MAKING THE WORLD WORK BETTER

MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

2023–2024 ANNUAL REPORT

me.engin.umich.edu/annualreport2024

Dear Friends...

I hope this message finds you well. This year, the University of Michigan Department of Mechanical Engineering (U-M ME) has made remarkable advancements towards shaping the future of science and impacting society for the better.

A long string of severe flooding events worldwide has pressed scientists to come up with better flood prediction models and safety plans. Increasing demands on energy have stressed the importance of diversifying and expanding energy sources, and this has brought new innovations in solar cell manufacturing into the spotlight. And as advanced materials have been developed to provide new capabilities in a variety of industries, scientists have worked out code to improve computer modeling for reliable material exploration and design.

This work could not be done without the expertise of mechanical engineers.

Looking back, I feel a sense of pride at all our ME community has accomplished and an inspiration to continue making forward strides in our mission to make the world work better. I'm excited to share some of our news and accomplishments with you now.

State-of-the-Art Solar Manufacturing

A new breed of semiconductors that could enable breakthroughs in solar cells and LEDs will benefit from cutting-edge manufacturing approaches, through a new project led by the University of Michigan and backed by $3 million from the National Science Foundation. The effort combines hands-on work that improves upon the process of layer-by-layer deposition of semiconductor materials during production with an information-sharing approach that boosts cooperation between companies while protecting proprietary information and worker interests.

Material Simulation with Quantum Accuracy

Accurately calculating interactions among electrons has been a major obstacle to reliable material exploration and design through computer modeling, but a U-M-led team developed code that brought quantum mechanical accuracy for large systems into the range of today's supercomputers. This breakthrough has now been recognized by the Association for Computing Machinery through the Gordon Bell Prize.

$7.5M to Predict and Communicate Flood Risk

To reduce the human and economic costs of extreme flooding events, which are on the rise due to climate change, a team led by the University of Michigan is bringing together researchers in science, technology, and the humanities for better flood risk predictions and better decision-making in response to those risks. They are supported with a 5-year, $7.5 million grant from the Office of Naval Research, through the Department of Defense Multidisciplinary University Research Initiatives (MURI) Program.

Faculty recognition

Our faculty continue to be recognized by prestigious institutions and professional societies for their many contributions to research, education, and service. A few examples include three NSF CAREER Awards, the Gordon Bell Prize, a 2024 ONR Young Investigator Prize, and the 2024 SME Education Award.

I hope reading about the accomplishments of our ME community gives you the same sense of pride and inspiration as it gives me. The work is not done, but the extraordinary gains we have earned over the past year make me hopeful about the future of our world.

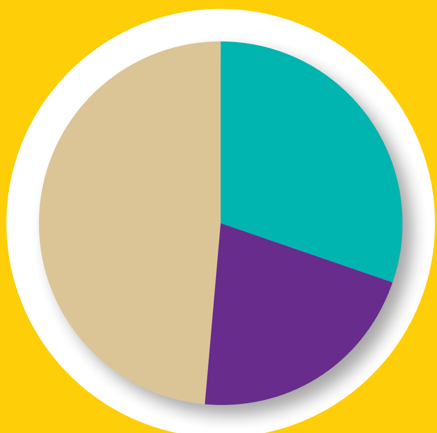
As always, we're grateful for your time and support of ME.

Ellen Arruda
Tim Manganello/BorgWarner Department Chair and Maria Comninou Collegiate Professor of Mechanical Engineering

2023-24
By the Numbers

Research Dollars Received

National Institutes of Health	$3,098,930
National Science Foundation	$5,869,966
Department of Energy	$8,696,170
Department of Defense	$16,456,775
All Other	$15,023,675
FY24 Total:	**$49,145,516**



Faculty

Assistant Professors	20
Associate Professors	14
Professors	32
TOTAL	**66**

BEST PROGRAMS IN THE U.S.

#5 Graduate Program

#8 Undergraduate Program

U.S. News & World Report

$7.5 Million Grant to Help Predict and Communicate Flood Risk

To reduce the human and economic costs of extreme flooding events, which are on the rise due to climate change, a team led by the University of Michigan is bringing together researchers in science, technology and the humanities for better flood risk predictions and better decision-making in response to those risks.

They are supported with a 5-year, $7.5 million grant from the Office of Naval Research, through the Department of Defense Multidisciplinary University Research Initiatives (MURI) Program.

The devastating floods that ripped through the northeast are among the most recent in a long string of severe flooding events occurring worldwide, which make it plain that better flood predictions and safety plans are needed. According to the Organization for Economic Cooperation and Development, flooding causes $8 billion in losses on average annually in the U.S. alone.

“Climate change is increasing the likelihood of extreme flooding — and particularly in urban areas. In the past four decades, 99% of U.S. counties were impacted by flooding, and since 2000, there have been 1,782 flood-related fatalities,” said **Valeriy Ivanov**, co-principal investigator and professor of civil and environmental engineering.

The team seeks to provide better answers to crucial questions that arise when communities are at imminent risk of flood. What are the chances the flood occurs, and how bad could it be? Where might flooding occur in the future as the climate continues to change? What information do leaders need to make decisions about evacuation? The goal of their project is to develop a suite of methods and case studies that ultimately will help leaders decide what actions need to be taken when a flood may be coming.

“We are looking at the full pipeline, from predictions and models to the psyche of decision makers where it will affect society,” said **Xun Huan**, co-principal investigator and assistant professor of mechanical engineering.

The team plans to collect data from two areas, one located in Michigan and the other in Texas, and run many computer simulations to determine the possibility and impacts of floods in the current climate — and under different scenarios of future climate. In addition to improving the accuracy of their simulations, they hope to find strategies, solutions and actions that can mitigate the impact of floods, minimizing the harm.

One key concern is measuring and communicating the uncertainties in their predictions. Similar to weather forecasts that provide a percent chance of rain on a given day, the team is designing a model that can provide information on the likelihood of the flood hazard and which communities may be impacted. This is of paramount importance for flood resilience and preparedness as well as supporting real-time decision-making immediately before, during and after flood events.

"Uncertainty plays an important role in decision-making, where one needs to consider what scenarios might play out and how likely. The importance of these considerations are further elevated when decisions have high consequences, for example when deciding whether to evacuate when faced with potential major flooding that may cause property damage and endanger people's lives," said Huan.

Another part of the project focuses on human decision-makers and what matters to them when making difficult choices.

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“We want to find out what information from the data and modeling are important for human users and decision-makers to know, how this information can be expressed in a useful and understandable manner, and how do these priorities change from community to community,” said **Nikola Banovic**, an assistant professor of computer science and engineering and a participating investigator, bringing expertise in human-computer interaction.

To find these answers, the engineers and atmospheric scientists will team up with psychologists and anthropologists.

“With climate change, new geographic areas will likely experience flooding for the first time, presenting interesting opportunities for behavioral science research to contribute to the overall effort of maximizing safety,” said **Richard Gonzalez**, the Amos N. Tversky Collegiate Professor of Psychology and Statistics at U-M and a participating investigator.

“This project will develop advanced mathematical models, but for these models to be useful and effective for policy makers and the general population, behavioral scientists can contribute evidence-based models to understanding the human-in-the-loop problem,” he added.

With more robust predictions and best practices for communicating about them, the team will then develop casebooks to help present data to leaders when their constituencies face flood risks.

By taking into account probabilities and risks along with other elements such as practicality, psychology, and societal and cultural effects, the team seeks to improve near- and long-term decision-making strategies.

The project includes researchers from Boise State University and the University of Illinois Urbana Champaign as well as stakeholders from Department of Defense facilities in the Detroit Area. Project ideas initially started with seed funding from the Michigan Institute for Computational Discovery and Engineering, which enabled researchers from multiple disciplines to come together and focus on computational aspects of the flooding problem.

Learn more about this story. Visit:
bit.ly/PredictingFloodRisk

Material Simulation with Quantum Accuracy Wins Gordon Bell Prize

Accurately calculating interactions among electrons has been a major obstacle to reliable material exploration and design through computer modeling, but a U-M-team led by **Vikram Gavini**, a professor of mechanical engineering and materials science, developed code that brought quantum mechanical accuracy for large systems into the range of today’s supercomputers.

This breakthrough was recognized by the Association for Computing Machinery through the Gordon Bell Prize.

“This provides a systematic path to realizing large-scale materials simulations at quantum accuracy,” says Gavini. “In turn, we can accelerate our understanding of materials properties and aid in computational design of materials. Application areas include designing better alloys, designing better catalysts, and drug discovery, to name a few.”

Learn more about this story. Visit:

bit.ly/GordonBellPrize

Improving Accessibility and Developing a Framework for Evaluating Equipment Setups

At the U-M Department of Mechanical Engineering, the heart of the undergraduate curriculum is a series of design courses through which students make use of mills, lathes, and other large machines to transform raw materials into parts and mechanisms. These are then deployed in projects aimed at developing foundational skills for future careers in industry and academia — but what if a student can't reach, maneuver, or manipulate those machines?

The Mechanical Engineering Undergraduate Machine Shop team received the University of Michigan's Distinguished Diversity Leaders Award to recognize and celebrate their dedication and commitment to fostering a diverse, inclusive, and welcoming campus culture for their work to improve accessibility in the shop and for the development of a new framework that evaluates industry standard equipment setups.

"We want students to feel welcome and comfortable," said **Don Wirkner**, instructional lab manager in mechanical engineering. "How can we make the experience working on the machines more inclusive, more accommodating?"

At the beginning of the Fall 2022 semester, a student participating in a design course, who used a power wheelchair, needed to use the shop's machinery to complete training and manufacturing of parts. These machines, said **Mike Klein**, engineering technician in mechanical engineering, "were built for very tall men a hundred years ago and their design really hasn't changed much since. They're big, and they're heavy. They're designed for a very specific kind of person."

While Wirkner has been interested in expanding accessibility in ME labs since joining the department in 2019, students generally did not require assistance. Some assists, like raised work platforms, were available, but these were not the right accommodations for their new student. Examining the shop's setup through a different lens, Wirkner found that there were additional needs, and available solutions were not ideal.

"The team could have assigned the student an assistant who would operate the machines for them," said **Susan Cheng**, manager of diversity and inclusion in mechanical engineering. "But they believed it was critical that all students have the chance to experience the feeling of accomplishment that is unique to machining something on your own from start to finish."

This was not quick to achieve, however. To begin making accommodations, the team would need to build a proposal, and that required a method to evaluate each machine beforehand.

In concert with the student, the team began by researching guidelines from NGOs and professional organizations, scholarly papers, and equipment setups at peer institutions. "The first thing we did," said **Kemal Duran**, design instruction engineer in mechanical engineering, "was we hit the books, trying to figure out what the general standards are for student accommodations, for people with wheelchairs, or for other people with other specific disabilities."

The team wanted their solutions to be wide-reaching, to address the needs of as many students — current and future — as possible, but they were unable to find an established framework to do so. "We really found that there is no standard for anything outside of walkways, doorways, and tables," said Wirkner.

Fortunately, the team found that their research could inform the development of their own framework. "So, we actually set up a system for assessing which of our machines were accessible and which ones just aren't," said Duran.

"It was critical that all students have the chance to experience the feeling of accomplishment that is unique to machining something on your own from start to finish."

Each machine setup should be assessed, according to the team's new system, for *reach*, *maneuverability*, and *manipulation* (RMM, for short). Can the operator *reach* all controls and display panels? Does the operator have the ability to *maneuver* around the machine at will? Is the operator able to apply enough pressure or torque to *manipulate* controls? This framework informed the team's proposal and helped to justify the changes they wanted to make.

Ultimately, the shop was able to engineer new methods for adjusting display panels and extending, or relocating, control interfaces on six mills and four lathes. They separately assessed the general layout and workflow of the shop and several other design laboratories, and existing workbenches were replaced with either smaller or height-adjustable tables. This also expanded aisleways, allowing students to enjoy greater navigation of the shop and flexibility with seating options.

"What was unexpected, afterwards, was that...we were getting feedback from other students — those who were shorter — that they were having an easier time using the machines too," Wirkner said.

These standard machine setups were not designed with every body type in mind, and it turned out that, when work was done to begin making them more accessible, the team discovered that many students could benefit from the targeted changes they were making, and those they hope to make in the future.

Next, Wirkner and his team aim to consider how accessibility can be promoted in more spaces on campus, to share their work widely, and to deepen their knowledge of universal design. As they see it, there's still a lot of work to be done.

"I think we had a pretty good first pass," Wirkner said. "We feel that there is much more that we can do, as time and funding become available. Things that we think are small and simple can collectively make a significant difference. Each step gets us closer to full participation for everyone."

Learn more about this story. Visit:
bit.ly/labaccessibility

$3M NSF Grant to Boost State-of-the-Art Solar Manufacturing

A new breed of semiconductors made from halide perovskites could enable breakthroughs in solar cells and LEDs through a project led by Associate Professor of Mechanical Engineering and Materials Science **Neil Dasgupta**.

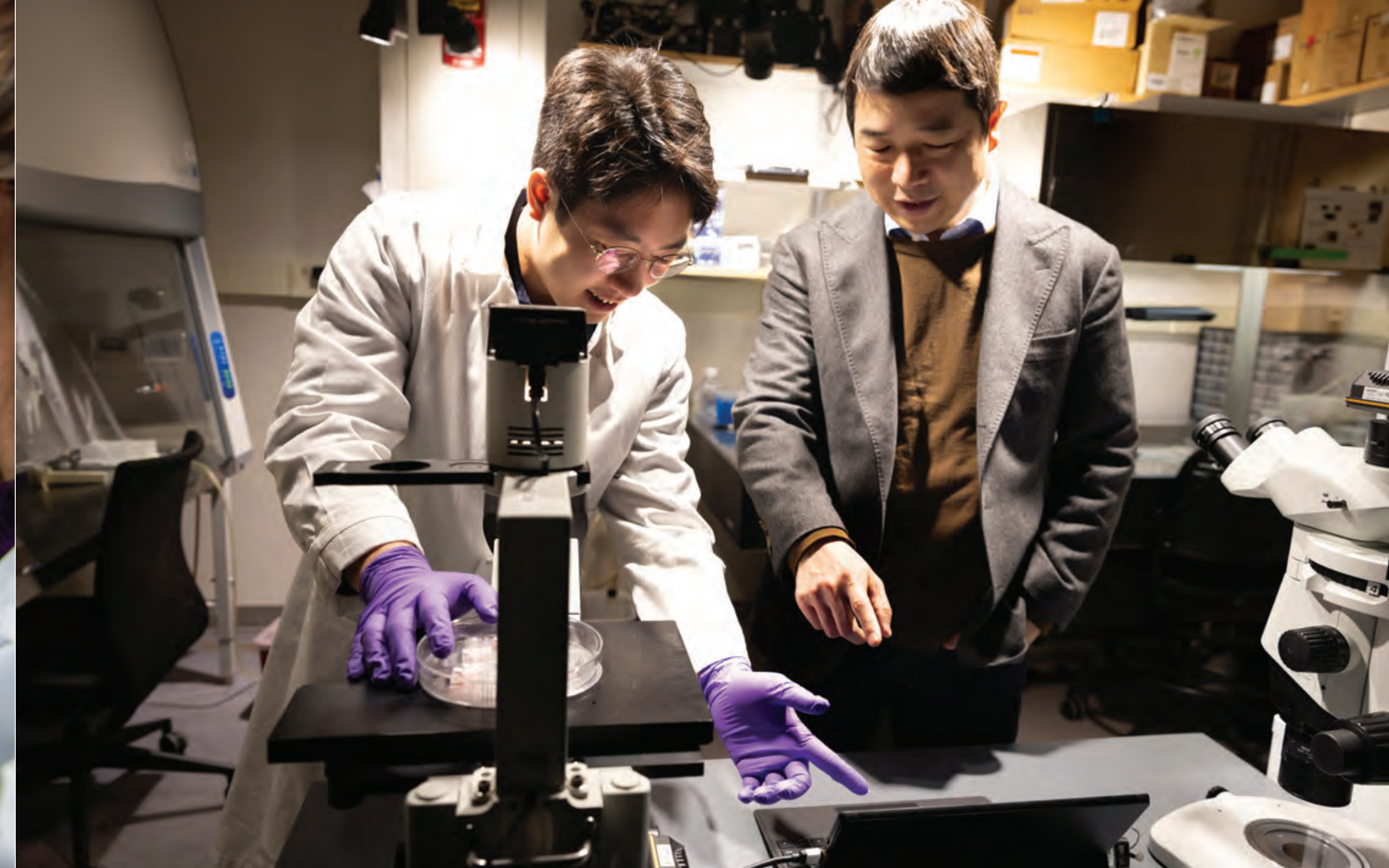
Backed by $3 million from the National Science Foundation, the effort combines hands-on work that improves the process of layer-by-layer deposition of semiconductor materials with an information-sharing approach that boosts cooperation between companies while protecting proprietary information and worker interests.

Halide perovskites represent a promising new semiconductor material that can boost solar cell efficiency. In less than 15 years of study, solar cells utilizing it have increased their efficiency from 10% to 26%.

This work includes partners at the University of California, San Diego.

Learn more about this story. Visit:

bit.ly/NSFSolarManufacturing



Human Stem Cells Coaxed to Mimic the Very Early Central Nervous System

The first stem cell culture that produces a full model of the early stages of the human central nervous system has been developed by a team that includes the University of Michigan.

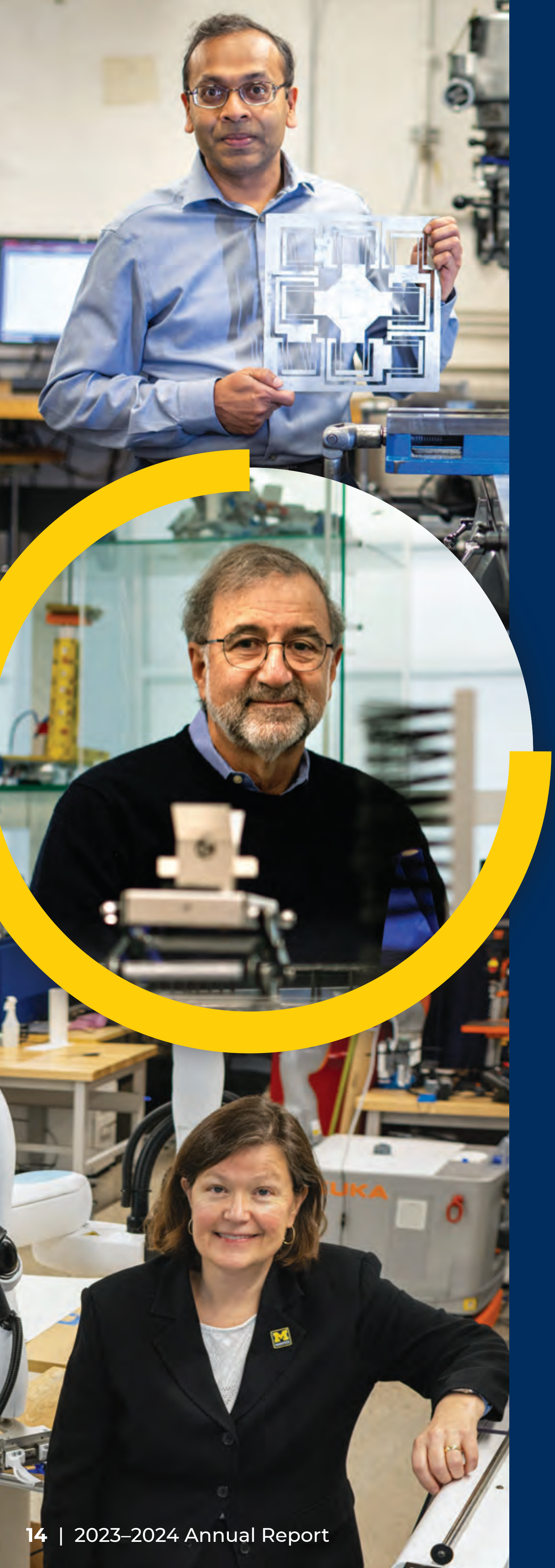
“This will open doors for understanding the early development of the human central nervous system and how it could go wrong in different disorders,” says **Jianping Fu**, professor of mechanical engineering.

The system is an example of a 3D human organoid — stem cell cultures that reflect key structural and functional properties of human organ systems. The groundbreaking model recapitulates the development of the embryonic brain and spinal cord simultaneously, a feat that has not been achieved before.

Joining U-M on this important work are the Weizmann Institute of Science and the University of Pennsylvania.

Learn more about this story. Visit:

bit.ly/EarlyNervousSystem



Three ME Faculty Elected to the National Academy of Engineering

A trio of mechanical engineering professors were elected as members of the National Academy of Engineering (NAE) — one of the highest distinctions in the profession.

Shorya Awtar, CEO of Parallel Robotics and professor of mechanical engineering, was recognized for "inventing and commercializing game-changing surgical products that have made minimally invasive surgery affordable and accessible around the world."

Panos Papalambros, the James B. Angell Distinguished University Professor Emeritus of Engineering, the Donald C. Graham Professor Emeritus of Engineering, professor emeritus of mechanical engineering and a professor emeritus of integrative systems and design, was recognized for his "contributions to complex systems optimization and leadership in advancing transformative engineering design research and education."

Dawn Tilbury, the Ronald D. and Regina C. McNeil Department Chair of Robotics, the Herrick Professor of Engineering, and a professor of mechanical engineering and of electrical and computer engineering, was recognized for her work in manufacturing network control and human-robot interaction.

Learn more about this story. Visit:

bit.ly/TwoNAEAwards and **bit.ly/TilburyNAE**