snyder, U-M President Mark S. Schlissel, and NIST Program Coordination Office Director Dr. Jason Boehm.

With a "breaker space," ultra-low vibration chambers and tissue culture rooms, a new world-class research complex at Michigan Engineering will let researchers study the forces at work at the smallest scales to advance nanotechnologies in energy, manufacturing, healthcare and biotechnology.

The $46 million Center of Excellence in Nano Mechanical Science and Engineering is a three-story, 62,880-square-foot addition to the GG Brown Laboratories on North Campus. It opened October 10, 2014.

"This addition enhances the impactful research, multidisciplinary collaboration and cutting-edge teaching that are hallmarks of our Department of Mechanical Engineering. It is a great example of how we can work with our strong federal, state, community and industry partners to advance education that will produce new products and spur growth in our economy," U-M President **Mark Schlissel** said.

The things mechanical engineers work on are changing, said **Noel Perkins**, associate chair for facilities and planning in the Department of Mechanical Engineering.

"For a long time, they were on the order of the size of our hands," Perkins said, "but it's no longer limited to that. Emerging technologies demand research at the nano- and microscales, and to do that, you need new infrastructure."

> This addition enhances the impactful research, multi-disciplinary collaboration, and cutting-edge teaching that are hallmarks of our Department of Mechanical Engineering.

In what professor **Ellen Arruda** calls the "breaker space," researchers will watch the degradation of materials that go into things like cars, airplanes and medical devices.

"Advancing our understanding of how things break is critical to preventing catastrophic failure in transportation, medical and commodity devices," said Arruda, professor of mechanical engineering, biomedical engineering and macromolecular science and engineering. She's one of several who will use the Materials and Mechanics Lab on the third floor of the building.

One floor down is the Microbioengineering Lab, with essential amenities such as tissue culture rooms. Normally reserved for biology labs, engineering researchers will now be able to grow the living cells they need to study how proteins might go haywire and lead to cancers, for example, or to test real-time blood infection sensors.

Katsuo Kurabayashi, professor of mechanical engineering and electrical and computer engineering, will culture immune cell lines. He's making biochip sensors for quickly finding proteins in blood that reveal conditions like sepsis, infection and immune deficiencies.

"This lab uniquely provides researchers with a means to develop new technologies and study fundamental biomechanics phenomena by combining micro and nano engineering with biology," Kurabayashi said.

On the ground floor in the Nanoengineering Lab are the ultra-low vibration chambers. They're tightly controlled not only to limit shaking, but also noise, temperature and humidity variations, as well as radio frequency and magnetic interference.

Inside what Perkins describes as a building-within-a-building, the chambers are supported by their own 8-foot-thick concrete slab foundation called a seismic mass. It's separate from the main building's foundation and is designed to withstand vibration from outside, such as traffic, and inside, such as heating and cooling systems. The chambers have a floating floor that bridges the gap in the main building's foundation. Tables sit atop concrete pillars that extend through openings in the suspended floor and anchor to the seismic mass. That way, even researchers' footsteps won't disturb experiments.

These conditions will enable researchers to understand energy transport at the molecular scale. For example, they'll study how heat moves across atoms in nanoscale devices. Another team will study how a single molecule of DNA responds to the slightest of forces, which could give insights into genetic diseases.

"With the emergence of nanotechnology and nanoengineering of the last two decades, a relatively small number of institutions and agencies have been able to construct facilities for ultra-sensitive measurements, and I know of none that are focused on the mission of a mechanical engineering department," said **Edgar Meyhofer**, professor of mechanical engineering and biomedical engineering. Meyhofer is leading the DNA work and will collaborate on the atomic heat transfer research as well.

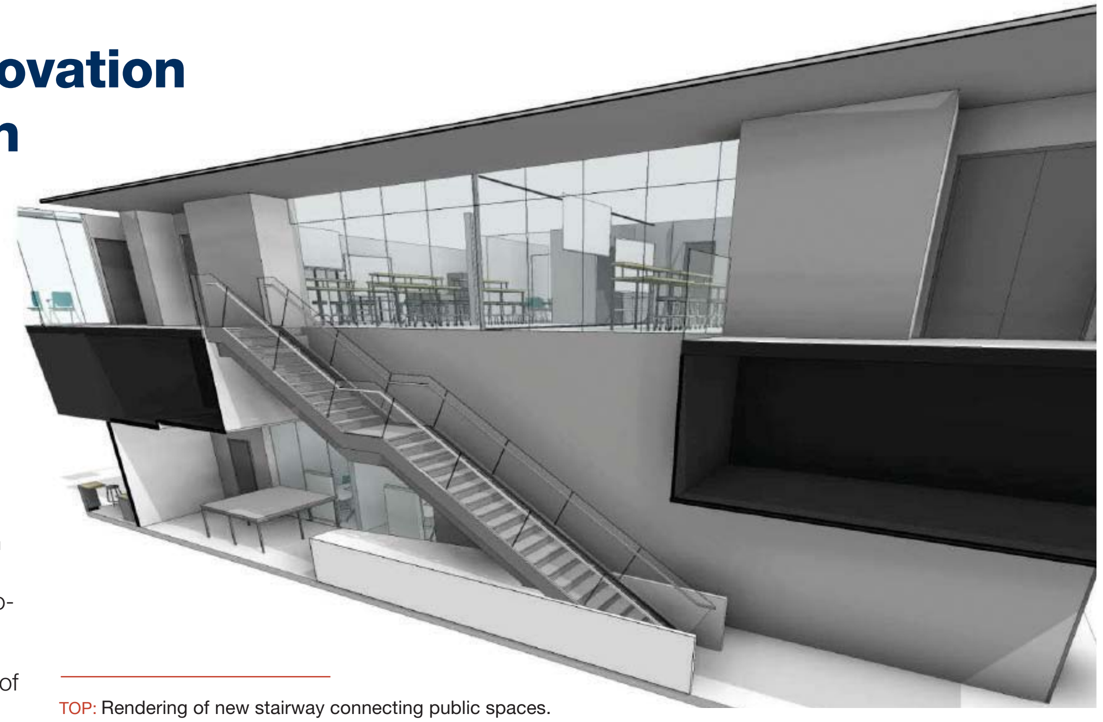
Other researchers will utilize the Nanostructures Lab, where they'll build artificial platelet cells for medical purposes and artificial neurons for advanced computers, for example. And in the Microdynamics Lab, they'll study the tiniest forces. They'll develop computational models that describe the mechanics of DNA and protein assemblies and the behavior of viruses, among other projects.

"Such a facility is indeed unique for mechanical engineering worldwide," said **Kon-Well Wang**, the Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor of Mechanical Engineering. "Our department is a top program that continues to lead, define and shape the future of mechanical engineering. This unique research complex will enhance our ability to do so by enabling transformative research that will impact society in areas such as energy, transportation, manufacturing, healthcare and biotechnology."

The addition was made possible in part by a $9.5 million grant from the National Institute of Standards and Technology. The project is supported by $15 million from U-M, $6.5 million from the College of Engineering and $15 million in private commitments.

"This facility will enable groundbreaking experiments by our faculty and students, resulting in landmark advances at the interface of mechanical engineering and nanoscience. We look forward to watching this progress unfold," said **David Munson**, the Robert J. Vlasic Dean of Engineering.

$50 Million Renovation of the GG Brown Memorial Laboratories



Construction continues on the $50 million renovation of the GG Brown Memorial Laboratories, with Phase 1 already complete. The renovation started in the summer of 2014.

"We're currently in the midst of Phase 3 of the renovation, with Phase 2 completed in August and Phase 3 scheduled for December (2015)," said **Noel Perkins,** Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor.

The renovation will bring new spaces designed for the MEX50 Design and Manufacturing class series as well as an office for ME student societies on the first floor of GGB. On the second floor, there will be new spaces designed for the lab measurement classes ME395 and ME495, the Learning Center, a larger classroom, a CAEN Lab, the ME Academic Services Office (ASO), a large conference room and other ME administration offices. A dramatic staircase will also be added to connect the first and second floors.

"This project has been a huge undertaking but with all of the growth the ME department has seen over the past decade, it was extremely important," said **Kon-Well Wang,** Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor. "It will allow the Department to provide our students, staff and faculty with state-of-the-art facilities and will create a truly outstanding student-centric environment."

TOP: Rendering of new stairway connecting public spaces.
BOTTOM: GG Brown during the construction phase.

This project has been a huge undertaking but with all of the growth the ME department has seen over the past decade, it was extremely important.

Walter E. Lay Automotive Lab to Undergo Interior Renovation

TOP: New glass walls at the central stairway.
BOTTOM: Renderings of the renovated second floor.

The U-M College of Engineering approved an interior renovation of ME's Walter E. Lay Automotive Laboratory building in winter of 2013 and following the recent completion of the design phase; construction is scheduled to begin in summer next year.

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. The lab 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."

According to **Noel Perkins,** Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor, the renovation includes updated corridors and staircases, improved lighting and display areas, a new lounge and conference rooms as well as updated restrooms and an added lactation room.

The Lab's flooring and walls will also receive new surface finishes and the faculty and student offices will be upgraded. The renovation project includes some HVAC and electrical upgrades as well.

Phased construction is scheduled to begin in 2016, as the GG Brown Memorial Laboratory building renovation (see related story on page 10) approaches completion.

Two U-M Mechanical Engineering Faculty Win Early Career Awards in 2015

Two ME faculty have won prestigious National Science Foundation (NSF) Faculty Early Career Development (CAREER) Awards in 2015. The NSF's CAREER program offers awards to junior faculty who have exemplified the ideal teacher-scholar dynamic.

2D NANOELECTRONIC DEVICES INTEGRATED WITH NANOFLUIDIC STRUCTURES FOR BIOSENSING APPLICATIONS

XIAOGAN LIANG

Assistant Professor **Xiaogan Liang** earned a CAREER award for his proposal, "2D Nanoelectronic Devices Integrated with Nanofluidic Stuctures for Biosensing Applications." The ability to detect and quantify low-abundance biomolecules is critical for clinical diagnostics and drug development. For example, such ability can be used for early-stage cancer diagnosis. Surface plasmon resonance is the standard method for such analysis, but it still suffers from drawbacks such as low sensitivity, poor detection limit and slow analysis process. These limitations motivate the efforts to create new nanoscale electronic biosensors for realizing efficient, label-free, multiplexing biomolecule quantification at low detection limits.

Liang's research aims to construct a new biosensor by integrating emerging two-dimensional (2D) nanoelectronic materials into nano/microfluidic structures. Such a 2D-material-integrated nanofluidic biosensor, if successfully realized, will greatly advance the capability for illness-related biomarker detection and quantification. His proposed work holds significant potential for realizing new cost/time-effective immunoassay chips that can address global needs for new capabilities for diagnosis and stratification of diseases and U.S. industrial competitiveness. Beyond advancing fundamental academic research capabilities, the proposed education/research integrated program will provide relevant knowledge and technical skills to a broad range of people, including K-12 students/educators, undergraduates, graduates and students from underrepresented and minority groups.

USING MULTIPLE GAITS AND INHERENT DYNAMICS FOR LEGGED ROBOTS WITH IMPROVED MOBILITY

DAVID REMY

Assistant Professor **David Remy's** CAREER proposal, "Using Multiple Gaits and Inherent Dynamics for Legged Robots with Improved Mobility," focuses on the investigation of legged robots that are faster and energetically more efficient. The project capitalizes on the currently untapped possibility of using different gaits at different locomotion speeds. The idea was inspired by nature. Humans, for example, switch from walking to running as they increase speed; horses transit from walking to trotting and galloping. Switching gaits is analogous to switching gears in a car. It increases versatility and reduces energy consumption. Additionally, in nature the choice of gaits is strongly coupled to an animal's morphology. A massive elephant moves differently than a slender gazelle. Remy's research will investigate this complex relation of gaits, motions and morphologies, and will transfer the underlying principles to robotic systems. The work will be conducted in simulation studies and with actual robots. In the long term, this CAREER plan aims at the development of robots that reach and even exceed the agility of humans and animals. It will enable us to build robots that can run as fast as a cheetah and with the endurance of a husky, while mastering the same terrain as a mountain goat. Moreover, it will provide us with novel designs for active prosthetics and exoskeletons.

This project seeks to understand the fundamental principles of designing, building and controlling legged robots that embrace and exploit their inherent mechanical dynamics. The underlying premise is that locomotion can emerge in great part passively from the interaction of inertia, gravity and elastic oscillations. The goal of this project is to identify systems in which such dynamics can be excited in a variety of different modes. Different modes would correspond to different gaits, and would enable efficient motion in different operational conditions.

JESSE AUSTIN-BRENEMAN

ME Welcomes New Faculty Members

The ME department is pleased to welcome **Jesse Austin-Breneman** and **Shanna Daly**, who are joining the faculty as assistant professors.

SHANNA DALY

JESSE AUSTIN-BRENEMAN

Austin-Breneman earned his PhD from MIT and has worked as a postdoctoral research associate in the MIT Ideation Lab and the MIT Global Engineering and Research Lab. His research focuses on system-level approaches to difficult engineering design problems, such as large-scale complex system designs and product design for emerging markets. His work uses empirical studies, practitioner interviews and simulations to gain insight into issues facing multidisciplinary design teams working in these fields. He is particularly interested in how teams manage competing objectives throughout the design process and formal strategies for helping them do so.

SHANNA DALY

Daly earned her PhD from Purdue University and is currently working as an assistant research scientist and adjunct assistant professor in Engineering Education at the University of Michigan. Her research focuses on strategies for design innovations through divergent and convergent thinking as well as through deep needs and community assessments using design ethnography, and translating those strategies to design tools and education. The National Science Foundation and the Helmsley Foundation support her research, and she teaches design and entrepreneurship courses at the undergraduate and graduate levels, focusing on front-end design processes.

David Moore Named 2015 Rhodes Scholar

In November, U-M Mechanical Engineering master's student **David Moore** became the 27th U-M student in the history of the University—and the third U-M student-athlete—to win a Rhodes Scholarship. He was one of the 32 students selected.

According to the Rhodes Trust website, recipients were chosen from a pool of 877 candidates who had been nominated by their respective colleges and universities. The scholarship, established in the 1902 will of Cecil Rhodes, is considered the oldest and best-known award for graduate international study.

Rhodes Scholarships fund two to four years of study at the University of Oxford in England and are awarded to students who demonstrate outstanding intellect, character, leadership and commitment to service, according to the Rhodes Trust.

"This is an exceptional honor and an outstanding opportunity for David," said **Kon-Well Wang,** Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor of Mechanical Engineering. "We are all extremely proud of him!"

"The scholarship was first brought to my attention by some of my professors who encouraged me to consider applying my junior year of my undergraduate degree, and although I was amazed by the opportunity, I knew I wanted to continue my masters at Michigan in Mechanical Engineering," said Moore.

DAVID MOORE

This past spring, Moore said he realized that he was still eager to learn more and wanted to apply for the Rhodes Scholarship to pursue further degrees in Oxford.

"I really wanted to challenge myself beyond my comfort zone and the 1+1 degree at Oxford seemed like an amazing degree. It combines a masters in computer science followed by an MBA to allow for direct application of technical background into product design, which is what I eventually want to do," said Moore.

Moore's scholarship will cover tuition and living expenses for two years at the University of Oxford in England where he hopes his studies will continue to help him design sustainable products that have a positive impact on society.

ARC Enters Fourth Phase of Funding in $40 million TARDEC Contract

The Automotive Research Center (ARC) is celebrating more than its 20th anniversary this year. The Center is also able to continue to thrive thanks to a $40 million, five-year contract renewal with the United States Army Tank Automotive Research, Development and Engineering Center (TARDEC). Since its inception, the ARC has served as a hub for basic scientific research to support the modeling and simulation of basic ground vehicles. The multi-university consortium led by U-M was created in 1994 and this contract renewal will mark the Center's fourth phase of funding. Current members of the consortium are Clemson University, University of Iowa, Oakland University, Virginia Tech and Wayne State University. In the past, it has included diverse institutions such as University of Wisconsin, Madison, Howard University, University of Tennessee and University of Alaska, Fairbanks.

The ground vehicles of the Army went through significant changes over the past two decades in response to changing threats and operational needs. They became safer, smarter, more powerful, more flexible and more fuel efficient, and, the ARC has been a critical research partner along the way. "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 U-M ME Professor **Anna Stefanopoulou**.

Over the years 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.

"It's vital that we work to further enhance the collaborative environment the ARC provides. As the Center continues to grow and develop, we're better able to address important multidisciplinary and dual-use research issues," said **Jack Hu,** U-M interim vice president for Research.

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 and demonstration of the value of modeling and simulation to TARDEC that led to its adoption of computational analysis in many of its processes.

"Through collaborative explorations, educational efforts and technology transfer initiatives, the ARC has contributed important design tools for military and commercial vehicles," said TARDEC Chief Scientist Dr. **David Gorsich.** "ARC projects have involved investigators and students working together on leading-edge fundamental research across a range of disciplines. These robust teams have pushed boundaries of vehicle mobility, survivability and operational efficiency with great success, leading to more than 700 publications with 23 best paper awards, eight books and two special journal issues in the past ten years."

With this continued funding, the ARC will be able to continue to create breakthrough engineering that will lead to increased levels of autonomy, better protected mobility and higher power density and energy efficiency. Vehicles will be more adaptive and responsive, will minimize physical and cognitive load on the user, will feature lightweight yet reliable structures, will have highly efficient and fuel neutral powertrains and will operate seamlessly as a system. The impact of the ARC research will not only be seen at the vehicle level, but also at the fleet level through new concepts such as modular fleets. The modeling and simulation capabilities developed in the ARC will lead to shorter development timelines. Stay tuned to see what the next five years will bring.

Investigating the Targets for the U.S. Light Duty Vehicles' Fuel Efficiency and Greenhouse Emissions

DRS. JASON MARTZ, GEORGE LAVOIE, ANNA STEFANOPOULOU, ROBERT MIDDLETON REVIEW A PRE-RELEASE DRAFT OF THE NRC REPORT ON CAFE AND GREENHOUSE STANDARDS FOR U.S. LIGHT-DUTY VEHICLES.

The National Research Council (NRC) released a new report on Corporate Average Fuel Economy (CAFE) and greenhouse standards for U.S. cars on June 18th. The report, titled "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," offers an independent assessment of the challenges and benefits of various technologies that are expected to contribute to meeting new standards implemented in 2012. These CAFE and greenhouse gas standards will require the U.S. new light duty vehicle fleet—passenger cars and light trucks offered for sale—to double its fuel economy by 2025.

The new standards, developed jointly for the first time by the National Highway Traffic Safety Administration (NHTSA) and the U.S. Environmental Protection Agency (EPA), are due to be reviewed in 2017 for the automakers' implementation hurdles and successes. The NRC report is contributing to this analysis.

Anna Stefanopoulou, University of Michigan Mechanical Engineering Professor and Director of the University's Automotive Research Center participated in the study.

"Light duty vehicles are contributing to 15 percent of CO2 and other greenhouse gases. So, they are to blame for the 15 percent of global warming or 15 percent of how humans adversely and perhaps irreversibly affect our planet," said Stefanopoulou. "This report looks into an important step our nation is taking toward taming this 15 percent monster."

Stefanopoulou was involved with a dozen other committee members to help to review powertrain technologies (engines, electrification and transmission) and especially the effectiveness of modeling, optimization and control vehicle fuel consumption.

According to Stefanopoulou, these last three years were very intense; a tremendous undertaking and specially rewarding due to the collaboration with exceptional individuals from industry, academia, and the non-profit public sector.

Apart from Stefanopoulou's contributions as a committee member, Dr. **Jason Martz,** Dr. **Robert J. Middleton** and Dr. **George Lavoie** from the ME department fed this report with an important analysis through their "Full Vehicle Simulation Study" commissioned by the committee.

U-M ME Faculty Hosted the 12th IFAC Workshop on Time Delay Systems

The 12th International Federation of Automatic Control (IFAC) Workshop on Time Delay Systems took place in Ann Arbor on June 28–30, 2015 and three of ME's own faculty were on the organizing committee. **Galip Ulsoy** served as the general chair, **Gabor Orosz** the program editor and **Tulga Ersal** the local arrangements chair. The workshop aimed for the same high quality as previous ones, with traditional applications like manufacturing and automotive systems, as well as newly arising topics like networked dynamics and biological systems.

The workshop featured both invited and contributed sessions with 81 papers presented and 103 registered participants. The schedule included an experimental demonstration session where researchers displayed their results *insitu* to the participants and a panel discussion that allowed researchers from academia and industry to discuss industrial applications where time delays play an important role. The workshop was preceded by a one-day course where the 32 participants had the opportunity to learn about advanced topics in time delay systems.

Lab-on-a-Chip
Novel Platform Speeds Immune System Monitoring

For critical care physicians, the ability to have an accurate picture of a patient's immune status can make the difference between life and death.

Doctors use information about immune status to monitor a patient's condition, determine whether treatments are working and to inform changes in treatment strategies if they are not.

But current immunological tests take 24 to 48 hours to deliver results, and they can require repeated sampling over time. Current tests also need large amounts of blood, which can be problematic for newborns and infants. And still, conventional tests don't provide as full a view of the immune system as clinicians might like.

"Doctors today have an arsenal of immune-modulating drugs available to them, but they can't always get the information they need as quickly as they need to prescribe the right drug," said assistant professor **Jianping Fu**, who leads the U-M Integrated Biosystems and Biomechanics Laboratory.

Timing is everything, Fu emphasized. "In patients with serious immune issues, such as sepsis, mortality increases by 7 percent per hour after onset."

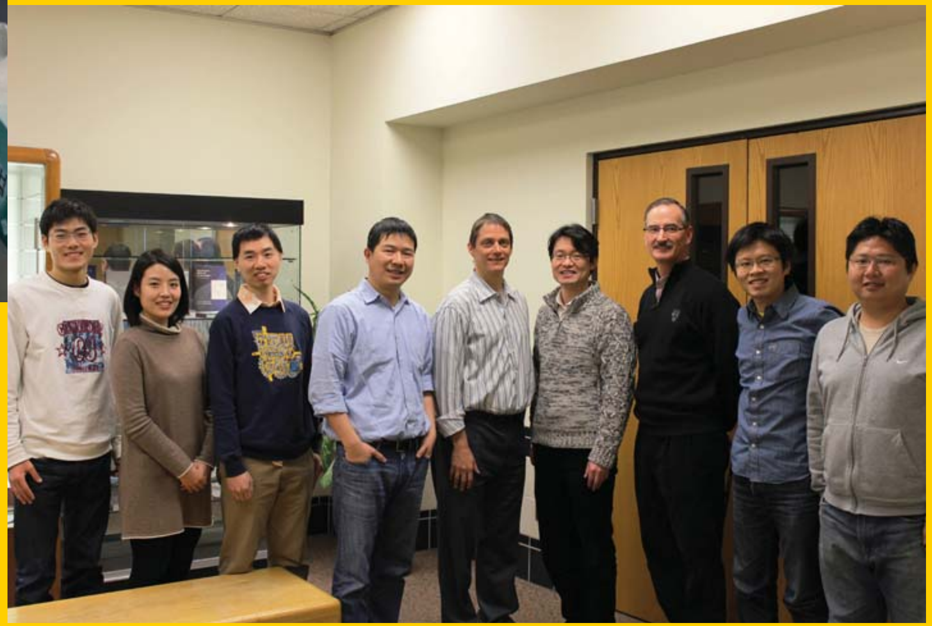
Sepsis is a dangerous complication of infection. It occurs when immune cells release cytokines, molecules that can signal an inflammatory response throughout the body and can lead to organ failure. The mortality rate for severe sepsis can reach 60 percent.

Fu and ME Professor **Katsuo Kurabayashi,** co-principal investigator, are developing a "lab-on-a-chip" platform for rapid analysis of immune system function by quantifying different types of immune cells and the cytokines they release.

The two investigators are working with clinical collaborators from the U-M Medical School: Drs. **Timothy Cornell** and **Tom Shanley,** both pediatric intensivists at C.S. Mott Children's Hospital.

The new device uses microbeads coated with antibodies to recognize specific types of immune cells. A specially fabricated silicone membrane helps sort the target cells, which are routed through other components of the microscale system. Biosensors detect cytokine secretion from the cells attached to the beads.

The device can detect and analyze four types of immune cells and up to six cytokines for each type. This has the potential to supply clinicians with an expanded panel of biomarkers, giving a more



It's motivating to know that what we're developing can benefit patients and have a real clinical impact.

FAR LEFT: Postdoc fellow Zeta Yu tests the integrated microfluidic chip he developed for functional immunophenotyping of patient blood samples.

TOP: A highly integrated microfluidics chip for rapid, automated, parallel quantitative immunoassays.

BOTTOM: Microfluidic immunophenotyping research team (from left to right) Xiang Li, Bo-Ram Oh, Zeta Yu, Jianping Fu, Timothy T. Cornell, Katsuo Kurabayashi, Thomas P. Shanley, Nien-Tsu Huang (now assistant professor at the National Taiwan University), and Weiqiang Chen (now assistant professor at New York University).

detailed, actionable view of a patient's immune system status and function.

The device requires just a fraction of a drop of blood, and results take less than 30 minutes. In addition, the technology has the capability to achieve a detection sensitivity of just a single cell.

The project received seed funding from U-M's MCubed program and the Michigan Institute for Clinical & Health Research. Both paved the way for the team to win funding from the National Institutes of Health R01 Program, a significant milestone.

Through the U.S. Food and Drug Administration's Expanded Access program, a patient already has benefited from the team's invention.

In late 2014, a young girl with cancer was experiencing organ failure due to a severe immune system reaction to treatment. With results from the device, the patient's doctor was able to rapidly and accurately measure her cytokines and adjust therapy accordingly. She recovered.

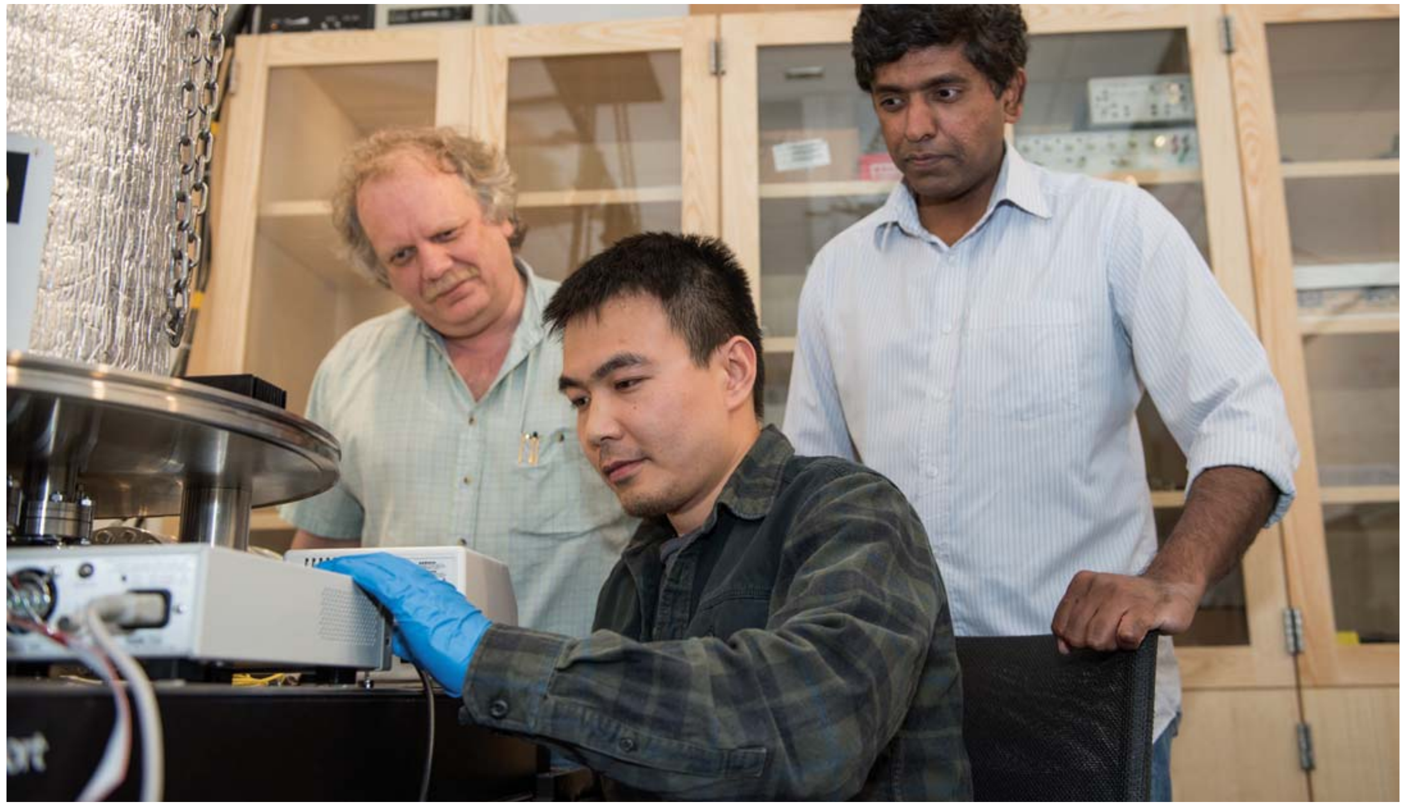
"It's motivating to know that what we're developing can benefit patients and have a real clinical impact," said Fu.

In the future, patients undergoing organ transplants or cancer immunotherapy may also benefit from the technology. In the case of transplants, doctors suppress patients' immune systems to prevent rejection of the donated organ.

The new platform may instead enable doctors to suppress only the specific types of immune cells involved in organ rejection. With this approach, patients could still retain immunity to fight off everyday infections.

In cancer immunotherapy, one of most promising directions for cancer treatment today, there currently is no good way to tell whether the treatment has in fact stimulated the necessary immune cells to attack cancer cells.

"Today no available technology exists to effectively capture and examine those immune cells and see if they're working. I believe that's where our technology can go," Fu said.



Measuring Near-Field Radiative Heat Transfer

A Novel Nanoscale Platform

> The platform and technique developed by Meyhofer and Sangi Reddy overcome several challenges to measuring near-field heat transfer at the nanoscale, including the effects of temperature changes, forces and mechanical motion.

How heat is transferred via radiation from a hot to a cold surface in the near field, meaning at sub-wavelength distances predicted by Wien's law, differs significantly from radiative transfer in the macroscopic world.

Scientists have predicted that, at room temperature and for objects less than ten micrometers, near-field heat transfer becomes dependent on the distance between the emitter and receiver. And it is enhanced by orders of magnitude, both for metals and dielectric surfaces, when the gap is reduced to tens of nanometers and below.

This holds the promise of dramatic improvements and new capabilities for micro- and nanoscale devices to efficiently generate energy or to enhance data storage in heat-assisted, magnetic recording, to name two applications.

To begin to leverage near-field radiative transport for such technical advances, it is critical to quantitatively confirm these predictions and to show that similar transport enhancements can be obtained when thin coatings of materials are used. Such coatings are typical in the fabrication of modern micro- and nanoscale devices.

But until now, no investigator had been able to achieve such measurements of near-field radiative heat transfer, owing to a range of extremely technical challenges.

In an article published in March 2015 in *Nature Nanotechnology*, a team of researchers from the ME Department and collaborators from Spain, led by professors **Edgar Meyhofer** and **Pramod Sangi Reddy,** describe their experiments. They are the first to demonstrate that near-field heat transfer across nanoscale gaps is enhanced at the sub-wavelength scale with the use of thin films.

LEFT: Meyhofer (in background, left), Sangi Reddy (right) and doctoral student Bai Song (front) are observing the progress during the measurement. Part of the experiment setup is visible on the left side of the image, which includes the vacuum chamber covered in reflective insulation.

BELOW: Bai Song, a doctoral student and lead author of the near-field study reported in *Nature Nanotechnology*, is carefully adjusting and monitoring the gap size during an experiment.

For the experimental measurements, Meyhofer and Sangi Reddy conceived of a calorimetry platform to measure heat transfer between a tiny silica sphere—50 microns in diameter, or about half the width of a human hair—that served as an emitter and a similar-sized silicon nitride plate that functioned as a receiver.

The silicon nitride plate was coated with gold or dielectric, insulating silica films of various thicknesses, ranging from 50 nanometers to three micrometers (thinner than the thermal wavelength). The high-resolution heat transfer measurements were made possible because the receiver was suspended by tiny beams (and therefore thermally well isolated) and equipped with an extremely sensitive thermometer, among many other enabling features.

"Scientists have been making theoretical predictions about near-field heat transfer for a long time, but it's only recently that the technology to measure such nanoscale phenomena come into its own to provide us with experimental capabilities and data," said Meyhofer.

"We knew that radiative heat transfer is strikingly different at the nanoscale. One of the most interesting theoretical predictions to us was that heat transfer could be enhanced with thin films. But no one had demonstrated it, so we began to think about how we could test it," he added.

The platform and technique Meyhofer and Sangi Reddy developed overcome several challenges to measuring near-field heat transfer at the nanoscale, including the effects of temperature changes, forces and mechanical motion.

Their system is able to modulate temperature, enabling resolution of heat flow down to about 100 picowatts (one picowatt equals one-trillionth of a watt) for the experimental conditions used in the study. It can measure as little as one picowatt of power, something Meyhofer and Sangi Reddy plan to leverage for obtaining biological measurements in the future.

Findings showed that near-field radiative heat transfer across nanoscale gaps is indeed dramatically enhanced when compared to the far-field situation. Surprisingly, the high heat fluxes observed with bulk silica can also be obtained with thin films, as long as the gap size between the emitter and receiver is reduced to the thickness of the thin film.

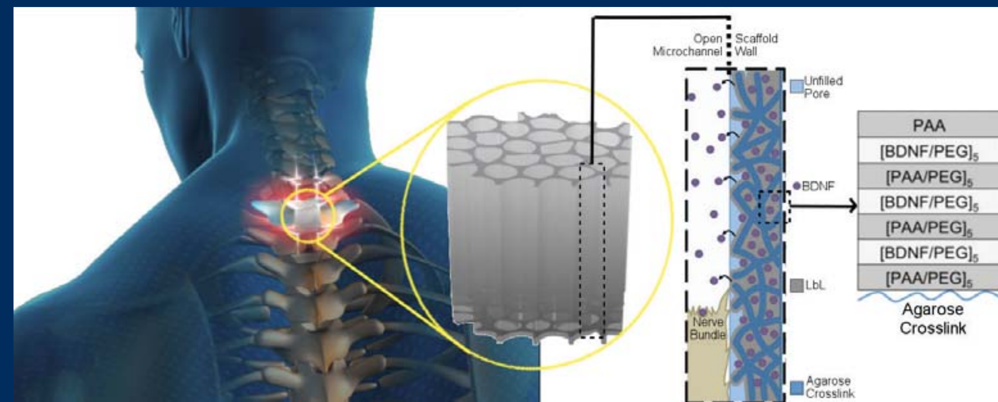
Likewise, the researchers also found that the enhancement is less when the gap between microsphere and plate is larger than the thickness of the film.

"It was important to us to study how this heat transfer would work with dieletric materials in a coating thickness that is relevant from a fabrication standpoint," Meyhofer explained.

"Do those thicknesses still support the high energy fluxes one needs for new nanoscale devices? Magically it works, although at first it was not intuitive to us. In fact, the computational work reported in our paper now provides detailed insights into the gap-dependent, radiant heat transfer of the various films," Meyhofer added.

The research effort took five years and is far from over. Still, the experimental platform developed by Meyhofer and Sangi Reddy as well as their findings will enable them to conduct more detailed studies of nanoscale near-field heat transfer phenomena, particularly in biological systems, that have not yet been investigated experimentally.

"Our research is motivated by practically minded ideas," Meyhofer said. "For example, if one has the appropriate materials and/or engineers suitable nano-structured surfaces, one could enable larger heat fluxes from emitters to receivers in desirable spectral windows. That will allow us to more precisely tune and better control all kinds of current and new technologies and devices."



Nothing Matters

Engineering the Absence of Matter

Associate Professor **Jeff Sakamoto** likes to say, ironically, that he has built a career out of nothing.

By “nothing,” Sakamoto is referring to the intentional removal of mass from materials in order to engineer unique properties. His work is highly interdisciplinary, driven by fundamental research and has enabled new technologies that address problems ranging from energy storage to spinal cord repair.

A GEM OF A SOLID STATE BATTERY

Energy storage is a major roadblock to widespread adoption of electric vehicles. “To meet the durability and safety requirements for vehicle electrification, today’s lithium-ion (Li-ion) batteries require a lot of TLC,” Sakamoto said. “They need thermal management to be cooled, which adds mass, complexity and cost to the battery pack, and you need additional electronics to balance resistance and voltage.”

Sakamoto is one of the first researchers to investigate the use of lithium lanthanum zirconium oxide (LLZO), a fast-ion conducting oxide based on the mineral structure of garnet. By tailoring garnet’s most common gemstone atomic makeup—that is, replacing iron and silicon and adding lithium, lanthanum and zirconium—he has advanced the understanding of ceramic electrolytes for Li-ion batteries.

The solid electrolyte membranes conduct lithium ions equally as fast as state-of-the-art liquid-based membranes, and at room temperature. They could enable more chemically robust batteries that simplify battery operation as well as improve safety, lower weight and reduce cost.

The heartier battery also overcomes the inevitable chemical degradation from conventional organic solvent liquid electrolytes.

Now Sakamoto, who collaborates with Ford Motor Company, Toyota and the U.S. Army Research Lab, is transitioning from fundamental research on the ceramic electrolytes to application. He is working on fabrication technologies to put the solid electrolytes into full cells and will further investigate the kinetics of the solid-to-solid interfaces inside the batteries.

He also is looking at other applications for solid state Li-ion batteries, including in implantable biomedical devices, tablet and e-readers and in down-hole drilling operations, which generate temperatures too high for batteries with liquid electrolytes to survive.

“Solid-state batteries get better when they get hotter,” said Sakamoto, who is in the process of commercializing the technology with support from the Advanced Research Projects Agency-Energy and the University of Michigan’s Energy Institute.

HONEYCOMB HYDROGELS FOR NERVE REGENERATION

In other research that involves the absence of matter, Sakamoto is developing new therapies for spinal cord repair in collaboration with Mark Tuszynski, PhD, MD, director of neural repair at University of California San Diego. The work was initially funded by a grant from the Christopher Reeve Paralysis Foundation.

Currently, interventions to treat spinal cord injuries involve microelectrodes that convey signals from the brain to the extremities.

“It’s not a natural fix,” Sakamoto said. “It doesn’t restore native tissue or native function, which is what we want to do.”

Sakamoto and his team are taking a two-step approach. First, he has developed a fabrication process using hydrogels to create a biocompatible, bioresorbable spinal implant.

The implant’s honeycomb-structured hydrogel walls contain tiny pores that range from two to 50 nanometers. The structure serves as a physical guide for regenerating axons, or nerve fibers, to grow.

> Currently, interventions to treat spinal cord injuries involve microelectrodes that convey signals from the brain to the extremities. It’s not a natural fix—it doesn’t restore native tissue or native function, which is what we want to do.

Biochemical growth cues come from brain-derived neurotrophic factor (BDNF), a protein that stimulates nerve growth. Sakamoto has developed the technology to embed BDNF within the implant’s pores—and to control the release of BDNF through pH.

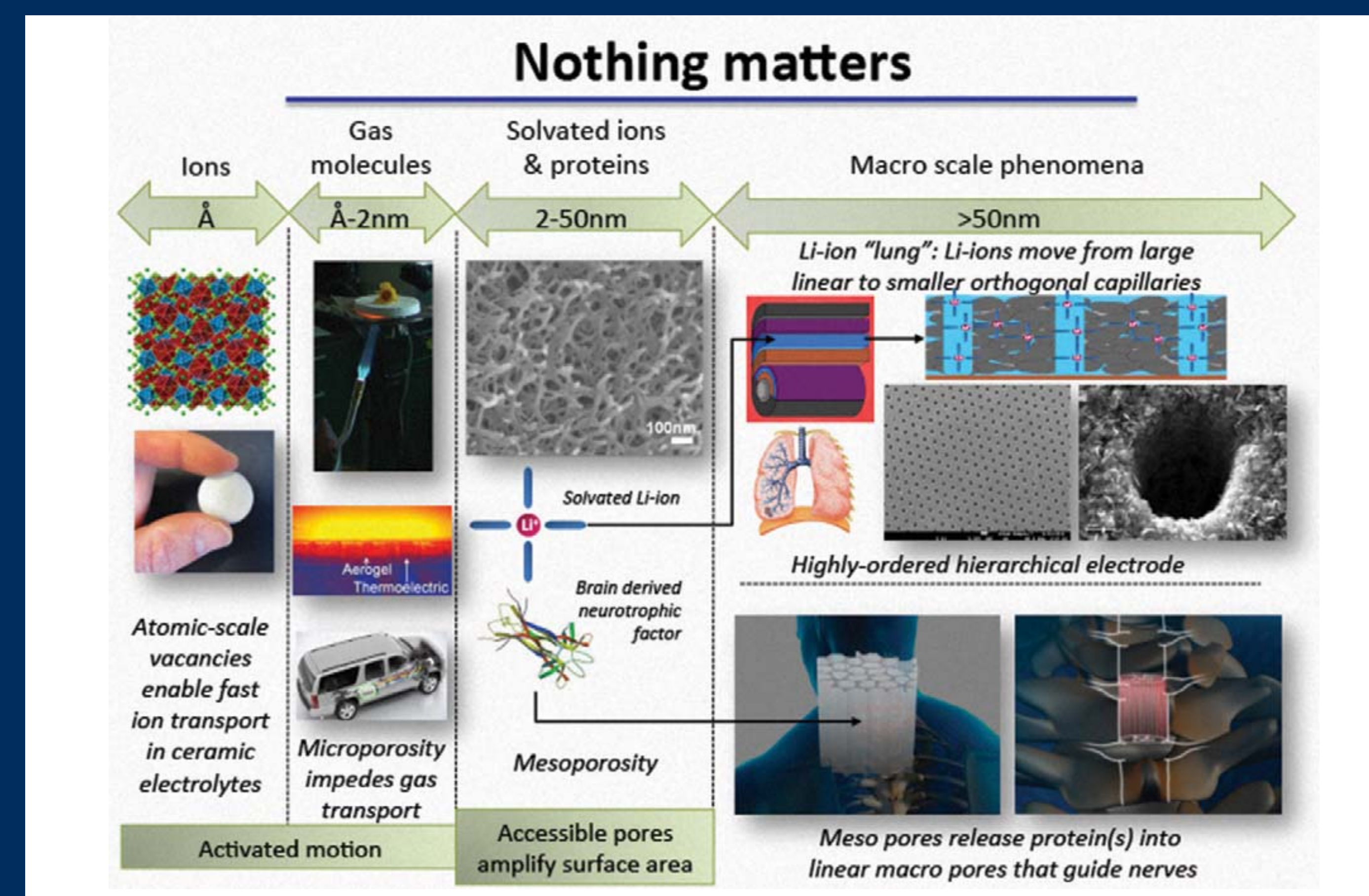
The growth factor is shelf-stable and immobile when pH is low. But when implanted into the body, which has a pH of about 7.4, BDNF is released in clinically relevant doses over the course of two to four weeks, the time required for axons to grow long enough to potentially reverse a typical injury.

Sakamoto and Tuszynski have been the first to demonstrate linear axonal guidance and growth over one centimeter. Clinical studies continue. Currently, the team is looking at peripheral nerve injuries and has formed a spinoff company, ReAxon, based in San Diego.

Sakamoto joined the U-M ME department in 2015. “Coming to U-M is enabling me to take my foundational research in materials science, chemistry and electrochemistry in new directions, toward mechanical design and assembly in order to address problems in many fields,” he said.

LEFT: When implanted in a spinal cord injury lesion, honeycomb scaffold channels provide chemical and physical cues to promote and guide regenerating nerve tissue, respectively. The images on the right depict the pH responsive drug delivery technology consisting of alternating layers of polyethylene glycol (PEG), brain derived neurotrophic factor (BDNF) and poly acrylic acid (PAA) deposited on a hydrogel such as agarose.

BOTTOM: Depending on the scale, the absence of mass can dramatically affect function. At the atomic scale (Angstrom) removing one out of approximately every 50 atoms per formula unit turns a good Li-ionic conductor into a super-ionic conductor; when interconnected pores are in the Angstrom - 2 nm range, molecular transport in ultra-porous materials is significantly impeded to create super-insulating materials; between 2-50 nm, practically all surfaces are accessible, thus amplifying surface area to increase electrochemical reaction rates and electrostatic interaction between proteins and hydrogels for drug delivery; and at > 50 nm ordered macropores can facilitate Li-ion transport in electrodes to improve power (emulating the function of a lung where large capillaries feed into a distributed network of smaller capillaries to improve the update of oxygen) and provide physical cues to guide axons in honeycomb nerve regeneration scaffolds.



Inspired by Nature
Nanoscale Design and Manufacturing

Engineers often find inspiration in the natural world, and that is especially true for Assistant Professor **Neil Dasgupta**, who works at the intersection of nanotechnology, energy science and manufacturing.

"We're continually inspired by natural materials and the way nature has evolved to produce precise and well-ordered nanoscale systems and hierarchical structures across multiple length scales," Dasgupta said. "We learn a lot from the integrated nanosystems observed in biology, and we apply design and manufacturing approaches to engineer new functional nanomaterials with tailored properties."

> We were able to work with the architects and construction team to develop unique capabilities for our lab that facilitate ALD research and our interdisciplinary work. Our research spans basic science and applied engineering and calls for a unique environment optimized for many disciplines. This state-of-the-art building is the ideal home for us.

The applications Dasgupta is particularly interested in include solar energy and electrochemical energy storage. In both of these areas, he uses a technique called atomic layer deposition (ALD). This technique enables him to precisely deposit thin films and generate distinct nanostructures on surfaces and interfaces in order to increase surface area, enhance and control material properties, and improve the efficiency of energy and mass transport processes across material interfaces.

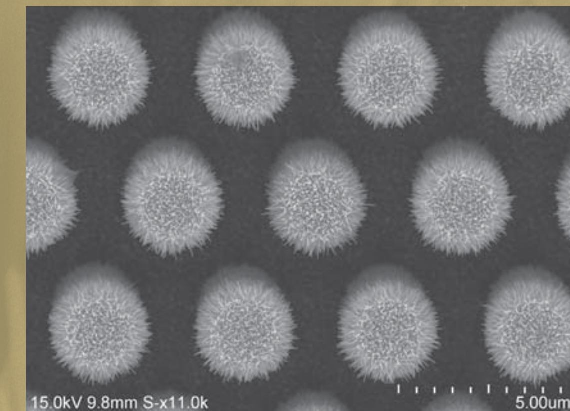
His group has developed the capability to deposit a variety of metal oxide, metal sulfide and metallic materials using ALD. He and the researchers in his lab investigate ALD chemistry using a variety of techniques, including high-resolution microscopy, spectroscopy and quantum simulations to gain atomic-scale insight into material growth and properties.

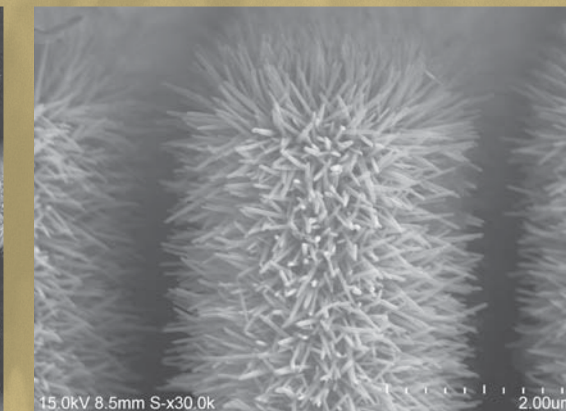
An affiliate of the U.S. Department of Energy's Joint Center for Energy Storage Research (JCESR) consortium, Dasgupta is using these nanoscale material technologies to address the challenges of today's lithium-ion (Li-ion) batteries.

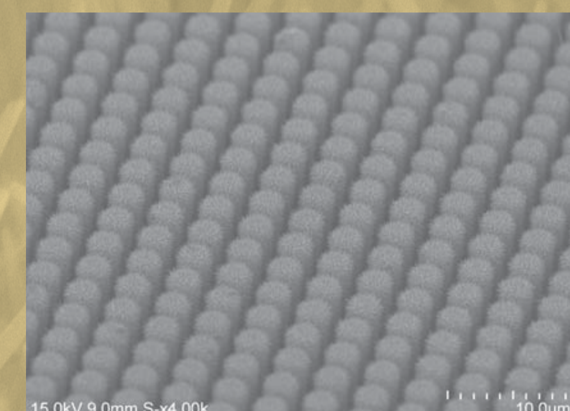
"It's going to take fundamental breakthroughs at the material level to move beyond Li-ion for a range of uses, from portable electronics to electric vehicles and grid-level energy storage," said Dasgupta.

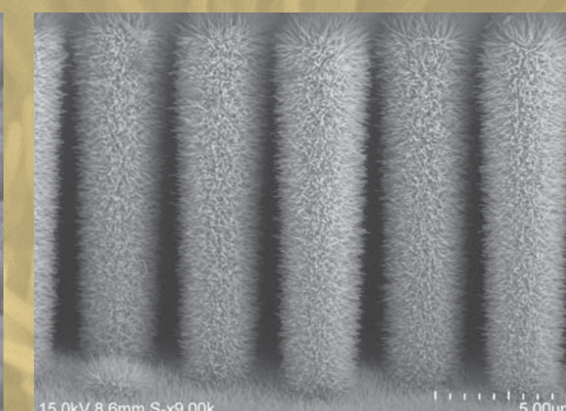
In a current project, he is using ALD to improve battery stability and performance during battery charge and discharge by interfacing Li-metal anodes with tailored nanoscale materials. He is also developing nanoscale solid electrolyte materials that may ultimately displace the flammable liquid electrolytes present in current Li-ion cells.

Drawing inspiration from natural photosynthesis, Dasgupta also uses ALD to stabilize materials and modify semiconductor nanowire arrays for solar energy conversion in a process known as artificial photosynthesis.









The aim of this work is to convert solar energy into fuels, much like leaves capture sunlight, water and carbon dioxide and convert them into fuel in the form of sugar. In artificial photosynthesis, energy is stored as chemical bonds in the form of fuels such as hydrogen and hydrocarbons.

In nature, the photosynthesis process occurs in chloroplasts, the high-surface-area organelles found within plant leaves. For artificial photosynthesis, Dasgupta applies his expertise in surface engineering and bottom-up synthesis of hierarchical nanomaterials to engineer efficient nanomaterial architectures for solar-to-fuel conversion. The nanostructured constituents of these material systems function as "essential building blocks," he noted, similar to the thylakoid stacks within chloroplasts.

For his achievement in mechanical engineering within ten years of graduation, Dasgupta has been selected to receive the 2015 American Society of Mechanical Engineers Pi Tau Sigma Gold Medal Award. He joined the U-M faculty in 2014 and says his work has benefitted greatly from his lab's location in the new GG Brown addition.

"We were able to work with the architects and construction team to develop unique capabilities for our lab that facilitate ALD research and our interdisciplinary work," Dasgupta said. "Our research spans basic science and applied engineering and calls for a unique environment optimized for many disciplines. This state-of-the-art building is the ideal home for us."

LEFT: PhD student Ashley Bielinski operates a customized ALD tool designed and built in the Dasgupta lab for synthesis of nanomaterials for artificial photosynthesis.

TOP: Hierarchical ZnO nanowires grown on silicon microposts via atomic layer deposition seeding and hydrothermal growth.

BOTTOM: Postdoc Kevin Wood and PhD student Eric Kazyak discuss methods for stabilization of Li metal anodes to enable next-generation batteries using an integrated glovebox-ALD environment.

Advancing Combustion Science

Predicting Ignition Behavior in Low-Temperature Regimes

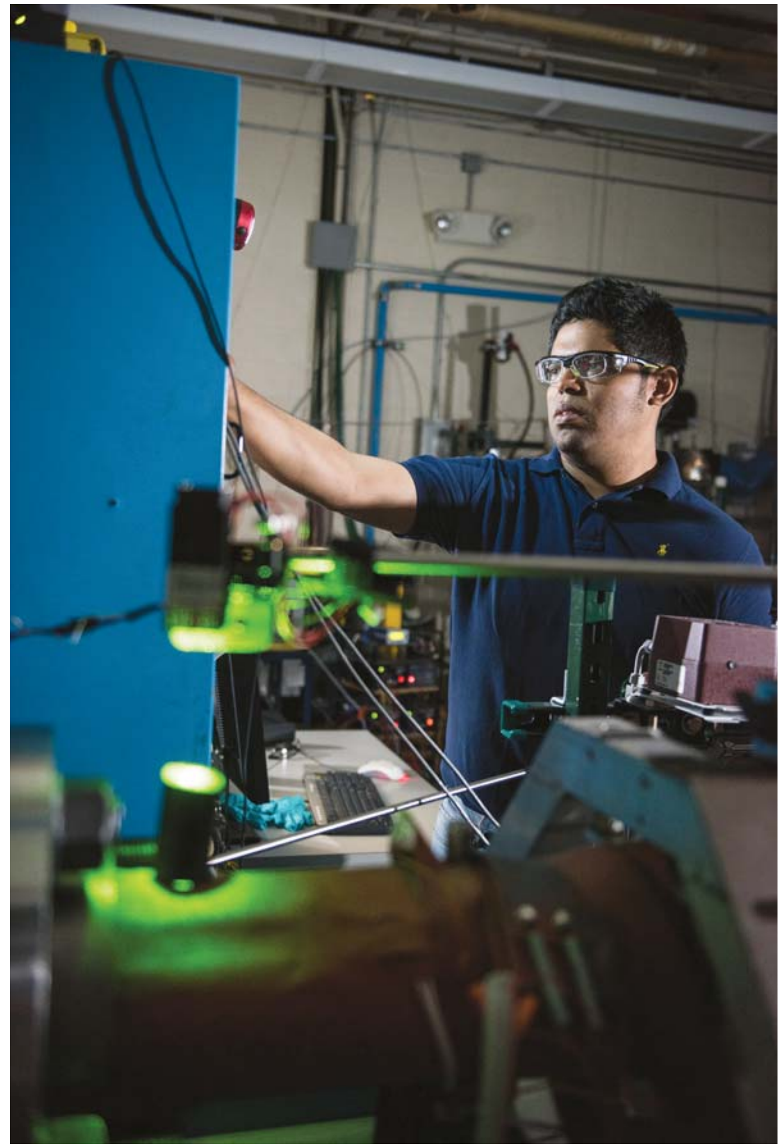
As the transportation sector looks to transition from reliance on fossil fuels to biofuels and sustainable alternatives, scientists need to understand precisely how such fuels react.

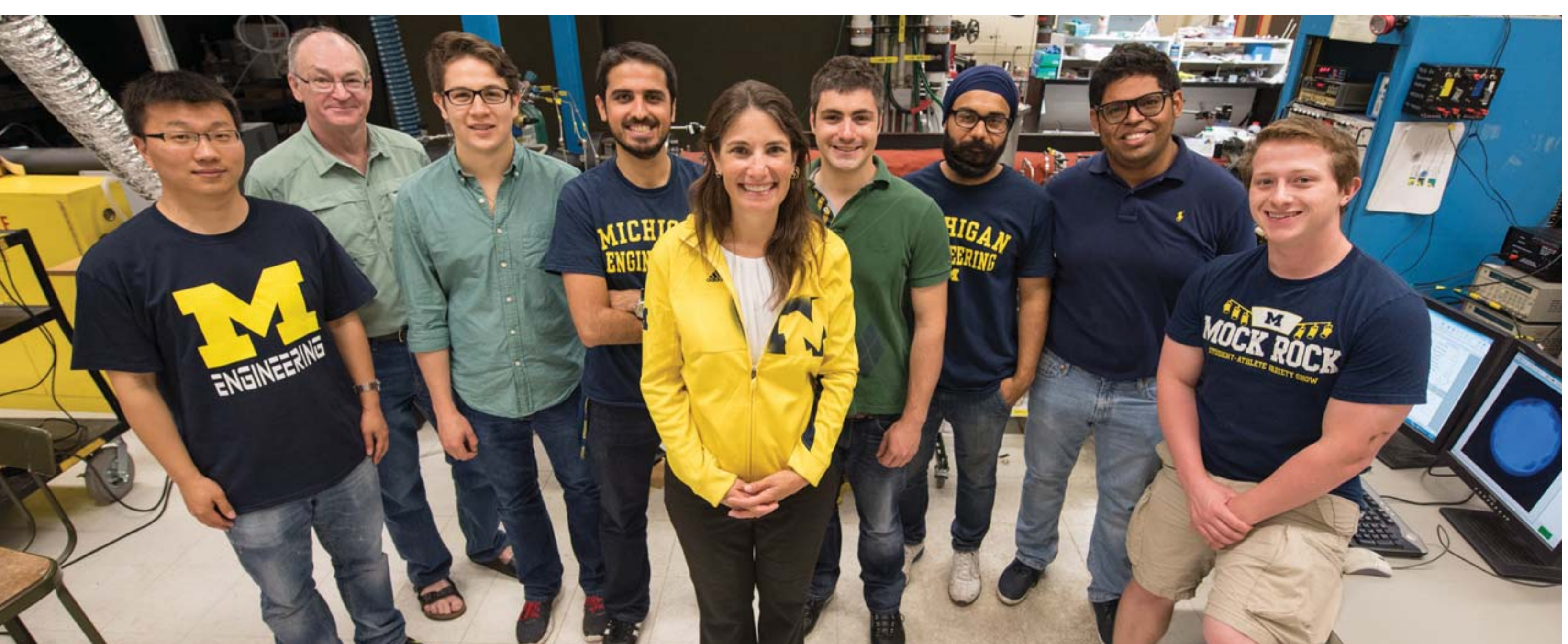
"We have a real opportunity here," said ME Professor **Margaret Wooldridge,** who holds a U-M Arthur F. Thurnau professorship. "Rather than aspire to the same performance as fossil fuels, let's better understand how to use and design these fuels so we leverage their best features and improve performance beyond fossil fuels."

Understanding fuel reactivity and ignition behavior helps improve efficiencies and reduce emissions. But the reactions are complex, and obtaining high-fidelity data to elucidate them is critical.

An international leader in combustion science, Wooldridge recently received the U.S. Department of Energy's prestigious E.O. Lawrence Award for her innovative contributions to energy science and to national energy security (see related story on page 5).

Wooldridge's novel approach to understanding combustion includes development of a powerful experimental platform to characterize fuel behavior, the Rapid Compression Facility, or RCF. Ignition experiments conducted in the RCF provide insights into fuel oxidation pathways and into ignition behavior under realistic combustion conditions.





TOP: Cesar Barraza-Botet (PhD student, right) conducting RCF ignition studies of ethanol.

BOTTOM: The 2015 Wooldridge Research Team From left to right: Hui Liu (visiting student from Tsinghua University), Dr. George Lavoie (research scientist), Luis Gutierrez (PhD student), Dr. Mohammad Fatouraie (research scientist), Professor Margaret Wooldridge, Dimitris Assanis (PhD student), Ripudaman Singh (PhD student), Cesar Barraza-Botet (PhD student), Tyler Huntress (undergraduate student); missing from photo Dr. Scott Wagnon (postdoctoral fellow).

GENERATING HIGH-FIDELITY IGNITION DELAY TIME DATA

Wooldridge and her research team have generated new data on numerous important species and reference compounds, including iso-octane and n-heptane (the two components used to define octane number), ethanol and n-butanol (two biofuels with high potential for reducing carbon emissions), and several esters that are components of biodiesel fuel.

Using the RCF, Wooldridge's research group determines ignition delay times for the fuels. Ignition delay is a measure of the fuel reactivity at controlled pressures and temperatures and is a critical metric to quantitatively compare fuels.

Fast gas sampling and gas chromatography enable further quantitative measurements of more elusive targets like stable intermediate species formed during the ignition delay period. The Wooldridge group uses such methods to monitor the time histories of dozens of compounds like alkenes, which are the building blocks of soot.

The speciation data from the Wooldridge research group are often the first measurements of their kind. The data have a high level of fidelity and are used to identify the specific reaction pathways important in the combustion process.

The research has been supported by the U.S. Department of Energy (DoE) Office of Basic Energy Sciences and Office of Vehicle Technologies. Several students have contributed to the work over the years, including **Scott Wagnon** (PhD ME '14); **Darshan Karwat** (PhD ME '12); **Xin He** (PhD ME '05); and **Cesar Barraza-Botet** (ME '16).

> We needed to develop new ways of conducting experiments and analyzing and presenting data for [ignition] studies. The U-M RCF is the ideal tool to interrogate these systems, and it turns out that 1,000 K is a very interesting place to be.

INVESTIGATING SYNGAS CHEMISTRY

With support from the DoE University Turbine Systems Research program, Wooldridge and former graduate student **Andrew Mansfield** (PhD ME '14) conducted new research using the RCF to investigate the chemistry of syngas, a fuel that is mostly hydrogen (H_2) and carbon monoxide (CO). Syngas can be synthesized from a broad range of feed stocks, including biomass, waste, natural gas and coal, providing a potential zero-carbon-emission pathway for coal.

With a simulated syngas of H_2 and CO, Mansfield conducted experiments at conditions typically found in gas turbine combustors. One of the objectives was to better understand anomalous ignition behaviors that have been observed in previous studies.

High-speed imaging of the ignition process allowed direct observation of irregular ignition. The results were placed on temperature and pressure maps and the outcome, Wooldridge said, was "eye-popping."

She and Mansfield included data from other researchers spanning several decades and derived from different experimental platforms. The results were entirely consistent and provided the first clear identification of ignition regimes.

"The regimes indicate small temperature changes—five or ten degrees here and there—really matter at some temperatures and pressures, but not others. The maps show us when we can expect anomalous behavior, and when theory stops being predictive," Wooldridge said.

Experimental results in hand, Wooldridge collaborated with ME Professor **Hong Im** to develop a regime diagram and theory to characterize syngas and other fuel systems, such as iso-octane, a stand-in for gasoline.

"Sure enough, it worked for that system, too," said Wooldridge, who now is working with PhD student **Pinaki Pal** (ME '16) to expand the regime analysis to include turbulence effects.

"The irregular ignition behavior virtually disappears at high temperatures—above about 1,500 Kelvin, which is where ignition studies have largely focused in the past," Wooldridge noted.

"But combustion efficiencies and emissions benefit significantly from operating at lower temperatures—about 1,000 K and lower," she continued. "We needed to develop new ways of conducting experiments and analyzing and presenting data for these studies. The U-M RCF is the ideal tool to interrogate these systems, and it turns out that 1,000 K is a very interesting place to be."

Internal Combustion Impact:
Improving Efficiency and Emissions

RIGHT: Stani Bohac and PhD students Vasileios Triantopoulos and Yan Chang with the ACCESS vehicle that demonstrated a 25% fuel economy improvement through the FTP75 drive cycle.

LEFT: ACCESS demonstration car turbocharger that enables engine downsizing, advanced combustion, and a 25% drive cycle fuel efficiency benefit.

In spite of the advances made in vehicle electrification, the internal combustion engine is here to stay at least for a while. "The reality is that for the next 25 years, most of us will be driving vehicles powered at least in part by an internal combustion (IC) engine," said **Stani Bohac**, research scientist and director of the Advanced Combustion and Emissions Characterization Laboratory.

Bohac's research centers on improving efficiency of and reducing emissions from IC engines. Given the number of IC-powered vehicles on the roads, even small improvements to IC technologies today can have a large impact on the environment.

ACCESS TO IMPROVED EFFICIENCY

Over the past five years, Bohac and his research team have been part of a U.S. Department of Energy (DoE) collaboration with Bosch, Stanford University and several other companies. At U-M, Bohac led the effort's combustion activities while ME Professor **Anna Stefanopoulou** led the controls-related activities.

The group's mission was to develop engine and powertrain technologies that enable a 25 percent improvement in fuel economy in a passenger vehicle while meeting California's super ultra-low emissions standards—without sacrificing performance.

For the effort, dubbed ACCESS (Advanced Combustion Concepts - Enabling Systems and Solutions for High Efficiency Light Duty Vehicles), Bohac's group developed and validated technologies through simulations and engine testing.

To meet the fuel economy goal, Bohac applied two main technologies: downsizing and boosting with turbo- and superchargers, and advanced, multimode combustion.

To reap the benefits and limit the compromises of different types of combustion, Bohac and his group including assistant research scientist **Jason Martz** simulated, implemented and tested three combustion modes on the same engine: homogeneous charge compression ignition at low loads, spark assisted compression ignition at medium loads and boosted spark ignition at high loads.

To meet the project's emissions goals, Bohac's group also conducted lab testing on several aftertreatment devices, including three-way catalysts with high oxygen storage capacity and passive selective catalytic reduction.

Bosch used the technologies developed to build a fully drivable demonstration vehicle that achieved the DoE's targets.

In addition to meeting engineering goals, the project also was highly successful with respect to education and scholarly contributions. Bohac's combustion and emissions efforts supported eight doctoral, four master's and four bachelor's students over the five-year period, and his team published almost two dozen peer-reviewed papers.

DIESEL ENGINE PARTICULATE EMISSIONS IN THE GREAT LAKES BASIN

In collaboration with the U-M School of Public Health and the U.S. Environmental Protection Agency, Bohac has characterized diesel particulate emissions, polycyclic aromatic hydrocarbons (PAH), nitro-PAHs and other exhaust toxins in the Great Lakes Basin.

"We know engines release toxins into the environment and we know toxins have accumulated in the environment, but it isn't always clear what the main sources of these accumulations are and how much comes from engines. Developing and implementing smart regulations requires that we understand the sources and nature of the pollution, including from diesel engines," Bohac said.

Under a variety of conditions, Bohac measured diesel particulates and related toxic compounds. His public health colleagues analyzed these, as well as material from the bottom of Lake Michigan and from birds and fish. They then compared the chemical profiles.

"We found that a lot of the PAHs and nitro-PAHs found in Lake Michigan likely came from diesel engines," Bohac said.

But his lab testing also showed that changing the composition of the fuel, by reducing aromatics for example, can greatly reduce emissions of these toxins. And using a diesel particulate filter, currently the only technology available to meet strict particulate-limit regulations, reduces the amount of the toxins over 1,000 times.

As a result, Bohac expects diesel engines' role as contributors to environmental PAH and nitro-PAH loading in the Great Lakes Basin to decline in the near future.

CURBING GASOLINE ENGINE EMISSIONS

With forthcoming regulations of gasoline particulate emissions challenging auto manufacturers and suppliers, Bohac is working on two new projects with Chrysler and Bosch.

An increasing number of vehicles are being produced with gasoline direct injection to improve efficiency, but these engines also emit more particulate matter. With Chrysler, Bohac, Associate Research Scientist **John Hoard** and Professor **Andre Boehman** are comparing different types of gasoline particulate filter technologies and production sensors for measuring particulate emissions.

> Bohac's combustion and emissions efforts supported eight doctoral, four master's and four bachelor's students over the five-year period, and his team published almost two dozen peer-reviewed papers.

With Bosch, Bohac is conducting in-cylinder imaging and particulate matter characterization to understand how different fuel injectors affect particulate formation.

"The engineering and scientific challenges of these collaborations are complex and interesting, since many important interrelated emissions phenomena occur in the engine, after-treatment system and the environment after exhaust leaves the tailpipe," said Bohac.

From Human Populations to Cells:

Using Advanced Systems Dynamics to Improve Human Health and Safety

Infectious disease epidemics, early diagnosis of neurodegenerative diseases and airplane engine safety all represent complex multi-scale nonlinear systems. Understanding their behavior lies at the forefront of new frontiers in improving human health, safety and welfare.

"Discovering new ways to use nonlinear dynamics principles helps us create transformative technologies and better understand and predict complex system behavior," said Professor **Bogdan Epureanu,** who heads the U-M Applied Nonlinear Dynamics of Multi-Scale Systems Laboratory.

INFECTIOUS DISEASE DYNAMICS – UNLOCKING THE SECRETS OF OUTBREAKS

"If we look at the dynamics of infectious diseases, for example," said Epureanu, "forecasting how such diseases reach a 'tipping point' and move through a population continues to challenge public health officials."

Outbreaks may appear to be unpredictable and random, but according to Epureanu, the dynamics of the disease before a tipping point occurs "leave us clues that tell us how close the dynamics are to a dramatic change."

As part of the National Institute of General Medical Sciences Models of Infectious Disease Agent Study (MIDAS), Epureanu is creating a new theory based on nonlinear dynamics and statistical signatures to forecast infectious disease behaviors before they reach a critical point. A recent review paper, "Anticipating Critical Transitions," published in *Science* and citing Epureanu's work, highlights the strategic importance of early warning methods for the U.S. Centers for Disease Control and the World Health Organization.

CELLULAR DYNAMICS—SIGNALING NEURODEGENERATIVE DISEASES

Scaling down from populations to cellular systems, Epureanu is exploring essential intracellular transport processes contributing to the burgeoning field of computational neuroscience. His approaches treat deterioration in communication among neurons as dynamic phenomena, which evolve with dramatic consequences in most neurodegenerative diseases. For example, current biomarkers for Alzheimer's disease detection lack sensitivity and can predict only advanced stages of the disease, where the rate of successful treatment is only 50 percent.

Recent breakthroughs in this field have shown that the excessive phosphorylation

> Discovering new ways to use nonlinear dynamics principles helps us create transformative technologies and better understand and predict complex system behavior.

of tau protein on microtubules—the "tracks" used for transport inside cells—mechano-chemically impedes transport of cellular cargoes along axons. A crucial emerging question is: What signs can reveal that tau has started to be an obstacle for nanotransport?

Epureanu's answer lies in key nonlinear dynamics inside axons, where motor proteins—tiny molecular carriers—start to exhibit changes in their journey along axons.

"Through an innovative dynamic interrogation, we conduct advanced computations and experiments to characterize nanotransport activities along axons to 'see' these modifications as they occur," said Epureanu. "This is a breakthrough, since it is difficult or even impossible to monitor *in vivo* this kind of cell activity."

Epureanu's models aim to speed detection of neurodegenerative diseases, so that drug treatment may still offer hope. "The new models we are proposing can improve the time to diagnosis, which can have a significant impact on disability, quality of life and mortality," he said.

With graduate student **Woochul Nam** (PhD ME '15), who earned the prestigious "Distinguished Dissertation" award from the U-M Rackham Gradaute School, Epureanu recently published the findings in *PLOS Computational Biology, Physica D* and *Physical Review E* journals.

AEROMECHANIC DYNAMICS—A DETECTIVE WITH UNIQUE MODELS AND DATA

Epureanu's passion for fundamental nonlinear dynamics applied in aeroelastic systems and turbomachinery precedes his arrival at U-M in 2002. His reduced order models allow unprecedented speeds in computational dynamics and enable structural health monitoring of fluid-structural systems such as wings and airplane engines. For example, tiny material defects in integrally bladed rotors (IBRs), which are essential components of modern engines, can be dramatically amplified when rotating tens of thousands of times per minute. This can lead to extreme failures.

"Sensor placement, enhanced sensitivity and data interpretation are key to structural health monitoring of complex systems," said Epureanu, who ingeniously tackles these challenges through nonlinear dynamics and unique system interrogation. His work in this area has been published in several journals, including *AIAA Journal* and the *Journal of Sound and Vibration.*

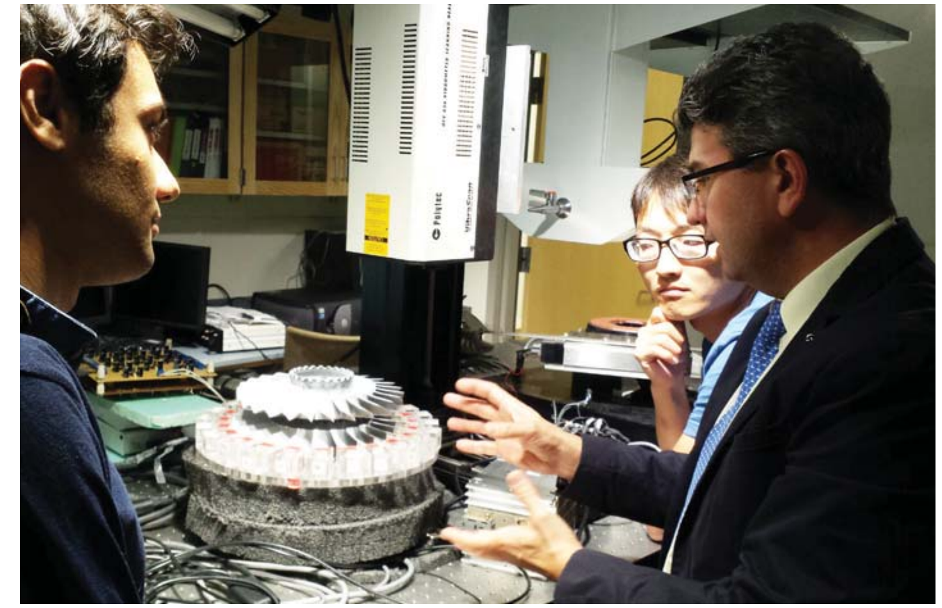
"We are creating high-performance computational tools capable of statistically predicting the response of blended IBRs equipped with complex damping systems," said Epureanu. His methods define a "solid roadmap" for designing the engines of the future.

The advanced computational tools are able to effectively analyze the effects of damping systems and blend repairs on IBR and engine performance and operability. This work is supported by the leading turbomachinery manufactures in the world—General Electric, Pratt & Whitney, Siemens—and by the GUIde Consortium, a collaboration of industry, university and government partners focused on aeromechanics. Epureanu's results have been awarded the Strickland Prize, a Petro-Canada Young Innovator Award and multiple journal citations.

INTEGRATIVE THINKING – SHARING A PASSION FOR RESEARCH AND TEACHING

Epureanu, who won a Pi Tau Sigma Professor of the Term distinction and several teaching awards, is quick to share his love of integrating research and teaching. "I am passionate about teaching our students the newest discoveries and most advanced knowledge. For that we have to engage our students in integrative, multi-scale, systems thinking. It is not news that today's technology initiatives are defined by challenges in energy, environment, human and natural threats and health—highly complex problems which require skills in integrative system thinking and design."

To that end, Epureanu spearheaded the creation of a new Master's program in Systems Engineering and Design. "Through this new program, our students learn to pose, and answer, complex questions, deal with uncertainty and appreciate the social and human aspects of complex engineered system design."



FAR LEFT: Nonlinear dynamics is a key synergy which Prof. Epureanu explores among intracellular transport processes and in neuronal networks (left), infectious disease dynamics (middle left), engineered systems like airplane engines (middle right), and complex transportation systems (right).

TOP: Integrative systems thinking and team work is essential in tackling complex system dynamics such as vibration of multi-stage turbomachinery blisks (left and right are graduate students Amin Ghadami and Jau-Ching Lu, center is Prof. Epureanu).

BOTTOM: Aeromechanics involves complex turbomachinery (left) which requires advanced system dynamics based on complex models and unique data analysis tools; these being synergistic to the spatio-temporal dynamics of infectious diseases and complex transportation systems (right).

Terrestrial Micro-Robots Drive New Actuation
Sensing and Control Technologies

> The robots really have pushed us to make technologies better….You're forced to look at what you can do with less, and that applies in a lot of areas. The robots have taken us to some very interesting places.

Micro-scale terrestrial robots have the potential to bring large-scale benefits to search and rescue operations, infrastructure maintenance and many other areas. But developing the actuation, sensing and control capabilities required at such a small scale present engineers with a number of challenges.

Enter the U-M Vibration and Acoustics Laboratory's Microsystems Group, run by Associate Professor **Kenn Oldham.**

"What's most interesting to our group are applications of microsystems where performance really can be enhanced by adding some measure of sensing and feedback control, or other regulation such as power system regulation, to the system," said Oldham.

Oldham's longest running project has been the development of terrestrial micro-robots, which requires extremely compact actuation technology coupled with low-power gait and motion control—all while receiving limited sensor feedback.

Oldham's work on the robots, on the order of a few millimeters to a centimeter in size, began in collaboration with the U.S. Army Research Laboratory (ARL). The ARL developed the actuation technology; Oldham's role was to understand what was necessary to translate that technology into a functioning micro-robot.

Oldham began investigating a number of issues: how to configure the actuators to get the most effective motion, how to allocate power for actuation and how to integrate sensing and control into the tiny system.

The actuators are based on thin-film piezoelectric technology and function well, but to enable such actuators to move robots off-chip, Oldham is integrating polymer joints into multiple actuator arrays. These serve as tendons and ligaments of sorts in order to make the auxiliary structure of the robot more reliable while increasing range of motion.

Work continues on building more robust and mobile prototypes. On-chip, tethered robots can take a step or two. Others have been released from the silicon wafers they were built on but are not yet able to walk.

The micro-scale walking robots have led Oldham in new but related directions, including foot-terrain modeling and new approaches to managing power consumption.

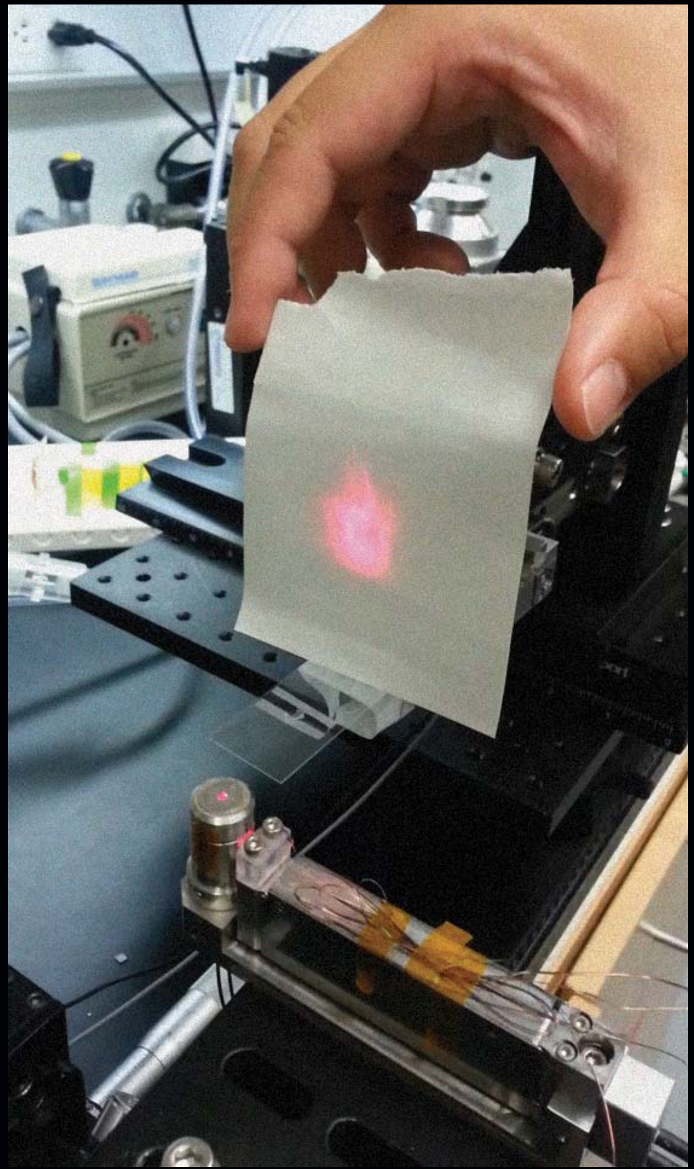
The robots also have led to new application areas. With collaborator **Thomas Wang,** PhD, MD, who holds appointments in Mechanical Engineering, Biomedical Engineering and Internal Medicine, Oldham is adapting the actuators to move scanning mirrors and lenses for laser scanning in advanced endoscopic microscopy instruments.

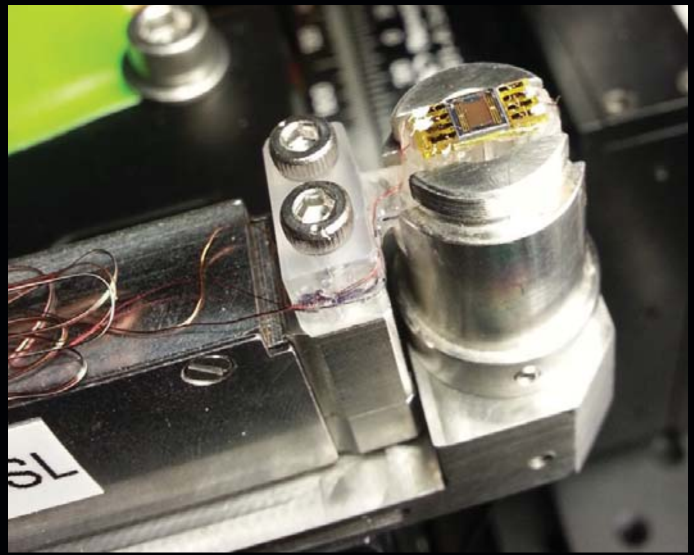
The dual-axis confocal microscopy technique enables deeper imaging of tissue and, by reducing the size of components, could allow physicians to obtain cross-section images during endoscopy, potentially eliminating the need for physical biopsy.

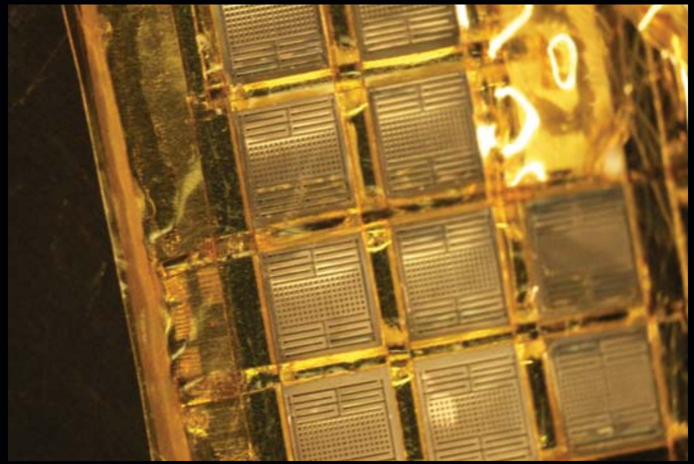
In collaboration with professors **Khalil Najafi** and **Yogesh Gianchandani** in Electrical Engineering and Computer Science, the Oldham group is applying its experience with low-power sensing and control to the calibration of MEMS gyroscopes.

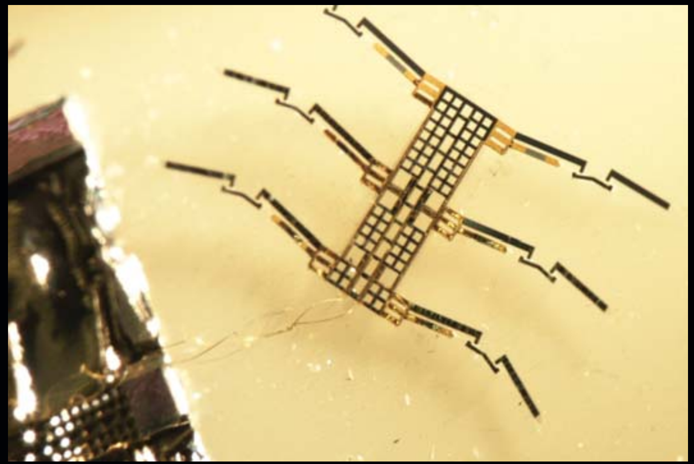
With Professor **Kayvan Najarian** and others in the Department of Emergency Medicine, Oldham is conducting dynamic systems modeling for portable cardiovascular sensing systems. Such systems measure blood pressure, as well as additional pressure fluctuations that have a significant dependence on cardiovascular health, and can provide physicians with further, critical information about their patients.

"The robots really have pushed us to make technologies better, because compared with a traditional controls environment, the environment is stripped down and has a lot of limitations. You're forced to look at what you can do with less, and that applies in a lot of areas," said Oldham. "The robots have taken us to some very interesting places."









TOP LEFT: Researchers from the Mechanical Engineering Department's Microdynamics Laboratory and School of Medicine's Optical Imaging Laboratory test the scanning behavior of a thin-film piezoelectric micro-mirror.

TOP RIGHT: An array of electromagnetic vertical actuators for miniature imaging instruments.

BOTTOM RIGHT: Closeup of bio-inspired hexapedal walking micro-robot.

BOTTOM LEFT: A thin-film piezoelectric scanning actuator installed in a prototype dual axes confocal endomicroscope.

Advanced high-strength steels will enable next-generation lightweight vehicles, but to make significant weight reduction a reality, we have to have new, optimized methods for joining these different steels and joining the steels with other materials.

Structural Integrity
Exploring Fracture and Fatigue in Engineering Materials

The auto industry is striving for change: vehicles that weigh less, cost less to manufacture and include electrification and other technologies to improve fuel efficiency—all while maintaining, if not improving, structural integrity.

The work of Professor **Jwo Pan** is contributing to vehicle improvements through fundamental and experimental research in the U-M Structural Durability Lab. His research explores metal joining technologies and fatigue and failure of engineering materials, including battery cells.

BATTERY TESTING AND MODELING

Automakers have embraced lithium-ion (Li-ion) batteries for vehicle electrification given the batteries' relatively light weight and high energy density. With their growing use in passenger cars, Li-ion batteries' mechanical performance is an important component of vehicle crashworthiness analyses.

But testing and modeling high-voltage battery cells, modules and packs is complex. Testing live batteries is hazardous. And developing computational models of battery behavior involves integrating multiple physics phenomena at multiple length scales.

First, Pan and his group developed testing methods to look at the mechanical properties of the representative volume elements (RVEs) of lithium iron phosphate batteries since no standard test had existed. The researchers developed test specimens made without electrolytes to reduce the hazards. They tested the specimens under different loading conditions, including compression, tension and metal punching.

Pan's research group then developed computational models that can be used to further investigate different types of behavior, including buckling at the micro- and macro-scales, kinking and the formation of shear bands at the macro scale.

The Pan group's experimental results validated its theory of small test-specimen size selection and advance the understanding of the mechanical behavior of Li-ion batteries and deformation processes. The work will enable others to develop new materials models for battery modules. It provides test data useful for developing computational models for multi-scale, multi-physics analyses of vehicle battery packs in crash conditions.

JOINING SIMILAR AND DISSIMILAR MATERIALS

Advanced high-strength steels, aluminum and magnesium alloys can help automakers reduce vehicle weight, but such lightweight materials also call for new and improved welding methods.

"Advanced high-strength steels will enable next-generation lightweight vehicles, but to make significant weight reduction a reality, we have to have new, optimized methods for joining these different steels and joining the steels with other materials," Pan said.

In one study, Pan and colleagues investigated friction stir spot welding (FSSW), a fairly new welding method, for advanced high-strength steels as well as for aluminum alloys. These welds have complex geometries, and Pan and colleagues looked at how the welds failed under different loading conditions.

The team found that kinked crack growth was a consistent failure mode and subsequently developed a related model to estimate weld life for both aluminum and advanced high strength steels.

The Pan group's work on FSSW for joining advanced high-strength sheets earned the Society of Automotive Engineers (SAE) Arch T. Colwell Merit Award for its potential to reduce vehicle weight.

In other work, supported by the U.S. Department of Energy Lightweight Vehicle Program, Pan looked at ultrasonic spot welding (USW), potentially used to join lightweight aluminum and magnesium alloys to steel vehicle structures. His group conducted an experiment investigating fatigue and failure of ultrasonic spot welds in magnesium and steel sheets welded with and without an adhesive.

The findings showed that kinked crack growth was again the consistent failure mode, and the related model that Pan's team developed can be used to estimate weld life.

In a separate study, Pan and his group looked at how discontinuous gas metal arc welded joints perform in traditional high-strength steels. Minimizing the length of the welds in these materials can lead to significant cost savings resulting from faster processing and less material use. But welds that are not the proper size can reduce structural integrity, a highly undesirable consequence.

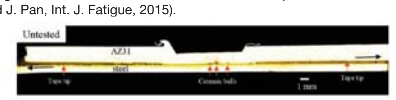
Pan and his team looked at high-strength steel specimens with various weld lengths and under various loading conditions to better understand the effects of weld geometries on, and mechanical properties of, the resulting joints.

Using scanning electron and optical microscopy techniques, investigators found that the welds failed in similar locations and via similar modes. They also conducted micro-hardness tests to assess mechanical properties of the base metal, the heat-affected zone and the weld metal and conducted several finite element analyses that led to the development of new models. Pan and his team also examined laser weld failure of the high-strength steel.

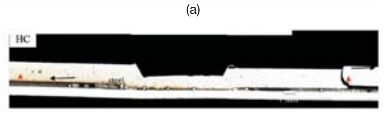
"A fatigue life estimation model of kinked crack growth appears to work for various types of welds in steels, aluminum and magnesium alloys," said Pan, summarizing the findings.

Mg/adhesive/steel testing

A top view of ultrasonic spot welded (USW), adhesive-bonded, and weld-bonded (ultrasonic spot welded and adhesive-bonded) lap-shear specimens of magnesium and steel sheets. Prior to applying the adhesive, two tapes, as shown in the figures, were placed between the magnesium and steel sheets to form two pre-cracks. The indentations of the sonotrode tip on the upper magnesium sheet of the USW and weld-bonded specimens are also shown (From W.-J. Lai and J. Pan, Int. J. Fatigue, 2015).



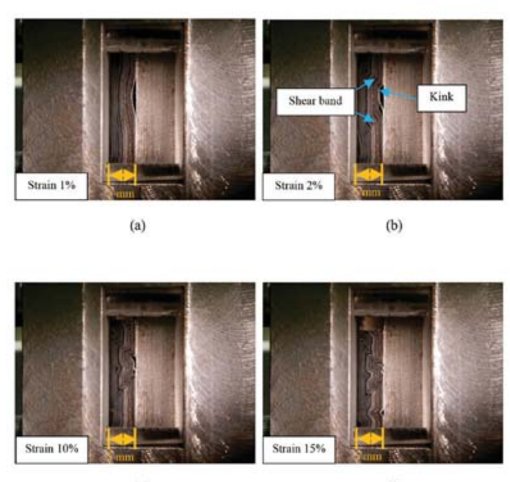
(a)



(b)

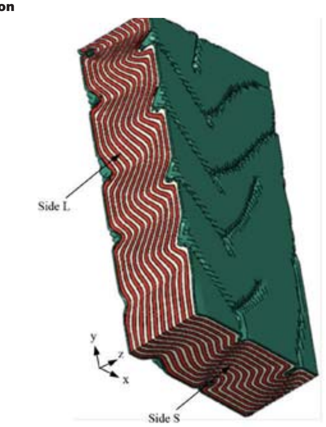
(a) A micrograph of the cross section near the joint in an untested weld-bonded lap-shear specimen of magnesium and steel sheets. Several zirconia balls are shown along the interface in the ultrasonic spot weld. (b) A micrograph of the cross section near the failed joint in a weld-bonded lap-shear specimen under high-cycle fatigue loading conditions. The arrows indicate the loading directions. A kinked crack is shown to initiate from the tape tip and grow up into the magnesium sheet at an angle (From W.-J. Lai and J. Pan, Int. J. Fatigue, 2015).

Battery cell testing



Deformation patterns of a battery cell specimen during a compression test: (a) at the nominal strain of 1% where a smooth buckling mode of the cell components is developed, (b) at the nominal strain of 2% where kinks and shear bands of the cell components are developed, (c) at the nominal strain of 10%, and (d) at the nominal strain of 15% where more kinks and shear bands of the cell components are developed (from W.-J. Lai, M. Y. Ali, and J. Pan, J. Power Sources, 2014).

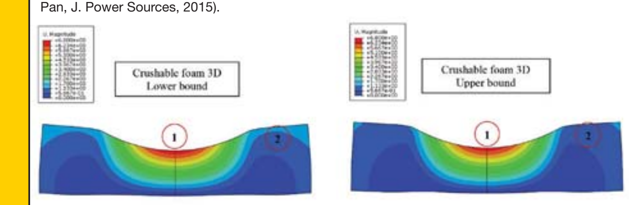
Computational simulation of a battery cell under biaxial constrained compression



The development of kinks and shear bands in a battery cell specimen under equal biaxial constrained compression at the nominal strain of 22% in the x and y directions from a detailed three-dimensional computational model of the anode, cathode and separator sheets (from M. Y. Ali, W.-J. Lai, and J. Pan, J. Power Sources, 2013).

A small scale battery module under punch indentation

A side view of a tested small-scale battery module specimen after punch indentation. The foam layers on both sides of the specimen were removed for clarity (from M. Y. Ali, W.-J. Lai, and J. Pan, J. Power Sources, 2015).



(a) (b)

The contours of the residual displacement magnitude of a small scale battery module specimen, after the punch is displaced statically downward by 8 mm and then released, from the finite element analyses based on (a) the macro homogenized crushable foam material model with the module test data adjusted to the lower bound, and (b) the macro homogenized crushable foam material model with the module test data adjusted to the upper bound (from M. Y. Ali, W.-J. Lai, and J. Pan, J. Power Sources, 2015).

Spitting Image

Understanding Saliva's Properties for Health

Saliva is critical to human health. It aids swallowing, helps maintain the body's pH as well as fights infection, protects teeth from decay and lubricates the tissues of the mouth to facilitate chewing and wound healing.

But changes in saliva's rheological, or flow-related, properties can cause it to become thick and stringy. Health professionals refer to this as "sticky saliva," and it can both impact a patient's health as well as signal changes in health status that could provide helpful clues to care providers.

Along with a colleague in the VA Ann Arbor Healthcare System Audiology & Speech Pathology Service, Professor **Bill Schultz,** Professor **Mike Solomon** (Chemical Engineering), and ME PhD candidate **Louise McCarroll** have been working to characterize liquids similar to saliva and their rheological properties. They are looking specifically at viscosity, elasticity and surface tension to better understand how changes might relate to both oral and systemic health.

Although health professionals use the term sticky saliva, "there really are no qualitative, or quantitative, measures of what that means," Schultz explained.

"We hope our work will be able to help health professionals recognize what properties make saliva stringy and sticky and how that might be indicative of, or cause, health problems such as tooth decay and swallowing issues," Schultz added.

Saliva has not been fully and accurately characterized before from a rheological perspective. In many respects, including its response to shear (similar to a sliding force), water and saliva behave similarly.

However, saliva differs from water when it is elongated, similar to pulling taffy. After elongation, water forms a short-lived filament that rapidly breaks up, while the saliva filament lasts much longer. This longevity indicates viscoelastic or surfactant effects.

Indeed, saliva contains mucins, proteins with attached carbohydrate molecules that are associated with viscoelasticity. If you've noticed how potato chips begin to taste sweet as you chew them, you're detecting mucins at work; they kick off the process of turning starches into sugars.

Another unique feature of saliva is the shape it takes on when elongated, first evolving cylindrically and then into a "beads-on-a-string" arrangement.

Schultz, Solomon and McCarroll believe the beaded arrangement is attributable to surfactants. Using standard, or Newtonian, fluids such as silicone oils, they have been developing tools to characterize rheological properties as part of a benchmark analysis.

To date, the team has developed an experimental technique, the apparatus to test samples, and a novel differential analytical framework to determine Newtonian properties from a fluid filament's shape. Initial experiments have validated their approach.

Schultz, Solomon and McCarroll hope to expand their methodology to analyze viscoelasticity, surfactant and rheological properties simultaneously, something that has not been studied before.

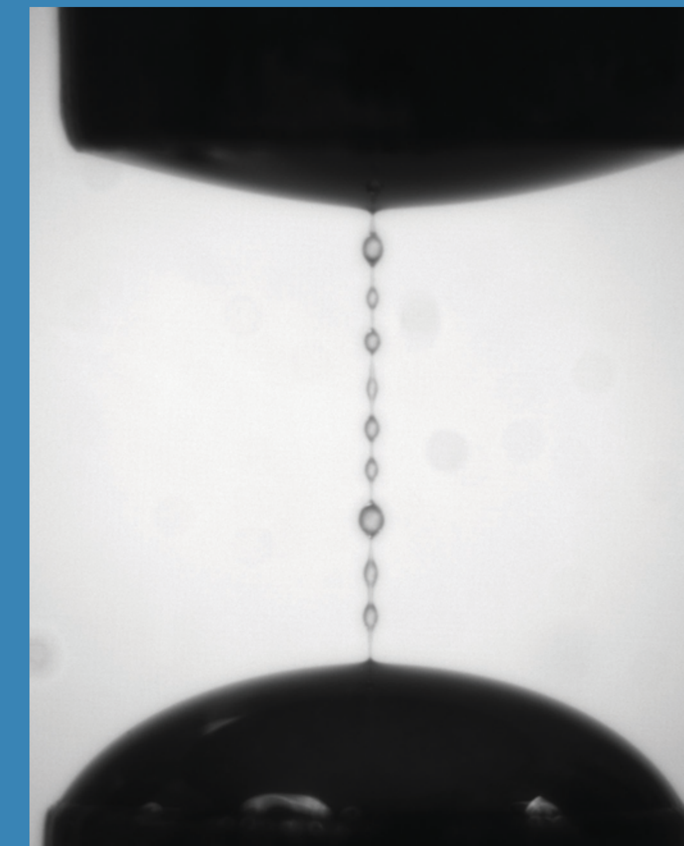
In the future the team also plans to characterize saliva wettability to understand how saliva and its properties interact with the mouth's hard and soft surfaces, that is, tooth enamel, cheeks and tongue.

The researchers will work with clinicians to compare qualitative observations of patients' oral and systemic health with the elongational response of the individuals' saliva. Their overarching goal is to quantify saliva mechanics in both healthy and unhealthy patients.

"We're hoping to get to a point where we could make our apparatus inexpensively and to be disposable and to the point where doctors could use it to conduct diagnostic tests to ascertain the health of their patients," Schultz said.

LEFT: A capillary break-up rheometer is a useful tool for measuring flow properties, such as viscosity and surface tension, when the fluid filament is in extension. Here, capillary break-up rheometry is demonstrated in a photographic time series with a saliva filament. A squat, cylindrical fluid filament is constrained by two circular and parallel plates initially separated by small gap. The plates are rapidly pulled apart and come to rest at a final separation length. The filament then continues to evolve due to capillary, viscous, gravitational and elastic forces. The filament shape evolution is monitored with a camera to determine the ratio of surface tension to viscosity.

RIGHT: As shown in the previous figure, the saliva filament initially thins in a nearly cylindrical fashion but slowly evolves into a final "beads-on-a-string" morphology. The research team believes surfactants in saliva play a large role in forming this beaded structure.



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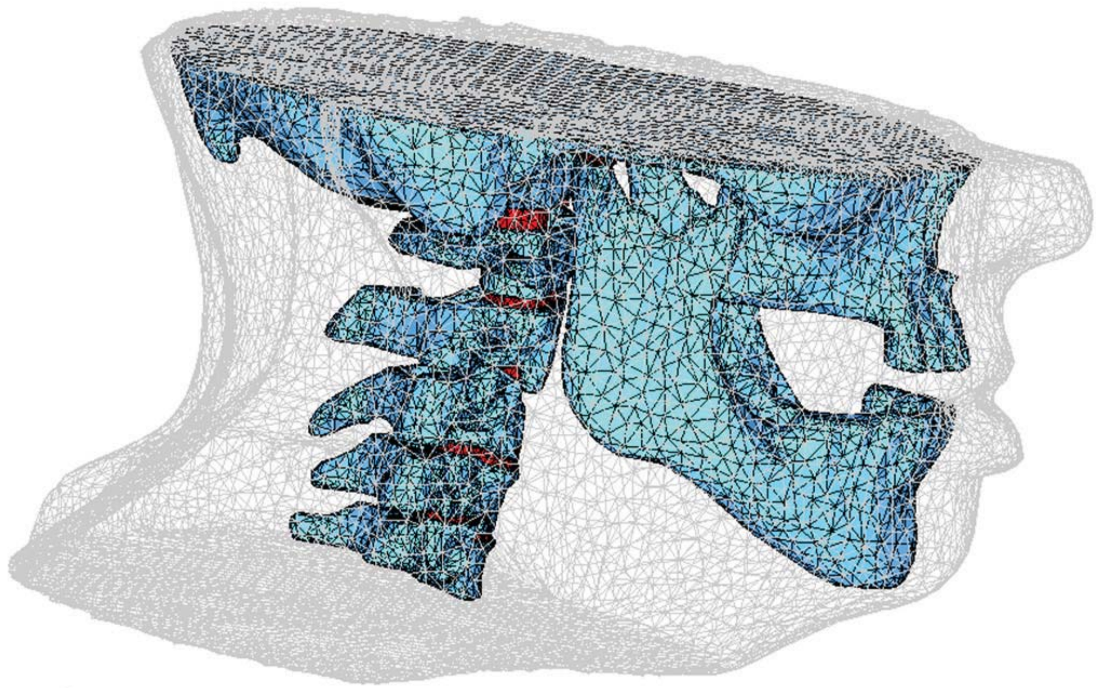


Algorithmic Synthesis
Improving Systems, Creating Solutions

Research in the Algorithmic Synthesis Laboratory (ASL) led by ME Professor **Kazuhiro Saitou** continues to stretch the traditional boundaries of mechanical engineering. The innovations Saitou and his students are developing are anything but conventional, and their work in the fields of biomedical systems and bioinformatics is being recognized for its impact and potential.

IMPROVING RADIATION TREATMENT PLANNING

Together with graduate student **Jihun Kim** (PhD ME '15), Saitou has led development of the computer code that improves the accuracy of radiation treatment for cancer.

Even small changes in patients' anatomy throughout the course of treatment can affect how well the therapy works. Saitou and his group have developed the code to enhance the current digital image registration algorithms used in treatment planning. These algorithms enable geometric mapping of anatomical changes so treatment can be adjusted based on the variations. The code provides new biomechanical guidance via tissue-specific constraints on physically realistic variations, and finite element methods that assesses the quality of image processing.

Saitou and Kim collaborated with professors **James Balter** and **Martha Matuszak** in the U-M Radiation Oncology department. The work was supported by the National Institutes of Health. The code has been incorporated into Elastix software, an open source medical image registration platform considered the de facto standard by researchers worldwide.

Kim will go on to serve as a postdoctoral fellow at Massachusetts General Hospital, under the supervision of a faculty member at Harvard Medical School.

PREDICTING PROTEIN BEHAVIOR

Predicting the behavior of protein structures is important to understanding countless biological processes, including the causes and development of many neurodegenerative diseases such as Alzheimer's and Parkinson's.

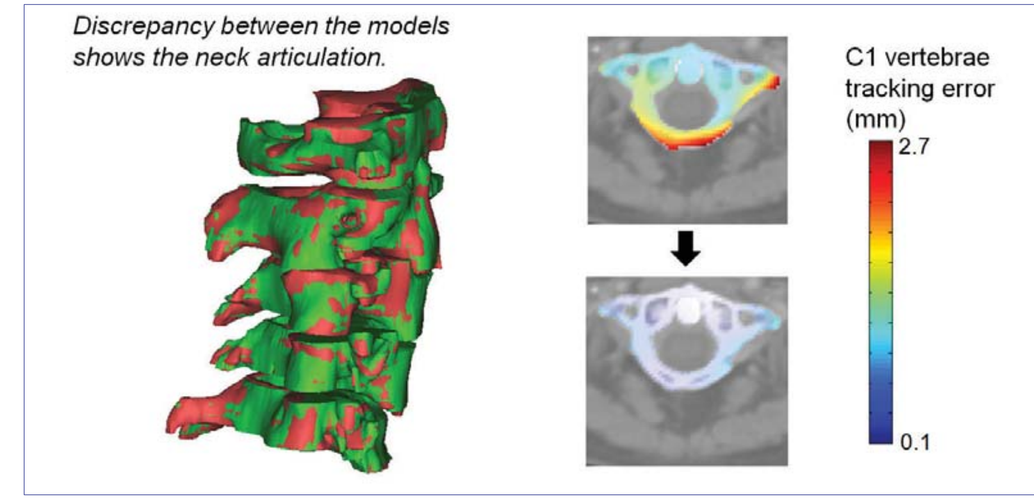
For his dissertation, postdoctoral research fellow **Jungkap Park** (PhD ME '13) achieved record accuracy in predicting the behavior of protein structures. Specifically, Park developed a new multibody statistical potential function to characterize the atomic-level interactions of tightly folded proteins.

The new potential function is the first to explicitly take into account a chemical bond's rotameric states, something previous work had not considered. Rotamers are low-energy conformations of protein side-chains. Park and Saitou named the new potential ROTAS, for ROTamer-dependent Atomic Statistical potential.

Benchmark tests on the standard test problems show that ROTAS predicts protein structures better than any existing potential functions. The new ROTAS potential function can be applied to the improved development of many applications in medicine (e.g., drug design and molecular docking simulation) and biotechnology (e.g., mutation analysis and novel enzyme design). Park and Saitou have made it publicly available at **https://sites.google.com/a/umich.edu/rotas/.**

LEFT: A computer simulation model of human head-neck system can mimic anatomical variations occurring over the course of radiation therapy.

RIGHT: Fundamental theory of mechanics can bring advancement to medical image processing, thereby improving quality of cancer treatment decisions. Tracking movements in the five cervical vertebrae were refined by incorporating a commonly acceptable fact, the distance between any two given points of a rigid body remains constant, into the image processing algorithm.



AUTOMATED CHEMICAL ANNOTATION

Researchers who use chemical databases may soon have more information at their fingertips, thanks to an early version of ChemReader, an automated annotation system.

The image-based annotation technology was conceived of by Park, Saitou and Professor **Gus Rosania** in the U-M Department of Pharmaceutical Sciences. ChemReader recognizes chemical structure diagrams in research articles and links them to chemical database entries using common, searchable file formats to enhance the information available to scientists.

Under Saitou's leadership, the team has developed an initial version. With continued development enabled by seed funding from the U-M Center for Entrepreneurship, the latest version of the software is being evaluated for potential adoption by several pharmaceutical companies.

IMPROVING MEDICAL IMAGE GUIDANCE

With funding from MCubed, Park developed a tracking system to model uncertainties in image-guided medical interventions. The system includes a simulation component to predict needle trajectory, an imaging component to observe the actual trajectory, and a tracking filter to integrate predicted and observed data.

Park and Saitou devised the needle insertion simulation algorithm and validated it experimentally in collaboration with ME Professor **Albert Shih.** The algorithm is capable of predicting needle deflection from effects of the bevel-tip as well as tissue deformation from interactions between the needle and tissue.

After earning his PhD and spending a year as a postdoctoral research fellow in the ASL, Park accepted a position in the Computational Biology & Bioinformatics group at Pacific Northwest National Laboratory, where he works in the area of computational proteomics.

"Both Jihun [Kim] and Jungkap [Park] have been very successful in producing high-quality work that is getting well-deserved recognition," said Saitou. "Their accomplishments show the real benefit of applying our mechanical engineering training and insights to conventional biology, medicine and bioinformatics."

The[se] accomplishments show the real benefit of applying our mechanical engineering training and insights to conventional biology, medicine and bioinformatics.

AN UNCONVENTIONAL CONCEPT

Again pushing traditional boundaries, Saitou and two students recently won $10,000 in a design competition for their innovative, lightweight vehicle architecture concept. The competition was part of the Lightweighting Technologies Enabling Comprehensive Automotive Redesign (LITECAR) Challenge sponsored by Local Motors and the Advanced Research Projects Agency-Energy (ARPA-E).

Saitou and **Yuqing Zhou,** an ME doctoral student, worked with **Jeff Xu,** an undergraduate of the Stamps School of Art & Design, to develop and illustrate their ideas. The architecture relies upon several innovative concepts to significantly reduce weight in a 5-passenger sedan, including a doorless and windowless cabin, rear-facing, detachable seating and an unorthodox tire layout that eliminates the heft of a differential gear box and oversized suspension systems.

"This was a fun challenge," said Saitou. "We proposed a really crazy concept, but we were backed by solid engineering knowledge about vehicle body architecture and engineering requirements. The project was a great example of how mechanical engineers and graphic artists can collaborate to produce scholarly work in a medium other than archival journals and conference proceedings."

Disruptive Innovation:

A Winning Formula for Cross-Disciplinary Design

Research in the Smart Materials and Structures Design Laboratory of ME Professor **Diann Brei** span industries and application areas, from automotive and military to medical. These projects include all stages of the design process, from early problem definition and fundamental research, to full-scale prototypes and fielded solutions.

"The common thread connecting all of our work is the how," said Brei, who also co-leads the Smart Materials and Structures Collaborative Research Laboratory with General Motors.

No matter the engineering problem, Brei works to solve it through a methodical process that fosters innovation. She and her research group, including Associate Research Scientist **Jonathan Luntz,** build strong, cross-disciplinary teams and apply extensive design and project management expertise to identify key design drivers at each stage of a project.

The how also includes creativity. "We aim for the game-changing solution to give stakeholders an edge. For an industry partner, that means competitive advantage; for a clinical partner, the edge is humanitarian, such as saving a life," Brei said.

Rigor is part of the equation as well. Brei and her group follow a rigorous design process and take a model-based scientific approach that ensures research findings are both robust and repeatable.

"That's critically important whether you're designing an automobile part made from a smart material or seeking FDA approval for new medical device."

Brei and her group have done both, bringing their unique blend of experience to bear on inventions that have been translated from bench-top lab curiosity to real-world practice in a number of settings.

We aim for the game-changing solution to give stakeholders an edge. For an industry partner, that means competitive advantage; for a clinical partner, the edge is humanitarian, such as saving a life.

GM/UM SMART MATERIALS AND STRUCTURES COLLABORATIVE RESEARCH LAB TURNS 10

Smart materials, including shape memory alloys (SMAs), shape memory polymers and dielectric elastomer polymers, represent an important strategic area for General Motors.

Over the past decade, the GM/UM CRL has developed materials theories, methodologies and design tools that have helped GM with early-stage design all the way through late-stage fielding and problem-solving during manufacturing.

GM's 2014 Chevrolet Corvette uses a wire made from a SMA to enable the trunk lid to close more easily. Shape memory alloys change shape when loaded and can "remember" and return to their original shape when heated.

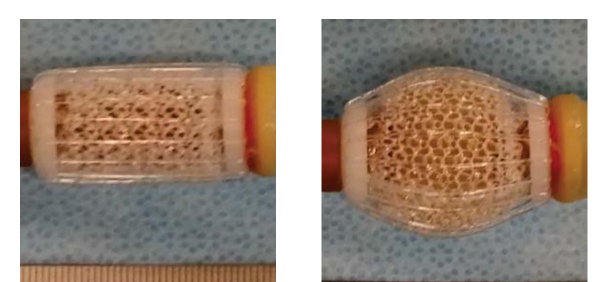
In the 2014 Corvette, the SMA wire opens and closes a hatch vent that releases air from the trunk so closing the lid is quieter and requires less user force. The SMA part weighs about one pound less than the part it replaces, so it helps lighten the vehicle, too.

COULTER TRANSLATIONAL RESEARCH AWARD FOR NOVEL MEDICAL DEVICE

About 10 years ago, **Dan Teitelbaum,** MD, a professor in the U-M Department of Surgery and director of the Intestinal Failure Program, approached Brei about the challenges facing patients with short bowel syndrome, whose small intestine is too short to absorb adequate nutrients. Current treatments for the condition are not consistently effective, and mortality rates are high.

In collaboration with Dr. Teitelbaum, Brei and Luntz amassed a cross-disciplinary team to develop a device that would induce the intestine to grow in length as well as possess absorptive and motile functionality.

The team has developed a curvilinear, hydraulic device based on the concept of mechanotransduction, whereby a force or stress is applied to the existing bowel, and the body responds to the load by growing new tissue.



a) Deflated Textured Balloon with Covering Material

b) Inflated Textured Balloon with Covering Material

A persistent hurdle, however, was how to safely attach the device to the patient's bowel. With a number of research projects and patents on smart attachment, Brei and Luntz applied their expertise and helped the team develop a novel solution using a dilating fenestrated mesh balloon.

In clinical studies in animals, the team has achieved over 50 percent growth in the intestine in two-weeks' time.

"What's most important," said Brei, "is that growth is *functional*—new tissue has grown and can absorb nutrients like native tissue."

The work has won a variety of awards over the years, most recently a Coulter Translational Research Award. It illustrates the breadth and depth of the rigorous design process Brei and colleagues use to develop innovative solutions to complex problems.

The team currently is working to have the device professionally manufactured and is seeking U.S. Food and Drug Administration (FDA) approval.

"We're hoping to have the device classified as a Humanitarian Use Device by the FDA and to see it used in children within the year," Brei said.

TOP LEFT: 2014 Corvette Active Hatch Vent (inset).

TOP RIGHT: GM/UM Smart Materials and Structures Collaborative Lab.

BOTTOM RIGHT: Dilating fenestrated mesh attachment, prior to implant.

Innovations in Parallel Kinematics

Lead to Multiple Technologies and Start-ups

Basic research and innovations from the Precision Systems Design Lab (PSDL) have led to the creation of several novel technologies that are impacting diverse application areas including minimally invasive surgery, semiconductor wafer inspection and educational exhibits for children. Associate Professor **Shorya Awtar,** ScD, created the PSDL in January 2007 and has engaged students, postdocs and staff engineers in a broad engineering research program encompassing machine and mechanism design, precision engineering and mechatronics.

Awtar's seminal contribution in machine design has been to develop a systematic constraint-based approach in the conception of multiple degrees of freedom parallel kinematic mechanisms. While traditional parallel kinematic designs suffer from significant coupling between these degrees of freedom, Awtar's methodology generates constraint maps that enable highly decoupled designs and implicitly take into account the requirements of sensor, actuator, and/or transmission integration. This results in functional yet simple designs, leading to practical implementation in various application areas.

MINIMALLY INVASIVE SURGERY

Minimally invasive surgery is performed via small incisions on a patient's body, resulting in reduced pain, blood-loss and recovery time. However, with the currently available instrument technology, surgeons have had to choose between affordability and functionality. Existing hand-held mechanical instruments either lack the necessary dexterity or are counter-intuitive to operate. On the other hand, robotic surgery systems provide exceptional dexterity and controllability, but are very expensive and lack haptic feedback.

To overcome this tradeoff, Awtar and his team ingeniously combined multiple concepts in machine design to create a forearm mounted instrument platform, FlexDex, that employs a parallel kinematic mechanism at the surgeon input. This spatial mechanism, made of flexure strips to ensure simplicity and robustness, was designed to project a virtual center of rotation coincident with the surgeon's wrist. The virtual center—a unique concept that Awtar has employed in many of his inventions—allows rotation about a point in space without the presence of any physical components at that point. In FlexDex, this intuitively captures the surgeon's wrist rotations and mechanically transmits them to an end-effector, making the instrument a natural extension of the surgeon's hand inside the patient's body.

Multiple PSDL graduate and undergraduate students along with ME450 teams have participated in the development of this technology. The engineering team closely collaborated with Dr. **James Geiger** (CS Mott Children's Hospital, U-M), a medical device innovator and recognized expert in minimally invasive surgery, to tailor the design to meet the stringent usability requirements in the operating room.

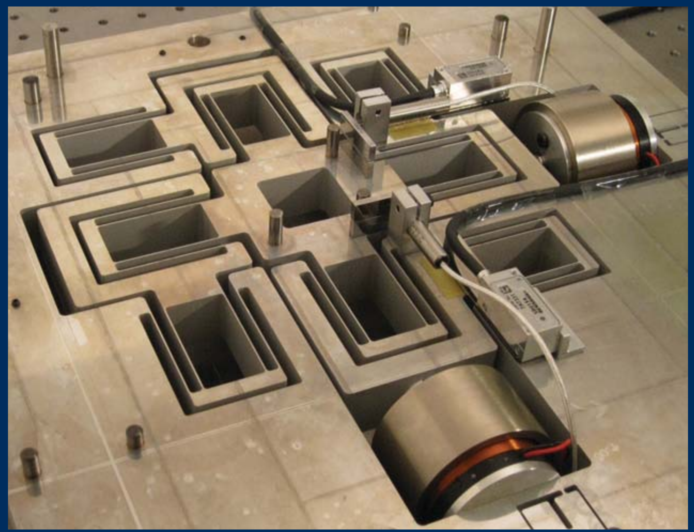
Given the platform nature of this purely-mechanical low-cost technology, it can serve multiple surgical specialties and bring the benefits of minimally invasive surgery to larger segments of the society. To realize this vision, Professors Awtar and Geiger, along with medical device entrepreneur Greg Bowles, co-founded the start-up FlexDex Surgical Inc., which has received SBIR as well as private funding. Awtar is currently on leave from the university, serving as the company's Chief Technology Officer leading the effort to develop its first product, an articulating needle-driver, for launch in 2016.

> With a purely mechanical design that costs a few hundred dollars, FlexDex technology offers surgeons the same intuitive articulation capability that is currently available only in multimillion-dollar robots.

SEMICONDUCTOR WAFER INSPECTION

In another major effort, Awtar and his team of students have overcome a long-standing challenge in flexure-based motion systems by demonstrating large range, high speed, and nanometric precision – all simultaneously. This has been accomplished via a mechatronic approach that encompasses research and innovations in mechanism design, sensing, electromagnetic actuation, structural dynamics, feedback controls, and systems integration. At the heart of this HIgh PERformance NAnoPositioning (HIPERNAP) technology, is a patented parallel kinematic flexure mechanism that provides highly decoupled translations in the X and Y directions, with an unprecedented range of 10mm. When integrated with existing motion stages and wafer inspection systems, HIPERNAP has the potential for reducing wafer inspection times by an order of magnitude, leading to significant gains in semiconductor throughput and yield

This technology has led to another start-up, HIPERNAP LLC, headed by PSDL alum David Hiemstra and funded by an SBIR grant. The team has been working closely with a leading semiconductor equipment manufacturer to translate the basic research from PSDL to commercial products.



EXHIBITS FOR ANN ARBOR HANDS-ON MUSEUM

In an ongoing partnership, PSDL has designed several new mechatronics exhibits for the Ann Arbor Hands-on Museum, which inspires children to discover the wonder of science, technology, and engineering. The latest such exhibit is a one-of-its-kind ball on plate balancing system that employs a spatial parallel kinematic mechanism to tip and tilt the plate and feedback to control the ball's rolling trajectory. PSDL designed exhibits are very popular at the museum because their fun and interactive presentation of advanced technology. Awtar currently serves as a Board Trustee of the museum.

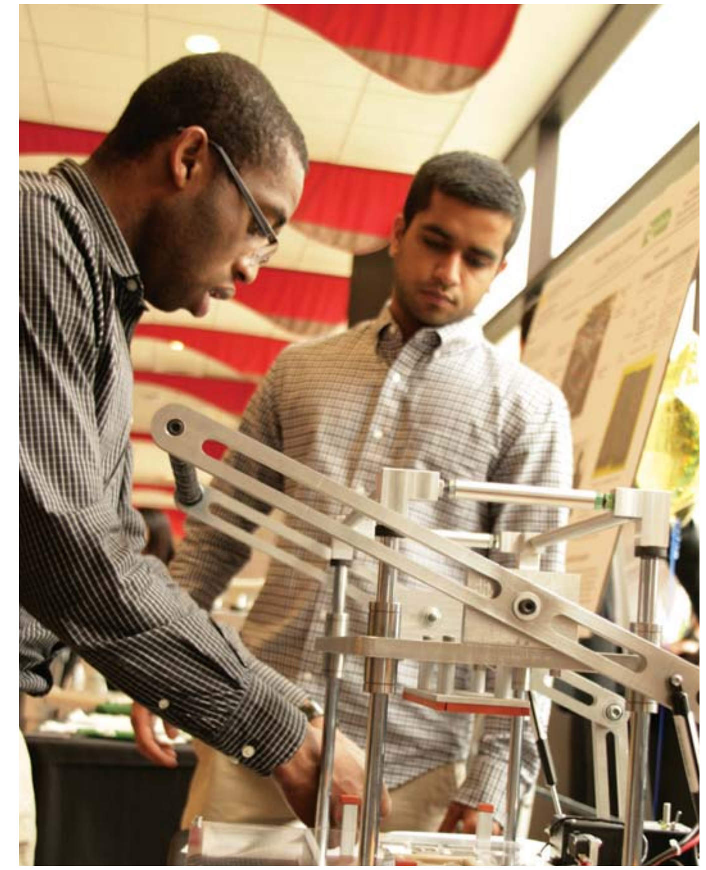
Awtar and PSDL engineers have won significant recognition for their research and technological impact in machine design and mechatronics. This includes multiple best paper awards at ASME conferences, young investigator awards, R&D100 awards for 100 most significant technologies of the year, and ASME's highest recognition for product innovation and machine design—the Leonardo da Vinci Award.

FAR LEFT: FlexDex Needle Driver Instrument

LEFT: HIPERNAP XY Motion Stage

ABOVE: Ball on Plate Balancing System

ME Department Holds Inaugural MEUS



FAR LEFT: A view from GG Brown's second floor at the 2015 MEUS.

LEFT: ME 450 student Milan Kalaria describes his group's project, Makapad Production Optimization: Sealing, to ME Assistant Professor Chinedum Okwudire at the 2015 MEUS.

BELOW: RISE ME 390 student Carlos Barajas describing heat and mass transfer effects on forced radial oscillations in soft tissue.

The inaugural ME Undergraduate Symposium (MEUS), kicked off last April. The symposium showcases the exceptional work of our undergraduate students in their independent X90 RISE (Research, Innovation, Service and Entrepreneurship) projects and the Design and Manufacturing X50 Core team projects.

"The launch of RISE and the MEUS this year was a great success, one that exceeded our expectations," said ME Professor and Associate Chair for Undergraduate Education **Diann Brei.** "Our students gained so much from the one-on-one RISE experiences with our faculty and the MEUS proved to be an incredible point of pride for them, building an even stronger ME community. I can't wait for the coming year and to watch this new initiative grow."

Everyone had an exciting day cheering for the ME 250 teams in their ping-pong ball squash competition, viewing the ME 350 four-bar linkage that automatically positions a mirror to reflect several laser beams onto a target and engaging with our seniors as they display their ME 450 capstone design projects.

RISE students presented their cutting-edge projects in a conference-style format with topics ranging from health and energy, nano- and bio-materials, robotic and mechatronics, actuation and control, engines and mechanisms, as well as the crowd favorite the giant Rubik Cube.

"The goal of the MEUS is to provide an intimate forum for a vibrant exchange of ideas and results within our University of Michigan Mechanical Engineering Community," said **Kon-Well Wang,** the Tim Manganello/BorgWarner Department Chair and Stephen P. Timoshenko Collegiate Professor of Mechanical Engineering. "We are thrilled with the exceptional response as the planning of MEUS has been a significant team effort of faculty, staff and students."

The goal of the MEUS is to provide an intimate forum for a vibrant exchange of ideas and results within our University of Michigan Mechanical Engineering Community.

We welcome you to the second MEUS, to be held December 10, 2015 in the Borg Warner Galleria (visit meus.engin.umich.edu for more information). For further information on RISE, visit me.engin.umich.edu/academics/rise.

U-M Mechanical Engineering Students' Project Impacts Braden Gandee's Life

Lyrics to the old classic "He Ain't Heavy, He's My Brother," perfectly describe the brotherly love between Temperance, MI siblings Hunter and Braden Gandee. On June 7th Hunter, 15, carried his brother Braden, 8, who has cerebral palsy, on his back for 57 miles to help raise awareness for the permanent movement disorder in this year's Cerebral Palsy Swagger. The journey started in Lambertville, in southeastern Michigan's Monroe County, and ended at the University of Michigan's Pediatric Rehabilitation Center in Ann Arbor.

The connection between the University of Michigan and the Gandee family reaches further than Braden's time as a patient at the U-M Pediatric Rehab Center. Earlier this year, four U-M Mechanical Engineering students took on a project that changed the eight-year-old's life for the better. **Ariana Bruno, Cameron Naderi, John Doherty** and **Scott Wigler** took on the challenge of creating a customized walker for Braden, one that allowed him easier mobility on certain terrains. The work was for a U-M ME class, Mechanical Engineering 450: Senior Design and Manufacturing.

"The students actually reached out to us about working on a walker for Braden," said Danielle Gandee, Braden and Hunter's mom. "The modifications they made to his walker, especially the rotating handlebars were great. It's trial and error and a real learning process when trying to create the perfect walker and I'm hoping that a future (ME450) group will choose this project again in the future and elaborate on the walker even more," she added.

Considering the ME450 group really enjoyed working with Braden and his family, there could be a good chance a future group would take on this project down the road.

"This project was our number one choice from the beginning because we wanted to create something that would truly make a difference in someone's life," said Ariana

Bruno. "Unlike some of the other projects, what stood out to us was having Braden and his family as sponsors and being able to develop that personal connection with them to adequately understand where improvements could be made to best suit Braden's active lifestyle. Since cerebral palsy is a disorder that affects each person differently, a universal walker design is not always an ideal solution. It was important for us to really get to know Braden and where he experiences difficulties."

The ME450 group arranged to have a 3D full body scan of Braden to obtain precise measurements. This allowed the students to locate the areas where Braden could use enhanced support. The group modified the Drive Medical walker with larger front wheels that had shock absorbing joints to help Braden maneuver the walker more easily over uneven terrains, such as the ones he experiences on playgrounds. They also worked with the Gandee family and Braden's physical therapist and were able to identify a need for an improvement on the current walker's handlebars to encourage better posture.

"We created adjustable handlebars that allow Braden to rotate the walker to various angles to achieve the optimal positioning for his posture and also reposition to allow a relaxed posture on days when his muscles were tight," said Bruno.

According to Scott Wigler, the group researched multiple wheel types and casters, and decided on a wheel that came in a caster with springs and dampers to lessen the vibration and allow easier transversal over uneven terrain.

"My team and I machined the wheel casters to make them compatible with the walker," he said.

ME450 instructor **Amy Hortop** was proud of the group's dedication.

"The students who worked on this project were really motivated to create a great walker for Braden," said Hortop. "After their first meeting with Braden and his family they were truly inspired. I know they hope their design will prove to have a positive impact on his life."

Braden's brother Hunter plans to continue supporting his younger brother; and it's evident his efforts have been paying off.

"I want to be able to help him in any way I can. I see how much work he has to do every day to just simply walk. A lot of people don't think of that and my goal is to get people to start thinking of ways they can help," he said.

Braden's school has plans to build a new playground, one that will offer more accessibility for him.

"With Braden it really all comes down to accessibility," said Hunter.

LEFT: University of Michigan Mechanical Engineering seniors (left to right) John Doherty, Scott Wigler, and Ariana Bruno discuss their design as they took a Drive Medical walker and redesigned the structure to host different wheels and restructure the handlebars.

TOP: Braden Gandee, 8, of Temperance tries out for the first time his new customized walker manufactured by the University of Michigan mechanical engineering seniors (centered); John Doherty, Scott Wigler, Ariana Bruno, and Cameron Naderi. The instructors Amy Hortop (back left) and Elijah Kannatey-Asibu (right) asked Braden what grade should they give the students, "A+" said Braden at the Design Expo showcasing undergraduate and graduate projects. Also watching are family members mother Danielle (left), brother Hunter and sister Kerragan.

BOTTOM: University of Michigan Mechanical Engineering seniors (left to right), Cameron Naderi, Ariana Bruno, Scott Wigler and John Doherty pose with their redesigned Drive Medical walker.

Photo captions and credit: Monroe News and photographer/reporter Tom Hawley.

ME Professor Volker Sick's Study Abroad Program Celebrates Ten-Year Anniversary

BY ANGELA FICHERA & BEN LOGAN

It started with ten students and three different lab projects and now, ten years later, more than 50 attended with five to six lab projects, making it the University of Michigan's largest undergraduate education abroad program.

The program, which was developed in 2005, was the result of a unique collaboration between U-M ME Arthur F. Thurnau Professor **Volker Sick** and Technical University of Berlin's (TUB) Professor for Energy Process Engineering and Conversion Technologies for Renewable Energies **Frank Behrendt** after receiving Deutscher Akademischer Austausch Dienst German Academic Exchange Service (DAAD) funding. Ten years ago, the duo couldn't have imagined the impact the program would have. "The phenomenal growth that we've seen shows that they really like it," said Sick. "It's enormously gratifying."

The program is a six-week cultural and educational experience unlike most study abroad programs because students participate in real-world, project-based learning as opposed to a lecture-oriented curriculum. Students also live in city apartments instead of dormitories. It's an incredibly immersive experience, which is simultaneously one of the biggest challenges and one of the biggest rewards for many of the students.

"The first time I was on an airplane was my flight to Berlin," said U-M ME junior **Sam Dion,** who participated in the program last summer. "I faced many challenges throughout the process, but I took everything as a learning experience."

The immersive nature of the program isn't the only thing that sets it apart. "It started out as a collaboration among faculty and their interest in creating something new and different," said **Miranda Roberts,** director of International Programs in Engineering at U-M. "It is not your traditional study abroad experience. Students are out doing projects and doing research—putting their classroom knowledge into practice."

This summer's cohort was able to choose among a variety of project focuses, including projects related to alternative energy biofuel, engine optimization and robot programming to name a few.

"It definitely opened my worldview and strengthened my passion for a certain kind of engineering," said mechanical engineering sophomore **Madeline Gilleran.** "The German culture and approach to infrastructure is really cool. It has made me want to combine my passion for mechanical engineering with architecture, urban planning and transportation."

Professor Sick is extremely proud of the program and looks forward to even further growth in the years to come.

"It's an interesting challenge to define and develop a shorter term summer program that has a lot of depth," said Sick. "An experience like this is invaluable for engineering undergrads because it's hard for them to get overseas for a full semester because they will be behind for a whole year. As we look to the next ten years, it's important to continue that personal faculty engagement because that is key to help to build and sustain the program."

Basking in the Race:
A Shining 25th Year for U-M Solar Car Team

The U-M Solar Car Team is celebrating its 25th anniversary as the top Solar Car team in the United States.

The team won the American Solar Challenge, an eight-day, 1,700-mile competition from Texas to Minnesota, again in 2014. Racing *Quantum*, a car originally built in 2011 and updated for the 2014 event, Michigan Solar Car won all five stages and finished by a margin of about four hours. The win was *Quantum's* second national championship and the team's fifth overall.

Quantum also got a new stamp in its passport in January 2015, when it made its way to an inaugural 700-mile race in Abu Dhabi. There, the team earned its first international championship and was presented a trophy from the Crown Prince of Abu Dhabi, Sheikh Mohammed bin Zayed Al Nahyan.

In July, *Aurum,* the newest car, was unveiled, the 13th in the team's history. The event took place at The Henry Ford in Dearborn, a fitting locale since the team's very first car, *Sunrunner* (1990), is showcased inside the museum's IMAX Theatre entrance.

A quarter-century ago, *Sunrunner* drove the U-M Solar Car Team to win the American Solar Challenge championship and to a top-three World Solar Challenge.

"The Henry Ford felt like the right place to celebrate 25 years when your original car is displayed there," said **Arnold Kadiu** (ME '15), the team's former engineering director and now crew chief. He will graduate in December.

Aurum took two years to build, a budget of nearly $1 million and considerable support from a cohesive team, dedicated alumni and sponsors, the ME department and the College of Engineering.

The new vehicle sports an asymmetrical catamaran body, improved electrical system and mechanical systems optimized for weight reduction and increased durability.

"*Aurum* is significantly thinner and streamlined," said Kadiu. "We looked closely at previous designs to see where we could improve the aerodynamic profile and improve efficiency."

A new antireflective surface on the vehicle's solar arrays provides increased power over previous cars.

Aurum is being put through its paces during a mock race in the Great Lakes region and other extended road tests in preparation for the upcoming World Solar Challenge.

The 2015 Bridgestone World Solar Challenge takes place in October and will take *Aurum* across the Australian continent in a 1,800-mile competition that begins in Darwin and finishes in Adelaide.

"As a team, we feel we have a really good chance of winning," said Kadiu. "But of course you never know what competitors have up their sleeves."

A larger goal for members like Kadiu, who will be graduating this year, is to leave the team in an improved position. "It's the duty of the older members to make sure we pass along knowledge. That's an even bigger goal for us than winning a single competition—it's so important in terms of the longevity of the team."

Interact with *Aurum* at the U-M Solar Car Team's Digital Gateway: dme.engin.umich.edu/solarcar25/3dmodels.html.

Bold Design Changes
Drive Baja Team to the Top

The U-M Baja Racing team finished the 2015 season on top, ranking first in the nation and winning the Mike Schmidt Memorial Iron Team Award. The annual award is given to the team earning the most points in competition.

At the season's three competitions in Alabama, Maryland and Oregon, U-M Baja finished first, second and first, respectively. It also progressed to the Design Finals event at all three competitions, a first in the team's history.

"Some of the design changes we made were risky," said **Justin Lopas,** 2016 team captain and a senior in the ME Department. "We took second place overall the prior year, and for everyone on the team, it was hard to say, 'Okay, we need to make radical changes.'"

But the spirit of innovation and an aversion to complacency inspired design improvements. Chief among them, the team developed a new axially stressed drive shaft, which eliminated a lower camber link and instead uses the drive shaft as the suspension link.

"What was key about the design was its simplicity," said Lopas, "but there were a lot of engineering considerations and analysis that went into it. In the end it really helped with endurance and overall vehicle reliability."

A second major design change was the development of custom brake calipers, which also required much engineering design and analysis work in addition to manufacturing and testing.

"Design percolates through the rest of the competition," said Lopas, "and the changes certainly paid off in performance."

Now Lopas and the rest of the team are looking forward to the coming season. A focus for the team's current leadership is sustainability and knowledge transfer. When there's an important meeting, discussion or event to attend, at least one senior, junior and sophomore all will participate.

"We want newer members to feel involved and also possess that institutional team knowledge they can call upon when they become juniors and seniors," Lopas said.

Thinking about the car the 2015–16 team will build, Lopas wants to see the team continue to push the boundary of what is possible in the Baja series.

"More detailed design and analysis, an increased focus on static events and a continuation of the expansion of the size of our team and sponsor community will be keys to our success," Lopas said. And since experienced driver **Brandon Amat** (BSE ME '14, MSE ME '15) graduated, "we want to make sure we allow for a lot of driver training and practice to fill that newfound void," he said.

Last but not least, when it comes to competition, "Next year, we want to win all three competitions," Lopas said, "and given our performance last year, we definitely believe that's possible."

MRacing: Driven to Learn and Achieve Goals

The U-M Formula SAE team, MRacing, went into the 2014–'15 season with two clear goals: reduce the overall mass of its vehicle, MR-15, and finish in the top five at competition.

The team accomplished both.

Vehicle weight dropped from 468 pounds in 2014 to 419 pounds for MR-15, more than a 10 percent reduction. And the team finished fifth at FSAE Michigan, held at the Michigan International Speedway (MIS) in Brooklyn. It was the team's best finish since the 2012 season.

"The 2015 team was comprised of mostly sophomores, and having such a young team meant a steep learning curve. Going forward the experience from this year will make the team even stronger," said **Keenan Temin,** 2016 MRacing captain.

Temin credits the team's success in part to an overall improvement in its business, cost and design presentations at competition as well as a number of new design features.

The most notable design feature was an extensive new aerodynamics package, necessitated by a FSAE rule change.

"Even though our [new] wings are smaller, our aero team was able to create a more efficient design, maintaining similar downforce numbers as in previous years while also weighing significantly less," noted Temin.

The team verified its design work by taking the car to Fiat Chrysler Automobile's wind tunnel and correlating its simulations to the data gathered during testing.

"The rule changes really encouraged us to think and experiment with new design and fabrication techniques," said Temin. "Although the experience tested our team's abilities, we were able to pull it off by sticking to our schedule and staying motivated."

Other design changes included integrating a new pneumatic shifting system that allowed the car to auto shift during straight-line acceleration events. On the engine side of design and development, the team used its dynamometer and custom-profiled camshafts to determine a better setup for its application.

Team alumni also pitched in and gave the team valuable feedback during the annual design review, held each September.

"The team turns over every four years, which means there is a huge opportunity for knowledge to get lost," Temin explained. "Getting input from our team alums, where they give us feedback based on their experience on the team and also from their time in industry, is incredibly helpful."

Looking ahead, the team plans to spend even more time on backend design and testing, since its testing time proved extremely beneficial last year.

"If we can have six weeks of testing time before our first competition, we'll be able to tune our car, gather useful data and have an overall better performance at competition," said Temin.

Like last year, Temin and the team are clear about its goal going forward: "build a faster, more innovative racecar. A top-three finish at MIS and a top-five finish at Formula Student Germany in 2016 will prove that we accomplished just that."

CARLA BAILO

Bailo Honored with 2014 Alumni Merit Award

Mechanical Engineering alumna **Carla Bailo** was selected to receive the 2014 Michigan Engineering Alumni Merit Award. Bailo (MS ME '86) was the first woman and the first non-Japanese executive to hold the post of senior vice president, research & development, in the Nissan Americas division. While in the role, she was responsible for all of Nissan's vehicle engineering and development operations in Michigan, Arizona, Mexico and Brazil. Bailo was also a member of Nissan's MCA, the company's highest-ranking decision-making body in the Americas region.

Currently, Bailo serves as president and CEO of ECOS Consulting LLC, which specializes in engineering, cost efficiency and organization optimization services. She is a passionate champion for the promotion of science and technology careers, and through her work with the Automotive Women's Alliance Foundation, she is influencing more women to enter these careers.

KEN SNODGRASS

Snodgrass Receives 2014 Distinguished Alumni Service Award

Mechanical Engineering alum **Ken Snodgrass** was selected to receive the 2014 Distinguished Alumni Service Award. Snodgrass (BSME '69 and MSE '71) is a mechanical engineer, automotive professional, and co-founder of the Michigan Engineering Zone (MEZ) in Detroit. After graduating from the University of Michigan College of Engineering, Ken accepted a position in Light Truck Engineering at Ford Motor Company where he would work for 30 years in a wide variety of management positions in product development including international assignments and joint programs with various Asian and European auto manufacturers.

The U-M CoE Distinguished Alumni Service Award was established to honor a graduate who has given generously of time and talent to further College projects and activities.

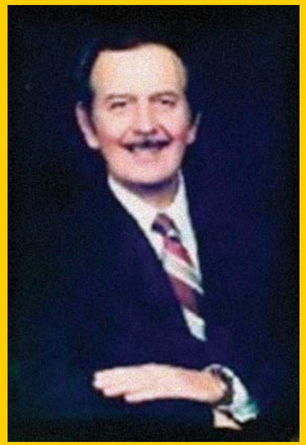
Remembering Donald William Van Doorn

Donald William Van Doorn, U-M ME alumnus, passed away this past March at the age of 93.

Van Doorn earned his bachelor's degree in mechanical engineering from the University of Michigan in 1943. He went on to work in Dallas as a design engineer for Lummus Cotton Gin Co. and was eventually promoted to Vice President in charge of Engineering/Chief Technical Officer there in 1959. Throughout his career at Lummus, Van Doorn was responsible for 68 patents for device inventions. He is survived by his wife Constance Elizabeth Carraway Van Doorn, their four children and five grandchildren.

The Donald Van Doorn Fund was created in his honor. The fund will be endowed if sufficient dollars are raised and gifts plus, at university discretion, surplus distributions will be invested and the income will provide scholarship support.

If you'd like to donate, please make your gift check payable to "University of Michigan" with memo line notation "In memory of Donald Van Doorn" and mail to: The Donald Van Doorn Fund University of Michigan College of Engineering 1221 Beal Avenue, Suite G264Ann Arbor, MI 48109-2102.



DONALD WILLIAM VAN DOORN

TOP: Dr. Bernard Amadei, Professor of Civil Engineering at the University of Colorado at Boulder and Founding President of Engineers Without Borders—USA, presents to the crowd at the 2015 Korybalski Lecture.

BOTTOM: (From left) ME Chair Kon-Well Wang, Dr. Bernard Amadei and ME alumni Michael Korybalski at the 2015 Korybalski Lecture.

Korybalski Lecture Brings Bernard Amadei to Campus

Dr. Bernard Amadei, Professor of Civil Engineering at the University of Colorado at Boulder and former Faculty Director of the Mortenson Center in Engineering for Developing Communities, delivered the eighth annual Korybalski Lecture on May 15, 2015. Amadei's talk, which was titled "Global Engineering for a Small Planet: A Vision of Success," focused on how a surge in global population, 95 percent of it being in developing or underdeveloped countries, will create unprecedented demands for energy, food, land, water, transportation, materials, waste disposal, earth moving, healthcare, environmental cleanup, telecommunication and infrastructure.

Being the Founding President of Engineers Without Borders—USA and the co-founder of the Engineers Without Borders—International Network, Amadei offered great insight on the role engineers will need to play in the next 20 years to fulfill the demands of those growing populations in developing and underdeveloped countries. He posed the question of whether or not today's engineering graduates and engineers will possess the skills needed to address the global problems that our planet and humans are facing in the future, and touched on the point that a new epistemology of engineering practice and education is needed, one that is based on the idea of reflective and adaptive practice, system thinking, engagement and a holistic approach to global problems.

Amadei earned his PhD in 1982 from the University of California Berkeley and among various other distinctions he was the 2007 co-recipient of the Heinz Award for the Environment, the recipient of the 2008 ENR Award of Excellence, an elected member of the U.S. National Academy of Engineering, a Science Envoy to Pakistan and Nepal for the U.S. Department of State in 2013 and 2014 and the recipient of five honorary doctoral degrees.

Amadei's lecture was a part of the annual lectureship endowed by **Michael Korybalski,** chair of the ME External Advisory Board and former chief executive officer of Mechanical Dynamics. The lectureship was created as a means to bring high-profile, inspiring speakers to the U-M community to help promote the impact of engineers on large societal problems, including energy and environment, health and quality of life, national security and disaster prevention.

ME Facilities Staff Member Sally Smith Retires

ME facilities assistant **Sally Smith** retired from the University of Michigan after 20-plus years of service on June 30th. Smith spent 15 of those years as a member of the ME facilities services office, but began her career at U-M in the College of Engineering's administration office. She then went on to work in CoE's facilities, planning and resource department as a staff member under CoE Director of Facilities John Keedy.

While in ME Sally's responsibilities were numerous and varied. She helped to oversee departmental housekeeping and maintenance issues, needs and followup. She worked closely with U-M Property Disposition, Key Shop and ITS as well as other Plant and CoE departments. She had many friends among her work associates and customers (faculty, staff and students alike) and will be greatly missed.

Professor Noboru Kikuchi Retires

NOBORU KIKUCHI

Noboru Kikuchi, PhD, Roger L. McCarthy Professor of Mechanical Engineering, retired this past June.

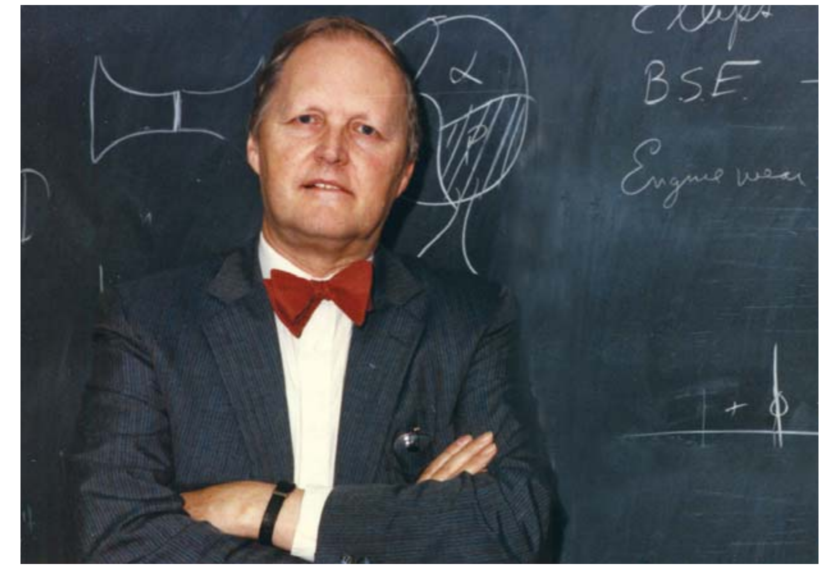
Kikuchi earned his BE and MS degrees from the University of Texas-Austin in 1975 and 1977, respectively. He received his PhD in civil engineering from the Tokyo Institute of Technology in 1974 and joined the University of Michigan faculty in 1980.

Kikuchi is a world-renowned scholar in adaptive finite element methods including automatic mesh generation and remeshing schemes for nonlinear problems in mechanical engineering and applied mechanics. His research achievements include the development of micromechanical models for unilateral contact friction of metal and sheet-metal forming processes, topology optimization for material microstructures and homogenization method in mechanics of composites. He developed the image based Computer Aided Engineering (CAE) methodology and the First Order Analysis Method for CAE of automotive body structures. He has published over 200 technical papers with over 8,800 total citations.

Throughout his career Kikuchi made exceptional contributions to education. He advised or co-advised over 40 doctoral students, and the individuals who graduated under his supervision have moved into industry and academia with highly responsible positions.

Kikuchi is serving as president of Toyota Central R&D Laboratories.

Remembering Ken Ludema, ME Professor and Innovator



KEN LUDEMA

Ken Ludema, former University of Michigan Mechanical Engineering Professor Emeritus and U-M ME alumnus, passed away this past April at the age of 86.

Ludema was a renowned scholar in the field of frictional, wear and lubrication who earned both a bachelor and master's degree in mechanical engineering from U-M and then went on to complete two PhD programs, one in materials science at U-M and one in physics at Cambridge University.

Among the honors he received were the Tribology Gold Medal from the International Tribology Council (1993), the Mayo D. Hershey Award from the Tribology Division of the American Society of Mechanical Engineers (ASME) in 1995, and the Excellence in Research Award from the Department of Mechanical Engineering and Applied Mechanics (1995). Ludema was a member of the ASME and served as chair of its tribology division. He served as the associate editor and regional editor (North America) of *WEAR Journal* and as associate editor for the *ASME Journal of Tribology*. He co-authored the textbook *Manufacturing Engineering Economics and Processes* and authored *Friction, Wear, and Lubrication: A Textbook in Tribology.*

Ludema is survived by his wife Johanna, sons Thomas, James, Rodney and Joel, and daughters Karen and Janet. He had 17 grandchildren and eight great-grandchildren.

Excellence in Staff Award
Michelle Beaudry Wins 2015 Award

MICHELLE BEAUDRY

Michelle Beaudry, former contracts and grants specialist for the ME department, was honored with a 2015 Excellence in Staff Service Award. The College of Engineering recognized Beaudry for being a true advocate for faculty, improving their productivity and allowing them to spend more time focused on proposal development and subsequent research activities. During her time at ME she created decision-making tools to help more efficiently budget and allocate funds and worked to streamline often-complex reporting and accounts management processes.

Self-motivated, Beaudry identified and alerted faculty to calls for proposals that might match their research interests. She was committed to helping faculty meet sponsor deadlines and would spend whatever time necessary to complete time-sensitive work.

During her time at ME, Beaudry's contributions helped to enable the research success of many junior and senior faculty. Her creativity, attention to detail, perseverance and dedication were vital to the financial administration of many grants, ensuring commitments to funding partners were met and often times exceeded.

Faculty Awards & Recognition

EXTERNAL AWARDS

ELLEN ARRUDA
Penn State Outstanding Engineering Alumni Award, 2015

JAMES ASHTON-MILLER
Cabaud Memorial Award, American Orthopedic Society for Sports, 2014
ASME H. R. Lissner Award, 2015

JAMES BARBER
ASME Ted Belytschko Applied Mechanics Award, 2015

KIRA BARTON
NSF CAREER Award, 2014
UIUC MechSE Outstanding Young Alumni Award, 2015
SME Outstanding Young Manufacturing Engineer, 2015

NEIL DASGUPTA
ASME Pi Tau Sigma Gold Medal Award, 2015

VIKRAM GAVINI
USACM Gallagher Young Investigator Award, 2015

S. JACK HU
NAMRI/SME S.M. Wu Research Implementation Award, 2014
National Academy of Engineering, 2015

ERIC JOHNSEN
NSF CAREER Award, 2014

ELIJAH KANNATEY-ASIBU
ASME William T. Ennor Manufacturing Technology Award, 2015
SME Education Award, 2015

YORAM KOREN
SME Honorary Membership, 2015

XIAOGAN LIANG
NSF CAREER Award, 2015

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

WEI LU
ASME Gustus L. Larson Memorial Award, 2014

JUN NI
IIE Andrew Heiskell Award for Innovation in International Education, 2014
NSF IUCRC Association Alexander Schwarzkopf Award for Technology Innovation, 2014

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 Leonardo da Vinci Award, 2015

DAVID REMY
NSF CAREER Award, 2015

KAZU SAITOU
ASME Kos Ishii-Toshiba Award, 2015
LITECAR Challenge Innovative Design Component, 2015

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

VOLKER SICK
ASME Internal Combustion Engine Award, 2015

MICHAEL THOULESS
ASEE Archie Higdon Distinguished Educator Award, 2015

DAWN TILBURY
ASME Michael J. Rabins Leadership Award, 2014

GALIP ULSOY
Hideo Hanafusa Outstanding Investigator Award, 2014

ANGELA VIOLI
ASME George Westinghouse Silver Medal, 2015

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

NEW FELLOWS

JOHN HOARD
SAE Fellow, 2014

U-M AWARDS

ELLEN ARRUDA
Rackham Distinguished Faculty Achievement, 2014
CoE Service Excellence Award, 2014

SAMANTHA DALY
CoE 1938E Award, 2014

JIANPING FU
ME Department Achievement Award, 2014
Caddell Team Award for Research (Yubing Sun PhD student), 2014
CoE Ted Kennedy Family Team Excellence Award, 2015

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

SRIDHAR KOTA
U-M Regents' Award for Distinguished Public Service, 2014

KATSUO KURABAYASHI
CoE Ted Kennedy Family Team Excellence Award, 2015

XIAOGAN LIANG
ME Department Achievement Award, 2015

WEI LU
Novelis Distinguished Professor Award, 2014

JUN NI
CoE Stephen S. Attwood Award, 2015

JWO PAN
Caddell Team Award for Research (Katherine Avery PhD student), 2015

HUEI PENG
CoE Education Excellence Award, 2015
CoE Research Excellence Award, 2014

PRAMOD SANGI REDDY
ME Department Achievement Award, 2015

KATHLEEN SIENKO
U-M Miller Faculty Scholar, 2014
Novelis Distinguished Professor Award, 2014

STEVE SKERLOS
Novelis Distinguished Professor Award, 2014

MICHAEL THOULESS
Arthur J. Thurnau Professorship, 2014

DAWN TILBURY
CoE Education Excellence, 2014
Willie Hobbs Moore Trailblazer Award, 2014

PROMOTIONS

STANI BOHAC
to Research Scientist

JIANPING FU
to Associate Professor with tenure

ALEX SHORTER
to Assistant Research Scientist

DONALD SIEGEL
to Associate Professor with tenure

ANGELA VIOLI
to Professor with tenure

Student Awards

GRADUATE STUDENT AWARDS

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

SERGEI AVEDISOV
Alexander Azarkhin Fellowship, 2015

KATHERINE AVERY
Caddell Team Award for Research (Jwo Pan faculty), 2015

JORDAN EASTER
NSF Graduate Research Fellowship, 2014

ANTHONY FIORINO
NSF Graduate Research Fellowship, 2014

JASON GEATHERS
Society of Experimental Mechanics International Student Competition–First Place, 2015
Society of Engineering Science Student Competition–First Place, 2015

JESSANDRA HOUGH
ASME Bioengineering Division Best Paper Award, 2014

BYUNG-JOO
ASME Dynamic Systems and Control Student Best Paper Award, 2015

CHEN LI
William Mirsky Memorial Fellowship, 2015

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

PHANI MOTAMARRI
Rackham Predoctoral Fellowship, 2014
Robert Melosh Medal, 2014

JOSHUA NOVACHECK
Dow Sustainability Fellow, 2014

HAESUN PARK
William Mirsky Memorial Fellowship, 2014

BRANDON PATTERSON
NSF Graduate Research Fellowship, 2014

YUE SHAO
Azarkhin Scholarship, 2014

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

DAKOTAH THOMPSON
NSF Graduate Research Fellowship, 2014

YUQING ZHOU
LITECAR Challenge Innovative Design Component, 2015

UNDERGRADUATE STUDENT AWARDS

BRANDON AMAT
R&B Tool Scholarship, 2014

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

CARLOS BARAJAS
Lloyd H. Donnell Scholarship, 2015

ARIANNA CARLEY
1000 Pitches Contest – Health Category, 2015

LEVON CIMONIAN
Caddell Memorial Scholarship, 2014

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

ANDREW DEVROY
R&B Tool Scholarship, 2015

DUANE GARDNER
Caddell Memorial Scholarship, 2014

ZACHARY GRIFKA
R&B Tool Scholarship, 2014

KELSEY HOCKSTAD
J. A. Bursley Mechanical Engineering Award, 2015

AMY LIU
Caddell Memorial Scholarship, 2015

CAMERON MCBRIDE
Lloyd H. Donnell Scholarship, 2014
J. A. Bursley Mechanical Engineering Award, 2015

ELIO MORILLO
ME Spirit Award, 2015

YUHAO PAN
R&B Tool Scholarship, 2015

STEPHANIE SINGER
ME Spirit Award, 2014

CHENGHAO WANG
R&B Tool Scholarship, 2014

FANGZHOU XIA
R&B Tool Scholarship, 2014 & 2015

TONG XIE
R&B Tool Scholarship, 2015

GABRIELLE ZACKS
Caddell Memorial Scholarship, 2015

HAOLU ZHANG
Caddell Memorial Scholarship, 2015

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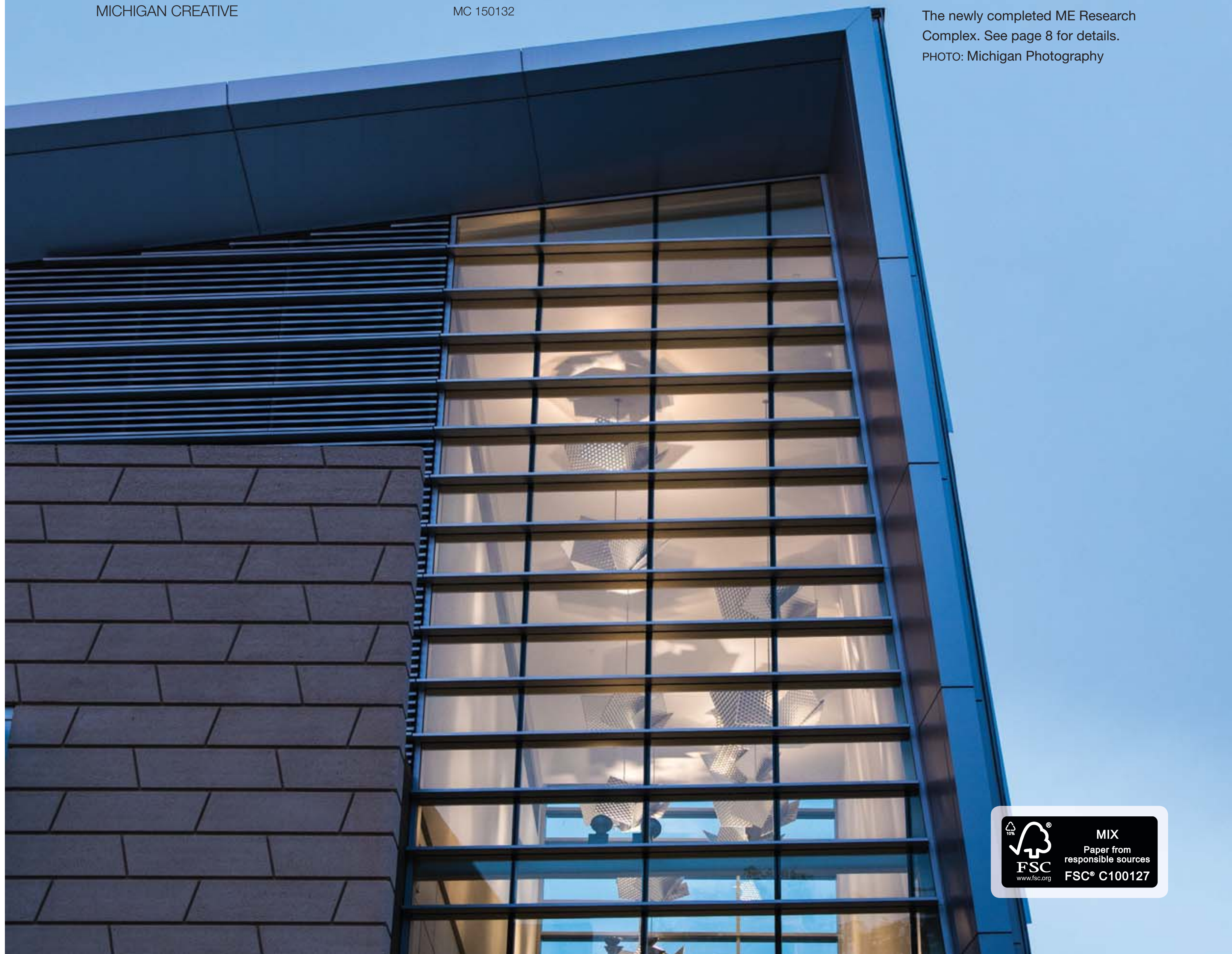

The newly completed ME Research Complex. See page 8 for details.
PHOTO: Michigan Photography

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