COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

2015–2016 ANNUAL REPORT

Mechanical Engineering Annual Report 2015–2016

Contents

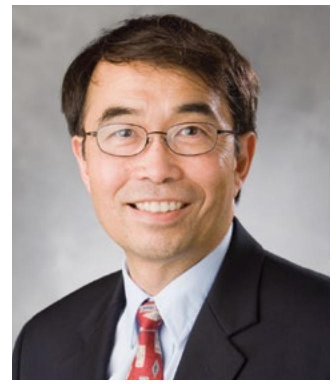
ON THE COVER: ME Professor Shorya Awtar became the youngest recipient of the American Society of Mechanical Engineers' prestigious Leonardo da Vinci Award for the invention of FlexDex. The start-up company based on this technology is launching its first product—an articulating needle-driver for minimally invasive surgery—this Fall. (See page 12 for details)

INSIDE SPREAD: Newly renovated ME facilities (See page 5 for details)

Photos: Michigan Photography

Message from the Chair

Our research is spurring advances that span the basic mechanical engineering core to emerging new areas. Our top-ranked educational programs are shaping the next generation of engineers who are well-prepared intellectually and passionate about the opportunity to make a significant impact on society.



I am excited to share our 2015–16 University of Michigan (U-M) Mechanical Engineering (ME) annual report with you. Our research is spurring advances that span the basic mechanical engineering core to emerging new areas. Our top-ranked educational programs are shaping the next generation of engineers who are well-prepared intellectually and passionate about the opportunity to make a significant impact on society.

Earlier this year, we were thrilled to learn that our new $46 million mechanical engineering research complex has been recognized with the 2016 AIA Michigan Building Award. Flexible core laboratory and collaborative spaces were designed to promote synergy and interdisciplinary engineering research at the nexus of core and emerging areas. Since completion, the project also has been honored with the 2015 AIA Detroit Honor Award and was LEED Gold Certified by the U.S. Green Building Council.

We have finished a major $50 million renovation of the GG Brown building to greatly improve existing infrastructure and to create mechanical engineering innovative, student-centric instructional spaces in support of the "Design, Build, Test" pedagogic paradigm. We could not have completed this significant project without support from the State of Michigan, which provided $30 million.

Since May 2016, construction has been underway on another major renovation project for the ME Department: the interior upgrade of the Lay Auto Lab. The project will include updated corridors and staircases, improved lighting and display areas, updated and new lounges, conference rooms, restrooms and a lactation room. Flooring and walls will receive new surface finishes, and faculty and student offices also will be upgraded. We can't wait to unveil the transformed space, which will provide an improved working environment both for occupants and for the Auto Lab's many visitors.

Our faculty are recognized consistently for their stellar research accomplishments, publishing seminal scientific papers in prestigious journals and generating inventions and patents that significantly impact our society. Some recent research activities highlighted in this report span mechanics, dynamics, controls and thermal/fluids to energy, bio-systems, transportation, nanotechnology and design and manufacturing. From news coverage of novel micro-sensor technology and sports equipment that improves performance and safety to a magazine article about devices that assist the blind, ME faculty are also often featured in the media.

As always, our faculty have earned many competitive awards this year, including a number of young investigator awards as well as various prestigious professional society awards that honor their exceptional achievements. We welcome four new faculty members joining the Department as assistant professors: Jesse Capecelatro, Daniel Cooper, Yue Fan and Bogdan Ioan Popa. This year, we also saw the retirement of Professor Galip Ulsoy after 36 years of service to the Department and University. He will be sorely missed.

Nine of our students—eight graduate and one undergraduate—earned prestigious NSF Graduate Research Fellowships this year, the highest among ME departments nationwide. Our ME students gain invaluable engineering experience in Ann Arbor going through our rigorous and comprehensive curriculum, as well as globally through a number of international programs. Our student teams have showcased the breadth and depth of their engineering education through their many competitive activities—with outstanding results, as you'll read shortly.

Last but not least, we would not be able to report such accomplishments were it not for our alumni network. Over 16,000 strong, it is one of the largest in the country and, we would argue, the most generous. Our graduates consistently inspire us with their contributions of time, knowledge, resources and innovations. We are indebted to them for their enthusiastic support.

Thank you for reading. Here's to a fruitful year ahead.

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

Faculty Profile

4 NAE Members

78 Society Fellows

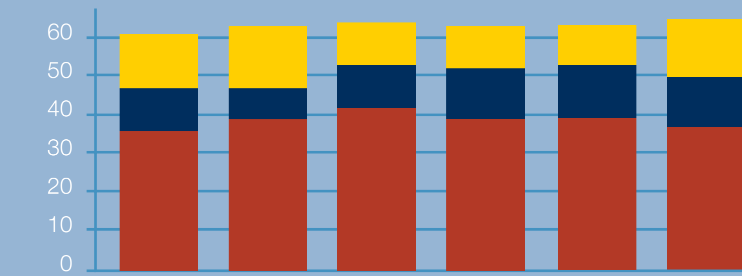
4 NSF PECASE or PFF Awards

37 NSF CAREER or PYI Awards

4 Current Journal Chief Editors

72 Current Journal Editorial Board or Assoc. Editor Appts.

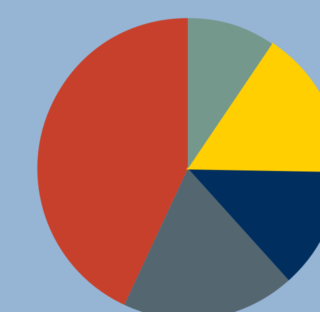
Faculty Trends: Tenured and Tenure-Track



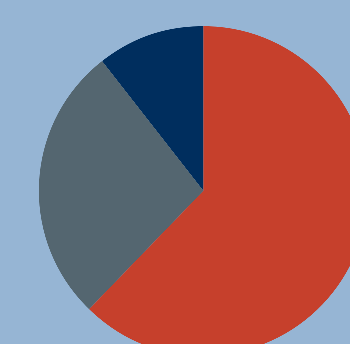
	FA11	FA12	FA13	FA14	FA15	FA16
Assistant	14	16	11	11	11	15
Associate	11	8	11	13	14	13
Professor	36	39	42	39	39	37
Total	61	63	64	63	64	65

Annual Research Expenditures

TOTAL RESEARCH EXPENDITURES
$31,613,656



Degrees Conferred



Nine ME students receive NSF Graduate Research Fellowships

Eight ME graduate students and one ME undergraduate student have received NSF Graduate Research Fellowships (GRF) this year. With a total of nine NSF GRF awardees, the U-M ME Department yielded the highest number of 2016 recipients among ME departments nationwide. The recipients are:


Alison Hake PhD student
Advisor: **Karl Grosh**


Michelle Harr PhD student
Advisors: **Sam Daly, Katsuo Kurabayashi**


Lixi Liu PhD student
Advisor: **Kazu Saitou**


Miriam Figueroa-Santos
PhD student
Advisor: **Anna Stefanopoulou**


Kimberly Ingraham PhD student
Advisor: **C. David Remy**


Ilya Kovalenko PhD student
Advisors: **Kira Barton, Dawn Tilbury**


Andrew Stephens
PhD student
Advisor: **Katsuo Kurabayashi**


Sarah Verner
PhD student
Advisors: **Krishna Garikipati, Vikram Gavini**


Carlos Barajas
Undergraduate student

$50 Million Renovation Boasts Mechanical Engineering State-of-the-Art Student-Centric Education Facilities

Construction of the GG Brown Memorial Laboratories began in the summer of 2014 and is currently wrapping up.

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

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

The renovation also allows for more accessible and efficient administrative spaces, and infrastructure has been updated to greatly improve effectiveness and efficiency.

The planning and design of the GG Brown renovation was an integrated effort involving faculty, staff and students. . .

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

"A renovation project on this scale and the fact that it occurred in an owner-occupied building took a massive team to plan and to complete. We are grateful for the wise counsel of our ME faculty, staff and students during the design phase, to the architectural firm of Integrated Design Solutions, and to the construction management team of Granger Construction and the University's Office of Architecture Engineering and Construction. We are also truly grateful for the strong commitment and support provided by our College of Engineering," said Noel Perkins, Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor.

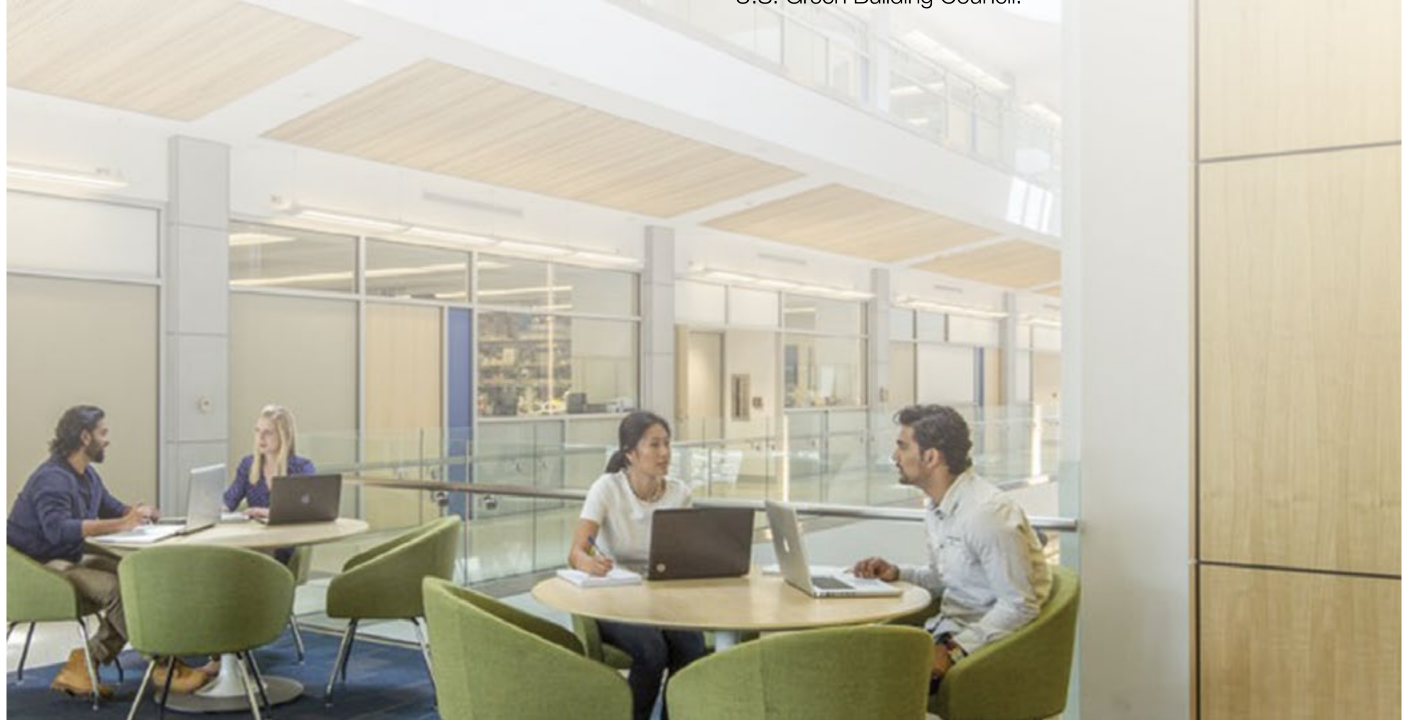
The State of Michigan provided $30 million for the renovation, with the College of Engineering and the U-M Office of the Provost funding the remaining cost.

ME New Addition awarded with the 2016 AIA Michigan Building Award

Mechanical Engineering's new Research Complex has been recognized with the 2016 AIA Michigan Building Award. The honor is part of AIA Michigan's Annual Awards Program, which is meant to encourage and promote excellence in architecture. This particular Building Award is presented as a means to recognize individual accomplishments as well as bring to public attention outstanding examples of architectural services rendered by Michigan firms.

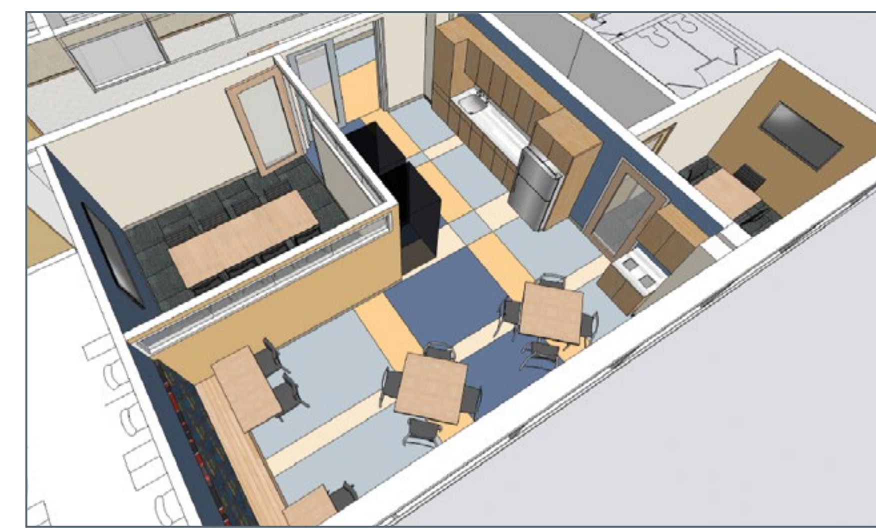
The architectural firms Perkins + Will and IDS (Integrated Design Solutions) worked closely on the building project. "Perkins + Will is honored to be recognized, with our partner IDS, for the design of this unique building," said Robert Goodwin, FAIA, design principal for the project. "The facility will help transform North Campus and advance a new generation of innovative, cross-disciplinary and sustainable engineering research facilities."

The new research complex enables researchers to study the forces at work at the smallest scales and to advance nanotechnologies in energy, manufacturing, healthcare and biotechnology. It houses The Center of Excellence in Nano Mechanical Science and Engineering and includes a state-of-the-art Ultra-Low Vibration Facility. Core laboratory and collaborative spaces are flexible and shared by the occupants, as well as other researchers in the building, to promote synergy and interdisciplinary engineering research. Since the project has been completed it has also been honored with the 2015 AIA Detroit Honor Award and was LEED Gold Certified by the U.S. Green Building Council.



Walter E. Lay Automotive Lab Interior Renovation Underway

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



Construction is officially underway on the interior renovation of ME's Walter E. Lay Automotive Laboratory building. The U-M College of Engineering approved an interior renovation of the space in winter of 2013 and Phase 1 of construction began in May 2016.

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

The renovation is slated to include 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.

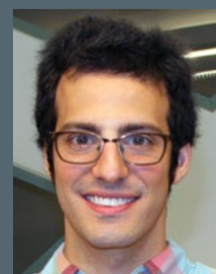
The Lab's flooring and walls will also receive new surface finishes and the faculty and student offices be upgraded. The renovation project includes some HVAC and electrical upgrades as well.

"Phase 1 will focus on the west end of the ground floor," said **Noel Perkins**, Associate Chair for Facilities and Planning and Donald T. Greenwood Collegiate Professor. "The remaining phases, 2 through 4, will follow in sequence with the last phase reaching completion in August of 2017. "We are excited for the result, which will be a major transformation," he added.

ME Welcomes New Faculty Members

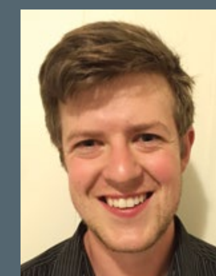
The ME department is pleased to welcome Jesse Capecelatro, Daniel Cooper, Yue Fan and Bogdan Ioan Popa, who are joining the faculty as assistant professors.

JESSE CAPECELATRO



Capecelatro earned his PhD from Cornell University and has worked as a research scientist at the Center for Exascale Simulation of Plasma-coupled Combustion (XPACC) at the University of Illinois Urbana-Champaign. His research endeavors include collaboration with the National Renewable Energy Laboratory on numerical modeling of fluidized bed reactors as well as high performance computing of turbulent multiphase flows and fundamental and numerical studies of particle-induced turbulence.

DANIEL COOPER



Cooper earned his PhD from the University of Cambridge and has worked as a post-doctoral scholar in the Laboratory for Manufacturing Productivity at MIT. His research interests lie in making impactful contributions to the area of manufacturing and sustainability and his PhD work focused on material efficiency in the steel and aluminum industries, including the reuse of manufacturing scrap, extending the lifespan of products, and the potential to reuse components at product end-of-life.

BOGDAN IOAN POPA

Bogdan Ioan Popa earned his PhD from the Politech University of Bucharest. He went on to work as a Postdoctoral Research Associate and Research Scientist at Duke University with his research focusing on complex artificial materials designed to control and manipulate the propagation of several types of physical waves, including electromagnetic and acoustic waves. Some of his most recent research is to embed electronic components into the fabric of materials in order to obtain a new generation of smart materials.

YUE FAN

Fan earned his PhD from MIT and is currently working as a Staff Scientist for the Materials Science and Technology Division at Oak Ridge National Laboratory. Fan's primary research interest is to provide substantive knowledge on the mechanics and micro-structural evolution in complex materials systems under extreme environments via predictive modeling. This will facilitate the development of new science-based high performance materials with novel functions and unprecedented strength, durability and resistance to traditional degradation and failure.

ME Faculty in the "News"

It's no secret that the ME faculty are continuously conducting cutting edge research, and it doesn't go unnoticed. Our faculty are making the news whether it be print or broadcast. Below is a sampling of those recently featured for their work.

PHOTO: SALWAN GEORGES, DETROIT FREE PRESS

NOEL PERKINS' MICRO-SENSOR FEATURED IN THE *DETROIT FREE PRESS* AND *MICHGAN RADIO*

U-M ME Professor **Noel Perkins**' groundbreaking work in micro-sensor technology could change the way you understand your golf swing and free throw or fly-fishing technique.

Read more in the article below:
http://www.freep.com/story/money/business/michigan/2016/02/08/um-perkins-sensor-technology/79870714/

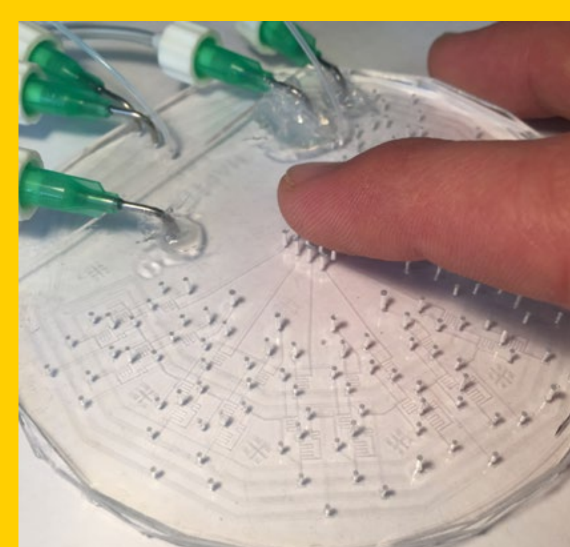


PHOTO: JOSEPH XU)

ELLEN ARRUDA'S FOOTBALL HELMET TECHNOLOGY FEATURED IN *MIT TECHNOLOGY REVIEW* AND *DBUSINESS*

U-M ME Professor **Ellen Arruda** creates a football helmet design that promises to protect the brain, not just the skull.

Read more in the article below:
https://www.technologyreview.com/s/600717/this-football-helmet-design-promises-to-protect-the-brain-not-just-the-skull/

Find out more about Arruda's research on page 16.

BRENT GILLESPIE'S TOUCH SCREEN BRAILLE TABLET FEATURED IN *POPULAR SCIENCE*

U-M ME Professor **Brent Gillespie** works to create a touch screen tablet that displays in Braille.

Read more in the article below:
www.popsci.com/new-touch-screen-design-could-display-in-braille

Find out more about Gillespie's research on page 18.

PHOTO: JOSEPH XU

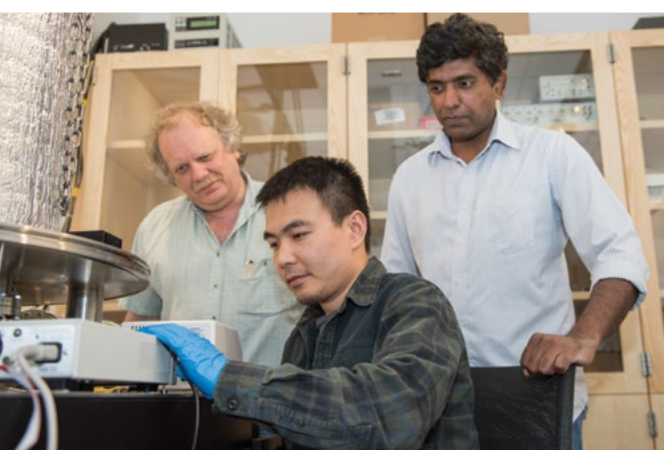
ME Faculty Published Popular Textbooks and Research Papers Featured in Top Scientific Journals

Our faculty's research is always catching the attention of the world's top scientific journals. During the past year, ME faculty have published over 415 journal papers. In addition, our colleagues have authored many important and popular books in recent years. Check out a few below.

KATSUO KURABAYASHI AND XIAOGAN LIANG'S RESEARCH FEATURED ON THE COVER OF *THE JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY B*

U-M ME professors **Katsuo Kurabayashi** and **Xiaogan Liang** present a study on the evolution behaviors of the transfer characteristics of MoS_2 and WSe_2 field-effect transistor biosensors when they are subjected to tumor necrosis factor-alpha and streptavidin solutions with varying analyte concentrations. This work advances the critical device physics highly relevant with the fabrication and implementation of reliable nonelectric biosensors based on emerging atomically layered semiconductors.

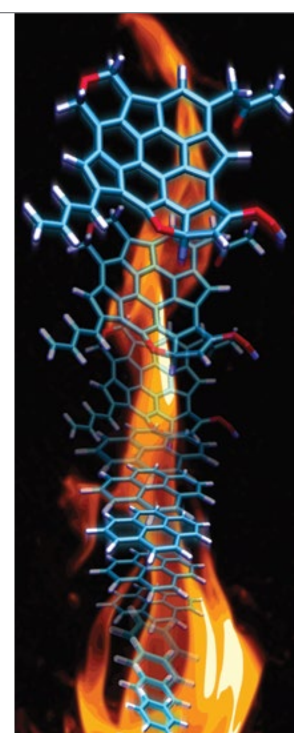
Read more details via the link below:
scitation.aip.org/content/avs/journal/jvstb/33/6/10.1116/1.4930040



EDGAR MEYHOFER AND PRAMOD SANGI REDDY'S RESEARCH FEATURED IN *NATURE*

U-M ME professors **Edgar Meyhofer** and **Pramod Sangi Reddy**'s research findings on heat transfer at the nanoscale level could help to advance next-generation information storage such as heat-assisted magnetic recording. In the U-M ME's unique ultra-low vibration lab, engineers are able to measure how heat radiates from one surface to another in a vacuum at distances down to 2 nanometers.

Read more details via the link below:
www.nature.com/nature/journal/v528/n7582/full/nature16070.html



Generation of furans and large oxygenated hydrocarbons during combustion of simple hydrocarbons, such as ethylene.

ANGELA VIOLI'S RESEARCH PUBLISHED IN *THE PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCE*

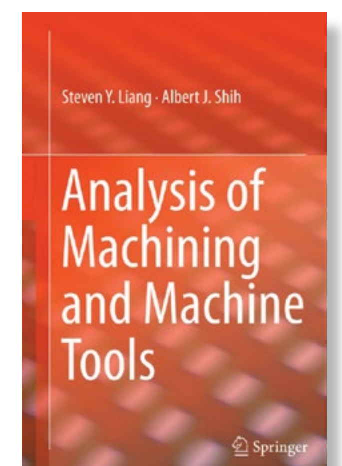
U-M ME Professor **Angela Violi**'s paper titled "Formation and emission of large furans and oxygenated hydrocarbons from flames" was featured in PNAS. The paper focuses on furan-formation pathways and the work being featured employs a multifaceted experimental and theoretical approach and demonstrates that combustion generation of furans and large oxygenated hydrocarbons can be significant, even during the combustion of very simple fuels, such as ethylene. The results suggest that furans are present from the inception of soot and are actively incorporated into the growing particles. These results are used to develop and validate a description of furan chemistry in the gas and particulate phases of combustion.

Read more details via the link below:
www.pnas.org/content/113/30/8374.abstract

JIANPING FU'S RESEARCH SELECTED FOR COVERS OF *ADVANCED HEALTHCARE MATERIALS* AND *SMALL*

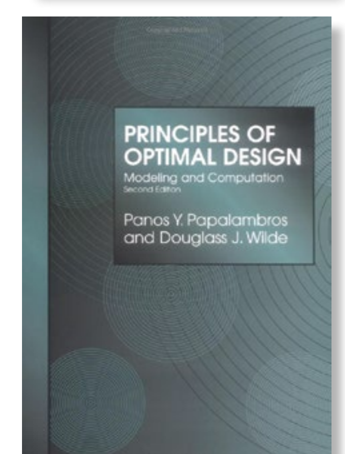
U-M ME Associate Professor **Jianping Fu**'s research made the covers of two scientific journals. The research featured was a result of the work of his lab to develop a microengineered chip mimicking the bone marrow physiological environment and demonstrating its utility to study leukemic cell-induced angiogenesis, a dynamic cellular process of the formation of new blood vessels from existing vasculatures.

Read more details via the link below:
https://me-web2.engin.umich.edu/pub/news/newsitem?newsItemId=843



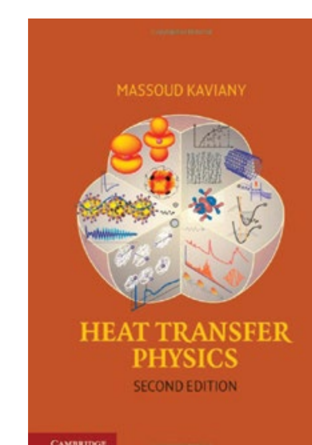
ALBERT SHIH'S *ANALYSIS OF MACHINING AND MACHINE TOOLS*

DAVID DOWLING'S *FLUID MECHANICS* (6TH EDITION)



PANOS PAPALAMBROS' *PRINCIPLES OF OPTIMAL DESIGN: MODELING AND COMPUTATION* (3RD EDITION)

*3RD EDITION TO BE COMPLETED BY JANUARY, 2017



MASSOUD KAVIANY'S *HEAT TRANSFER PHYSICS* (2ND EDITION)

ME Faculty member Sridhar Kota leading $5.8 million national manufacturing 'think-and-do' tank

University of Michigan ME Professor **Sridhar Kota** is leading a national consortium to identify emerging advanced manufacturing technologies to enhance the country's innovation ecosystem, manufacturing competitiveness and national security. Kota, the Herrick Professor of Engineering, professor of Mechanical Engineering, and director of the Institute for Manufacturing Leadership, is heading up MForesight: The Alliance for Manufacturing Foresight.

The National Science Foundation (NSF) and the U.S. Commerce Department's National Institute of Standards and Technology (NIST) funded MForesight with a three-year, $5.8 million cooperative agreement. The University of Michigan's Institute for Research on Labor, Employment, and the Economy (IRLEE), a unit within the Office of Research that provides technical assistance to hundreds of struggling manufacturing firms, has been charged with managing the operations and staffing for this national project.

With at least 30 leaders from industry, professional associations and academia, MForesight is helping to align advanced manufacturing research with national priorities to ensure efficient use of federal funding for the greatest possible return on investment. MForesight is making connections across industry sectors by building an advanced manufacturing community.

"With collective access to over 30,000 subject matter experts across a wide range of industries, MForesight is able to serve as a continuous mechanism for research coordination across the public and private sectors," Kota said. " 'Foresight' is the key word. In this 'think-and-do' tank, we're working toward identifying emerging technologies early on so the nation can invest public and private sector dollars in a way that builds the infrastructure, knowledge and workforce skills needed to anchor manufacturing technology in this country."

The alliance currently includes representatives from automotive, aerospace, pharmaceutical, chemical, consumer products and semiconductor companies; seven other universities (in addition to the University of Michigan) including the University of California-Berkeley, UCLA, the University of Cincinnati, MIT, The Ohio State University, University of Pittsburgh, and Rensselaer Polytechnic Institute; as well as several trade associations and other thought leaders.

Professor Awtar and Geiger's Start-Up, FlexDex Surgical, Ready to Launch First Product

Nine years in development, an invention by ME Associate Professor **Shorya Awtar**'s team has been garnering much industry and media attention and is about to make its debut in the operating room.

Awtar worked with several graduate and undergraduate students in Mechanical Engineering and partnered with world-renowned laparoscopic surgeon, **James Geiger**, MD, at the C.S. Mott Children's Hospital to create a cost-effective platform technology, dubbed FlexDex, that enables minimally invasive surgery.

Minimally invasive surgery (MIS) uses small incisions on the patient's body and typically leads to reduced blood loss and postoperative pain, along with faster healing. But existing instrument technologies for MIS are limited in functionality and require extensive training for surgeons, or are prohibitively expensive for healthcare facilities such as in the case of surgical robots.

In contrast, the FlexDex technology precisely, comfortably and instinctively translates the surgeon's hand, wrist and arm movements outside the patient into corresponding movements of an articulating instrument tip inside the body. This is accomplished via an elegant, purely mechanical design that is cost-effective because of its inherent simplicity.

"FlexDex effectively makes the instrument a natural extension of the surgeon's hand," Awtar explained. The key enabling innovation in FlexDex is that of the Virtual Center™, which creates a natural interface between the instrument and surgeon's wrist. It is based on a parallel kinematic flexure mechanism that captures and mechanically separates the two rotations of the surgeon's wrist and transmits them to the instrument tip.

Other features that add to FlexDex's unique functionality include an ergonomic attachment of the instrument to the surgeon's forearm and an infinite roll capability, making it especially useful for suturing and other difficult minimally invasive procedures.

The FlexDex project originated in a Mechanical Engineering capstone design course project sponsored by ME Professor **Sridhar Kota**. The continued innovation and development was made possible through basic research in Awtar's Precision Systems Design Lab in partnership with Geiger.

In 2010, Awtar became the youngest recipient of the American Society of Mechanical Engineers' prestigious Leonardo da Vinci Award for the invention of FlexDex.

Along with **Greg Bowles**, a medical device entrepreneur, Awtar and Geiger founded the company FlexDex Surgical to develop, manufacture and commercialize their innovation. Bowles brings decades of experience introducing advanced surgical products to the healthcare market, a difficult and complex ecosystem. Continual innovation at the company has been fueled by a talented group of engineers, many of whom are U-M ME graduates.

FlexDex Surgical has raised almost $10 million through government grants, including an SBIR award from the National Science Foundation, and Series A and B private investments. The company is preparing to launch its first product —an articulating needle-driver for minimally invasive sewing (see front cover).

"We purposefully designed the FlexDex platform to be highly versatile," said Geiger, "so that it can potentially serve multiple surgical specialties and thereby bring the benefits of minimally invasive procedures to a much broader population." Given its functionality, versatility and affordability, the FlexDex surgical platform can positively impact a multibillion-dollar healthcare market worldwide.

FlexDex has received widespread media attention lately. *MedGadget* wrote that "it takes just a few minutes to instruct someone on how the device works and after just a bit of practice it starts to feel like second nature....[I]n our eyes the FlexDex has set itself far apart from the competition. It provides the agility, strength and intuitive operation that's completely unlike anything else."

The *MedTech Strategist* showcased FlexDex Surgical on its May 2016 cover under "Start-ups to Watch," along with an article entitled "Achieving the Dexterity of a Robot in a Mechanical Device."

The *Detroit Free Press* has highlighted FlexDex Surgical as an example of a university innovation being commercialized for societal impact.

Videos of FlexDex in action can be found on the ME department and FlexDex Surgical's websites.

Awtar (left) and Geiger (right), coming from different disciplines, forged a unique partnership to realize FlexDex.

New Microfluidic Platform and Start-up
Help Scientists Study Aging

For decades, research scientists have turned to small organisms such as the worm *C. elegans* to better understand a number of biological phenomena, including the aging process.

C. elegans has a transparent body and each of its fixed number of somatic cells has a unique position, making it relatively easy to view under a microscope. In addition, more than 50 percent of *C. elegans* genes have human homologues, making it a favorite among researchers. But although *C. elegans* is a powerful vehicle to help scientists study aging, it can be a challenging organism to work with.

Since the aging process is so complex and heterogeneous, research demands large sample sizes in order to discern patterns and trends that are statistically significant. Achieving a high-throughput experimental platform that limits manual handling of *C. elegans* and enables repeatable, accurate functional imaging of large populations has been a stumbling block.

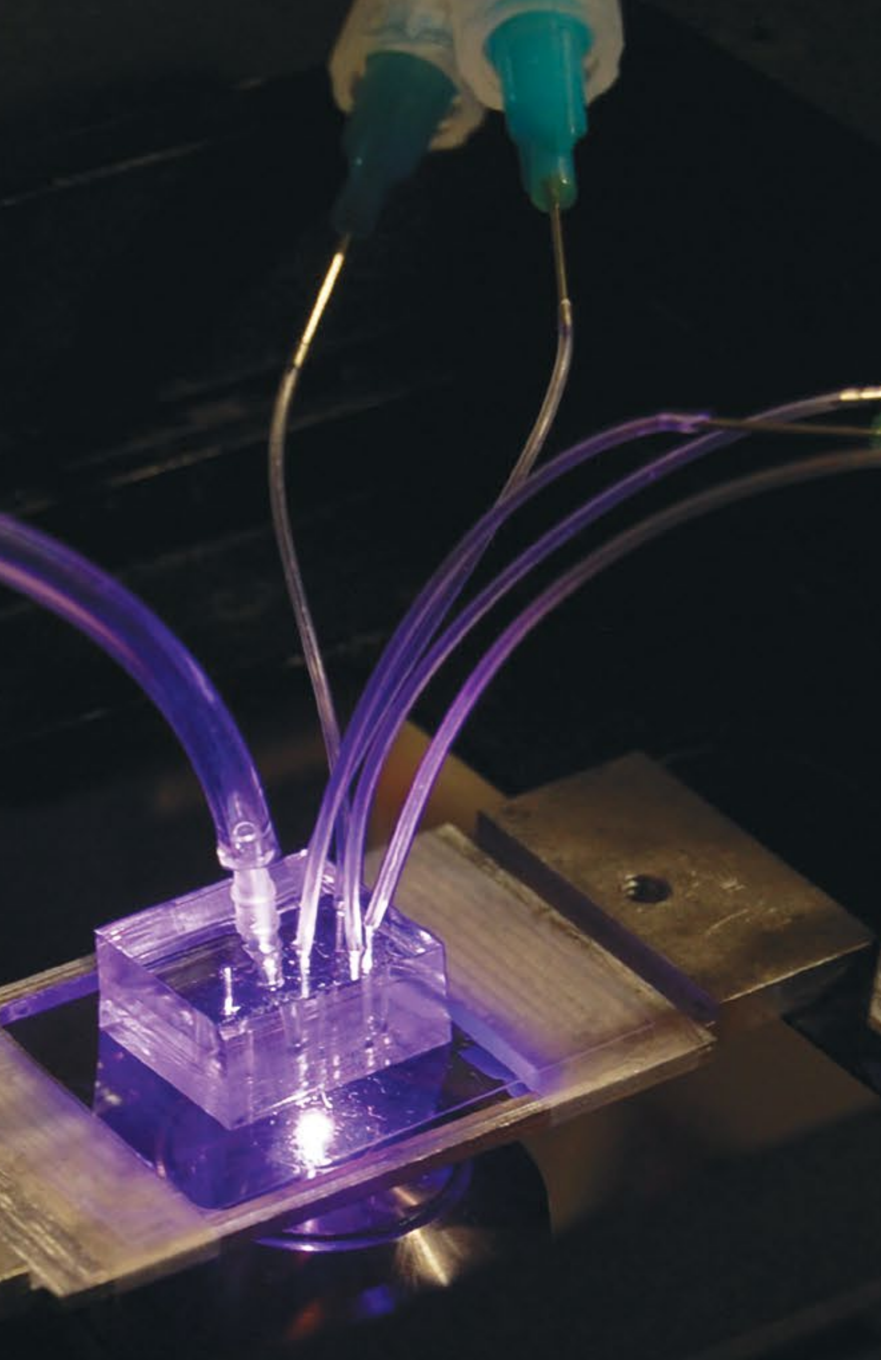
Work from the laboratory of ME Associate Professor **Nikos Chronis** is solving those long-standing challenges. Chronis' work focuses on micro and nano electro-mechanical systems (MEMS/NEMS) and microfluidics technologies to address both fundamental questions in neuroscience and clinical needs in the medical field.

While conducting research into the aging process in the nervous system of *C. elegans*, Chronis realized he needed a more efficient way to handle the live and tiny worms—between 20 to 40 microns in diameter—in his studies. Such handling includes loading and noninvasively positioning and immobilizing a specimen, exposing it to a carefully controlled stimulus, imaging and recording the response and releasing it.

"Microfluidics technology emerged in the 1990s and mainly has been used in research for clinical diagnostic applications and cell, protein and DNA analysis, but our own research in neuroscience highlighted the opportunity for this technology to facilitate research on live organisms," explained Chronis.

Chronis set out to create an automated platform to simplify the experimental process. The system he developed includes two main components: a microfluidic biochip and an integrated fluorescence microscope.

The customized design and specialized microfabrication of the biochip guides worms to enter the device in the correct orientation and noninvasively immobilizes an individual worm. Once the specimen worm is in place, the device delivers a measured amount of a gas or chemical stimulus to the nose for a precisely controlled period of time. Researchers locate the cells of interest and image them to determine the target cells' response to the stimulus. Pressurizing the device flush channel once testing is complete guides the worm to exit.



A microfluidic device for performing functional imaging of the *C.elegans'* brain.

C. elegans **homologues have been identified for at least**
60%
of human genes

> We believe our system can be a game-changer in this arena, especially with drugs targeting the nervous system. Our platform automates many aspects of the research process, enables standardization of assays and lets researchers collect a high volume of quality data efficiently.

In a paper published in the journal *Lab on a Chip* in 2010, Chronis and collaborators in the U-M departments of Electrical Engineering and Computer Science and Biomedical Engineering demonstrated the novel platform. They also demonstrated, *in vivo*, functional, age-dependent changes in the nervous systems of older worms down to the single-neuron level, something that had not been achieved to date. Their findings further support the validity of previous research related to aging and neurological decline.

The microfluidic platform Chronis developed from a decade of foundational research has since led him to co-found a start-up company, MicroKosmos, LLC, with **Daphne Bazopoulou**, a former postdoctoral research fellow in the Chronis lab. The company is based in Ann Arbor, and its mission is to accelerate breakthrough discoveries by automating experimental protocols.

To date MicroKosmos has microfabricated devices for studying *C. elegans* and *Drosophilia melanogaster*, commonly known as the fruit fly. Customized devices can be fabricated for other organisms and experimental setups.

The microfluidic platform also holds promise for the time-consuming and costly process of drug screening, which is critical to new drug discovery.

"We believe our system can be a game-changer in this arena, especially with drugs targeting the nervous system," said Chronis. "Our platform automates many aspects of the research process, enables standardization of assays and lets researchers collect a high volume of quality data efficiently. We still have a long way to go—of course *C. elegans* is not human—but we're off to a good start."

Keeping Athletes in the Game:
New Technologies to Prevent Injuries and Improve Performance

It reduced impulse by 80% and peak pressure by 30% compared with a conventional helmet

Today's sports and military helmets can prevent skull fractures by absorbing much of the force of an impact or blast, but they are less effective at preventing traumatic injury to the brain.

That's because "force is only part of the picture," said Professor **Ellen Arruda**, whose laboratory explores the mechanics of materials, soft tissue and knee biomechanics and design of blast and impact resistant materials and structures.

After an impact or blast event, the force of the impact travels through the helmet as a stress or pressure wave. Energy that isn't dissipated continues forward, through the skull and the brain, as impulse.

Arruda and colleagues have devised a new helmet design to address both force and impulse. Dubbed MItigatium™, the helmet technology recently won the Head Health Challenge III, a competition sponsored by the National Football League, General Electric, Under Armour and the National Institute of Standards and Technology. The $250,000 prize funds a year of continued prototype development.

The multi-layered design of MItigatium™ is comprised of three materials: a hard plastic seen in many off-the-shelf bicycle helmets; flexible plastic; and a viscoelastic damping material. This critical third layer is responsible for dissipating the energy that remains, i.e. the impulse.

Arruda's design ensures the key inner viscoelastic layer meets its challenge through tuning, or optimizing the frequency of the traveling pressure wave for impulse mitigation.

"The impact or blast event contains a spectrum of frequency content," Arruda explained. "By choosing the right elastic and physical properties of the first two layers, we can bin all of that energy into specific frequencies, which we match to the frequency range of the damping material."

The team validated the concept in simulation using finite element models and experimentally through impact experiments, which monitored displacement, strains, accelerations and velocities of the brain model after impact.

The MItigatium™ prototype reduced strain, velocity and acceleration over existing helmet designs. It reduced impulse by 80 percent and peak pressure by 30 percent compared with a conventional helmet. An article describing the work was published in the Journal of the *Mechanics and Physics of Solids* in December 2015.

Not only is the new helmet technology effective; it also is lightweight, can be manufactured from widely available and affordable materials and, since it is unlikely to crack or break, is designed for repeated use.

By carefully selecting the materials based on physical and mechanical properties, the technology can be modified for use in any number of protective applications, including helmets for first responders and construction workers as well as for vehicle cabins, playground surfaces and packaging materials.

CREATING A MODEL EXERCISE AND SPORTS SCIENCE INITIATIVE

Arruda's work on safer protective equipment is continuing through a unique, multidisciplinary collaboration, the Exercise and Sports Science Initiative (ESSI). The goal of the initiative is to improve individual and team performance while simultaneously preventing injuries through improved sports technologies, safer sporting equipment and data analytics.

The broad effort will encompass the research arm of the University, the Michigan Institute for Data Sciences and the Athletics department as well as Student Life, club teams and even recreational exercisers on campus.

"Imagine collecting sensor data from athletes while using motion capture to analyze performance, learning what specific actions affect outcomes and helping players function better as a team overall —that's all part of our vision," said Arruda, who serves on the initiative's planning board.

The vision also includes improved individual performance and injury prevention. The ESSI might include nutritionists who study the role of hydration, rest and recovery using data collected by sensors in an athlete's clothing or experts in circadian rhythms who investigate optimal exercise routines, as examples.

"There are research efforts all over campus, not only within the College of Engineering, that feed into this," Arruda said.

Such a collaboration among researchers, athletics and recreational athletes is unique, and U-M is well poised to pave the way.

"We have such a strong research community here, and we also have such an athletic student population," said Arruda. "That rare combination, and our shared vision, organically led to this powerful partnership."

Currently, the group is continuing to identify strategic industrial and research partners. Arruda's own longstanding work in the area of biomechanics and knee-injury prevention will undoubtedly play a role.

"The idea of personalized preventive medicine underlies the biomechanics work I do, and it also underlies the ESSI mission. Imagine using imaging and biomechanics data from an athlete to create a computational model and determine his or her injury risk. Then we could develop personalized prevention strategies to change those specific risk factors," Arruda said. "I think of it as technology transfer to student athletes, and eventually to the broader population."

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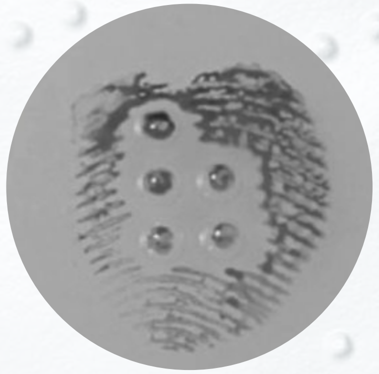


The Holy Braille

Seeking a Low-Cost, Full-Page Refreshable Braille Display

Braille literacy is a predictor of academic advancement and job opportunities for blind individuals, just as print literacy is for sighted individuals, but the production and distribution of hard copy braille materials are declining in today's digital age. In spite of ready access to text-to-speech renderings of electronic documents and audiobooks, such formats are passive; they don't allow the user to control the pace of reading or to develop spatial or relational memory—key literacy skills—of the material being heard.

Devices do exist to digitally render braille text, but they are large and expensive due to the complex technology used to dynamically raise and lower the braille dots, or pins. Most portable versions of these devices therefore can only display one or two lines of braille at a time, making it especially challenging to read spatially distributed or graphical information, such as maps, spreadsheets, infographics, and mathematical and musical notations.

"The limitations of current refreshable braille displays (RBD) make reading very difficult for the blind and visually impaired," said ME Associate Professor **Brent Gillespie**, "and it makes reading a map or other spatially distributed information all but impossible."

Full-page displays are available, but the cost can reach upwards of about $1,000 per line of braille, creating the need for a low-cost, tablet-style, full-page RBD. Gillespie's HaptiX Laboratory is developing an innovative solution to meet that need.

"The technology to raise and lower the pins in current RBDs has not changed much since the late 1970s," said Gillespie. "Most rely on piezoelectric actuators, and they can't be miniaturized any further."

Working with **Alex Russomanno**, a graduate student in Gillespie's lab, **Mark Burns**, professor of Chemical Engineering and **Sile O'Modhrain**, a professor in the School of Music, Theatre and Dance and in the School of Information, Gillespie is taking a different tack, using microfluidic technology to create pneumatic membrane actuators—pressure-controlled valves—that raise and lower braille "bubbles" or dots.

The pneumatic valves operate in an analogous way to an electric transistor. Instead of voltage and current, pressure and fluid flow control and initiate the bubbles' movement.

"We're controlling the bubbles using the fluidic equivalent of electronic logic and circuitry," said Gillespie. The fluidic circuits save binary information—1s and 0s—in the form of high and low pressure. A complex network of these circuits can be integrated in the same substrate as the bubbles, much like computer chips are manufactured in a batch process, instead of transistor-by-transistor. In this way, a long string of braille dots can be controlled using only two input valves.

The team's display can present spatially distributed and differentiable tactile information within the user's finger contact area. Early prototypes have rendered braille characters that were easily read by blind braille readers.

The display can be manufactured through standard microfluidic molding and bonding techniques, thereby significantly reducing fabrication costs.

The device also can be made thin enough to be placed onto a sensing layer, such as a tablet computer screen to provide simultaneous touch input and tactile feedback. Such an advance would give blind users the same tactile feedback and sense of immediacy and interaction that so-called "direct manipulation interfaces" give sighted computer users, for example, when dragging a document to the trash bin icon or swiping screens on a smart phone.

The team's technology may have broader application, too, including as tactile interfaces for mobile phones and touchscreens in vehicles.

The University of Michigan and National Science Foundation have supported the work to date, and the team has worked with the National Braille Press as a strategic partner.

Direct manipulation interfaces, like **moving to the trash**, would give blind users the same tactile feedback and sense of immediacy.

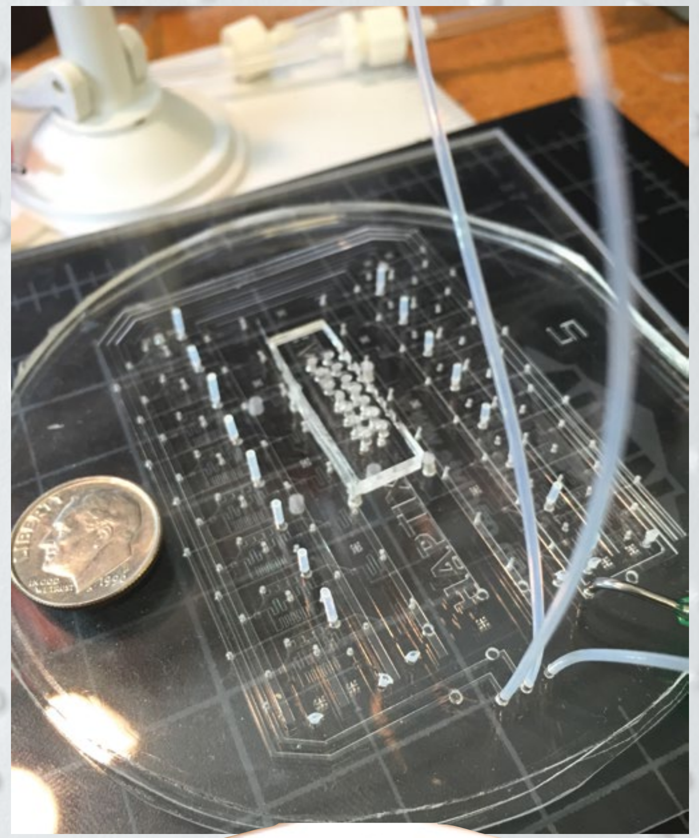
> The limitations of current refreshable braille displays (RBD) make reading very difficult for the blind and visually impaired, and it makes reading a map or other spatially distributed information all but impossible.

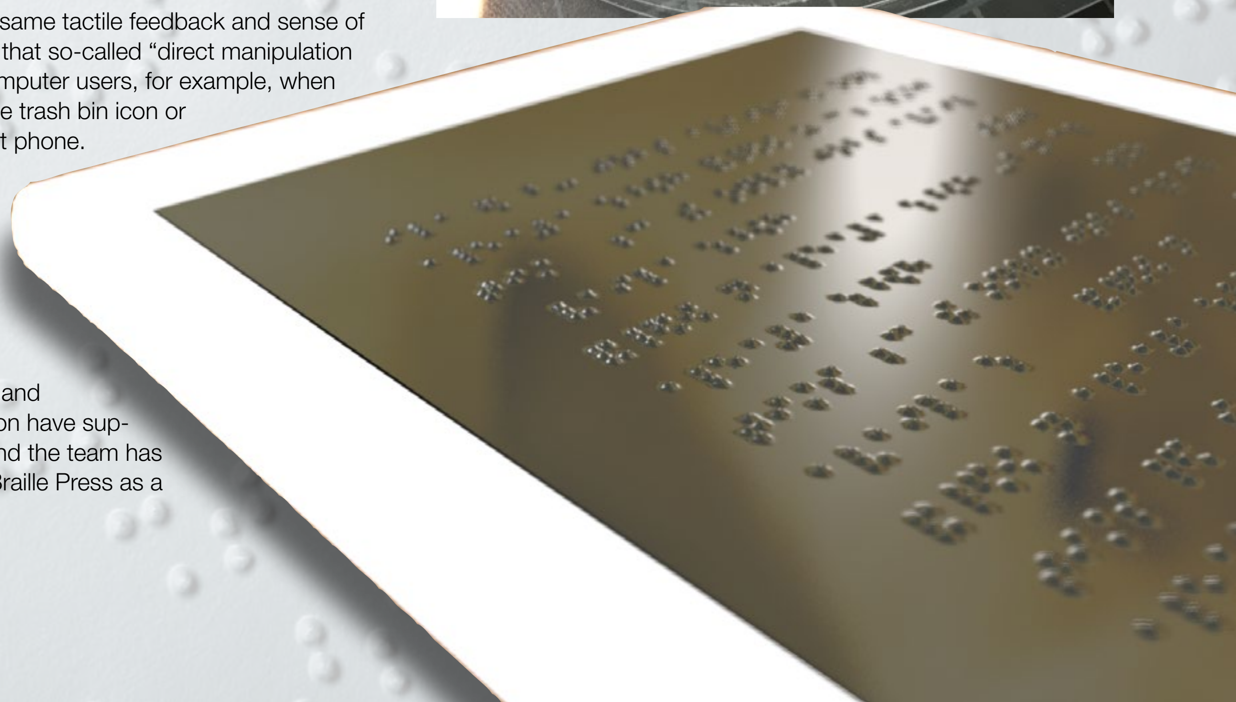
TOP LEFT: Two hands reading braille text.

BOTTOM LEFT: Showing the size of a braille character, how it fits the fingerpad.

TOP RIGHT: A proof-of-concept device that uses microfluidics to raise "bubbles" on the surface of a thin, clear substrate.

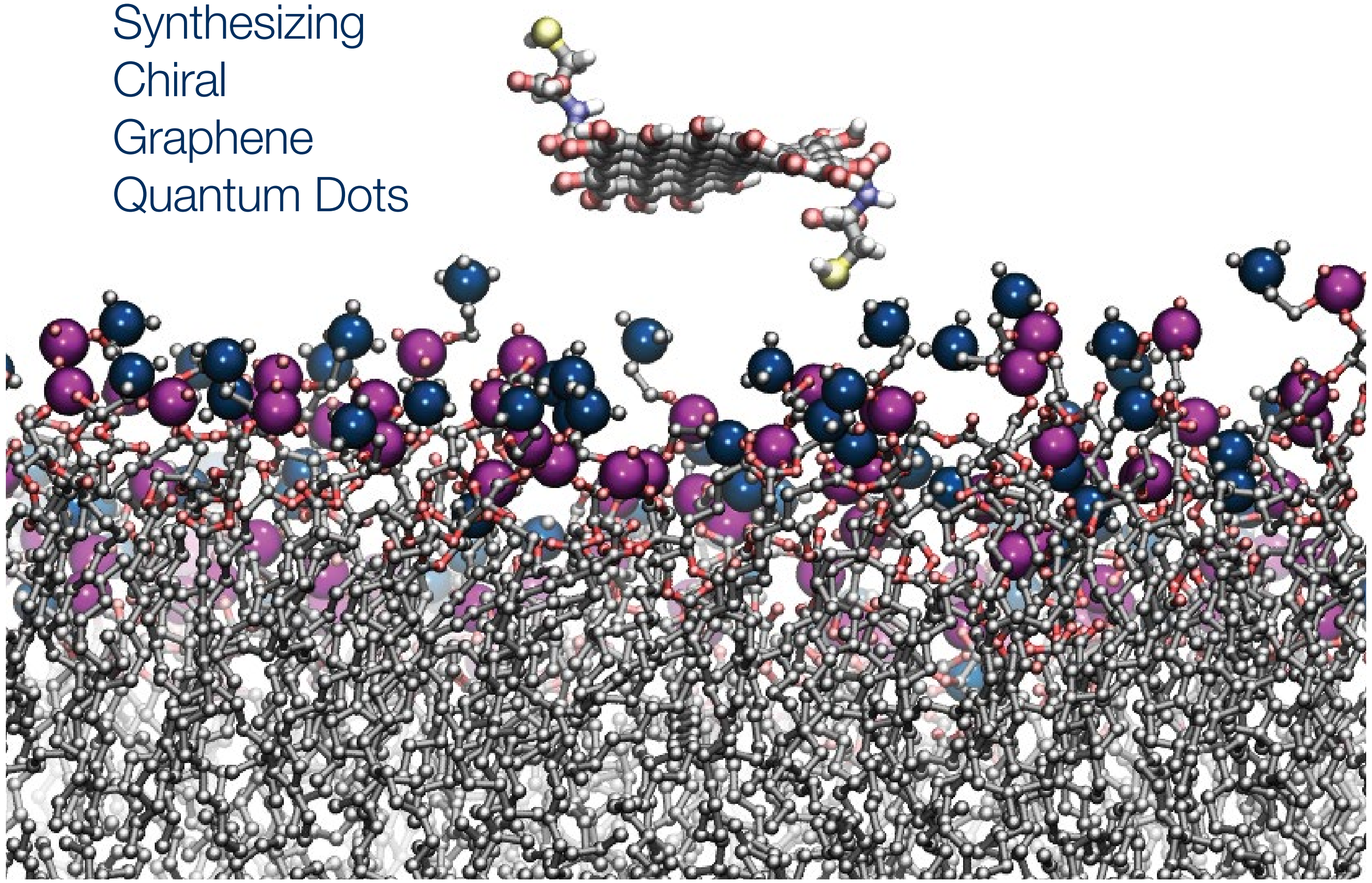
BOTTOM RIGHT: A digital concept of what a low-cost, full-page refreshable braille display would look like using the technology.

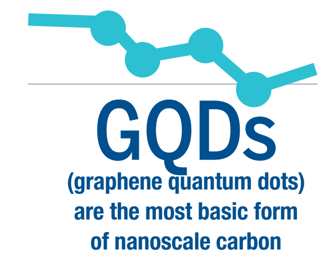




> Understanding the molecular dynamics of chiral GQDs is critical for their future use. This is especially true in health and medical applications, such as for drug delivery.

An Organic Nanoscale Twist:
Synthesizing Chiral Graphene Quantum Dots





Chiral nanostructures—that is, a structure whose mirror image cannot be superimposed on itself—have been the focus of much attention in recent years since such structures make for compelling components in a number of application areas, including optoelectronics, biosensing and drug delivery. But much of the research has focused on structures made from inorganic, and bio-incompatible, materials, such as gold, cadmium sulfide or cadmium telluride.

Professor **Angela Violi**'s laboratory explores the nexus of nanoscience, biomedical science and combustion, including the design, assembly and characterization of nanomaterials and their interactions with biological systems through advanced multiscale modeling approaches.

With colleague **Nicholas Kotov**, Professor in the Chemical Engineering Department, and co-workers, Violi has demonstrated the chiral properties of cysteine functionalized graphene quantum dots (GQDs). Their work was published in early 2016 in the journal *ACS Nano*.

In the experimental portion of the work, led by Kotov, the team attached either the amino acid L- or D-cysteine to the edges of GQDs, the most basic form of nanoscale carbon for the applications of interest mentioned above. Attaching each of the amino acids caused the flexible GQDs to twist; L-cysteine caused the graphene sheets to twist clockwise, while D-cysteine caused a counter-clockwise helical buckling.

"This twisting, based on the 'handedness' of the attached amino acid, is very different from what we would see in metal and semiconducting nanoparticles and in carbon nanotubes," said Violi.

Violi and Kotov looked at the potential biocompatibility of chiral GQDs, since "understanding the molecular dynamics of chiral GQDs is critical for their future use. This is especially true in health and medical applications, such as for drug delivery," she said.

After exposing human liver cells to the chiral GQDs *in silico*, Violi found that the interactions with the external cellular membranes depend on the chirality of the nanostructures. GQDs with D-cysteine were far more likely to partially entered the membrane's fatty double layer, than the GQDs with L-cysteine attached. The latter tended to lay parallel to the cell surface, resulting in a much weaker bond.

"It was interesting and surprising to us that the cell membranes had differentiated responses to the GQD chirality," said Violi. "This suggests to us that one of the keys to potential clinical use of these materials will be a continued and deeper understanding of the specific molecular interactions with cell membranes of many types of cells."

The current findings, and future work, will enable investigators to better differentiate the effects of particular materials from the effects of chirality itself vis-à-vis cellular interactions, another important step toward new medical applications and potential clinical use.

The work has generated interest among the research community. It was featured in a "Research Highlights" article in *Nature Reviews Materials*, and Violi and Kotov were interviewed for an ACS Nano Podcast, available at **https://player.fm/series/acs-nano-podcast/episode-103-acs-nano-february-2016**.

2D Vision:
Enabling New Applications for the Thinnest Materials

With his background in electrical engineering, ME Assistant Professor **Xiaogan Liang** is all too familiar with a longstanding challenge: how to simultaneously shrink the size and boost the power of electronic devices.

"If you shrink components such as a microchip too aggressively in the directions of the x and y axis, you also need to shrink in the direction of the z axis, otherwise you create detrimental short channel effects, and those cause a lot of trouble," explained Liang, who runs the U-M Nanoengineering and Nanodevice Laboratory.

In contrast, two-dimensional (2D) materials, including molybdenum disulfide (MoS_2) and other layered materials that can be exfoliated in atom-thick sheets, possess attractive semiconducting and other properties. As a result, they open up possibilities across a broad range of applications from high-speed electronics and optoelectronics to energy storage and biosensing, to name only a few.

But a major obstacle to leveraging 2D materials has been the lack of reliable, repeatable, scalable fabrication methods to produce consistent, ordered, single- and multi-layer nanostructures and functional arrays.

"There are well-established processes for fabricating silicon-based devices, but not yet for 2D materials and devices," said Liang. "We've been at the early stage of using adhesive tapes to exfoliate some of these materials but you can't create scalable arrays that way, which impedes large-scale applications."

With a number of collaborators, including ME professors **Katsuo Kurabayashi** and **Wei Lu**, Liang has developed a new process, nanoimprint-assisted shear exfoliation (NASE). The NASE process uses a pre-patterned MoS_2 stamp to press into a fixing layer. The imprinted nanoscale features are then peeled away in ordered few-layer flakes from the bulk material in a sideways direction.

Liang's process is more efficient than other exfoliation methods and yields nanostructures of consistent thickness as well as with consistent electronic and biosensing properties and performance. The work was published in 2015 in the journal *ACS Nano*.

For Liang, highly interdisciplinary research such as this and innovative, practical application go hand in hand, and he has identified three directions to leverage the distinct advantages of 2D materials.

LOW-CONCENTRATION-MOLECULE BIOSENSING

In collaboration with Kurabayashi, Liang developed a novel biosensing platform that can detect, and quantify, trace amounts of biological molecules—for instance, biomarkers associated with cancers and other serious diseases—in solution, down to femtomolar levels, potentially enabling single molecule detection.

In an article published in *Nature Scientific Reports*, Liang demonstrated the fabrication of multiple sets of biosensors made from MoS_2 transistors. The sensors successfully detected and quantified the concentration of tumor necrosis factor (TNF), a class of proteins that signal cells during the inflammatory process. TNF is an important biomarker of immune system status in humans.

"Since 2D materials are so thin and the surface is so smooth, the attachment of just a single target molecule generates a significant signal, which makes the molecule easy to detect. These sensors are extremely sensitive and therefore ideal for this application," Liang said.

LIGHT DETECTION

With strong light absorption capabilities and energy conversion efficiency, 2D materials also offer major advantages for photodetection applications.

"Half a nanometer of a 2D semiconductor can absorb as much sunlight as 50 nanometers of silicon," Liang said. And given the high surface quality of 2D materials, they lack the "blue response reduction" that diminishes light-generated current in conventional semiconductors.

In work published in *Applied Physics Letters* in 2014, Liang and ME Professor **Edgar Meyhofer** showed that a layered 2D material of MoS_2 and graphene, doped with plasma, greatly improves efficiency in the blue-near ultraviolet region. Their findings support the promise of new, more efficient nanoscale light detection and energy conversion devices.

DATA STORAGE

Liang also is investigating 2D materials for multibit data storage, an application area discovered by happenstance when a PhD student, **Mikai Chen**, inadvertently put a multilayered 2D structure into a plasma chamber. The plasma only affected the top layer of the structure, creating a wavy pattern much like a wet piece of paper develops ripples. Liang observed that the rippled, "floating" sheet functioned as a charge trapping layer.

"Charging and discharging changes the conductance of the other layers and, in this way, the structure has memory," Liang explained.

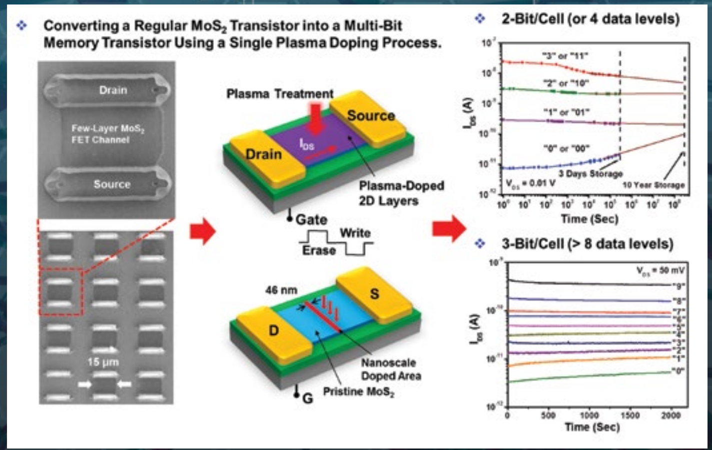
In further work, published in *ACS Nano*, Liang demonstrated multilayer plasma-treated MoS_2 transistors that act as multibit memory devices appropriate for nonvolatile, long-term data storage.

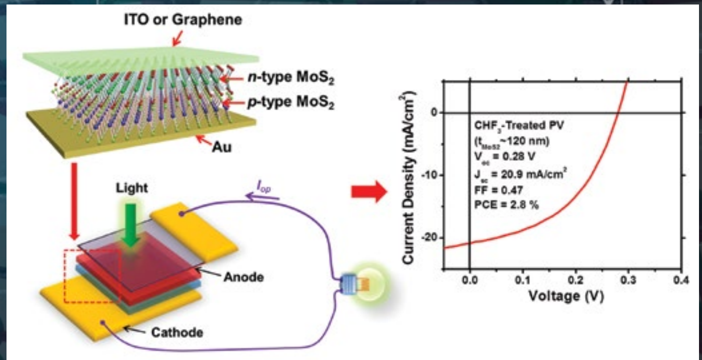
"These were interesting, promising findings," Liang said. "No matter how much plasma we might use, there would be no way to create this type of a rippled structure in a conventional material. But with 2D materials, you can do a lot of surprising things."

Much of Liang's 2D materials work was funded by the National Science Foundation, including through a Faculty Early Career Development (CAREER) award, which Liang received in 2015.

Half a nanometer of a 2D semiconductor can absorb as much sunlight as 50 nanometers of silicon

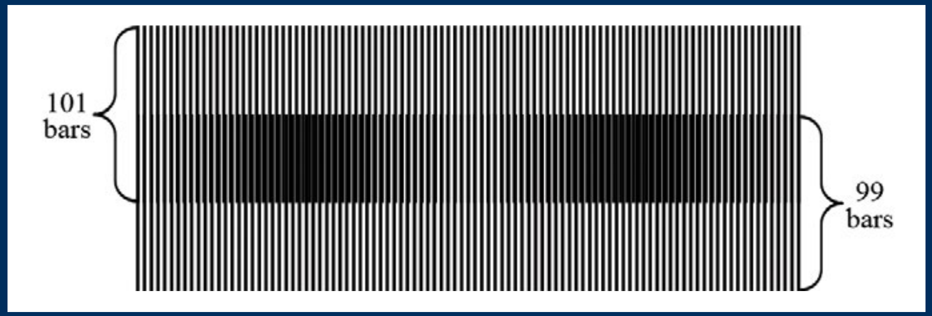
> There would be no way to create this type of a rippled structure in a conventional material. But with 2D materials, you can do a lot of surprising things.





LEFT: New multi-bit data storage devices made from plasma-doped layered materials.

RIGHT: New photo-response devices (photodetectors and photovoltaic cells) made from emerging 2-D layered materials that exhibit attractive optical and optoelectronic properties.



A lot of people might say this is impossible and, for ordinary signal processing, it is impossible. But when you introduce nonlinearity and consider out-of-band signal processing, the impossible becomes possible.

New Techniques for Underwater
Sound Surveillance and Remote Sensing

Imagine listening to a musician in an orchestra playing high notes on the flute and, from those sounds alone, being able to discern the notes coming from the bass fiddle. It may seem impossible, but that's an analogy ME Professor **David Dowling** often uses to explain a new class of acoustic remote sensing techniques he developed, which he calls out-of-the-signal-band processing.

A wide variety of array signal processing methods have been used for many years in underwater acoustic remote sensing applications, but most techniques for determining the direction toward, or the location of, a remote sound source aren't successful for signals in the higher frequency ranges.

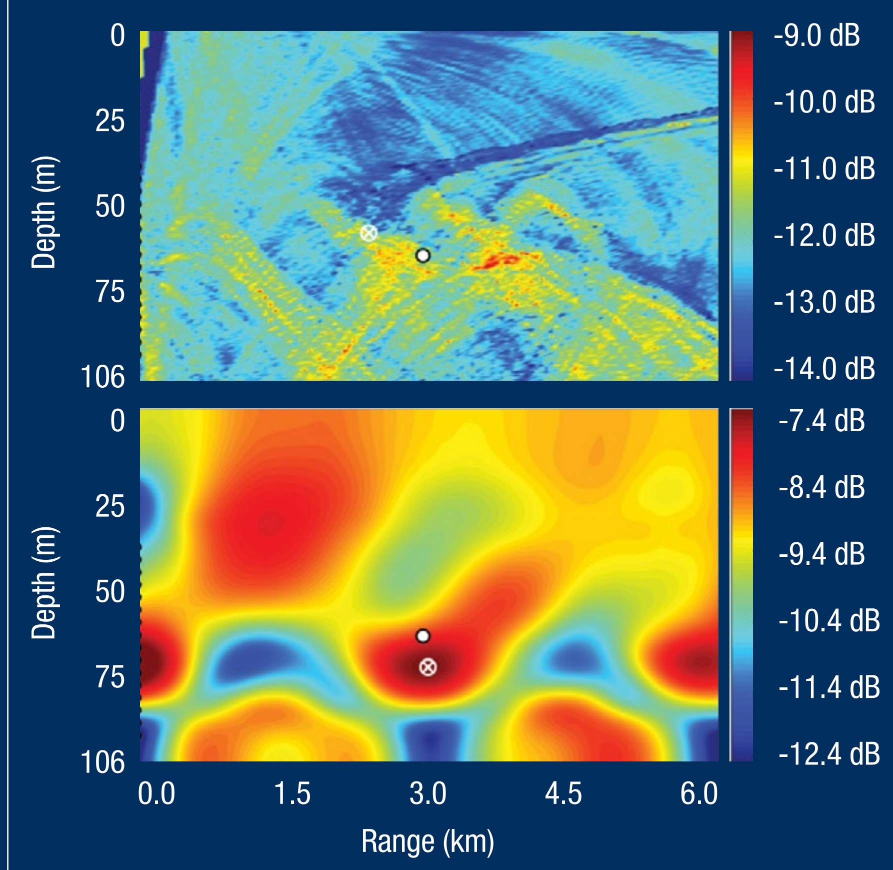
Dowling again explains in musical terms: "Music is made up of notes. Each note has a tone, and you can associate a frequency with each tone." If one plays lower notes on the piano, the frequency might range from 100 Hz to 500 Hz, then human hearing and underwater listening systems can detect and isolate the source of such sounds. However, at high frequencies—like those from a smoke alarm—human hearing and underwater listening systems might only detect the sound; the location or direction toward the sound source is ambiguous.

"Thus, converting high-frequency sound into low-frequency sound is possibly advantageous," said Dowling, who is working on techniques involving frequency differences and sums to aid direction-finding and source localization for sonar surveillance and remote-sensing purposes.

Dowling's frequency difference technique involves the intentional use of nonlinearity to shift the frequency range of a recorded high-frequency sound downward in order to construct incoming remote sensing information in a frequency range where direction-finding and source localization can be done with confidence.

With collaborators **Brian Worthmann**, a PhD student in the U-M Department of Applied Physics, and **Dr. Heechun Song**, a researcher at the Scripps Institute of Oceanography, Dowling first applies well-established techniques for turning recorded incoming sounds from amplitude as a function of time into amplitude as a function of frequency. Once in the frequency domain, he then multiplies two amplitudes at different frequencies but with a known frequency difference.

"At that point, you've formed something nonlinear," he explained. "That's the magic of working in the frequency domain—you can extract information at the difference frequency that can be used to determine the direction toward, and even the location of, the source."



FAR LEFT: A Moiré pattern, a visual illustration of how a low-frequency (long wavelength) pattern can be produced from two high-frequency (short wavelength) patterns.

LEFT: Comparison of the conventional (upper panel) and out-of-band (lower panel) source localization. The upper panel indicates many possible source locations (red dots) and none are correct. The lower panel shows one larger red region near the actual source location at a depth of 68 meters and a range of 3 km.

In effect, Dowling creates acoustic Moiré patterns using high-frequency sound recordings, which mimic the characteristics of lower frequency sound coming from the same sound source. Yet, such lower frequency sound was not broadcast by the remote sound source, so the technique appears to be "magical," since it utilizes information carried by the recorded acoustic waves in a range of frequencies not part of the recorded signal.

To validate his techniques experimentally, Dowling used sound data collected in the Pacific Ocean off Kauai on a vertical underwater hydrophone array as part of underwater communications research Song was conducting.

"What I really liked about Dr. Song's experiment is that it was not designed as a sound source localization experiment. The signal frequencies intended for underwater communications are far too high for conventional direction finding or source localization," Dowling said, "so the data really put our ideas to the test."

The results were positive. Dowling's technique effectively downshifted the frequency from a range of tens of kilohertz to a range of a few hundred hertz, enabling him to localize the source.

shortening the computation time by about
1,000x

In addition, shifting the frequency range downward lessened the density of points needed to analyze the search space for the remote source. Dowling's approach shortened the computation time by about 1,000 times and thereby reduced its computational cost.

Although the method does not yield perfect localization resolution, it represents a significant improvement over conventional in-the-signal-band processing approaches.

"Even without perfect resolution, there are circumstances where Navy personnel might know something is going on underwater, but they can't tell in what direction or at what depth," said Dowling. His approach can provide additional tools to extract more information from data already being collected.

"A submarine commander might pick up a 10 kHz sound. It's loud, and it's likely a manmade device—an adversary's perhaps—but the frequency is too high to identify its location. If you can discern that the sound is coming from one or two kilometers away, or from 100 to 200 meters away, and from what direction, the commander now has actionable information that can help make more informed decisions about what to do," Dowling said.

Out-of-band signal processing might also be exploited for radar, biomedical ultrasound and reflection seismology technologies, opening up a wide range of potential applications.

"A lot of people might say this is impossible and, for ordinary signal processing, it is impossible," said Dowling. "But when you introduce nonlinearity and consider out-of-band signal processing, the impossible becomes possible."

The most recent work on this topic was published in the *Journal of the Acoustical Society of America* in December 2015 and was funded by the U.S. Office of Naval Research and the National Science Foundation.

Driving Sustainability in Transportation Systems

In the United States, eighteen-wheeler, "big rig" trucks haul some 70 percent of all freight tonnage and consume over 37 billion gallons of diesel fuel annually. Improving engine, fuel and drivetrain efficiency of these heavy duty Class 8 trucks is key to reducing fossil fuel consumption as well as greenhouse gas and particulate emissions.

SUPERTRUCK PUSHES THE ENVELOPE

Developing and deploying advanced technologies to improve truck efficiency has been the objective of SuperTruck, a public-private initiative launched in 2010 by the U.S. Department of Energy. Four teams led by truck manufacturers and suppliers set out on an ambitious odyssey: identify a path to improve freight efficiency by 50 percent in order to ultimately demonstrate a 55 percent brake thermal efficiency (BTE) engine concept.

SuperTruck already enabled the transition of some advanced technologies into commercialization. In 2017, Volvo will incorporate in their trucks some advanced combustion and aerodynamics technologies demonstrated under SuperTruck.

"SuperTruck already enabled the transition of some advanced technologies into commercialization. In 2017, Volvo will incorporate in their trucks some advanced combustion and aerodynamics technologies demonstrated under SuperTruck," said Professor **André Boehman**, a member of the Volvo Group North America SuperTruck team.

Boehman has been investigating advanced combustion processes in support of achieving a 55 percent BTE engine. "We had a lot of freedom early on to explore concepts," he said. Once they were winnowed down to the most promising, his team examined the combustion behavior of surrogate fuel mixtures that behaved like the gasoline being used by Volvo in the partially pre-mixed charge combustion (PPC) process, to enable numerical simulation of PPC combustion.

Boehman has collaborated with professors **Daniel Haworth** and **Jacqueline O'Connor** of Penn State University. These

Big rig trucks consume over 37billion gallons of diesel fuel annually

three faculty and their students used engine studies, numerical simulation and imaging of fuel jet interactions to explore post-injection strategies, including use of a second fuel pulse to burn away soot from the first injection. Boehman's group is performing on-engine work in the U-M Auto Lab, including calibration of engines to run with various fuel injection schedules.

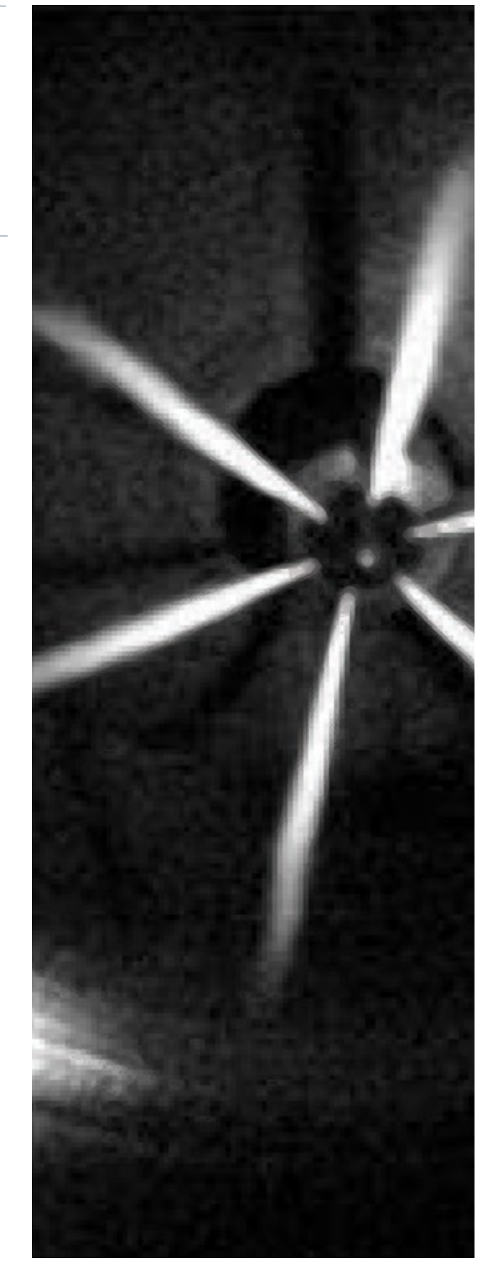
The final task as the SuperTruck I program came to an end was to investigate how piston and injector designs could be optimized to support 55 percent BTE.

"The SuperTruck I target of 55 percent BTE engine concepts is aggressive, but Volvo achieved a concept that could meet it," Boehman said. "Under the SuperTruck II program, we will be working with Volvo to move from concepts to reality, by demonstrating 55 percent BTE in an engine in a test cell. That truly will be a major accomplishment, which we are very glad to be able to pursue with our partners at Volvo."

The team has included ME PhD candidates **Jonathan Martin** and **Chenxi Sun**. Martin recently presented a paper on post-injection scheduling for soot reduction at the 2016 SAE World Congress.

EXPERIMENTAL VALIDATION OF SURROGATE JET FUELS

Boehman also is experimentally validating surrogate jet fuels, developed by ME Professor **Angela Violi** and Assistant Research Scientist **Jason Martz**. Simplified or surrogate mixtures help researchers build detailed descriptions of



the chemical reactions of new, alternative fuels. Such descriptions enable predictive modeling and more complete and accurate engine simulations.

"If you consider the range of jet fuels the U.S. Army may be faced with needing to use, predictive modeling can save significant time and money on engine development costs and can improve engine robustness," said Boehman. "Ignition delay can vary substantially among fuels, and this can impact performance and operability. Engines become increasingly picky as we demand higher efficiency and performance."

SPEEDING THE PATHWAY TO ALTERNATIVE FUELS

In an MCubed collaboration with Professor **Brad Cardinale** of the School of Natural Resources and Environment and ME Professor **Levi Thompson**, also the Richard E. Balzhiser Collegiate Professor of Chemical Engineering, Boehman is expanding ongoing U-M work on development of algal fuel production and processing to consider the performance of such fuels in combustion engines.

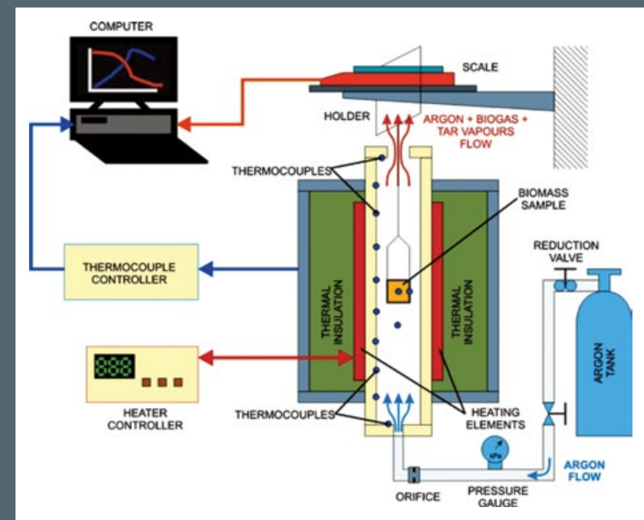
In a parallel initiative, Boehman and graduate student Taemin Kim have demonstrated a method to improve the viscosity of the liquefied gas dimethyl ether, or DME. The low viscosity of DME—about .2 centiStokes—is problematic, since it can cause significant wear in fuel injectors and pumps.

"Despite 20 years of effort, no one has been able to commercialize an engine that runs on DME," Boehman explained. More development work may make such engines a reality, but "in the meantime, if we can improve the viscosity of DME, we may be able to use it in the diesel engines of today."

Boehman serves on the scientific advisory board of Oberon Fuels (San Diego, CA), which has developed the technology to use biogas to make DME with -5 grams of carbon dioxide equivalent per megajoule. By contrast diesel fuels emit about 95 grams of CO2e per megajoule.

"Such a low carbon footprint fuel could drive large improvements in the sustainability of our transportation system," said Boehman.

Burning Questions About Combustion:
Developing New Technologies for Sustainable Energy



For nearly all of his three-decade career, Professor **Arvind Atreya** has been playing with fire, developing new concepts and technologies to reduce energy consumption and create more efficient and sustainable, lower-cost sources of fuel.

CONVERTING BIOMASS TO BIO-OIL

Biofuels from biomass are one of the few, if not only, sources of sustainable energy to make liquid hydrocarbons. Biomass from forests and agriculture, including fallen leaves and branches, stalks and corn cobs for example, not only are renewable but abundant—and poses the risk of devastating forest fires if not removed or managed through controlled burning. Woody biomass also is significantly less expensive than crude oil, costing about $15 per barrel energy equivalent.

But per unit of volume, biomass has low energy content and it is expensive to transport from remote forest areas. Current approaches to creating bio-oil from biomass require costly and time-consuming drying and grinding into millimeter-size particles.

"With over a billon tons of renewable biomass produced by our forests annually, it would be much more efficient to process it locally into a form that is simpler and less expensive to transport, such as bio-oil," explained Atreya.

In response, Atreya has developed a conceptual design for a novel transportable, autonomous biomass reactor to process biomass into bio-oil. In recent work he has conducted experiments and numerical simulations to investigate the combustion characteristics of different sizes and shape of biomass chips and the behavior of firebrands under different thermal conditions.

The resulting models advance his goal of designing and producing a portable reactor. Since the bio-oil is highly acidic, and therefore corrosive, he also is working to develop a catalytic process to remove oxygen. Deoxygenation is a necessary step in order for the bio-oil to be safely and efficiently processed in existing petroleum refining plants.

Atreya's biomass work has been funded by the National Science Foundation.

RADIATIVE FLAMELESS COMBUSTION (RFC)

Industrial furnaces used to produce steel, aluminum and glass as well as for metal casting and petroleum refining not only consume enormous amounts of fuel; they also operate at only about 50 percent efficiency, and they produce high concentrations of pollutants.

In part, the low efficiency is due to indirect heating inside conventional industrial furnaces. Flames heat the furnace walls, and the material being processed is heated to its melting point by radiation from the walls, not by the flames directly. This indirect process means that gas inside the furnace must be heated to, and remain at, temperatures significantly higher than the melting point of the target material.

"The only thing you can do with that gas is exhaust it, and all of the heat contained in that exhaust gas is wasted," said Atreya, who has developed several solutions.

First, Atreya has demonstrated a flue gas recirculation device to circulate the exhaust energy back into the furnace to help maintain the high temperatures. But preheating the combustion air with recirculated exhaust gas raises flame temperature as well as pollutant formation, so Atreya developed a method to dilute and simultaneously preheat the air to the higher temperatures required for flameless combustion. The results are improved efficiency and a 10-fold decrease in pollutant formation.

Secondly, Atreya's approach creates a larger reaction zone within the furnace by burning the fuel in a distributed reaction zone -- all without burning additional fuel. As temperature rises inside the furnace, radiation increases by the fourth power. The larger reaction zone means more radiation from the distributed reaction zone or homogeneous burning.

"With a larger reaction zone and uniform burning, heat is radiated a lot more efficiently to the material you're working with," said Atreya, who has demonstrated the RFC approach on a laboratory-scale furnace. He also has developed real-time sensor technology for furnace monitoring.

The RFC approach lowers fuel consumption per unit of output by more than half. The process also improves furnace productivity and lessens pollutants and carbon emissions. Product quality is improved, too, since dross and other waste products that accumulate inside furnace are also reduced.

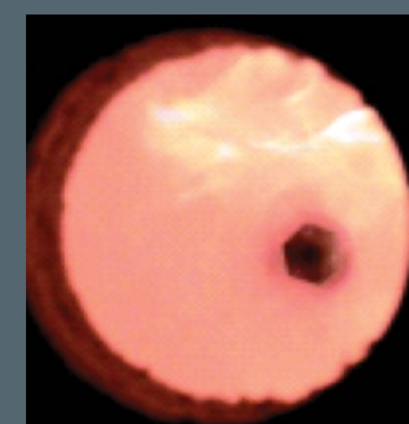
TOP LEFT: Forest Fires caused by too much excess biomass that should be used to produce biofuels.

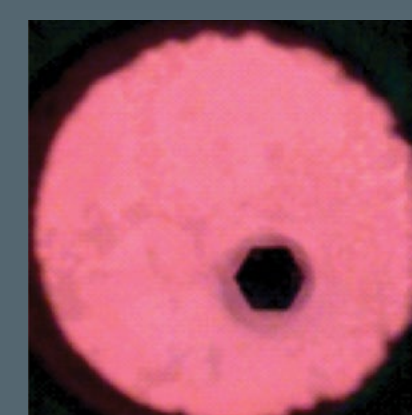
TOP RIGHT: Laboratory Experiments to produce liquid bio-fuels from solid biomass.

TOP BELOW: Flaming Combustion Mode - less efficient and more polluting.

BOTTOM BELOW: Flameless Combustion Mode - more efficient and less polluting.

> Our success in reducing energy consumption in manufacturing plants has led to a request for improving energy efficiency of water and wastewater treatment plants.





Water systems and treatment facilities can account for about 1/3 of a municipality's energy expenditures

IMPROVED WATER TREATMENT EFFICIENCY

Atreya's focus on energy efficiency has led to the expansion of a program he launched several years ago, funded through the U.S. Department of Energy, to help manufacturers reduce their energy costs and shrink their carbon footprint.

Atreya is now offering the program to municipalities to improve the energy efficiency of water and wastewater treatment plants. Water systems and treatment facilities can account for about one-third of a municipality's energy expenditures. The aging infrastructure not uncommonly found in many towns and cities today only raises those costs.

"Our success in reducing energy consumption in manufacturing plants has led to a request for improving energy efficiency of water and wastewater treatment plants," said Atreya.

Harnessing Vibrational Energy
for Improved Heat Management

Our findings show that the electron-phonon coupling remains strong, so that graphene alloyed with boron nitride can succeed as a pV material. Indeed, theoretically, it can double the thermoelectric efficiency.

The heat produced by today's electronics has proved a limiting factor in reducing the size and power of commonly used devices, including computers, mobile phones and power amplifiers. Solid-state thermoelectric generators (TEGs) that generate power from heat, can help manage and recover excess heat from a system in order to improve efficiency, but TEGs themselves are inefficient, and their benefit declines precipitously in microscale and nanoscale devices.

"Heat has a lot of entropy and it isn't a particularly good source of energy, so TEGs tend to work best in situations where reliability is more important than efficiency, such as generating power in hostile environments," said **Corey Melnick**, a graduate student working in the laboratory of ME Professor **Massoud Kaviany**. Kaviany's lab explores heat transfer physics and efficient, innovative energy transport and conversion through atomic tailoring of energy carriers.

In work recently published in early 2016 in the journal *Physical Review B*, Melnick and Kaviany took a step back, so to speak, to intervene before heat gains entropy in order to improve system efficiency.

Working with phonons, or vibrational energy that acts as a precursor to heat, the two developed the concept of a phonovoltaic (pV) cell. Much like a photovoltaic (PV) cell converts light into energy, a pV would overcome energy barriers within a material, i.e. the band gap, by absorbing phonons to produce energy.

"Since heat is all sorts of vibrations, moving at many different frequencies, targeting phonons can be simpler since a specific phonon oscillates at a specific frequency," said Melnick.

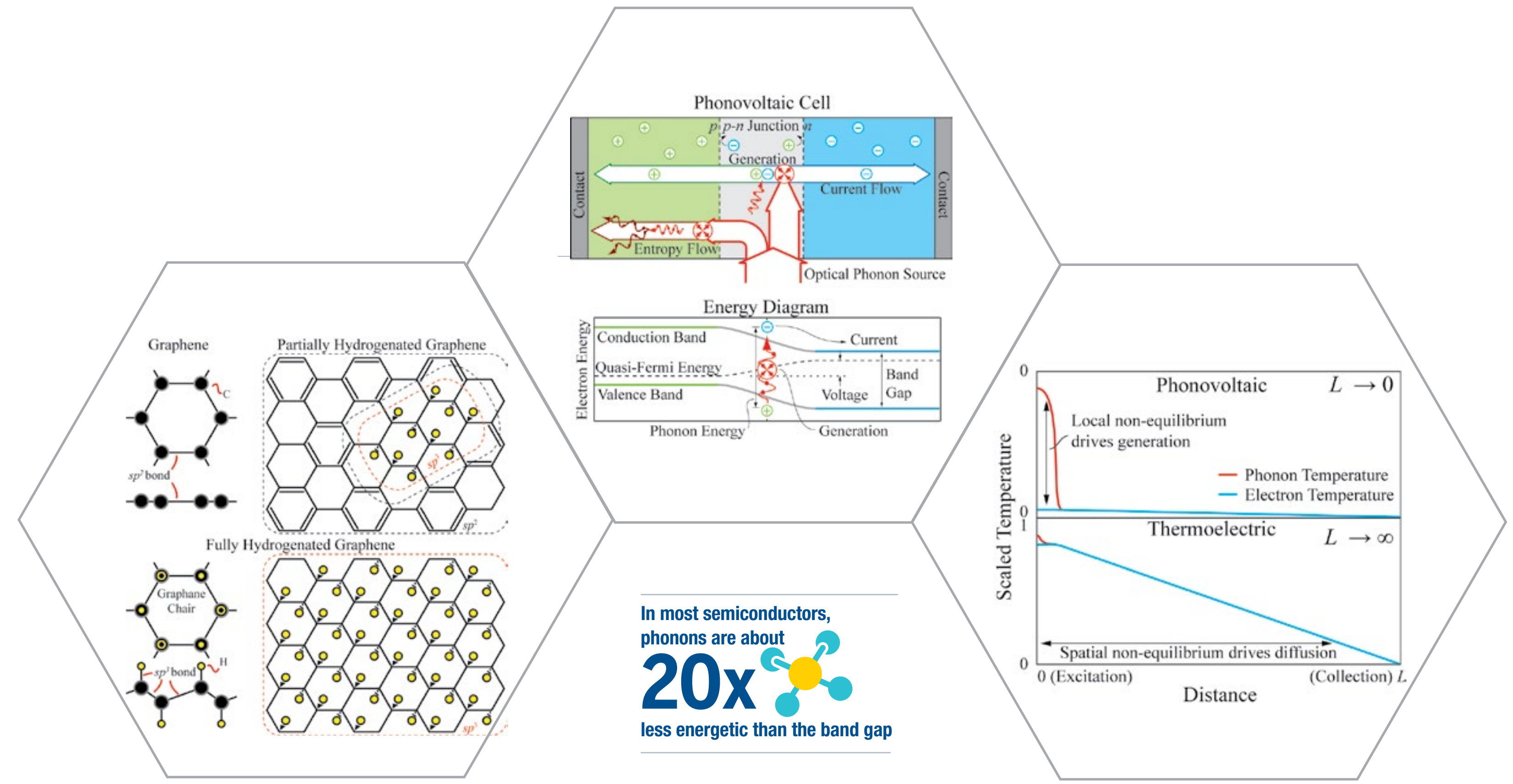
Melnick and Kaviany developed an analytical model and numerical value of a theoretically efficient pV cell, then tested their model using Monte Carlo and hydrodynamic simulations.

Theoretically Kaviany and Melnick found that a pV offers significant improvements over thermoelectric efficiency if three conditions are met: the material has a phonon more energetic than its band gap; the phonon is more energetic than the thermal energy of the device; and the phonon is strongly coupled with the atom's electron. They also identified several pV cell design factors that would influence pV cell operation.

But finding a material that meets the conditions has been difficult since no existing material has phonons energetic enough to surpass its band gap.

"In most semiconductors, the phonons are about 20 times less energetic than the band gap," Melnick said.

He and Kaviany focused on materials with the most energetic phonons, with small band gaps or with band gaps that could be tuned, including graphene, which has relatively energetic phonons and no band gap.



TOP LEFT: The graphene structure and its hydrogenated variants: partially hydrogenated graphame and fully hydrogenated graphane. Hydrogen atoms open a band gap by disrupting the bonds between carbon atoms.

TOP CENTER: Illustration of the phonovoltaic cell, the flow of energy and entropy within it, and an energy diagram depicting its central processes. The phonovoltaic harvests optical phonons like a photovoltaic harvests photons.

TOP RIGHT: A comparison between the non-equilibrium, length (L), and behavior within the phonovoltaic and thermoelectric cells. The phonovoltaic cell must have a length less than a few hundred nanometers, or it behaves much like a thermoelectric does.

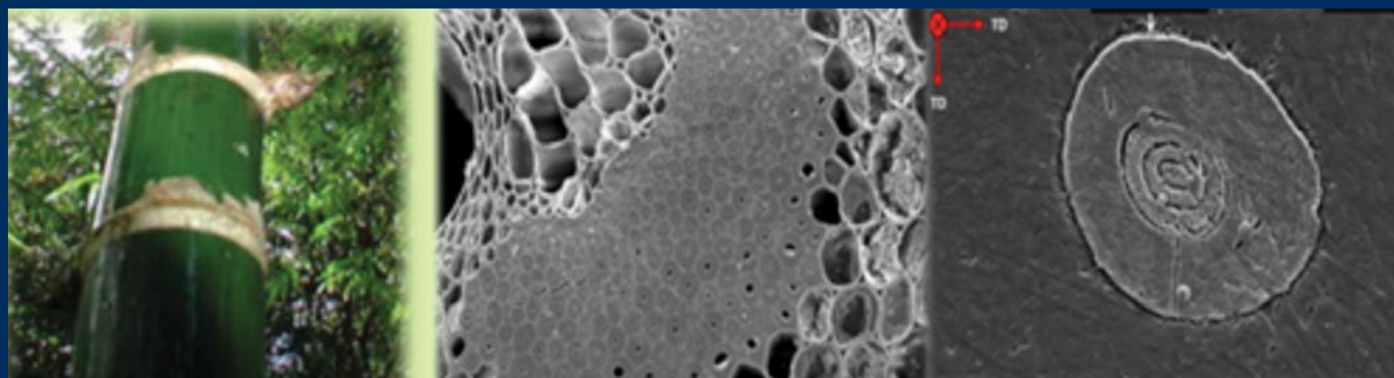
For years, scientists have tried to open a band gap in graphene using a variety of approaches, but no one had yet tried to open a small band gap close to the phonon energy, or to tune the gap precisely.

Kaviany and Melnick used density functional theory and quantum mechanical simulation of materials to test their concept theoretically. In a second paper, also published in *Physical Review B*, the two investigators showed that by adding hydrogen, they could in fact open a band gap close to the optimal phonon energy.

In more recent work, the two investigators have identified a pV material that meets all three requirements. The material is again based on graphene, but with a dilute concentration of boron and nitrogen substituted for carbon atoms. These atoms disrupt the symmetry of graphene and, as a result, open a band gap.

"Our findings show that the electron-phonon coupling remains strong, so that graphene alloyed with boron nitride can succeed as a pV material," said Melnick. "Indeed, theoretically, it can double the thermoelectric efficiency."

Collaborators include Professor **Ctirad Uher** of the U-M Physics department, an expert in graphite materials, and Professor **Jamie Phillips** of Electrical Engineering and Computer Science. The work was funded through the National Science Foundation, with computing resources through the U.S. Department of Energy Research Scientific Computing Center.



Novel Lightweight Materials
Spin New Ventures and Green Manufacturing

Lightweight composite materials in transportation reduce vehicle weight, which can have a large impact on improving fuel efficiency and reducing CO_2 emissions. "The ecological impact of lightweight innovations is one of the key steps in green technologies, and sustainable manufacturing to transform these materials into components and assemble them in a final product are sorely needed," said **Miki Banu**, ME research associate professor.

Banu's research focuses primarily on lightweight materials, with emphasis on developing micro- and nano-cellulose composites, natural fiber composites and associated manufacturing processes for automotive and aerospace applications. Spanning the macro-scale to the nano-scale, her research aims to synthesize new materials with enhanced mechanical properties and high formability. Her research activities include experimental work, multi-scale modeling of materials and simulation of forming processes.

HARVESTING THE BENEFITS OF BAMBOO

"The ability to use tried and true metal forming processes such as stamping on new composite materials, especially green composites, has the potential to speed the adoption of lightweight materials in automotive and other applications," said Banu.

Banu makes this observation from her extensive research experience and achievements in the area of metal forming of lightweight materials and the development of new lightweight composite materials. Banu joined the U-M ME department in 2013. "Coming to U-M is enabling me to combine my knowledge in materials science and manufacturing and take it toward sustainable and green manufacturing," she said.

At U-M, Banu joined forces with ME Professor **S. Jack Hu** and in 2013 created a remarkable patented composite material made from structural bamboo fibers and a polymer matrix.

"Bamboo is one of the strongest natural materials, but it was also interesting to us because it's environmentally friendly—it absorbs a lot of carbon dioxide from the environment—and it grows fast," Banu said.

The new material contains natural bamboo fibers—a green and ecologically beneficial component—and it is 40 percent lighter than glass fiber composites. It's also stronger in flexural strength than carbon fiber composites, and it is cheaper.

Banu won a Michigan Translational Research and Commercialization (MTRAC) award with Hu as co-principal investigator for translating this technology for commercialization. In 2014, they co-founded Optimal Materials in Plymouth, Mich., where Banu serves as the company's chief technology officer in residence.

"The skills, the language and the entire experience of scaling up our technology and presenting it to prospective customers are thrilling, and it's an amazing opportunity to see see these new materials in automotive components as well as in use in other sectors," said Banu, who also is working with a major auto manufacturer to create prototype components using the new composite.

Banu's passion for new materials has inspired others. She organizes the Biocomposites session for the American Society for Composites Conferences, and other events, which helped spark connections across campus, too. A team of like-minded entrepreneurs from the Taubman College of Architecture engaged Banu in the creation of unique sports equipment for professional athletes. They started by creating a team of ME and Materials Science and Engineering students—some in their senior capstone design class – who used the new material to build a lightweight hockey sledge.

FAR LEFT: Bamboo fibers as reinforcement for polymeric composites.

TOP RIGHT: Postdoctoral Fellow Kaifeng Wang (left) and Summer Undergraduate Research in Engineering student Steven Gordon (right) analyze the quality of a formed bamboo composite sheet. This part will be used for manufacturing a lighter sledge hockey sled.

MIDDLE RIGHT: Drs. S. Jack Hu and Miki Banu analyzing bamboo strips which will be used for fiber extraction.

BOTTOM: Scanning Electron Microscopy showing the LDPE-BFsMA interface (BF – bamboo fibers, LDPE – Low Density Polyethylene, MA – Maleic Anhydride) (Right) Molecular configuration of interfacial chemical reactions between the BFsMA and LDPE matrix in the case of LDPE-BFsMA composite sheets.

In 2013 a remarkable patented composite material made from structural bamboo fibers and a polymer matrix was created.

> Bamboo is one of the strongest natural materials—it absorbs a lot of carbon dioxide from the environment—and it grows fast.

MODELING MANUFACURING PROCESSES FOR NEXT-GENERATION TRANSPORTATION SYSTEMS

Banu has developed finite element models to optimize forming technologies of lightweight metals and composites to make them cost effective. Her research group focuses on development of models to predict the behavior of aluminum during forming to optimize the process and achieve higher accuracy in the resulting formed components. She explores the most advanced metal forming processes for low volume production. Application areas include aerospace and prototyping, such as by incremental forming, a new and unconventional manufacturing method that does not require dies. Flexible and low cost compared to conventional processes, this approach allows fast fabrication of complex configurations.

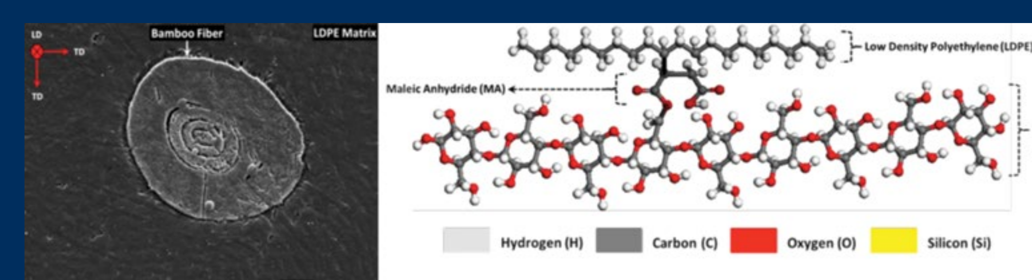
Almost immediately upon arriving at U-M, Banu began work with ME Professor **Alan Taub** on a competitive proposal to establish a large research consortium focused on lightweight materials. The proposal subsequently was selected by the Department of Defense as part of the National Network for Manufacturing Innovation.

Today, Banu serves as technology portfolio manager of the resulting $148 million American Lightweight Materials Manufacturing Innovation Institute (subsequently renamed LIFT), based in Detroit, sponsored by Office of Naval Research. Banu's role dovetails with her research, including her work on incremental forming.

Her work was recognized by Boeing, which now sponsors a $2.8 million LIFT project in incremental forming, with Banu serving as principal investigator for the U-M team. Her work will focus on incremental forming for complex advanced aluminum shapes.

"Modeling is a cost effective tool to optimize an early stage process to become available at industrial scale," she said. "Incremental forming is a very flexible process, and it's reconfigurable. We can change the profile of each component, which is important in sectors such as aerospace that need to produce smaller numbers of components for equipment—say a military aircraft—that has a long life."

Within the GM-UM Collaborative Research Laboratories - Advanced Vehicle Manufacturing, Banu creates models and designs new methods for joining lightweight materials. A first application is ultrasonic welding of lithiumi-ion battery tabs, as published in the *Journal of Manufacturing Science and Engineering*.



> How do we understand systems and devise strategies and tools for making them do what we need them to do? That's our foundation and, from there, our lab's passions, interests and skills take us in many interesting directions.

Cooperation and Control: A Systems Perspective

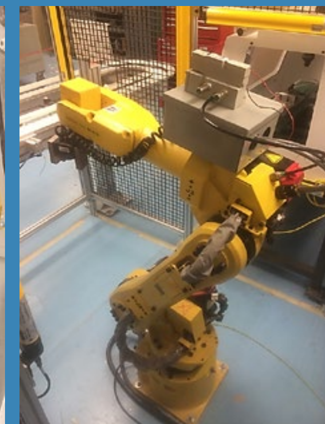
Improving the functionality of robotic and manufacturing systems "comes down to understanding your system and identifying a strategy for improving performance," says ME Assistant Professor **Kira Barton**, whose laboratory combines fundamental and experimental modeling and controls research, from multi-agent coordination to additive manufacturing. Often, those improvement strategies involve cooperation.

ENHANCING COOPERATION UNDERSEA

Barton's group looks at how to enable and enhance cooperative behavior between and among systems in a range of environments. In a project with the Brookfield Zoo in Chicago, she is collaborating with U-M ME assistant research scientists **Alex Shorter** and **Lauro Ojeda**, and **Matthew Johnson-Roberson**, assistant professor in the Naval Architecture and Marine Engineering department, to investigate interactions between dolphins and autonomous underwater vehicles.

"Autonomous systems are controllable and yet they're operating in the same environments as biological systems, which are not. What we aim to learn is how we can achieve the objective of the autonomous system—in our project, the task is to map real-time environmental conditions—while minimizing disturbances to the biological system," Barton explained.

The environmental data collected will provide contextual information to supplement on-animal measurements taken by bio-logging tags, while the two systems simultaneously meet a cooperative agent objective.



The objective is to better understand the animals' interactions with the autonomous systems and the potential effects. For example, how does the presence of the autonomous systems change the dolphins' behavior? What impact might they have on the dolphins' energy use? How can the autonomous systems "learn" and adapt their behavior through more effective control strategies?

Investigators will use video to validate the localization and sensor data and algorithms in the controlled environment at the zoo before conducting similar future experiments in the wild.

"Gathering this type of information about the animals should help answer some important biological questions," Barton said.

TOP LEFT: The confluence of virtual design environments, agent-based reasoning and learning and high-performance computing is revolutionizing system-level manufacturing. Experimental demonstrations of this research are conducted on the System-level Manufacturing Automation and Research Testbed (SMART) at the University of Michigan.

TOP RIGHT: New efforts in cyber-manufacturing, inspired by the software defined network community, are aimed at enabling more secure and efficient system-level manufacturing.

BOTTOM RIGHT: Controllable agents (autonomous boats) and uncontrollable biological agents (bottlenose dolphins) often coexist within the same environment. The aim of this research is to control interactions between these agents in order to minimize disruptions to the biological systems.

The project has created over 35 new opportunities for students

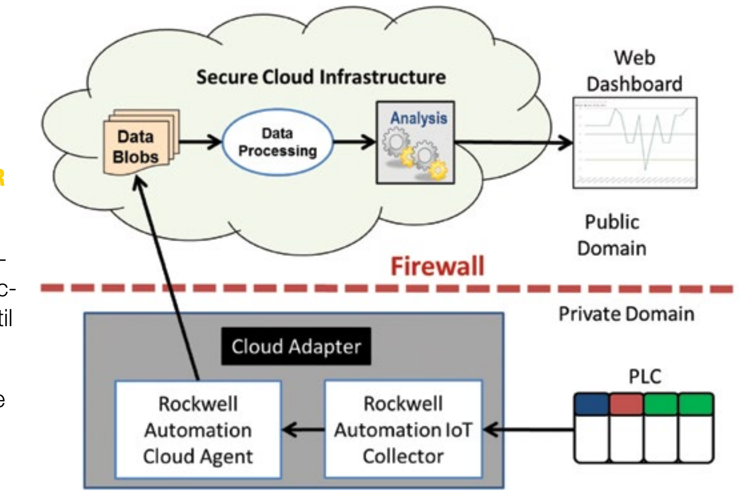
COOPERATION AND CONTROL ON THE FACTORY FLOOR

In the manufacturing environment, systems-level modeling and control of cooperative behaviors can help enterprises detect malfunctions during a process, localize problems, isolate the malfunctioning machine, i.e. robot, and potentially reroute production until the issue can be resolved.

"Cooperation among agents in a manufacturing system can save companies significant amounts of money in terms of preventing lost productivity when you don't have to shut down the entire line," Barton said.

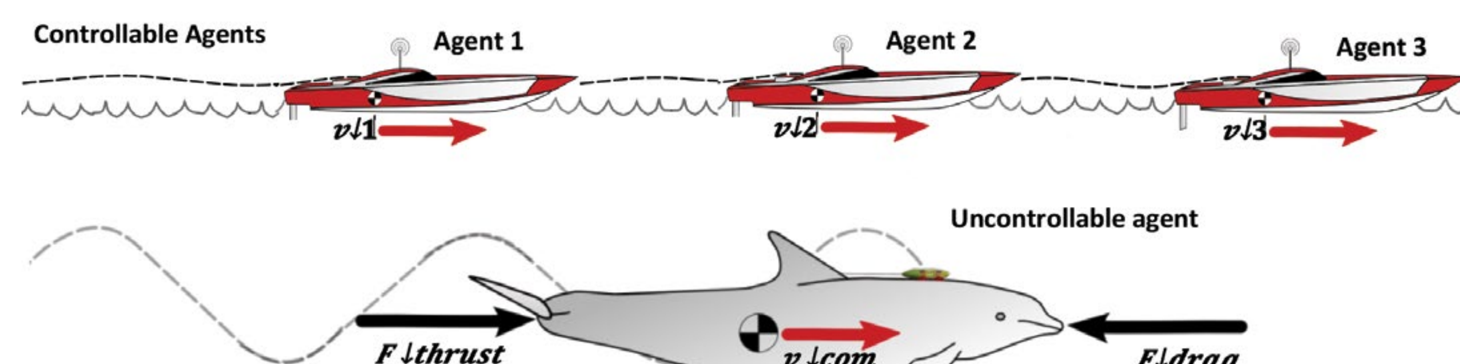
The research, a collaboration with ME Professor **Dawn Tilbury** and Computer Science and Engineering Professor **Morley Mao**, is being conducted on a System-level Manufacturing and Automation Research Testbed (SMART). First built within the U-M Engineering Research Center for Reconfigurable Manufacturing Systems in the early 2000s, the testbed has recently been upgraded in partnership with Rockwell Automation and equipped with the latest manufacturing and control system technologies.

"Our testbed is unusual in terms of its capacity," Barton said, "and we leverage it a tremendous amount. We don't only run simulations; we can validate our work experimentally on a real manufacturing setup, with robots, milling machines, conveyors, state-of-the-art safety and connection to the cloud."



The project already has created new opportunities for more than a dozen undergraduate and graduate students in the U-M Multidisciplinary Design Program. Students work in teams on both fundamental and experimental problems, including modeling, simulation, controls, sensor design, integration, and analytics in the Cloud.

The diverse projects in Barton's lab share a common thread. "It all comes back to control," she said. "How do we understand systems and devise strategies and tools for making them do what we need them to do? That's our foundation and, from there, our lab's passions, interests and skills take us in many interesting directions."



WALKING TO LEARN

Cooperation between systems and the way in which each system learns and adapts to the other is the focus of a third collaborative project. In addition to Barton's group, investigators from the ME department include Ojeda as well as Professor **Albert Shih** and Research Professor **James Ashton Miller**. Outside the ME department, collaborators include Professor **Thomas Armstrong** of Industrial and Operations Engineering; Professor **Toni Antonucci** of Psychology; **Deanna Gates**, of Kinesiology; and **Emily Mower Provost**, of Computer Science and Engineering.

The multidisciplinary team is designing a customized human assistive device, a 3D-printed ankle-foot orthosis, ultimately capable of learning and adapting to its user. If users are fatigued, the device could augment their efforts; if users are improving, for example healing from an injury, the device could provide less support.

The key to device control will be an adaptive, learning-based controller developed by Barton's laboratory that incorporates models of both device and human behavior, including human intent.

"Developing the models and building a control framework for human intention during walking can smooth transitions between movements and make the interactions between human and device much more symbiotic," Barton said.

Predicting the Unpredictable:
Modeling, Optimization and Control to Improve Health and Safety

> The hardest part of figuring out how to control a system is understanding how to grapple with the uncertainty of human beings; in a sense, we are the wildcard.

To ensure that the systems that they design operate as intended, engineers construct controllers which ensure the largest possible set of configurations of a system behave as intended. This is no easy task, and its complexity is compounded when trying to devise models for systems that include humans, since they are constantly interacting with a changing environment in difficult to predict ways.

"The hardest part of figuring out how to control a system is understanding how to grapple with the uncertainty of human beings; in a sense, we are the wildcard," said ME Assistant Professor **Ram Vasudevan**, who directs the Robotics and Optimization for the Analysis of Human Motion (ROAHM) Laboratory.

UNDERSTANDING HUMAN INTERACTIONS WITH THE ENVIRONMENT FOR FALL PREVENTION

A primary application of Vasudevan's work has been to improve individual stability to prevent falls, a leading cause of accidental injury and death. Particularly among the elderly, a fall and its resulting injuries can have a tremendous impact on one's independence and quality of life.

Currently doctors and physical therapists use only heuristic measures to gauge an individual's risk of falling. In contrast to diabetes or heart disease, explained Vasudevan, there exists no automated tool to aid healthcare providers in definitively predicting a risk of falls.

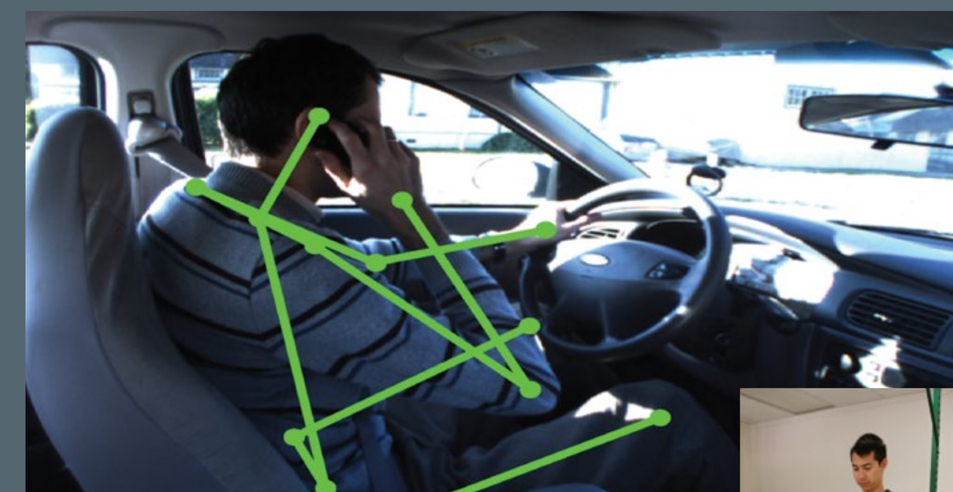
The BOS corresponds to the set of states that ultimately result in standing for a single strategy. The BOS indicates the amount of perturbation, such as stepping on ice or colliding with an object, that a person can withstand.

For any given motion, a larger BOS corresponds to a lower probability of falling. In the instance of standing up, the BOS would correspond to all states of the individual that are able to get upright despite disturbance. Since standing is critical to many activities of daily living, detecting a reduction of the BOS for standing can identify individuals who are at higher risk of falling.

Moreover, if a portion of the BOS is lost, with age or injury, the set of states that have left the BOS could correspond to specific biomechanical deficiencies. Monitoring the shape of a patient's BOS over time could help therapists design personalized rehabilitation programs to maximize stability

Vasudevan uses motion capture data from an entire sit-to-stand motion to calculate a BOS for each individual. His approach is the first to enable automation of personalized stability analysis, and provides detailed information about when and how a person's stability changes while standing up.

Similar strategies also can be employed to construct controllers that improve the stability of legged robotic systems despite terrain that is difficult to model. The ROAHM Lab is currently conducting research on legged robotic systems in collaboration with Assistant Professor **C. David Remy** with support from the National Science Foundation.



HUMAN-MACHINE INTERACTIONS IN AUTONOMOUS VEHICLES

Autonomous vehicles hold the promise of improving vehicle safety by reducing accidents that arise from driver error. While autonomous vehicles can perform well in known conditions, they are unable to deal with uncertainty, such as other vehicles, pedestrians or imperfect knowledge of environmental conditions.

To address this, Vasudevan's research group is taking a three-pronged approach: building models of intent, exploring techniques to develop automated interventions despite uncertainty, and devising automated techniques to validate these new systems.

To construct these models, Vasudevan is working in collaboration with the U-M's Transportation Research Institute, to leverage over 30 million miles' worth of driving data collected through the Ann Arbor Connected Vehicle Test Environment.

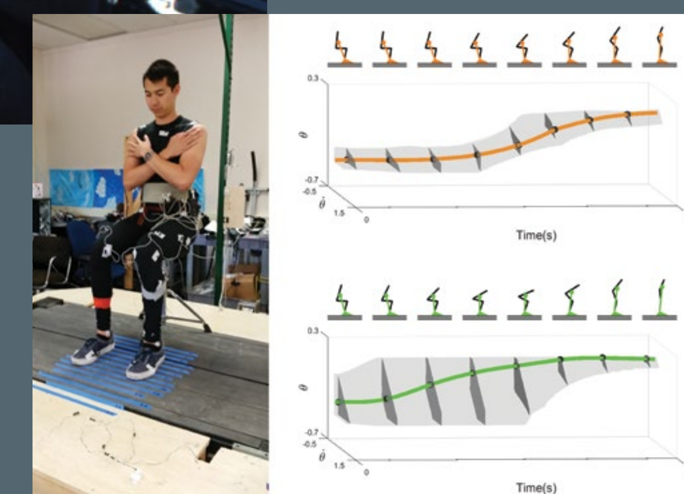
"That data is a treasure trove," said Vasudevan. "It's an order of magnitude larger than data collected in other major autonomous vehicle research efforts, and—this is one positive aspect of Michigan winters—collected in more inclement, and therefore uncertain, conditions."

In addition, Vasudevan is leading the academic side of Ford's autonomous vehicle effort. He is leveraging these constructed models of human behavior to devise optimization methods that can, in real-time, safely control an autonomous vehicle. In addition to providing financial support for several students, this collaboration includes direct control by Vasudevan of several autonomous vehicles that are housed at U-M.

Falls are the leading cause of unintentional injury death amongst the elderly and their associated direct medical costs are more than

$34 billion

annually



"Autonomous systems have the potential to drastically improve the lives of humans," said Vasudevan. "However, their success will depend entirely upon devising algorithms that understand human behavior and motion."

FAR LEFT: Vasudevan's team will validate the performance of their algorithms to safely control autonomous vehicles on the pictured Ford Fusions which are on loan to his lab.

TOP LEFT: To estimate a driver's intent, Vasudevan's team builds models of driver behavior, often in response to distraction or uncertain conditions.

RIGHT: Vasudevan's approach uses motion capture data of a participant (left) to determine the stability of a movement strategy. Two different strategies (right, orange and green) differ in the size and shape of their BOS (gray). The BOS of the green strategy is larger, indicating that this strategy is more stable.

Filling a Gap in Engineering Education

Insitu | Center for Socially Engaged Design

An important marker of Insitu's success will be U-M graduates who possess a heightened awareness of and the skills to integrate economic, environmental, social and cultural factors into their design decisions.

INSITU

The work of engineers impacts just about every aspect of society, from clean energy and healthcare to economic development and transportation. But as engineers solve problems globally, they often find themselves disconnected from the ultimate end user of their designs and the context in which the solution resides.

Without a broad and deep understanding of the real and context-specific needs of stakeholders, engineers' solutions may not in fact fully solve the problem or deliver desired outcomes. Ultimately, solutions may fail to be adopted. In some cases, the end result might even prove detrimental to users or to the environment.

"In engineering, context truly is critcal to the success and sustainability of technology," said ME Assistant Professor **Shanna Daly**. Together with ME Associate Professor **Kathleen Sienko** and Professor **Steve Skerlos**, Daly co-founded and co-directs the new U-M Center for Socially Engaged Design, or Insitu.

Gaining this key contextual understanding lies at the heart of what Daly, Sienko, and Skerlos refer to as socially engaged design. And it demands engineers with strong skills in key areas, including communication, creativity, and the ability to collaborate across diverse cultures and disciplines.

"These are must-have skills for engineering students today if they are going to contribute to society in meaningful, effective and lasting ways," said Sienko. "Currently, however, most engineering curricula don't provide enough opportunities to develop these skills inside or outside of the classroom."

With its vision to serve as a leader in education and research to advance socially engaged engineering design, Insitu aims to fill that gap. Four complementary initiatives build upon existing strengths, programs, organizations and expertise within the ME department as well as the College of Engineering and the University.

EFFECTIVE, HANDS-ON SKILLS TRAINING

The Socially Engaged Design Academy (SEDA) learning platform enables students and others to engage in self-directed online and in-person coaching. Learning blocks cover a broad range of topics, including front-end design, design ethnography, community engagement, teamwork and management, concept generation, prototype use and sustainability evaluation.

SEDA is available to all U-M students, faculty and staff and is anticipated to be heavily used in design-related courses and by students participating in co-curricular activities, such as BLUELab and M-HEAL. In the future, students may be eligible to earn academic credit for completing a series of learning blocks.

GAINING PROFESSIONAL EXPERIENCE

In 2015 and 2016, Insitu supported 14 paid summer interns in partnership with the U-M Global Health Design Initiative. Interns were assigned to design teams working on projects within maternal health, water access and family planning contexts. Interns spent seven weeks in Ann Arbor and eight weeks at a field site in Ghana, Ethiopia or Kenya. They were trained using the SEDA and received iterative feedback on their work through the Insitu consultation service.

Going forward, Insitu will continue to support partnerships with industry, government agencies and nongovernmental organizations to give students broader opportunities for real-world, professional-level design experience in humanitarian technology design.

SHARING KNOW-HOW

With a team of about 20 experts from diverse disciplines who serve as design consultants, Insitu also offers expertise in many aspects of socially engaged design to support student and faculty research and design projects. Launched in early 2015, the consulting program has been extremely successful, with over 2,000 consultations to assist students and faculty with specific design challenges encountered in their projects.

Since 2015, the consulting program has been extremely successful, with **2,000** consultations

INSPIRING LEARNING

Insitu grew out of educational programs created by the co-founders, including the Global Health Design Initiative and the Program in Sustainable Engineering. Specialized Study Programs in Global Health Design and Socially Engaged Design were launched this year for undergraduate students. Tracks focused in Global Health and Sustainable Technology Design for Master's of Design Science students are launching in fall 2016. The leadership team envisions similar tracks reaching other master's and doctoral programs and professional and executive education programs in the future.

ADVANCING RESEARCH

Building on the co-founders' strong research programs, Insitu will continue to advance research related to the design process, outcomes and pedagogical models for most effectively teaching students. Research focal areas span front-end design processes and design team dynamics to engineering specification development and concept generation.

INFUSING SOCIALLY ENGAGED DESIGN CAMPUS-WIDE

Seed funding for Insitu was provided by the College of Engineering and the U-M Transforming Learning for a Third Century initiative. The Center's goal is to transform socially engaged design education within the Mechanical Engineering department and throughout the College and University.

"An important marker of Insitu's success," said Skerlos, "will be U-M graduates who possess a heightened awareness of and the skills to integrate economic, environmental, social and cultural factors into their design decisions."

TOP: A BLUElab student collaborates with a local a stove-builder in Gujarat, India on a prototype of an efficient cookstove.

BOTTOM LEFT: A Global Health Design Initiative student interviews midwives at Komfo Anokye Teaching Hospital in Kumasi, Ghana.

BOTTOM RIGHT: Student notes from the Socially Engaged Design Academy module on Sustainability.

ME Project-Based Design/Manufacturing Class Series Thrives

> The training allows ME students to utilize our state-of-the-art facilities including a manufacturing, mechatronics and assembly area.

The ME department's undergraduate curriculum has a unique team-based, Design-Build-Test spine of required classes. In Design and Manufacturing I, II and III (ME250, 350 and 450 respectively), sophomores, juniors and seniors turn concepts into real, working engineered systems and manufacturable products.

In ME250, lecture material and hands-on experience introduce students to systems and design thinking as well as cascading objectives and requirements, a routine part of professional engineering projects in industry. The process is an in-depth one that according to ME Instructional Lab Manager **Toby Donajkowski**, requires all the students involved to go through a series of vigorous training modules.

"The modules are structured as to build a solid foundation in manufacturing and electronics. Once completed, the training allows ME students to utilize our state-of-the-art facilities including a manufacturing, mechatronics and assembly area," said Donajkowski. "To pull this off there is an incredible amount of teamwork taking place throughout the ME faculty and support staff. Highly skilled technicians work directly with the students on a day-to-day basis throughout the semester. Behind the scenes are administrators, accountants, IT techs and a host of others who all play intricate rolls in providing our students with the best service and experience possible."

The 2015–2016 academic year saw some new additions to ME250. Assistant Professor **Jesse Austin-Breneman** joined **Mike Umbriac**, ME lecturer and instructor in teaching the course.

"Austin-Breneman brings a lot of energy to the class, with innovative ideas for how to engage students during the lecture," said Umbriac. "He also promotes the value of prototyping at several stages of the design process."

Michigan Ninja Relay, a new ME250 project for the 2015–2016 academic year, was also introduced. This project, developed by Professor **Kazu Saitou**, Umbriac, and GSI **Jean Chu**, allows teams of four to five students to design, build and test a remote-controlled machine to move plastic cubes through a section of an obstacle course. Each squad of four teams cooperates to try to score the most points by moving the most cubes.

In ME350, the emphasis is on modeling-based system design. Projects change frequently to add new challenges and stress new topics. This academic year, ME Assistant Professor **Chinedum Okwudire** and Umbriac introduced a "Guessers vs. Geeks" activity into the ME350 lectures. At the start of this activity, students decide whether to be a Guesser or Geek. The Guessers guess the answer to a mechanical problem related to the lecture material. Problems include things like "how much force does it take to break a #6-32 bolt?" or "how much torque does it take to stall this small motor?" Then, the Geeks calculate the answer to the same problem using methods taught in class. This is followed by an in-class demonstration to see which group got closer to the real answer.

"The goal of this activity is to engage the students, and help them to better appreciate the failure analysis topics from lecture that are not also covered in the project," said Umbriac.

The final course of the series, ME450, affords an opportunity for students to employ design processes to find solutions to real-world design challenges as part of a capstone design experience.

"Students collaborating in teams work with end-users and stakeholders to elicit user needs and generate requirements," said ME Lecturer and ME450 Coordinator **Amy Hortop**. "They're able to develop and analyze concepts and validate their prototypes at a Design Expo held each April."

Each semester, various projects are proposed from industry and the U-M research community so that each team is working on a unique project.

"Thanks to our sponsors, we are very fortunate that we're able to offer a variety of projects every semester so that all students are working on a project that they are personally excited about," said Hortop.

According to Hortop, students are always interested in working on projects that will make an impact on the community.

"We currently have a team working with White Lotus Farms in Ann Arbor to find ways of using waste heat to warm a hoop house, allowing for longer, local growing seasons," said Hortop. "Teams working with the VA Hospital in Ann Arbor and Kids in Danger, for example, are learning how important it is to engage in human-centered design. And students are getting a taste of 'real-world' industry challenges through projects with Toyota, Ultra-Electronics, Packsize and many others," she added.

ME450 is always looking for capstone projects. To learn more about the program or if you have a project that you would like students to work on, please contact Amy Hortop at abhortop@umich.edu or visit **me450.engin.umich.edu**.

MEUS Continues to Grow

The third annual ME Undergraduate Symposium (MEUS) was held this past April and it continues to gain momentum. The event provides a venue for ME's undergraduate students to showcase their projects for RISE (Research, Innovation, Service and Entrepreneurship) as well as their Design and Manufacturing X50 Courses.

Since its inception in 2015, feedback from students has helped to shape the event to include workshops, and an interest in RISE has increased each semester. MEUS now also includes a best poster, best paper and best session award.

The next MEUS is scheduled for December 8th, 2016. To read more about MEUS visit **meus.engin.umich.edu**. For more information on RISE, visit **me.engin.umich.edu/academics/rise.**

ME's Inaugural Career Week Helps Students to Navigate the Road to Success

U-M ME launched its inaugural Career Week this past Spring. The event, which took place March 14–18, served as a means to aid students in early career exploration in both industry and academic paths within the field of mechanical engineering.

With over 45 student participants, there was something for both undergraduate and graduate students including on-site industry representatives spanning automotive and energy to manufacturing, networking receptions with alumni, resume building workshops, and faculty office hours for career mentoring.

The U-M Solar Car Team Had a Shining Season, Taking First Place in the 2016 American Solar Challenge and Fourth Place in the 2015 World Solar Challenge

The U-M Solar Car Team had a shining season, taking first place in the 2016 American Solar Challenge and fourth place in the 2015 World Solar Challenge.

The eight-day, 1,975-mile race began in Brecksville, Ohio, and finished in Hot Springs, South Dakota, passing through many national historic sites to celebrate the 100th anniversary of the U.S. National Park Service.

To prepare *Aurum*, U-M Solar Car's 13th vehicle, for the race, the team made a number of modifications to improve competitiveness and also to meet American Solar Challenge regulations. Regulations for the American race differ from those for the World Solar Challenge, in which Aurum competed in October 2015.

The team's changes included improving internal air flow control to decrease drag and stiffening suspension components to enhance dynamic performance. To meet regulations, the team also decreased the area of the solar array and added an external crush zone to the side of the car. The changes enabled U-M Solar Car to compete in the American competition, but the team was penalized six minutes per day; the added crush zone pushed the car over regulation width.

The penalty wasn't the only challenge. Sun was scarce the final two days of the race. The U-M team was the only team to finish the race entirely on solar power. And a less experienced team, comprised predominantly of rising sophomores and juniors meant "our young race crew has had to overcome some knowledge gaps and learn many essential skills on the fly," said **Clayton Dailey** '18, team engineering director. "They were excited and anxious to compete, and they really proved themselves during this race."

At the World Solar Challenge, a five-day, 1,800-mile competition across the Outback from the north to the south coast of Australia last October, *Aurum* qualified for a second place starting position with the team's best qualifying lap time ever.

Once the race began, the team quickly took first place—and held it for the entire day, a first in U-M Solar Car's 25-year history. But cloudy skies resulted in less charging than anticipated, and mechanical issues required repairs, which ate up the team's lead. With an average speed of 55.5 mph., Michigan finished the race in fourth-place—just four minutes behind the third-place team and 54 minutes behind the winner, Nuon Solar from Delft, Netherlands.

"This was Michigan's closest place time-wise to first place in the World Solar Challenge, and we hope to take this momentum into the 2017 race," Dailey said.

With a younger crew this year, alumni support was especially crucial to the team's success. "Team alumni helped immensely by passing down information they learned during their project cycles," said Dailey. "The alumni design reviews we held provided crucial feedback and advice and helped guide the next generation Michigan solar car."

This year, the team will design a new car to compete in the 2017 World Solar Challenge. Dailey says an important focus will be on design validation and analysis of parts. "Every component will be thoroughly and rigorously tested before it sees the road to save major time debugging problems. Most importantly this will give us more time to tune and model the car for the race across the Outback."

The team plans to build upon its many relationships with University faculty and researchers. "We want to integrate some of the amazing work being done here on campus, for example related to battery chemistries and cutting-edge solar cell technologies," Dailey said. "The 2017 regulations constitute a large departure from those of 2015 and earlier years, and they open doors to a number of exciting possibilities."

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

Formula for Success:
MRacing Team Celebrates 30 Years' Strong

As it sped across the finish line of Germany's famous Hockenheimring, MRacing's Formula race car MR-16 was first among all American teams at Formula Student Germany. Overall, the U-M team finished 20th in the competition.

When it was unveiled in March, MR-16 boasted an innovative change from a steel chassis to a hybrid monocoque, with a carbon chassis in the front and a steel rear frame.

"The change afforded the team an opportunity to reduce overall vehicle mass for years to come, to increase design flexibility and improve the team's hands-on experience designing and manufacturing a large structural carbon fiber component," said **Keenan Temin** '17, MRacing captain.

At its first competition in May at Michigan International Speedway (MIS), the team struggled to make the car quiet enough to pass rules. "We were able to compete in all events but with significantly reduced power, causing us to not place as well as we knew we could," Temin said.

The disappointment was motivating. The team spent the summer working long hours to prepare the car for the Hockenheimring in August. Members also reaffirmed a valuable lesson: "Test, test and test some more," said Temin. "Testing is the most important aspect of competition, and we're focused on giving ourselves more time to test for the upcoming season."

The upcoming season will be the team's 31st. In addition to celebrating its 30th anniversary this year, it also celebrated 10 years with BorgWarner as its title sponsor.

To celebrate, the team rewrapped a previous vehicle, MR-13, in BorgWarner livery, and it is now on display in the company's lobby in Auburn Hills. As part of Bring Your Child to Work Day in April, employees' children had the opportunity to sit in the car and take a photograph with their parent. "We recruited some future Wolverine racers that day," Temin joked.

Other events included hosting an MRacing booth at the North American International Auto Show. In addition, Jeff Gordon, former professional stock car racing driver and an announcer for NASCAR on Fox, and representatives from Axalta took a tour of the MRacing shop on the U-M campus.

The team also hosted visits from Louisiana State and many other universities. "A lot of teams come to see our shop, which is unique to Michigan because of the 30 or so teams that we share space with," said Temin.

MRacing hosted Joanneum Racing Graz from FH Joanneum the week before the May MIS competition to give the Austrian team space to prepare for the event. "It's a great learning experience because we were able to test with them and see how their team operates," Temin said.

Looking ahead to the upcoming season, the team's goal is the same as always, Temin said: "Go and win the competition. There's a lot that goes into winning a Formula Student event that allows us to learn and grow as engineers, but we are always looking to return to the podium."

Rocking the Competition:
Baja Team Wins Top Honor

The U-M SAE Baja team had a record-setting season, placing first overall and winning the Mike Schmidt Memorial Award for the second year in a row. The award recognizes the team earning the most points during the competition season.

"This was especially meaningful to us because we were able to repeat the same success we had in 2015, making us back-to-back national champions," said **Cal Salisbury**, team captain for the 2016–17 season.

Each year SAE Baja teams design and build a prototype of an off-road, all-weather, single-seat recreational vehicle. The car must withstand the rigors of competition, that is, rugged, often wet, terrain and obstacle-laden courses.

The team's 2015–16 vehicle featured a completely redesigned front and rear suspension, decreasing its unsprung mass by seven percent. A mechanical redesign of the custom continuously variable transmission (CVT) that integrated lighter composite components lowered mass and rotational inertia by 20 percent. Optimizing the cross-sectional area of the vehicle and tuning the CVT led to a top-speed gain of two miles per hour. At 282 pounds, the vehicle is the lightest in U-M team history.

At the first race of the 2015–16 season, held at Tennessee Tech, U-M Baja placed fourth overall, including top finishes in the design presentation and acceleration events. The team was pleased but motivated to do better to keep the prior season's top spot.

"The Tennessee competition put us about 100 points behind our competition in the run for the overall season win," said Cal Salibury (BSE ME, '17) team captain. "With our goal of winning first place overall, we sat down and discussed our strategy for the next competition in California. A new game plan and a few minor design tweaks set us up nicely."

At the California event, the team paid particular attention to tuning for low-end performance and the hill climb event, according to **Justin Lopas** (BSE ME,'16), 2015–16 team captain. The event took teams up a long, steep, sandy hill locals call "the Himalaya," and the U-M team was one of only two teams to make it to the top. U-M Baja finished the endurance race in first place. It also placed first in acceleration and maneuverability, setting a record for the most points earned in a single competition.

At the season's final competition at Rochester Institute of Technology, U-M Baja won its third straight design competition, another team record. It also placed first in acceleration, hill climb, design, dynamics and endurance, ending the competition—and the season—in first place overall.

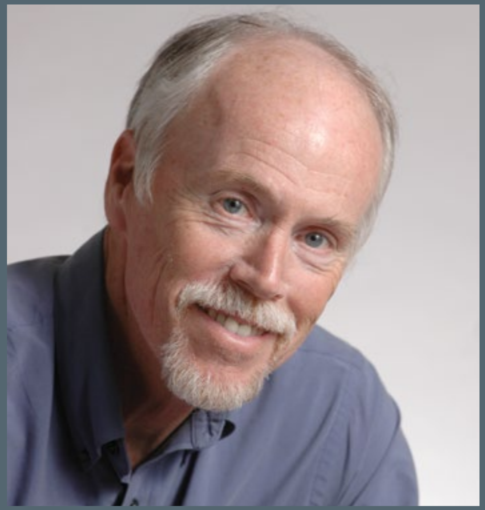
"Teamwork has played a huge role in the success of our team," Salisbury said. "It's not just one or two members who contribute to our success; we have a large group of members who have come together to build a championship-winning race car."

Recruiting those team members has been a high priority for the team. "We added numerous highly involved freshmen to our roster," said Salisbury, "and we're looking to continue our recruiting success in 2016–17."

This year, the team again will travel to an unofficial race at Michigan Technological University. "We use it as an opportunity to get younger members, especially first-year students, into the cars and have them really develop a passion for SAE Baja and racing in general," Salisbury said.

It will take passion to achieve the ambitious goals the team has set for the coming season: to become "three-peat national champions" and win a third Mike Schmidt Memorial Award, experience no endurance race failures in any competition and, Salisbury added, "We want to have a podium finish in every event."

Hedrick Honored with 2016 Alumni Merit Award



Mechanical Engineering alumnus **Karl Hedrick** has been selected to receive the 2016 U-M ME Alumni Merit Award. Hedrick (BSE ME '66) is the James Marshall Wells Professor of Mechanical Engineering at University of California-Berkeley. He is a world-renowned scholar in the field of automatic control systems, where his research has made tremendous impact on the application of advanced theory to a wide variety of vehicle dynamic systems including automotive, aircraft and ocean vehicles.

Throughout his career he has been awarded numerous honors including the ASME Dynamic Systems and Control Division's Outstanding Investigator Award, ASME Nyquist Lecture Award and ASME's Rufus Oldenburger Medal, which recognizes significant contributions and outstanding achievements in the field of automatic control. He is a member of the U.S. National Academy of Engineering.

U-M ME Alum Spearheads Project,
Inspires High School Students to Learn to Love Engineering

Autonomous vehicles may be the way of the future, and what better approach to get high school students interested in pursuing careers in engineering than creating a two-part workshop focused on learning more about them.

That's exactly what U-M ME alumna **Katherine Avery** (MSE '11, PhD '16) hoped to do when she developed Exploring Autonomous Vehicles in a Connected Infrastructure (EAVICI), a two-part workshop designed to introduce high school students from the FIRST (For Inspiration and Recognition of Science and Technology) Robotics teams in Detroit to engineering concepts involving autonomous vehicles, connected infrastructure and the interaction between the two. The purpose of exciting and engaging them in engineering as a potential career.

According to Avery, who is currently a research scientist at the Ford Research and Innovation Center in Dearborn, MI, the idea struck her after meeting with **Jeanne Murabito** of the Michigan Engineering Zone (MEZ). The MEZ is a safe and supportive forum where Detroit students acquire the knowledge and tools they need to propel themselves to higher education and careers in the Science, Technology, Engineering and Mathematics (STEM) fields. Outfitted with computer labs complete with CAD software, a machine shop, robot testing area and collaborative workstations, Detroit's engineers and U-M faculty, staff, students and alumni provide training and mentoring within an environment of learning, leadership, teamwork and fun. In MEZ's flagship program, more than a dozen Detroit high schools and 230 students work to design, build and test their robots for the FIRST Robotics Competition.

"I reached out to Jeanne to offer to host a workshop for the FIRST teams on a vehicle technology and autonomous vehicles seemed like the natural option, given how much they're in the news lately," said Avery. "I thought this workshop series would give us a great opportunity to deconstruct a very relevant and uniquely-challenging engineering problem."

Avery then got to work, owning the project from inception through execution. She worked on all the aspects of the event from grant writing and lesson planning to project management and platform development.

The first part of the two-part workshop at the MEZ took place in early May and students were able to gain hands-on experience designing, programming and evaluating algorithms that could make autonomous vehicles safer and more effective. All of the programming was designed to be done at a very student-appropriate level through a custom-designed web interface. U-M ME alumnus and current research fellow **Steve Vozar** (BSE '08, MSE '09, PhD '13) was involved with the initiative and couldn't have been more thrilled with the outcome.

"We were very impressed with the students' desires to learn and participate. They tackled every programming challenge with creativity and focus, but never forgot to have fun and collaborate," said Vozar. "At the end of the day, we came up with a really hard bonus challenge for them since they had been doing so well with the previous exercises. This one required some pretty extreme creative thinking, and each group had its own strategy to try and solve the problem. Although only one team was able to complete the challenge, the whole room erupted in cheers. The camaraderie that we saw from the MEZ teams was really inspiring," he added.

The second part of the workshop took place a few weeks later where the MEZ students were given a tour of U-M's North Campus led by Avery, followed by lunch with a panel of experts including the director of the University of Michigan's Transportation Research Institute (UMTRI) **Jim Sayer**. The group then headed to the U-M Mobility Transformation Center's (MTC) Mcity, a unique test facility for evaluating the capabilities of connected and automated vehicles and systems, where they were given rides on the U-M SmartCart, U-M APRIL Robotics Laboratory's autonomous 3D printed gold cart platform, learned about how the robots make and use maps to navigate and were able to see Ford's autonomous hybrid vehicle firsthand.

"Overall, I think this was a really unique experience for these students to get to work with and hear from world-class researchers in the fields of autonomous vehicles and connected infrastructure," said Vozar. "Plus, Mcity is not usually open to the public, so this was really special for them to get the opportunity to tour it and see live demos there. I like to think that this workshop will get these students thinking about the issues the researchers in these fields are tackling, and inspire them to pursue similar tasks in their careers."

The workshop and all of the equipment used, including a small-scale connected city and a fleet of miniature autonomous vehicles, were developed from the ground up by U-M volunteers.

"I had about 25 volunteers working on this project, all of whom are current students or postdocs from U-M ME, Computer Science Engineering (CSE) and Naval Architecture and Marine Engineering (NAME). The platform on which we built up our vehicles is the Finch robot. The Finches were donated to the MEZ by U-M CSE professor **Jeff Ringenberg**," said Avery.

The workshop also wouldn't have been possible without the generous grants funded from the Ford Motor Company's STEM Program Office as well as Detroit and Downriver Area Robotics Alliance.

Avery's initiative was also well received by MEZ Senior Mentor **Bob Koehl**.

"Katherine and her term are very talented and exceeded my expectations," said Koehl. "The adaption of inexpensive robots to wire communications and interfacing them to a custom created MEZ city was well done. And, the initial workshop introduced the students to some of the programming problems and methods in guiding autonomous vehicles and did it in a way that all could understand."

Avery said she hopes to hold this two-part event annually for the high school students and teachers at the MEZ and is currently looking for opportunities to use the classroom and programming portions in other settings.

"We've adapted it for Xplore Engineering this year to include an abbreviated, 20 minute lesson on autonomy and decision-making for kids as young as fourth grade and, we added an age-appropriate programming challenge. We would also love to implement the full day activity for other groups or classrooms," said Avery. "As a part of that goal, we're planning to provide an open source license for the custom software we developed during this project before the end of the year. We're also working on a second, customized version of the vehicles to make them more inexpensive and easier to use out-of-the-box."

Anyone interested in contributing to the EAVICI program, or using it in their classroom, is encouraged to contact eavici@trendingup.org.

PHOTO: AP PHOTO/DAVID GOLDMAN

U-M Alums Represent ME at 2016 Summer Olympics

PHOTO: AP PHOTO/NATACHA PISARENKO

U-M ME had a real presence at the 2016 Rio Olympics.

Connor Jaeger and **Sean Ryan**, both 2014 ME graduates, competed on the U.S. Men's Swim team, while **Bruce Gemmell** U-M ME alum, (BSE '83 and MSE '84), served as an American women's swim coach.

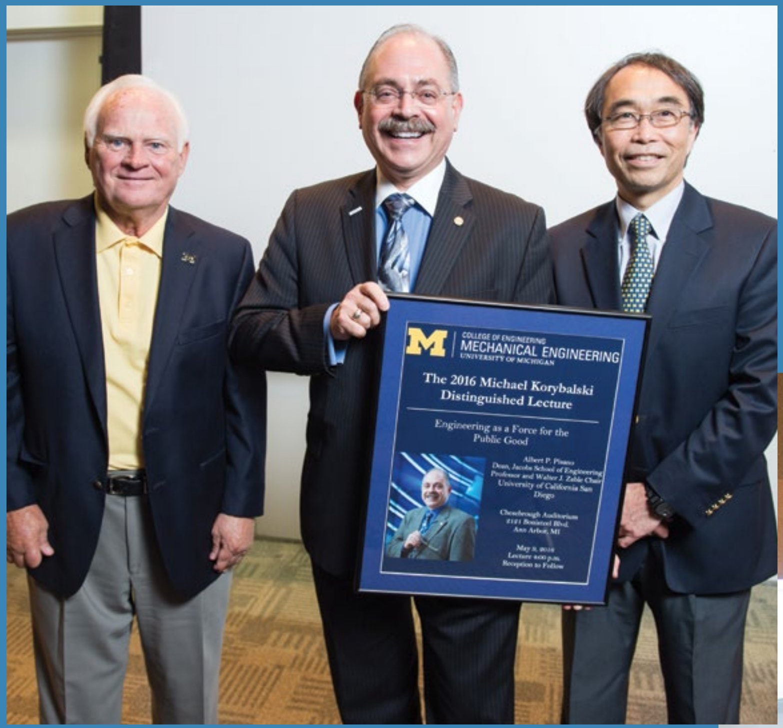
Jaeger, a 10-time All American and three-time NCAA champion at U-M, earned a silver medal in the 1,500-meter freestyle, finishing the race in 14:39.48, a new American record in the event while Ryan competed in the Olympic 10K open water race, securing the position as the 14th fastest swimmer in the world.

PHOTO: DOUG MILLS/THE NEW YORK TIMES

TOP: Sean Ryan competed in the Olympic 10k Open Water, placing 14th, at the 2016 Rio Olympics.

MIDDLE: Connor Jaeger earned a silver medal and secured an American record in men's swimming at the 2016 Rio Olympics.

BOTTOM: Bruce Gemmell served as an American women's swim coach at the 2016 Rio Olympics.



TOP: (From left) ME alumnus Michael Korybalski, Dr. Albert P. Pisano and ME Chair Kon-Well Wang at the 2016 Korybalski Lecture.

BOTTOM: Dean of the Jacobs School of Engineering at the University of California-San Diego and Professor and Walter J. Zable Chair Albert P. Pisano presents to the crowd at the 2016 Korybalski Lecture.

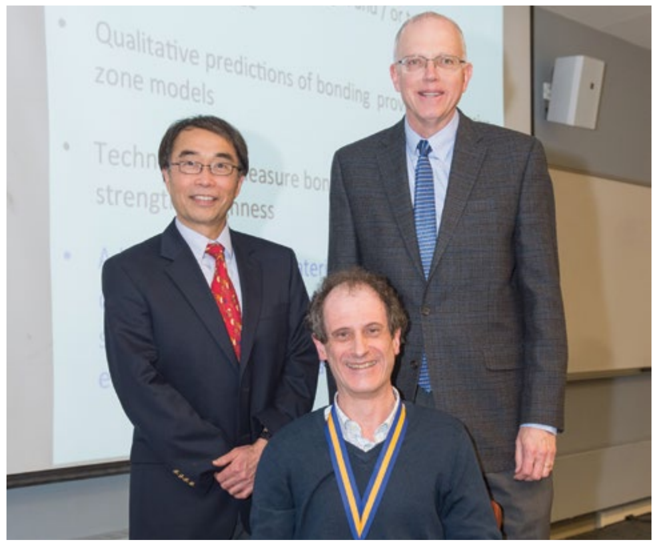
Korybalski Lecture Brings Albert P. Pisano to Campus

Dr. **Albert P. Pisano**, Dean of the Jacobs School of Engineering at the University of California-San Diego and Professor and Walter J. Zable Chair, delivered the ninth annual Korybalski Lecture on May 9, 2016. Pisano's talk, which was titled "Engineering as a Force for the Public Good," focused on a unique view of how engineering fits into a major research university, and then represented a myriad of ways that engineers make a difference in the world. Pisano focused on how this difference arises from a number of contributions starting with the technology engineers develop and following through to the innovation and entrepreneurial efforts that derive from engineering.

A self-described technology polymath, Pisano's research is driven by a passion for developing, mastering and advancing technologies to solve problems. He is a co-inventor listed on more than 20 patents in micro-electro-mechanical systems (MEMS) and has co-authored more than 300 archival publications. He is the co-founder of 10 start-up companies in the areas of transdermal drug delivery, transvascular drug delivery, sensorized catheters, MEMS manufacturing equipment, MEMS RF devices and MEMS motion sensors. In 2008, he was named one of the 100 Notable People by Medical Development and Diagnostic Industry Magazine and in 2001 was elected to the National Academy of Engineering for his contributions to the design, fabrication, commercialization and educational aspects of MEMS. He is a Fellow of the American Society of Mechanical Engineers and an awardee of the Thomas Egleston Medal for Distinguished Engineering Achievement by notable alumni of Columbia University.

Pisano's lecture was a part of the annual lectureship endowed by **Michael Korybalsk**i, 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.

Four ME Faculty Receive Named Professorships



(From left) ME Chair Kon-Well Wang, Michael Thouless and Robert J. Vlasic Dean of Engineering David L. Munson.

MICHAEL THOULESS

JANINE JOHNSON WEINS PROFESSORSHIP

The Janine Johnson Weins Professorship in Engineering is made possible through the generosity of Janine Johnson Weins, and is intended to support the teaching and scholarship of a distinguished faculty member in the U-M ME Department.

Professor Thouless began his career at U-M in 1995 and is currently a Professor of Mechanical Engineering. He is an eminent scholar in the field of mechanics and materials and has made seminal research contributions in fracture mechanics of films, coatings and interfaces. Thouless is a fellow of the American Society of Mechanical Engineers, and he is a chartered engineer and fellow of the Institute of Materials, Minerals and Mining in the United Kingdom. He was elected an overseas fellow of Churchill College, Cambridge, and appointed as an Otto Monsted guest professor at the Danish Technical University. Internal awards include an Arthur F. Thurnau Professorship, the College of Engineering Research, Service and Teaching Excellence awards, and the U-M Distinguished Faculty Governance Award.

(From left) ME Alumnus Roger L. McCarthy, Huei Peng, ME Chair Kon-Well Wang and Robert J. Vlasic Dean of Engineering David L. Munson.

HUEI PENG

ROGER L. MCCARTHY PROFESSORSHIP

The Roger L. McCarthy Professorship in Mechanical Engineering is made possible through the generosity of Dr. Roger L. McCarthy, and is intended to support the teaching and scholarship of a distinguished faculty member in U-M Mechanical Engineering.

Professor Peng began his career at U-M in 1993 and is currently a Professor of Mechanical Engineering. His research interests include adaptive control and optimal control, with an emphasis on their applications to vehicular and transportation systems. His most recent research focuses on the design and control of electrified vehicles and connected/automated vehicles.

Peng is a world-renowned scholar and researcher. Because of his achievements in research and education, Peng has received many awards, including both the CoE Research Excellence Award and Education Excellence Award. He is also a Fellow of the American Society of Mechanical Engineers and the Society of Automotive Engineers.

STEVE CECCIO

ABS PROFESSORSHIP

The ABS Professorship in Marine and Offshore Design Performance is made possible through generous gifts from the American Bureau of Shipping.

Professor Ceccio is currently a Professor and Department Chair of Naval Architecture and Marine Engineering, and has a joint faculty appointment in Mechanical Engineering. His research has focused on the study of multiphase flows through the creation of a world-class laboratory at U-M and through the use of large-scale testing facilities located throughout the country. He has concentrated on the experimental examination of these complex flows with the goal of understanding fundamental processes responsible for their underlying dynamics and transport. Ceccio's contributions have earned him several awards including his election as fellow of the American Society of Mechanical Engineers in 2005 and the American Physical Society in 2009. He was also appointed as an ASME Freeman Scholar in 2014.

KATHLEEN SIENKO

ARTHUR F. THURNAU PROFESSORSHIP

The Arthur F. Thurnau Professorship is named after alumnus Arthur F. Thurnau and supported by the Thurnau Charitable Trust. Appointees demonstrate a strong commitment to students and to teaching and learning, excellence in teaching, innovations in teaching and learning, a strong commitment to working effectively with a diverse student body, a demonstrable impact on students' intellectual or artistic development and contributions to undergraduate education beyond the classroom, studio or lab.

Associate Professor Sienko initiated an ambitious Global Health Design program, which a colleague describes as "an intensive, life-changing experience for students." The program involves participation in international, collaborative projects, as students work in multidisciplinary teams to develop low-cost medical devices at field sites in Ghana and China. In the process, students gain first-hand experience in real-world settings, learning to engage with individuals from diverse backgrounds.

Sienko is joining an elite group of ME colleagues who are holding this prestigious title—Jim Barber, Noel Perkins, Volker Sick, Steve Skerlos, Michael Thouless, Alan Wineman and Margaret Wooldridge.

ME Faculty Administration Appointments

HU APPOINTED VICE PRESIDENT FOR RESEARCH

S. Jack Hu, the J. Reid and Polly Anderson Professor of Manufacturing Technology, was appointed vice president for research by the U-M Board of Regents this past December. Hu had previously served as interim vice president for research since January 2014.

The appointment continues through 2018. Hu will oversee the U-M Office of Research and have overall responsibility for nurturing excellence and integrity of research across the University, including the Ann Arbor, Dearborn and Flint campuses as well as the Health System. Annual research expenditures at the University of Michigan total $1.3 billion.

Over the years, Hu has provided great leadership. He launched several important interdisciplinary initiatives, including the opening of the Mcity test environment at U-M's Mobility Transformation Center as well as a new campus-wide initiative in data science. He has been a member of the U-M community since 1985 and is a professor of Mechanical Engineering and Industrial and Operations Engineering.

PENG NAMED DIRECTOR OF U-M'S MOBILITY TRANSFORMATION CENTER

U-M ME Professor **Huei Peng** was named director of U-M's Mobility Transformation Center, an interdisciplinary research unit of the U-M Office of Research, this past January.

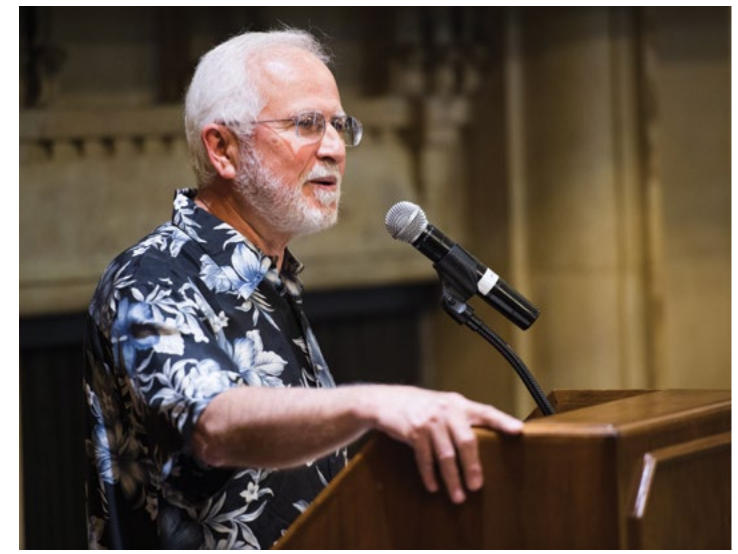
Peng is the Roger L. McCarthy Professor of Mechanical Engineering, and has served as associate director of MTC since its launch in 2013. His research focuses on the design and control of electrified vehicles and connected and automated vehicles.

Peng also has been the U.S. director of the Department of Energy-sponsored Clean Energy Research Center—Clean Vehicle Consortium (CERC-CVC), which supports more than 30 projects related to the development of clean vehicles in the U.S. and China.

As director, Peng will provide overall leadership of the MTC, which is working with industry, government and academic departments across campus to develop the foundation for a commercially viable ecosystem of connected and automated vehicles that will dramatically improve safety, sustainability and accessibility.

The MTC has partnerships with more than 50 companies as well as with federal, state and local governments.

Professor Galip Ulsoy Retires After Serving U-M for Over Three Decades



GALIP ULSOY

> In addition to his exceptional professional achievements, most of all, Galip is a great citizen and a wonderful colleague to many people that he worked with. He is a person with great compassion. He not only worked hard for his own success, but has worked hard and fought for many other people's success.
>
> — KON-WELL WANG, TIM MANGANELLO/BORGWARNER DEPARTMENT CHAIR AND STEPHEN P. TIMOSHENKO COLLEGIATE PROFESSOR

Galip Ulsoy, PhD, C.D. Mote, Jr. Distinguished University Professor Emeritus and William Clay Ford Professor Emeritus of Manufacturing retired this past June after 36 years with the U-M.

Ulsoy earned his BS degree from Swarthmore College in 1973 and his MS degree from Cornell University in 1975. He went on to receive his PhD in mechanical engineering from the University of California-Berkeley in 1979 and joined the U-M ME faculty in 1980.

A world-renowned research leader in dynamic systems and controls, Ulsoy has an exceptional record of high quality publications under his belt, authoring over 300 journal articles. Throughout his career he made extraordinary contributions to education as a passionate teacher and mentor, advising over 40 PhD students. He has been responsible for a variety of education programs at U-M, including the College of Engineering Professional Master's and Doctor's of Engineering and the Interdisciplinary Program in Manufacturing. Ulsoy has been a strong leader who served the University with distinction. He has served as the Founding Director of the Ground Robotics Center, the Founding Deputy Director of The National Science Foundation (NSF) Center for Reconfigurable Manufacturing, and as Department Chair of Mechanical Engineering.

Because of his distinguished contributions, Ulsoy has been the recipient of numerous prestigious awards, including the U-M College of Engineering Stephen S. Attwood Award (2012), the ASME Rufus Oldenburger Medal (2008) and the SME Albert M. Sargent Progress Award (2007) to name a few. He was elected to the National Academy of Engineering in 2006.

GALIP AND WIFE SUSAN

Faculty Awards & Recognition

EXTERNAL AWARDS

ELLEN ARRUDA
Penn State Outstanding Engineering Alumni Award, 2015

JAMES ASHTON-MILLER
ASME H. R. Lissner Award, 2015
ORS/AAOS Kappa Delta Award, 2016

JAMES BARBER
Ted Belytschko Applied Mechanics Award, 2015

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

SAM DALY
SEM James W. Dally Young Investigator Award, 2016

NEIL DASGUPTA
ASME Pi Tau Sigma Gold Medal Award, 2015
AFOSR Young Investigator Research Program Award, 2016
American Vacuum Society (AVS) Paul Holloway Young Investigator Award, 2016

VIKRAM GAVINI
USACM Gallagher Young Investigator Award, 2015

JACK HU
National Academy of Engineering, 2015

XIAONING JIN
SME Outstanding Young Manufacturing Engineer, 2016

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

CHINEDUM OKWUDIRE
SAE Ralph R. Teetor Educational Award, 2016
SME Outstanding Young Manufacturing Engineer, 2016

NOEL PERKINS
ASME Leonardo Da Vinci Award, 2015

C. DAVID REMY
NSF CAREER Award, 2015

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

ALBERT SHIH
ASME Blackall Machine Tool and Gage Award, 2015
Outstanding Alumnus Award, Mechanical Engineering, National Cheng Kung University, 2015

VOLKER SICK
ASME Internal Combustion Engine Award, 2015

DAWN TILBURY
Engineering Society of Detroit (ESD) Gold Award, 2016

MICHAEL THOULESS
ASEE Archie Higdon Distinguished Educator Award, 2015

ANGELA VIOLI
ASME George Westinghouse Silver Medal, 2015

U-M AWARDS

KIRA BARTON
ME Department Achievement Award, 2016

STANI BOHAC
CoE Kenneth M. Reese Outstanding Research Scientist Award, 2016

BOGDAN EPUREANU
CoE John F. Ullrich Education Excellence Award, 2016

TULGA ERSAL
UMOR Research Faculty Recognition Award, 2016

JIANPING FU
CoE Ted Kennedy Family Team Excellence Award, 2015

KATSUO KURABAYASHI
CoE Ted Kennedy Family Team Excellence Award, 2015

XIAOGAN LIANG
ME Department Achievement Award, 2015
CoE 1938E Award, 2016

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
Roger L. McCarthy Professor, 2016

PRAMOD SANGI REDDY
ME Department Achievement Award, 2015

DON SIEGEL
ME Department Achievement Award, 2016

KATHLEEN SIENKO
Arthur F. Thurnau Professorship, 2016

STEVEN SKERLOS
CoE Trudy Huebner Service Excellence Award, 2016

MICHAEL THOULESS
Janine Johnson Weins Professor, 2016

MARGARET WOOLDRIDGE
CoE David E. Liddle Research Excellence Award, 2016

Student Awards

GRADUATE STUDENT AWARDS

SERGEI AVEDISOV
Alexander Azarkhin Fellowship, 2015

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

LONGJI CUI
Caddell Team Award for Research (Edgar Meyhofer & Pramod Sangi Reddy, Faculty, 2016)
Alexander Azarkhin Fellowship, 2016
Rackham Summer Award, 2015

SAMIT DAS
Michigan Institute for Computational Discovery and Engineering Fellowship, 2016

MARC HENRY DE FRAHAN
Rackham PreDoctoral Fellowship, 2016
CoE Richard F. and Eleanor A. Towner Prize for Distinguished Academic Achievement, 2016

XIN DONG
American Society of Precision Engineering Best Oral Paper Award, 2015
(with ME Faculty Chinedum Okwudire)
Rackham Summer Award, 2015

MOLONG DUAN
Dynamic Systems and Controls Best Paper Award, 2015

MIRIAM FIGUEROA-SANTOS
NSF Graduate Research Fellowship, 2016

ANTHONY FIORINO
Caddell Team Award for Research (Edgar Meyhofer & Pramod Sangi Reddy, Faculty, 2016)

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

HAOWEN GE
CoE Distinguished Achievement Award, 2016

NEIL GOPAL SYAL
Bursley Mechanical Engineering Award, 2016

ALISON HAKE
NSF Graduate Research Fellowship, 2016

MICHELLE HARR
NSF Graduate Research Fellowship, 2016

KIMBERLY INGRAHAM
NSF Graduate Research Fellowship, 2016

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

DEVYANI KALVIT
Rackham Summer Award, 2016

ILYA KOVALENKO
NSF Graduate Research Fellowship, 2016

CHEN LI
William Mirsky Memorial Fellowship, 2015
Rackham Summer Award, 2015

NAN LI
William Mirsky Memorial Fellowship, 2016

LIXI LIU
NSF Graduate Research Fellowship, 2016

BRYAN MALDONADO
Rackham Summer Award, 2016

LOUISE MCCARROLL
Rackham Summer Award, 2015

MAZIAR MOHAMMADI
Howard Hughes Medical Institute International Student Research Fellow, 2015

LAURA MURPHY
CoE Harry B. Benford Award for Entrepreneurial Leadership, 2016

SHAOWU PAN
Rackham Summer Award, 2015

LYNDSEY POHL
William Mirsky Memorial Fellowship, 2015
Rackham Summer Award, 2015

VAHID RASHIDI
CoE Distinguished Achievement Award, 2016

MAURO RODRIGUEZ
Rackham Summer Award, 2015

HOSSEIN ROKNI DAMAVANDI TAHER
Ivor K. McIvor Award, 2015

YUE SHAO
Ivor K. McIvor Award, 2015

BAI SONG
Caddell Team Award for Research (Edgar Meyhofer & Pramod Sangi Reddy, faculty, 2016)

ANDREW STEPHENS
NSF Graduate Research Fellowship, 2016

XINYU TAN
Helen Wu Award, 2016
Rackham Summer Award, 2015

DAKOTAH THOMPSON
Caddell Team Award for Research (Edgar Meyhofer & Pramod Sangi Reddy, faculty, 2016)

DANIEL URSU
Rackham Summer Award, 2015

SARAH VERNER
MICDE Fellowship, 2016
NSF Graduate Research Fellowship, 2016

PENGCHUAN WANG
Rackham Summer Award, 2015

KEVIN WELD
William Mirsky Memorial Fellowship, 2016

SHINUO WENG
Rackham Summer Award, 2015

DEOKKYUN YOON
3M/ASPE Scholarship, 2015

XIAOWEN ZHANG
American Society of Precision Engineering Best Oral Paper Award, 2015
(with ME Faculty Chinedum Okwudire)

YUQING ZHOU
Michigan Institute for Computational Discovery and Engineering Fellowship, 2016

UNDERGRADUATE STUDENT AWARDS

CARLOS BARAJAS
NSF Graduate Research Fellowship, 2016
ME Spirit Award, 2016
Lloyd H. Donnell Scholarship, 2015

JIEXIN CHEN
R&B Tool Scholarship, 2016

ANNA CROUCH
Rackham Summer Award, 2016

ANDREW DEVROY
R&B Tool Scholarship, 2015

T.J. FLYNN
National Defense Science and Engineering Graduate Fellowship, 2016

YOONSEOB KIM
McIvor Memorial Award, 2016

AMY LIU
Caddell Memorial Scholarship, 2015

JESSICA LIPA
Donnell Scholarship, 2016

ELIO MORILLO
ME Spirit Award, 2015

YUHAO PAN
R&B Tool Scholarship, 2015

LINDSAY FRASER PURVIS
Caddell Memorial Scholarship, 2016

MENGYAO RUAN
Caddell Memorial Scholarship, 2016

CAL SALISBURY
R&B Tool Scholarship, 2016

ANDREW STEPHENS
NSF Graduate Research Fellowship, 2016

QIANYU SUN
Caddell Memorial Scholarship, 2016

CLARK TEEPLE
RISE Best Paper Award, 2016 (with ME Professor Kenn Oldham)

SHINUO WENG
Ivor K. McIvor Memorial Award, 2016

TONG XIE
R&B Tool Scholarship, 2016

GABRIELLE ZACKS
R&B Tool Scholarship, 2016

HAOLU ZHANG
Caddell Memorial Scholarship, 2015

WENXUAN ZHOU
R&B Tool Scholarship, 2016

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Design
MICHIGAN CREATIVE

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The newly renovated ME facility.
See page 5 for details.
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