2019

ME-EM 2018-19 Annual Report

Department of Mechanical Engineering-Engineering Mechanics, Michigan Technological University

ME-EM

MECHANICAL ENGINEERING — ENGINEERING MECHANICS

LAUNCHING EXCELLENCE

PAGES 2-49 →

Michigan Technological University

1885

[2018-19] ANNUAL REPORT

WELCOME

ON THE COVER

The student-build Oculus-ASR nanosatellite is now orbiting Earth after being launched on the SpaceX Falcon Heavy, collecting data and monitoring objects circling the world.

SEE PAGE 92

CONTRIBUTORS

COMMITTEE: Kimberly Geiger, Karen Bess, Marlene Lappeus, Dr. William Predebon

DESIGN & WRITING: Monte Consulting

PHOTOGRAPHY: Monte Consulting, Michigan Tech, Contributors

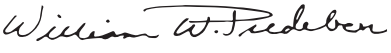
We have witnessed the rise of big data as the fourth industrial revolution gets underway. To produce leaders during this change, our Department is rapidly evolving our educational methods and our methods of research. Furthermore, the University has identified nine initiatives to strengthen our campus, including advanced materials and manufacturing and autonomous and intelligent systems, each being led by ME-EM faculty (see page 52).

In preparing our students to become digital mechanical engineers, I have challenged the faculty to integrate big data and data analytics into our curricula. Working in parallel tracks for undergraduate and graduate programs, our faculty is conducting studies to determine best practices and workflows for students at each level. The Mechanical Engineering Practice courses we discussed in last year's Annual Report are highly adaptable and will serve as the foundation where we embed these critical skills. In this year's Report, we feature all our faculty and staff to convey their breadth of research and dedication to teaching.

On June 25 we also celebrated a milestone achievement for our Department, the Aerospace Enterprise, and the University, when the SpaceX Falcon Heavy successfully launched with the Oculus-ASR nanosatellite aboard.

Aerospace Enterprise, part of Michigan Tech's award-winning Enterprise Program, has helped secure careers for many of our graduates. It was an honor to witness the awe and excitement of many students and alumni at the launch. We also look forward to students on campus to receiving data from space.

This kind of success is only possible when the full circle of our community is engaged: with students at the center, surrounded by dedicated faculty and staff, and supported by the generous contributions of alumni, friends, and corporate partners.



William W. Predebon, PhD
J.S. Endowed Department Chair
& Professor • wwpredeb@mtu.edu

RESEARCH BUILDS INNOVATION

The ME-EM Department is strengthening educational programs by attracting high quality and diverse faculty and staff, who support a broad spectrum of research.

Through a $500,000 National Science Foundation CAREER Award, Dr. Ye Sarah Sun is enhancing health monitoring systems through embroidered wearable electronics, which will extend into driver awareness in autonomous vehicles and in mines for situational awareness (see page 15).

Dr. Sajjad Bigham is pushing the limits of additive manufacturing to create heat exchangers suitable for extreme temperature and pressure. The 3D printing challenge is funded by the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E), the second ARPA-E project granted to ME-EM faculty (see page 20). Additional research funds were secured by Bigham through the Department of Energy and Samsung Electronics America to develop a next-generation desiccant-based gas clothes dryer. The three year, $534,565 project will lead to higher efficiency dryers.

After outfitting a fleet of eight Gen II Chevy Volts, the first ARPA-E project, is in the final phase of validation and verification. Led by Dr. Jeff Naber, leveraging a partnership with GM and support of faculty, staff, and students, the group is closing in on the final year of the $3.5 million research project and realizing their goal of achieving a 20 percent reduction in energy consumption in light-duty hybrid electric vehicles (see page 12).

The NASA-funded Ultra-Strong Composites by Computational Design (US-COMP) project is halfway through the five year $15 million project to create lighter and stronger carbon nanotube-based materials for the next generation of space exploration, leading a collaboration of 11 universities, two partner companies, and the US Air Force Research Lab (see page 5).

Drs. Darrell Robinette and Jason Blough are impacting torque converter design by employing microtelemetry systems to minimize noise and gain insight to key design factors. With background in industry, they merge theoretical and applied approaches to rapidly innovate.

Through the diversity of our faculty's research success, our influence is expanding on automotive, aerospace, biomedical, manufacturing, structural, and energy industries.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

- 8 in BSME enrollment, 27 in BSME degrees awarded
- 10 in MSME enrollment, 6 in MSME degrees awarded
- 23 in PhD enrollment, 33 in PhD degrees awarded

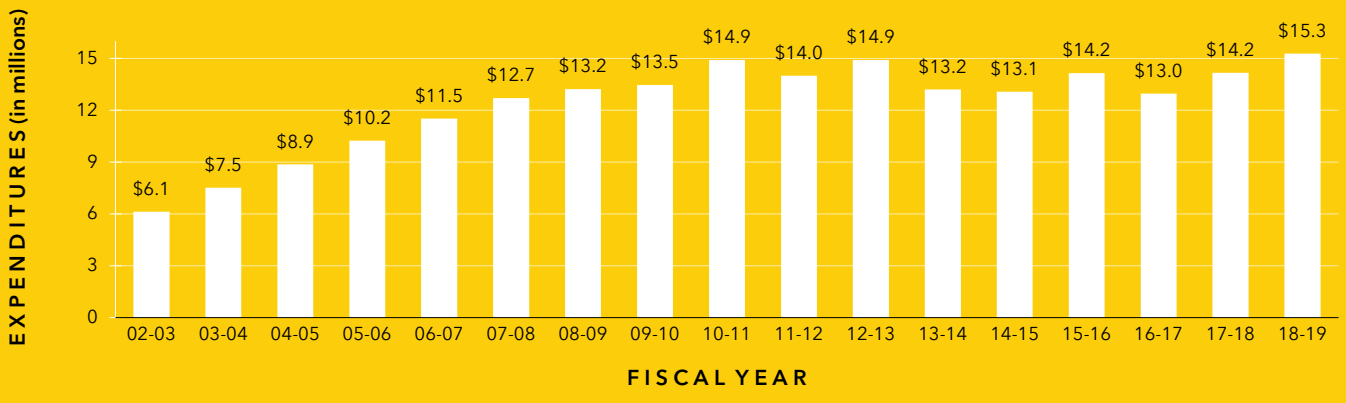
NATIONAL SCIENCE FOUNDATION

19 in research expenditures ($15.278M) among all mechanical research in the US

US NEWS & WORLD REPORT AMERICA'S BEST GRADUATE SCHOOLS

58 among the top 181 (top 32%) doctoral-granting ME departments

RESEARCH EXPENDITURES: 2002-2019



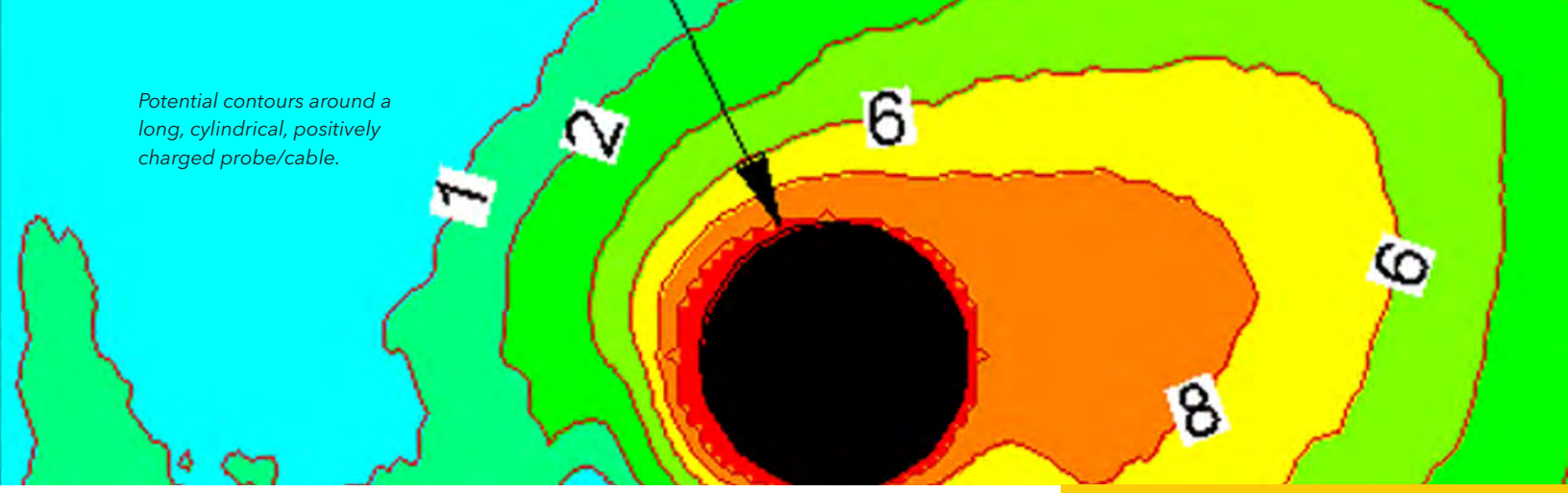
Research expenditures are an estimate at publication time and are corrected in the next annual report.

AEROSPACE

From the molecular to the orbital, our faculty and students are shaping the future of engineering through education and research. By improving the materials needed for space and the fuel used to get there, our researchers are laying the foundation for expanded space travel.

FACULTY INVOLVED

- DR. CHUNPEI CAI
- DR. BRAD KING
- DR. GREG ODEGARD
- DR. PAUL VAN SUSANTE



Potential contours around a long, cylindrical, positively charged probe/cable.

Steadily Unstable

DR. CHUNPEI CAI
ASSOCIATE PROFESSOR

When a spacecraft operates in low orbit, engineers need to predict how the diffuse atmosphere will affect its components. Traditional numerical simulations of the plasmas generated at orbit speeds are only loosely coupled to the problem. However, through research being conducted by Dr. Chunpei Cai, the fundamental physics behind the numbers will be uncovered to validate or improve the expressions.

"Expressions have several physical properties embedded, such as the current and the voltage, but we need to do some theoretical derivation work to get to those expression details," says Cai. "We are working with simulation of dilute gases and plasmas flowing over spacecraft and around the spacecraft antenna to better understand fundamental physics expressions."

Plasma is a charged state of matter and therefore has an interference effect on the antenna. As a result, electrons may be absorbed into the surface, creating a current. The arcs generated as a result of the accumulating charges can damage the spacecraft.

"From physics, we understand there is motion across these magnetic fields, which can collect current. If we have motion, we have current and by looking at it in reverse, we can put current through a cable to generate a force, called tethered cable propulsion," says Cai.

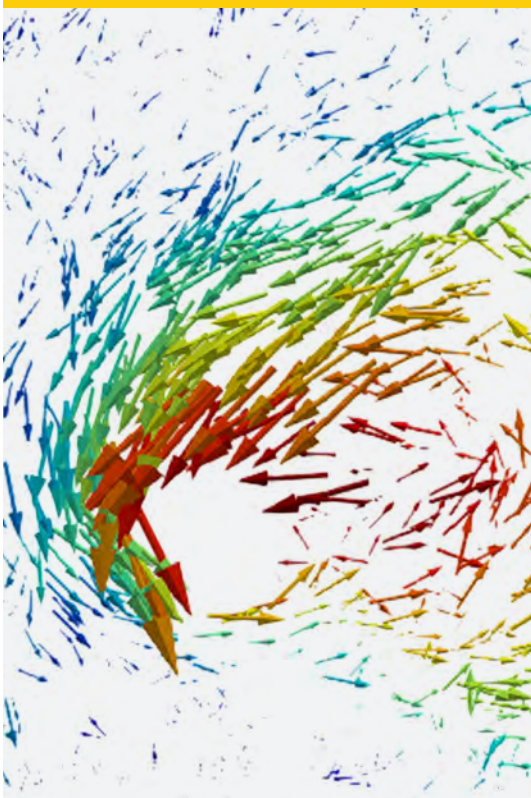
As part of the Air Force Research Lab (AFRL) funded project, Cai has developed his own in-house fluid dynamics code, which compares well to the AFRL packaged code with accurate results through numerical and theoretical derivation work.

> *"Numerical simulations only provide numbers, but there are more fundamental physics buried by those numbers. The derivations we are working on help us to confirm those fundamental physics expressions and ultimately validate the fundamental physics, which has been incredibly fascinating to work on."*

–Dr. Chunpei Cai

RESEARCH AREAS

- **RAREFIED AND NON-EQUILIBRIUM GAS DYNAMICS**
- **PLASMA SIMULATIONS**
- **ELECTRIC PROPULSION**
- **COMPUTATIONAL FLUID DYNAMICS**



Electron velocity vectors around a long, cylindrical, positively charged probe/cable, colored by electron number density.

> *"The end goal for all space engineering is to see your baby operating well in orbit."*
>
> –Dr. Brad King

The Solution Within

DR. BRAD KING
RICHARD & ELIZABETH HENES
PROFESSOR OF SPACE SYSTEMS
ENGINEERING

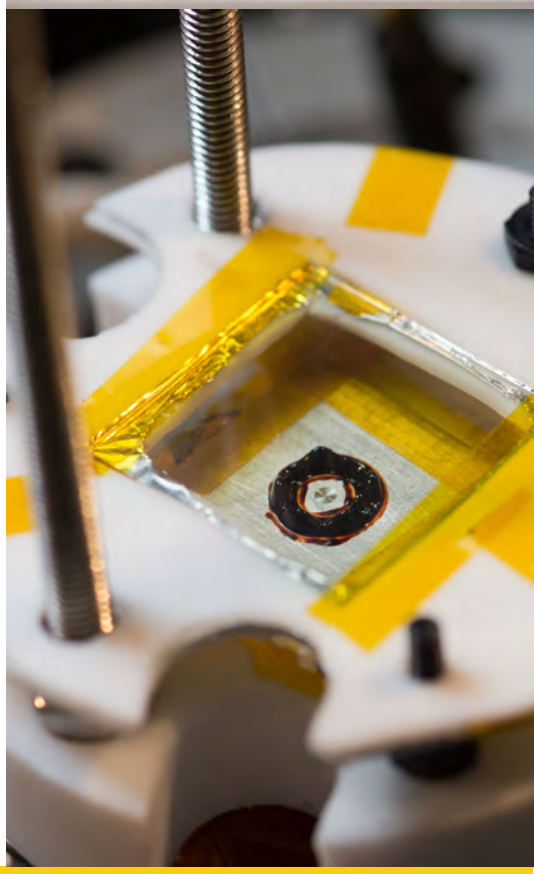
A limitation in costly micromanufacturing had Dr. Brad King at a disadvantage, as he sought to improve tiny satellite propulsion emitters. But innovation is sometimes born from unexpected circumstances, and this constraint led King's research team to ask, "How else could we make an emitter?" A team member suggested shaping a liquid into the tiny points needed to emit propellant. But how does one shape a liquid in space?

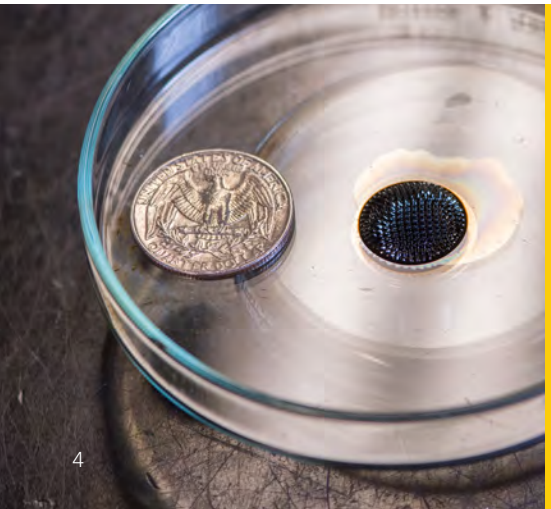
King's team is exploring the use of an ionic-liquid ferrofluid electrospray to build emitter points for the on-board micropropulsion of mini-satellites. The way around the micromanufacturing obstacle was to let the liquid manufacture itself.

"Rather than building a microstructure in silicon, we put a magnet under the liquid and it takes care of the rest," says King. "The ferrofluid consists of magnetic nanoparticles dispersed in a liquid, which can be manipulated with magnetic and electric fields."

The peaks formed by the interaction of magnetic and electric fields ultimately emit small beams of ions for a reactive thrust to propel a small satellite through space. "The benefit to this solution is that it has no degradation of performance over time because it is made entirely out of propellant," says King.

Through funding from the US Air Force Office of Scientific Research, the team is on phase II of the project, investigating the physics to achieve an optimal shape, specifically concerned with the magnetic and electric forces and controlling the peak spacing.





RESEARCH AREAS

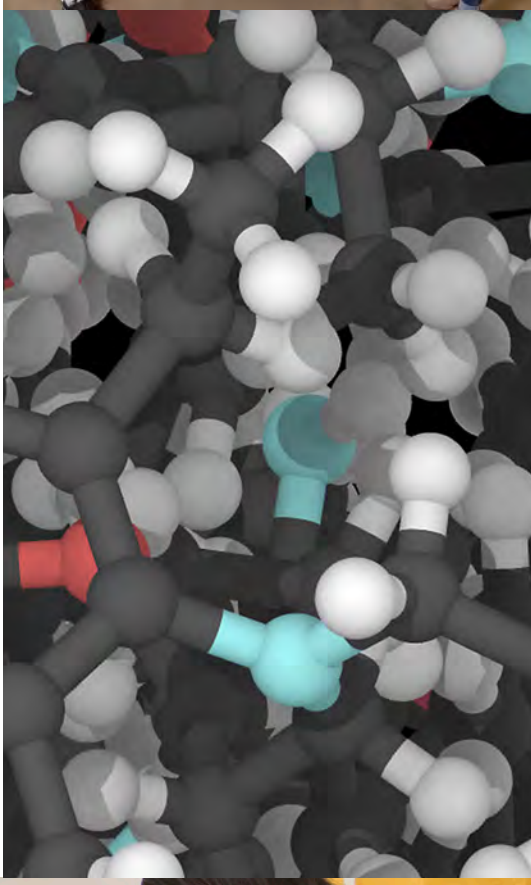
- **AURIS NANOSATELLITE FOR RF SPACE SITUATIONAL AWARENESS -** Air Force Research Laboratory (AFRL)
- **STRATUS NANOSATELLITE TO MEASURE CLOUD HEIGHT AND CLOUD-TOP WIND -** NASA
- **LOW-POWER XENON HALL-EFFECT THRUSTER PERFORMANCE STUDY -** Orbion Space Technology

Quantum Step Forward

DR. GREG ODEGARD
RICHARD & ELIZABETH HENES PROFESSOR
OF COMPUTATIONAL MECHANICS

RESEARCH AREAS

- **US-COMP -** NASA
- **PROCESS MODELING -** NASA



To advance the future of deep space exploration, Dr. Greg Odegard and a team of collaborators from 11 universities, two partner companies, and a national lab are developing lightweight material made of carbon nanotubes and polymer resins with triple the performance of the current state-of-the-art.

"In this past year of work, we have made significant progress in the three-fold stronger material development, both computationally and experimentally and have validated that in the lab," says Odegard.

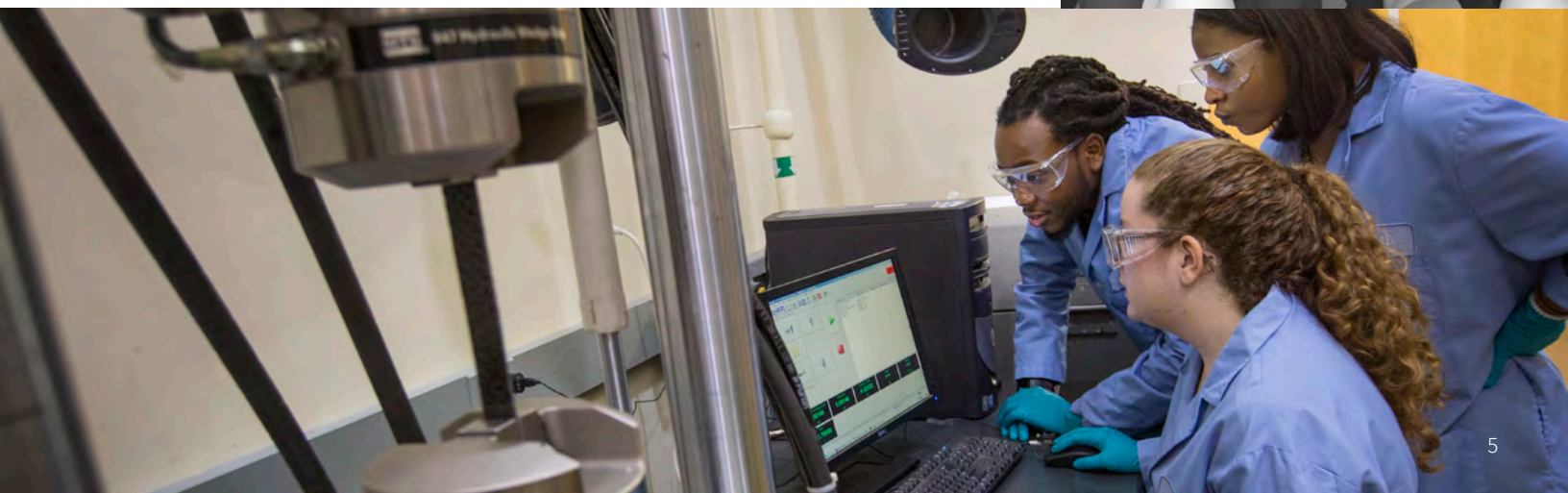
On the computational side, the team is using molecular-level composite design and simulation tools at various scales and structural levels. They are performing modeling and manufacturing simultaneously with testing of 12-inch square panels.

"We tested our first material prototype this winter and when we looked at the results we saw clear improvements over the state-of-the-art. In spring our second prototype showed a continued trend upward," he says. "Once we achieve the three times stronger, we will scale it up to confirm we are able to mass manufacture these materials, rapidly and economically."

But perhaps the biggest accomplishment with this project has been the collaboration. "We are creating a new paradigm of large-scale, public-private collaboration with a huge team of individuals modeling, synthesizing materials, manufacturing, and testing across universities," he says.

> *"This model of collaboration and this approach to making a quantum step forward are bearing fruit. No university could have achieved this alone; it is only through working together that our success has been possible."*

–Dr. Greg Odegard



RESEARCH AREAS

- **LOW MASS, LOW POWER, NON-MECHANICAL EXCAVATION OF GYPSUM AND OTHER EVAPORITES FOR WATER PRODUCTION ON MARS -** NASA
- **REDWATER: EXTRACTION OF WATER FROM MARS' ICE DEPOSITS -** NASA
- **MTU NODE OF CENTER FOR LUNAR AND ASTEROID SURFACE SCIENCE -** NASA

Mining Mars

DR. PAUL VAN SUSANTE
ASSISTANT PROFESSOR

Human trips to the moon or to Mars are on the horizon for space agencies; however, to achieve this goal, researchers like Dr. Paul van Susante are developing solutions for producing the propellant needed for return trips to Earth.

His team is exploring the extraction of water from hard-rock gypsum on Mars using a water jet system to break down the rock into a slurry of gypsum particles, which can be heated up to extract the water bound in the rock.

"Anything you can produce on Mars and do not have to bring from Earth, means you reduce the mass of the spacecraft, the complexity, and size," says van Susante. "Now instead of launching just liquid oxygen and hydrogen for propellant, we can launch useful payload."

As part of another closely related project, his team is developing and testing industrial robots that could perform excavation, resource extraction, and construction tasks under the extreme conditions of the lunar and Martian surface.

Van Susante will use a dusty thermal vacuum chamber on campus to mimic the conditions of the moon and Mars to stress the equipment and ensure durability and process feasibility.

"Once you create the rocket propellant, it changes the game in how to explore the rest of the solar system," he says. "You can get there faster, go when you want, and not be energy limited."

> *"These projects are helping humanity get back to the moon to establish a research base and do more than just mine oxygen and hydrogen, but to create and build things to explore beyond the moon."*

–Dr. Paul van Susante

AUTONOMOUS

Our research aids in the development of intelligent systems from wearable electronics to controls for robotics and engines, along with the cleaner power sources they require. With these technologies, our faculty advance communication and adaptation, better preparing for the fourth industrial revolution.

FACULTY INVOLVED

- DR. BO CHEN
- DR. JOHN JOHNSON
- DR. SEONG-YOUNG LEE
- DR. SCOTT MIERS
- DR. JEFF NABER
- DR. RUSH ROBINETT
- DR. DARRELL ROBINETTE
- DR. YE (SARAH) SUN
- DR. JASON YANG
- DR. GORDON PARKER*
- DR. WAYNE WEAVER*

*These faculty members are featured elsewhere in the Annual Report in a separate research area.

"Understanding connected vehicles and enhancing the technologies, while also improving electric vehicle infrastructure on smart grids has been an exciting part of the research project."

–Dr. Bo Chen

Controlling Complexity

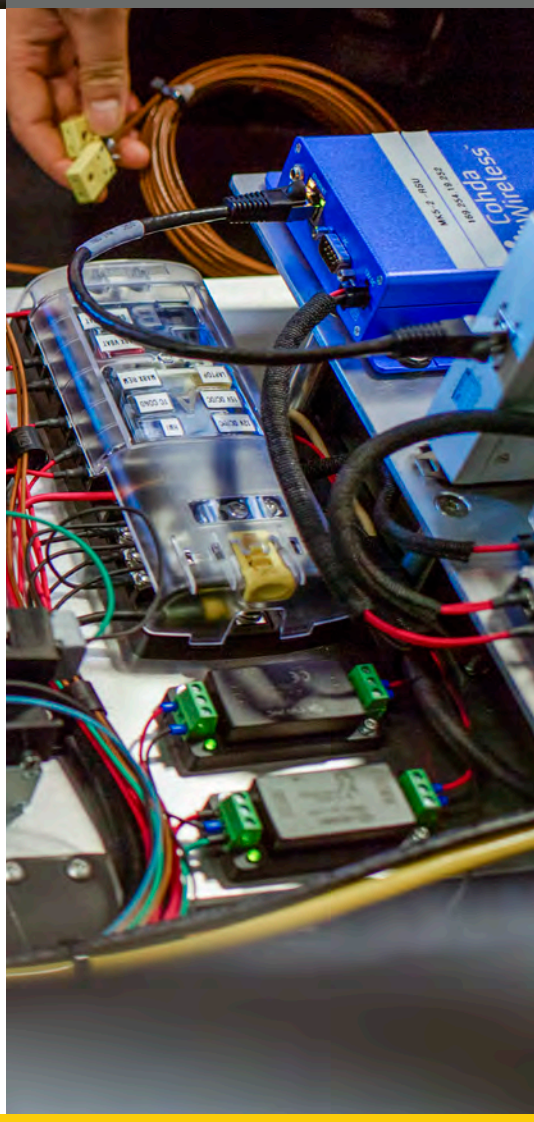
BO CHEN
DAVE HOUSE PROFESSOR
OF MECHANICAL &
ELECTRICAL ENGINEERING

Lane departure warnings. Regenerative braking. Navigation. As automotive autonomy takes small steps forward, Dr. Bo Chen is seizing the opportunity to advance model predictive controls to improve performance. Supporting the NEXTCAR project, she is focused on short term, real-time powertrain control and traffic conditioning.

"We are incorporating road grade changes and sensors to design a short-term vehicle velocity profile within the bounds of 10 to 30 seconds," says Chen. "For example, for a vehicle traveling at 25 mph and approaching a hill, we are adding features to efficiently prepare the vehicle for loading while also enhancing opportunities for regenerative braking."

Using the Gen II Chevy Volt and model parameters provided by GM, the research team is developing control performance and conducting on-vehicle testing in designing and optimizing the controls.

"We are also utilizing LIDAR and camera technologies to design control schemes for object avoidance and path planning. Then, in the design scenario, we are analyzing different weather conditions, roads, traffic lights, and vehicle to vehicle communication and incorporating that into Simulink to validate control algorithms," says Chen.



RESEARCH AREAS

- **NEXTCAR: CONNECTED AND AUTOMATED CONTROL FOR VEHICLE DYNAMICS AND POWERTRAIN OPERATION ON A LIGHT-DUTY MULTI-MODE HYBRID ELECTRIC VEHICLE -** Advanced Research Projects Agency – Energy (ARPA-E), US Department of Energy (DOE)
- **MODELING AND CONTROL DEVELOPMENT FOR ELECTRIC VEHICLE AND SMART GRID INTEGRATION -** Argonne National Laboratory
- **COMBUSTION SENSING AND CONTROL -** Ford Motor Company

Leading the Curve on Regulations

DR. JOHN JOHNSON
PRESIDENTIAL PROFESSOR EMERITUS

Research often leads to new research projects, which resulted from a Department of Energy funded study of aftertreatment system experimental and modeling research under the leadership of Dr. John Johnson.

The Diesel Engine Aftertreatment Consortium formed as a result of the study and is led by Johnson, along with Drs. Jeff Naber and Gordon Parker. The goal of the Consortium is to develop and conduct precompetitive research on advanced aftertreatment systems through experimental and modeling studies to stay ahead of the changing regulations for diesel engines and educate students moving into the field.

"We interact with industry on various research topics, developing and understanding complex models from both a chemical and thermal standpoint," says Johnson. "The industry is focused on controlling the nitrogen oxide emissions, following goals set by California and the EPA to reduce the current standard of 0.2 to 0.02 gram/bhp-hr."

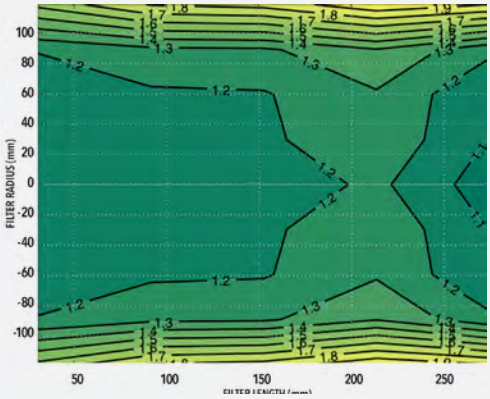
We focus research on diesel particulate filters that control both the particulate matter and the nitrogen oxides by coating the filter with a SCR catalyst. The complex models the students work on as part of the research gives them experience in understanding the reactions happening in the filter.

"To be effective in this industry, students need a broad understanding. As a result of our work with industry, we are not only producing a long list of publications, but are also producing students who go into the field with that broad knowledge base," says Johnson.

> *"I continue my involvement in graduate research because I enjoy staying up to date with the latest in engineering diesel engines, while also having the opportunity to mentor and develop the next generation of engineers."*
>
> –Dr. John Johnson

RESEARCH AREAS

- **DIESEL AFTERTREATMENT EXPERIMENTAL AND MODELING STUDIES**
- **DIESEL AFTERTREATMENT SYSTEM CONTROLS**
- **HEAVY DUTY VEHICLE TECHNOLOGIES FOR REDUCING FUEL CONSUMPTION**



Diesel particulate matter distribution in a selective catalytic reduction catalyst.

DIESEL CONSORTIUM

The Michigan Tech Diesel Engine Aftertreatment Consortium has been funded during the past six years by: Cummins, Isuzu, Deere, Daimler-Detroit, Johnson-Matthey, and Tenneco. Twelve students that carried out research in the Consortium have graduated and 28 theses and journal papers have been published.

Laser Focused

DR. SEONG-YOUNG LEE
PROFESSOR

We've all seen the result: a heavily loaded diesel emitting clouds of black soot. But few have seen the mysterious source of that smoke in the complex interactions of fuel spray on the cold wall of a cylinder or piston. Dr. Seong-Young Lee leads this research effort to improve spray-wall interactions and thereby reduce emissions.

Supported by a grant from the Department of Energy and through collaboration with Argonne National Lab and University of Massachusetts Dartmouth, Lee and his team are running computational fluid dynamic simulations and validating them using Michigan Tech's constant-volume combustion vessel.

"In addition to the simulation and the validation, we are also working from experimental data. The need to measure precisely in this scenario is challenging due to the large temperature gradient near the wall," says Lee. "We are developing a number of laser-based diagnostics, where we shine laser through the air-fuel mixture formed in the vicinity of the material and measure the laser scatter to gather optical values."

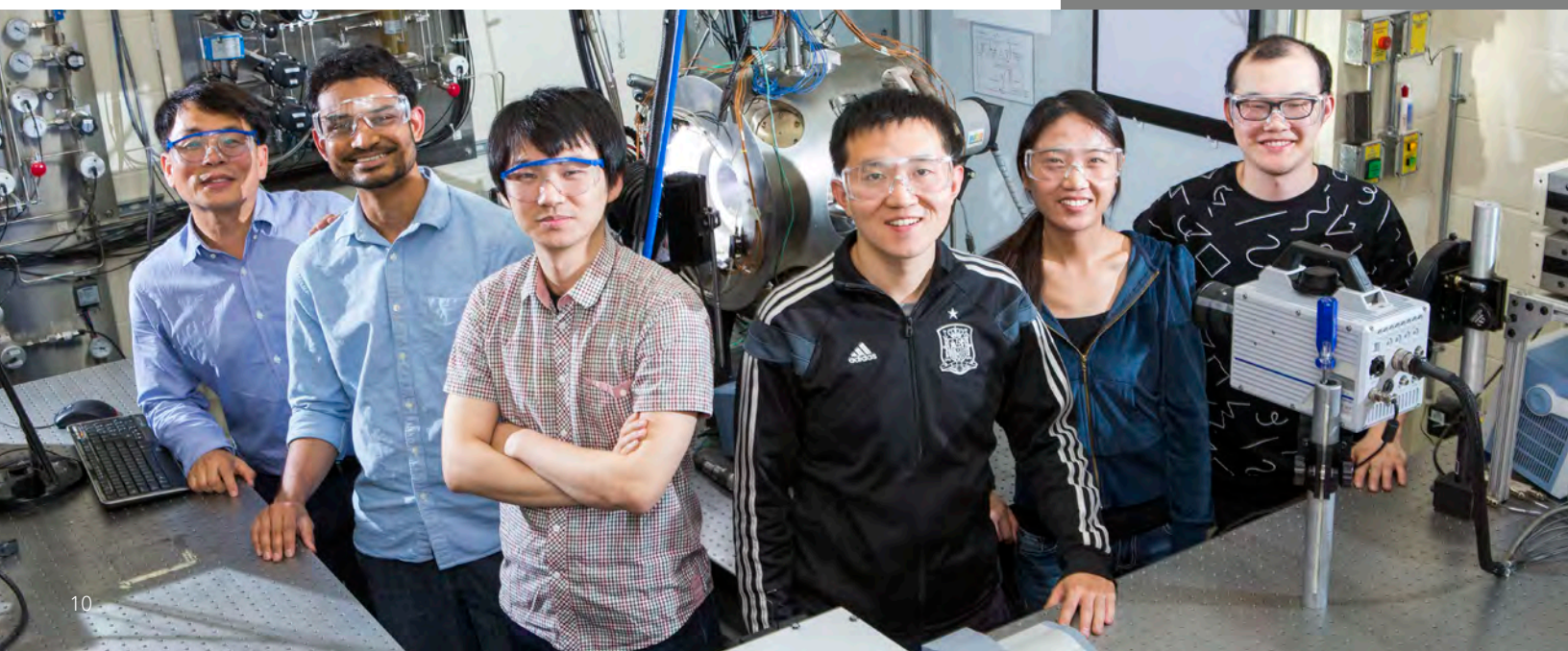
To capture the phenomenon, Lee employs a 1.1 liter optically-accessible, constant-volume combustion vessel. A high speed, high resolution camera captures the process frame-by-frame to examine the complete process, understand the extreme gradients, and identify major emission species and velocities.

In using the lasers, Lee hopes he and his team can understand reactions between the particles in the various combustion stages to identify process boundaries and optimize combustion performance.

RESEARCH AREAS

- **EVAPORATION SUB-MODEL DEVELOPMENT FOR VOLUME OF FLUID (EVOF) METHOD APPLICABLE TO SPRAY-WALL INTERACTION INCLUDING FILM CHARACTERISTICS WITH VALIDATION AT HIGH PRESSURE-TEMPERATURE CONDITIONS -** DOE
- **CO-OPTIMIZED SI-LTC-PPCI ENGINE SYSTEM DEMONSTRATOR TO IMPROVE FUEL ECONOMY WHILE MEETING LEVIII EMISSIONS -** Hyundai-Kia America Technical Center (HATCH) Inc. through DOE

> *"We understand that soot and emissions are formed through the spray-wall interaction on a cold start engine and hope that through this research we can minimize the soot and reduce emissions."*
>
> —Dr. Seong-Young Lee



Tracking Real-World Emissions

DR. SCOTT MIERS
ASSOCIATE PROFESSOR

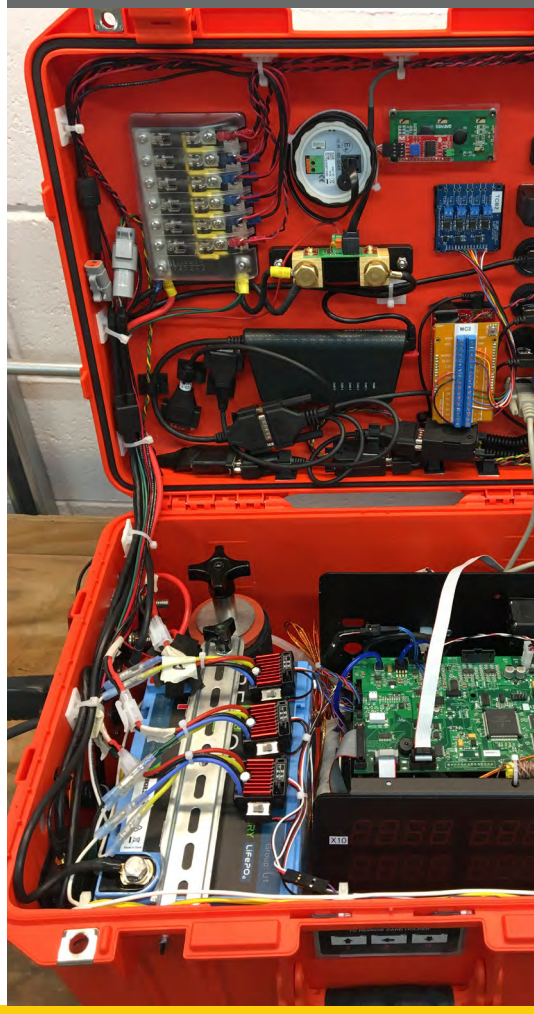
> *"This real-world driving emissions focus is pushing the market, but with this technology, small engine OEMs can accurately test their emissions."*
>
> –Dr. Scott Miers

Consumers and governing agencies are driving a change in emission tracking across the recreational vehicle markets. Dynamometers are heavily relied on for exhaust emissions certification testing in ATV, snowmobile, motorcycle, and marine applications; however, there is a trend toward measuring real-world, on-snow, on-dirt, on-water emissions. After initially helping develop a pull-behind emissions analyzer sleigh for the SAE Clean Snowmobile Challenge, Dr. Scott Miers and Senior Research Engineer Dr. Brian Eggart set out to find a lighter weight solution that reduced the impact on emissions, fuel consumption, and vehicle operation.

The Canadian Government funded his team to build an extremely lightweight, backpack-sized, mini-PEMs analyzer that minimizes the impact on vehicle operation. The primary constraint: the unit had to be less than 50 pounds, which includes the analyzer, data acquisition, case, and mount.

"We began the project this past winter and finished in April after developing a portable emissions analyzer that is only 35 pounds. We've measured real-world emissions with excellent transient response," says Miers. "The manufacturers have been amazed we pulled it off. We were all in unchartered territory. Through an iterative process, we made the timeline, tested on the snow, and our measurement accuracy was better than expected."

Using the lightweight analyzer, industry and regulators may now be able to measure real-world emissions with driving styles typical of consumers.



RESEARCH AREAS

- **CONVERSION OF A MICRO, GLOW-IGNITION, TWO-STROKE ENGINE FROM NITROMETHANE-METHANOL BLEND FUEL TO MILITARY JET PROPELLANT -** US Army Combat Capabilities Development Command (CCDC) Ground Vehicle Systems Center
- **THERMAL CHARACTERIZATION OF COMBUSTION CHAMBER COMPONENTS IN A GASOLINE TURBOCHARGED DIRECT INJECTION ENGINE -** DOE
- **IMPACT OF NATURAL GAS DIRECT INJECTION ON THERMAL EFFICIENCY IN A SPARK IGNITION ENGINE -** Argonne National Laboratory
- **DEVELOPMENT OF A TURBULENT FLAME SPEED MODEL BASED ON FLAME STRETCH CONCEPT FOR SPARK IGNITION (GTDI) ENGINES -** Internally funded (MEEM TA)
- **EFFECT OF SPARK ADVANCE AND FUEL ON KNOCKING TENDENCY OF SPARK IGNITED ENGINE -** Internally funded

Driving with Data

DR. JEFF NABER
RICHARD & ELIZABETH HENES
PROFESSOR OF ENERGY SYSTEMS

> *"This is a major step toward intelligent mobility with a number of direct connections to our educational programs including enhancing the HEV and Automotive Systems certificates as a result of this project."*
>
> –Dr. Jeff Naber

Traffic density, driver behavior, and climate all play a role in energy consumption. Dr. Jeff Naber and his team are analyzing these factors and modifying vehicle controls to achieve a 20 percent reduction in energy consumption in light-duty hybrid electric vehicles. Through a $3.5 million research project funded by the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E), the team is in their final year of the three year program.

"We are in the final phase focused on validation and verification in demonstrating the requirements have been met," says Naber. "The real-world driving scenarios we are analyzing will be tested and optimized for single vehicles, as well as in our fleet of eight Gen II Chevy Volts to showcase our vehicle-to-vehicle computing capabilities."

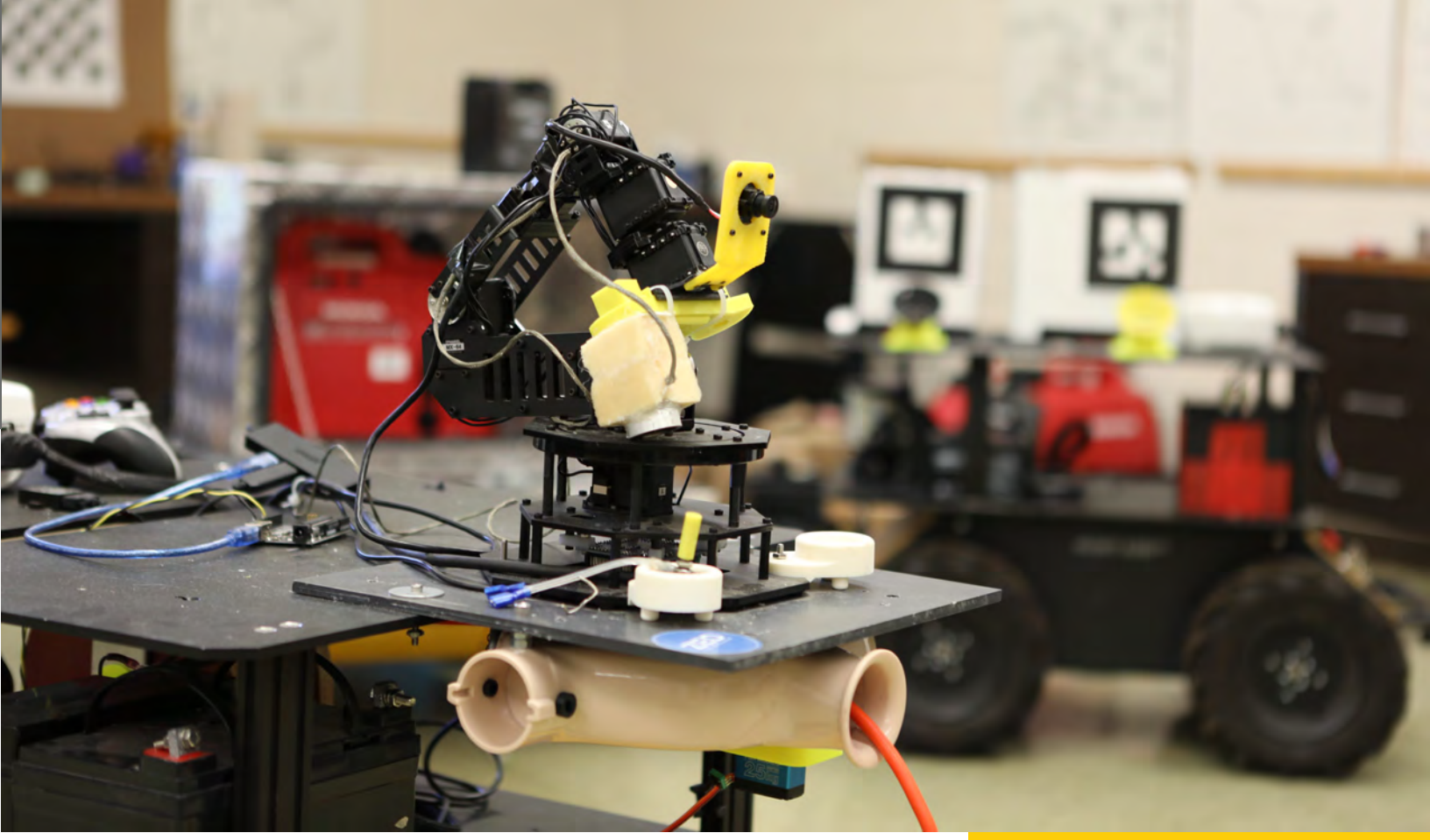
In order to monitor vehicle performance, the team is continuously streaming terabytes of data that must be interpreted. "Our work relies on receiving data about the vehicle, location mapping, and real-time traffic information to enhance controls," says Naber.

Using the fleet of vehicles from industry partner, General Motors, the team runs a 24-mile loop that incorporates city, highway, urban, rural, and elevation changes to conduct maneuvers in specific scenarios to validate overall reduction in energy consumption.

As the lead on the project, Naber focuses on integrating all facets of the research from Michigan Tech faculty and staff including Dr. Darrell Robinette, Dr. Bo Chen, Dr. Mahdi Shahbakhti, Mr. Chris Morgan, and Dr. Kuilin Zhang (CEE).

RESEARCH AREAS

- **HEAVY DUTY ADVANCED AFTERTREATMENT CONSORTIUM -** Michigan Tech & industry partners
- **LIGHT DUTY ADVANCED ENGINE CONSORTIUM -** Michigan Tech & industry partners
- **ENGINE AND CONTROL IGNITION RESEARCH -** Ford
- **HIGH PERFORMANCE, HIGH EFFICIENCY ENGINES VIA WATER INJECTION -** Nostrum Energy
- **HIGH BMEP AND HIGH EFFICIENCY MICRO-PILOT IGNITION NATURAL GAS ENGINE -** DOE
- **A COMPRESSION-IGNITION MONO-FUELED NATURAL GAS HIGH-EFFICIENCY, HIGH-OUTPUT ENGINE FOR MEDIUM AND HEAVY-DUTY APPLICATIONS -** DOE
- **CO-OPTIMIZED MIXED-MODE ENGINE AND FUEL DEMONSTRATOR FOR IMPROVED FUEL ECONOMY WHILE MEETING EMISSIONS REQUIREMENTS -** Hyundi Motor Group



Logical Control

DR. RUSH ROBINETT
RESEARCH PROFESSOR

As technology advances, researchers and businesses look to robot swarms as a solution to a wide range of challenges. Dr. Rush Robinett is working with a team of researchers at Michigan Tech to develop microgrid power hardware on mobile robotics and to enable effective communications.

"In the past, it was believed that centralized control of the robot should outperform decentralized control, but as we grow our knowledge of robotics, we are finding that connections don't grow linearly and choke points are created in centralized protocol," says Robinett. "With decentralized control, robots are able to self-select their task or behavior and optimize their energy expenditure."

Using decentralized control logic on robots to solve the microgrid problem is a novel approach that seeks the most effective route for establishing a microgrid in scenarios of disaster relief and forward operating bases.

"The robots are helping to find paths to reroute power systems and to locate cell towers that are still intact. They'll identify pathways in for Marines to put up a tent and provide equipment necessary for a forward operating base," says Robinett.

The group is looking for opportunities to incorporate air assets to surveil an area struck by disaster and hope to use ground assets to recharge the aerial vehicles and share information on path planning.

RESEARCH AREAS

- **POWER/ENERGY PACKET CONTROL FOR EMP-RESILIENT POWER SYSTEMS -** Sandia
- **ADVANCED COOPERATIVE CONTROL FOR HIGH-EFFICIENCY WIND TURBINE FARMS -** Sandia

> *"I find this project to be an exciting demonstration that simplistic, insightful theory can be demonstrated in hardware in a quick and effective manner."*
>
> –Dr. Rush Robinett

Challenging Enterprise

DR. DARRELL ROBINETTE
ASSISTANT PROFESSOR

The automotive and mobility sector is undergoing a monumental transformation unlike that seen in the previous 100 years. Transformation in the education and training of engineers entering the field for product design and safety robustness is necessary. Drs. Darrell Robinette and Jeremy Bos are committed to preparing engineers and computer scientists for the challenges of enhancing autonomous mobility through participation in the AutoDrive Challenge, sponsored by General Motors and the Society of Automotive Engineers (SAE).

Through the competition, undergraduate and graduate students will outfit a Chevy Bolt EV with sensors, controls, and platforms to perform at an SAE level four of autonomy by the end of the three year competition.

"This student design competition functions across department boundaries, involving mechanical, electrical, computer engineering, and computer science," says Robinette. "It's a hands-on project whose focus is not on traditional vehicle fabrication and performance, but rather on the integration of a broad range of sensor systems fused to perceive real world driving scenarios and coupled to vehicle dynamic controls for robust and safe autonomous operation."

In the final year of the competition, the team will continue to integrate sensor systems and refine controls, adding new autonomous features, while optimizing for object detection and avoidance in autonomous mode in an urban driving course with a safety driver present to intervene as necessary.

"The AutoDrive challenge equips student engineers with skill sets that are highly relevant to the auto industry. It enhances autonomous educational opportunities, while maturing top talent to recruit," says Robinette.

RESEARCH AREAS

- **TORQUE CONVERTER TESTING -** Ford
- **TORQUE CONVERTER CFD -** Ford
- **DRIVETRAIN DYNAMICS -** Ford
- **TORQUE CONVERTER DYNAMICS -** GM
- **TRANSMISSION SYNTHESIS -** GM
- **NEXTCAR CONNECTED AUTOMATED VEHICLE (CAV) -** ARPA-E DOE; Partner: GM
- **AUTODRIVE CHALLENGE -** SAE, GM

> *"With LiDAR's, RADAR's and cameras on board, our graduate engineering students explore structured environments but also the ice and snow of unstructured environments, building an understanding of the problem, so we can develop a feasible solution."*
>
> –Dr. Darrell Robinette

Sewing & Sensing

DR. YE (SARAH) SUN
ASSISTANT PROFESSOR

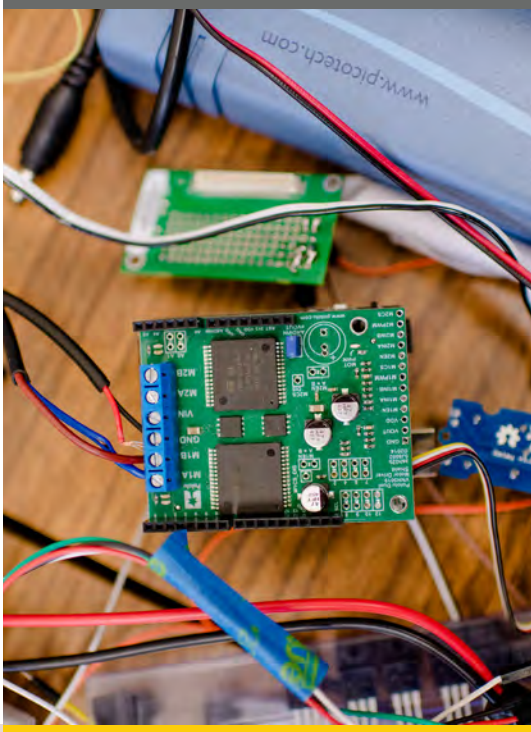
Health data tracking devices are appearing all around us—in our phones, on our wrists, and as heart monitors; however, many have drawbacks in detection and comfort. Through a CAREER award from the National Science Foundation, Dr. Ye Sun is designing cloud-based, wearable technology for health and human behavior monitoring.

"As a PhD student, I was focused on sensor networks for driver monitoring and the echocardiogram monitoring in wearable devices. We were finding that the circuits would suddenly stop working without reason, often due to the supporting fabrics," says Sun. "As a result, I started to study the fibers and found that I could convert fabrics into sensors and turn the problem into the solution."

Using her novel approach, Sun has developed an embroidered wearable electronic monitoring solution. She leverages her background in electrical engineering with her experience in mechanical and coding to design the circuit and the sensors that are embroidered directly into the fabrics. She hopes to further the technology by incorporating cloud-based manufacturing.

"Using our cloud-based manufacturing website, a user can upload their circuit design to generate an industry-standard stitched embroidery file that is recognized by an embroidery company's machine to sew in the sensor and realize the dream," says Sun.

> *"This technology has a lot of applications from monitoring driver awareness in autonomous vehicle scenarios, to health monitoring either remotely or within a hospital setting, and in mines to track situational awareness."*
>
> –Dr. Ye (Sarah) Sun



RESEARCH AREAS

- **UNDERSTANDING AND MITIGATING TRIBOELECTRIC ARTIFACTS IN WEARABLE ELECTRONICS BY SYNERGIC APPROACHES -** National Science Foundation (NSF)
- **CAREER: SYSTEM-ON-CLOTH: A CLOUD MANUFACTURING FRAMEWORK FOR EMBROIDERED WEARABLE ELECTRONICS -** NSF

Finding Flow

DR. JASON YANG
PROFESSOR

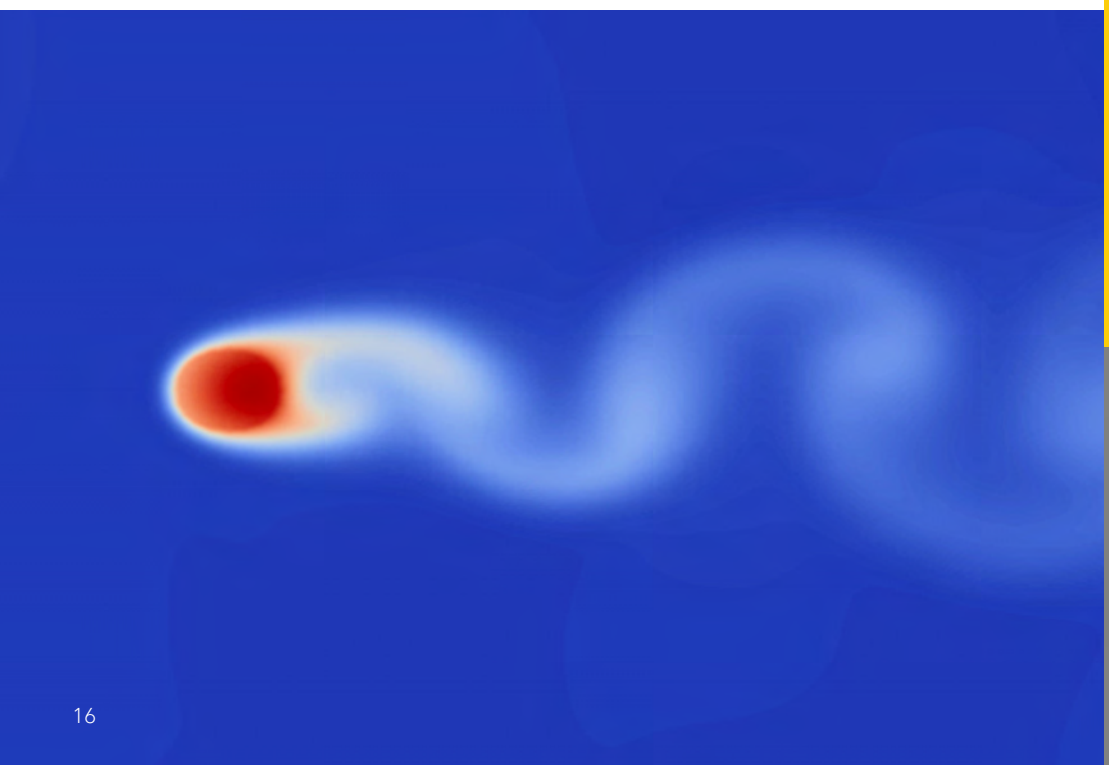
Turbulence flow has traditionally been expensive to model, as it fluctuates quickly and has a short timescale. This flow is described by eddy size with the smallest eddies closest to the wall, but the spatial resolution required to achieve this large eddy modeling of turbulence flow is a hindrance. Dr. Jason Yang has found that he can capture both effects by applying the principles of the lattice Boltzmann method, where you start at the molecular level and work up, in contrast to conventional approaches.

"We are able to solve the large eddy directly while modeling smaller eddies using a semi-empirical method," says Yang. "We work our way upward for numerical simulation to determine turbulence flow."

The large eddy simulation using the lattice Boltzmann method can be applied to internal or external flow of a vehicle and can be used to determine drag for a given geometry or air flow to find lift and drag for aerospace applications. Eventually, he hopes to apply his work to high speed flows—supersonic or hypersonic.

"If we find that the lattice Boltzmann method isn't suitable for this type of high speed flow, then we'll use an approach called Gas Kinetic Scheme," says Yang.

Having worked on complex and novel approaches in the past, Yang thrives in his work on theoretical applications, focusing on fluid mechanics, combustion, and heat transfer.



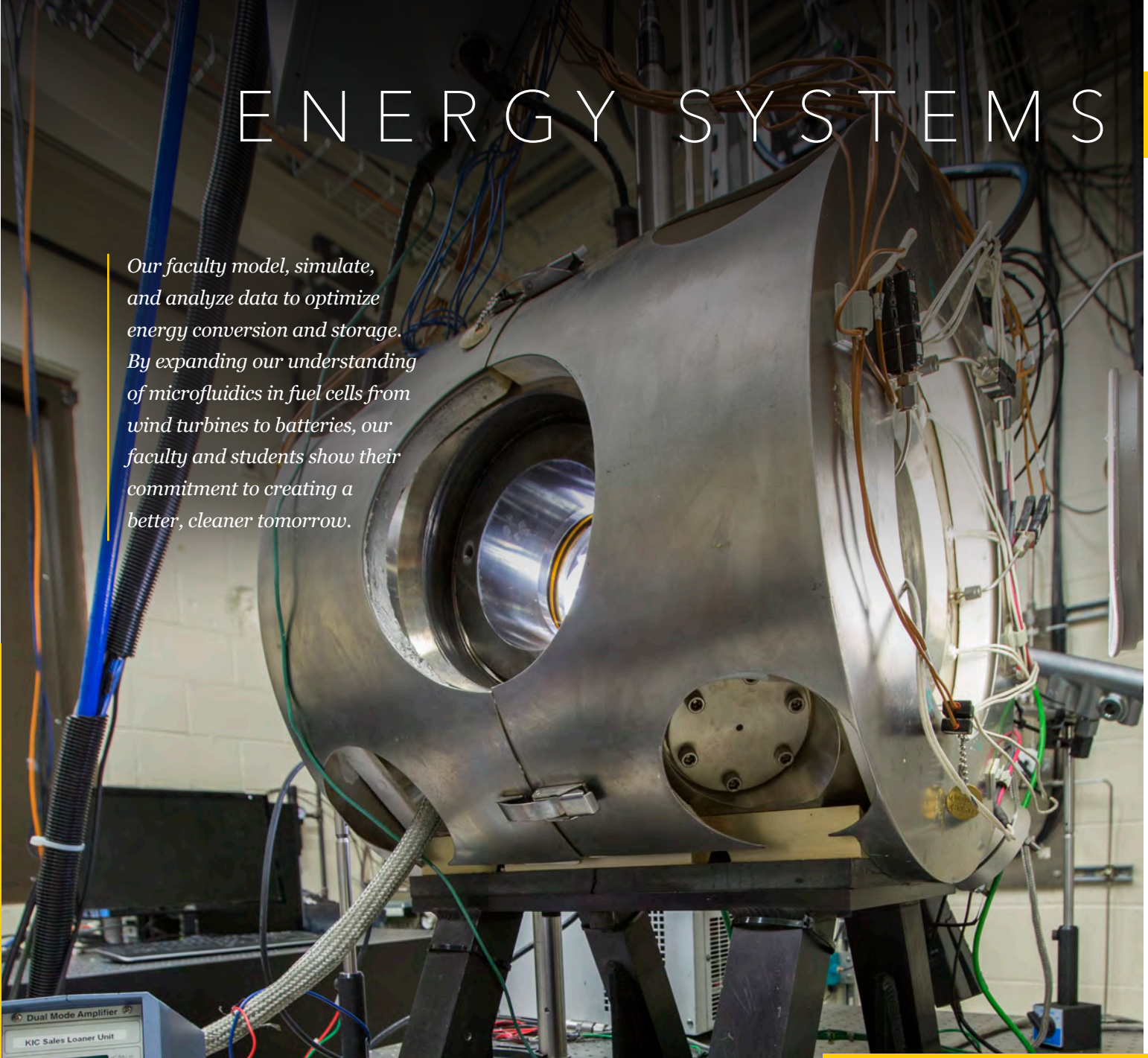
RESEARCH AREAS

- **COMPUTATIONAL FLUID DYNAMICS (CFD)**
- **MODELING AND NUMERICAL SIMULATION OF DIESEL PARTICULATE TRAP (DPF) PERFORMANCE DURING LOADING AND REGENERATION**
- **DIESEL OXIDATION CATALYST (DOC) CONVERTER CODE DEVELOPMENT**
- **LATTICE BOLTZMANN METHOD FOR POROUS/ DISORDERED MEDIA**

> *"This is research at the fundamental level. I enjoy solving the challenges of the theoretical side before taking on the numerical methods."*
>
> —Dr. Jason Yang

ENERGY SYSTEMS

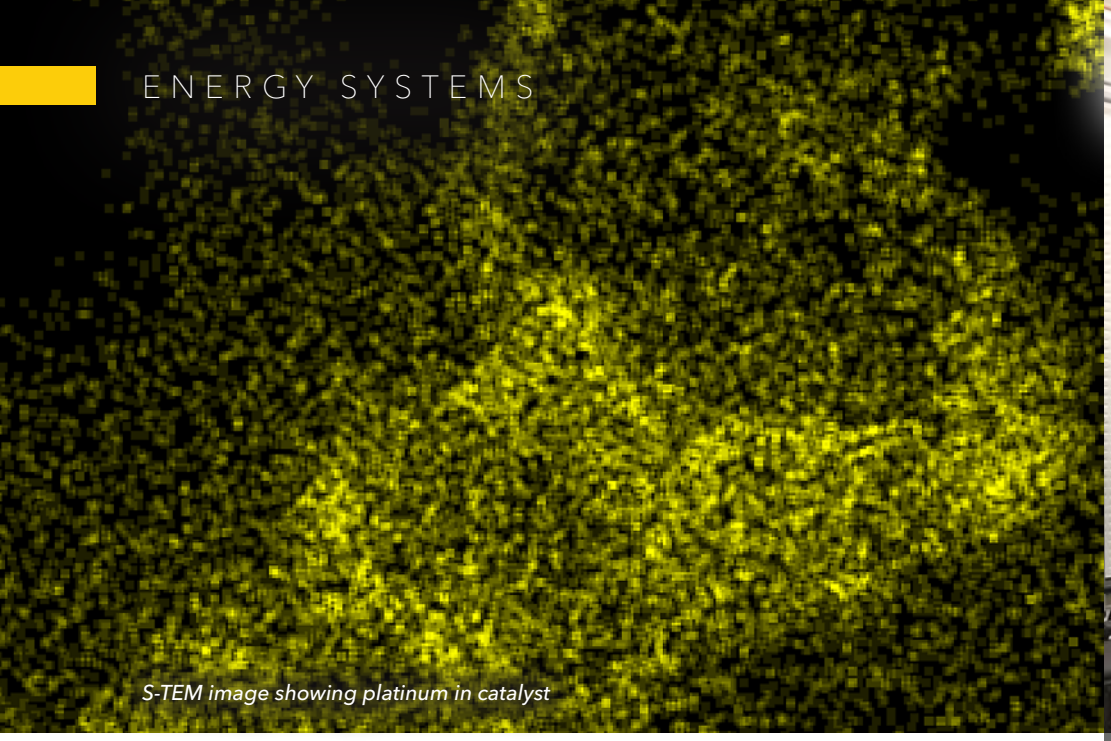
Our faculty model, simulate, and analyze data to optimize energy conversion and storage. By expanding our understanding of microfluidics in fuel cells from wind turbines to batteries, our faculty and students show their commitment to creating a better, cleaner tomorrow.



FACULTY INVOLVED

- DR. JEFF ALLEN
- DR. EZRA BAR-ZIV
- DR. SAJJAD BIGHAM
- DR. HASSAN MASOUD
- DR. EZEQUIEL MEDICI
- DR. AMITABH NARAIN
- DR. FERNANDO PONTA
- DR. YOUNGCHUL RA
- DR. MAHDI SHAHBAKHTI
- DR. KAZUYA TAJIRI
- DR. CK CHOI*
- DR. LUCIA GAUCHIA*

*These faculty members are featured elsewhere in the Annual Report in a separate research area.



S-TEM image showing platinum in catalyst

Michigan Tech's FEI 200kV Titan Themis S-TEM microscope

Catalytic Changes

DR. JEFFREY ALLEN
JOHN F. & JOAN M. CALDER PROFESSOR IN MECHANICAL ENGINEERING

Fuel cell technology has been developed to be both efficient and reliable; however, it remains an expensive solution due to durability and manufacturability of the catalysts. Dr. Jeffrey Allen, through a joint project with the Department of Energy and 3M, is improving the nanoscale level design of the fuel cell materials without introducing performance loss.

"Through the project, we are creating mathematical models, and experimentally testing these models to understand how water behaves in automotive fuel cells," says Allen.

Allen's team is creating networks for each transport mechanism: heat, oxygen, water vapor, liquid water, protons, and electrons. This includes a network for the pore phase of reactants and liquid water, a network for the polymeric ionomer consisting of protons and water, a network for the solid phase made up of heat and electrons, and a network for the catalyst phase where the chemical reactions occur.

"With the analog network, we are able to put in a distribution of parameters that is representative of the things that would vary," says Allen. "Our net of resistances is mapped and we can see conductivity and distribution based on an abstract representation of geometry."

Through the improved nanoscale design, they will convey the liquid water away from the active area, while maintaining networks required for the oxidation reaction and electrical current generation to take place. By capturing the spatial dependencies in the process, the system will preserve performance and enhance system-level durability.

> *"Through the network analogy, we create possible solution paths. Once we understand how complex reactions and materials interact, we can begin to tailor materials and manufacturing methods to optimize battery and fuel cell electrodes for each application."*
>
> –Dr. Jeffrey Allen

RESEARCH AREAS

- **TESTING THE EQUIVALENCE OF EVAPORATION AND CONDENSATION COEFFICIENTS USING THE CONSTRAINED VAPOR BUBBLE DATA FROM ISS EXPERIMENTS** – NASA
- **LOW MASS, LOW POWER, NON-MECHANICAL EXCAVATION OF GYPSUM AND OTHER EVAPORITES FOR WATER PRODUCTION ON MARS** – NASA
- **NOVEL IONOMERS AND ELECTRODE STRUCTURES FOR IMPROVED PEMFC ELECTRODE PERFORMANCE AT LOW PGM LOADINGS** – DOE & 3M

Fuel Not Wasted

DR. EZRA BAR-ZIV
PROFESSOR

After finding that plant-based biomass was cost prohibitive as a clean replacement for coal in the power generation industry, Dr. Ezra Bar-Ziv and his team set to work finding industry-supported solutions for power sources.

"Instead of plant biomass, we decided to use municipal solid waste that the consumer, industry, or households are paying to get rid of," says Bar-Ziv. "With this transition, we were able to go from a feedstock for which we paid $120 per ton to one we are paid to use. We changed the business model."

Working with the state of Michigan, the Department of Energy, and the National Science Foundation, they retrofitted the biomass testing facility infrastructure, enhanced it to work with municipal waste, and are in the final stages of testing and proving the product as a solid fuel with a future goal to produce liquid fuels.

"Twelve months from now, we will know whether or not the fuel that we produce in massive quantities is suitable for industrial applications," says Bar-Ziv. "We are ironing out all of the technological adaptations with the goal of our product being used as a drop-in fuel requiring no changes to industry's existing systems."

Already working with industrial consumers, the team hopes to commercialize the technology with coal-powered facilities in the near future and to continue to shift the trend as a sustainable society via zero solid waste.

RESEARCH AREAS

- **PROOF-OF-CONCEPT AND A PROTOTYPE OF AN INTEGRATED TORREFACTION-EXTRUSION UNIT FOR ORGANIC WASTES STREAMS -** NSF-Partnership for Innovation
- **INDUSTRIAL INTERNSHIP IN WASTE MANAGEMENT AND WASTE TO ENERGY -** NSF-INTERN
- **TORREFACTION OF SORTED MSW PELLETS FOR UNIFORM BIOPOWER FEEDSTOCK –** DOE-L045-Advances in Biomass & MSW Torrefaction
- **CHLORINE REMOVAL FROM PLASTIC WASTES -** MEDC-MTRAC-BioAg

> *"It has been rewarding to see states change their classification of municipal solid waste from burning trash to now viewing it as an energy production process."*
>
> –Dr. Ezra Bar-Ziv

Printing For Extremes

DR. SAJJAD BIGHAM
ASSISTANT PROFESSOR

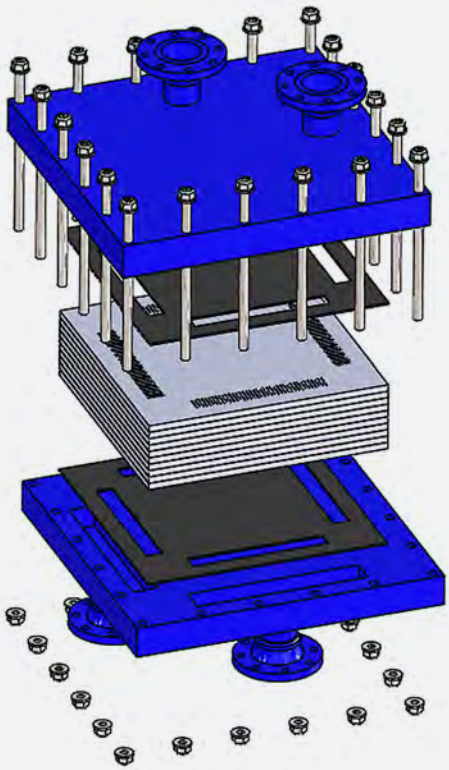
Additive manufacturing continually pushes the boundaries for what is possible. Dr. Sajjad Bigham, through a grant from the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E), is challenging the limits of an additive manufacturing process to 3D-print a monolithic sintered silicon carbide (SSiC) heat exchanger that can sustain high temperatures and high pressures (HTHP).

"We are using advanced ceramic-based 3D printing technology to develop next-generation light, low-cost, ultra-compact, HTHP heat exchangers to operate at temperatures above 1100°C and pressures above 80 bar," says Bigham. "Today's technologies cannot produce the monolithic SSiC material required for HTHP recuperators."

The harsh atmosphere of aero gas-turbine engines creates a daunting operating condition under extreme temperatures and pressures and a highly corrosive oxidizing environment. The team—that stretches across academia and industry, including a national lab—will focus on thermodynamics and heat transfer, ceramic 3D printing, corrosion, and extensive testing.

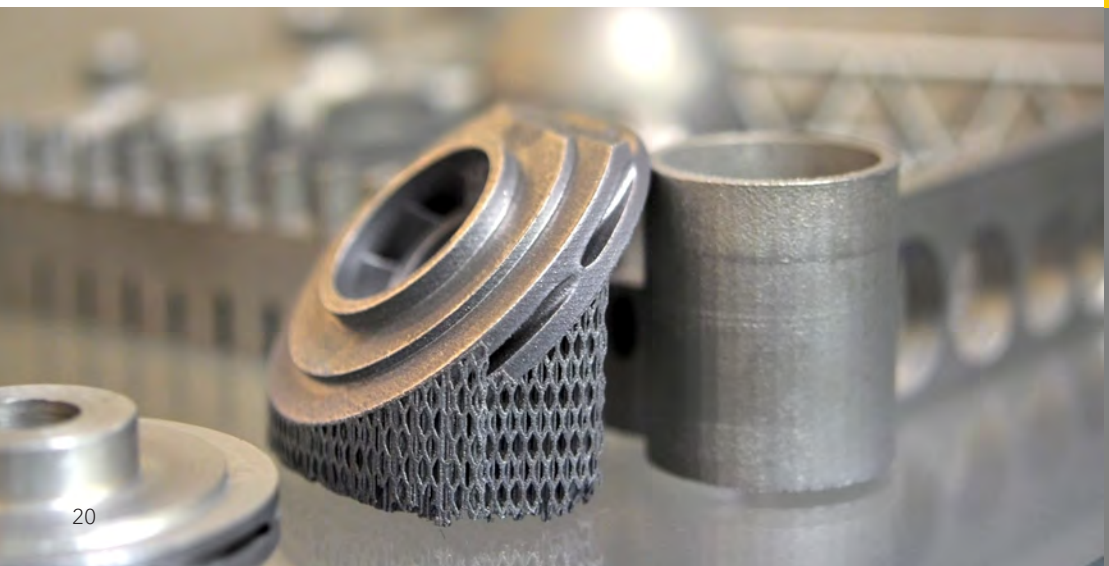
"We will work together to design features, modules, and consider materials. This scientifically challenging problem, if successful, will represent a leap beyond today's technology in reducing the risk of thermo-mechanical failure and ensuring heat exchange durability and quality," he says.

Being a high-risk, high-reward technology, the project represents an ambitious step forward. Bigham excitedly looks onward to collaborating with his diverse team toward a clear goal of commercialization as the project closes out in three years.

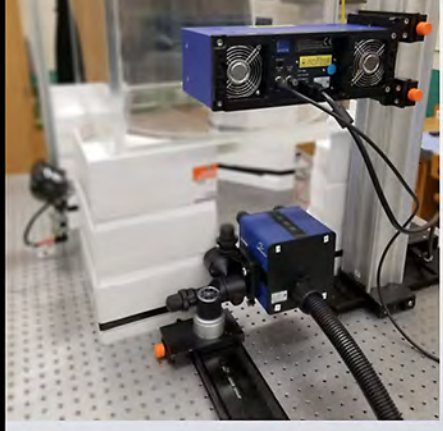


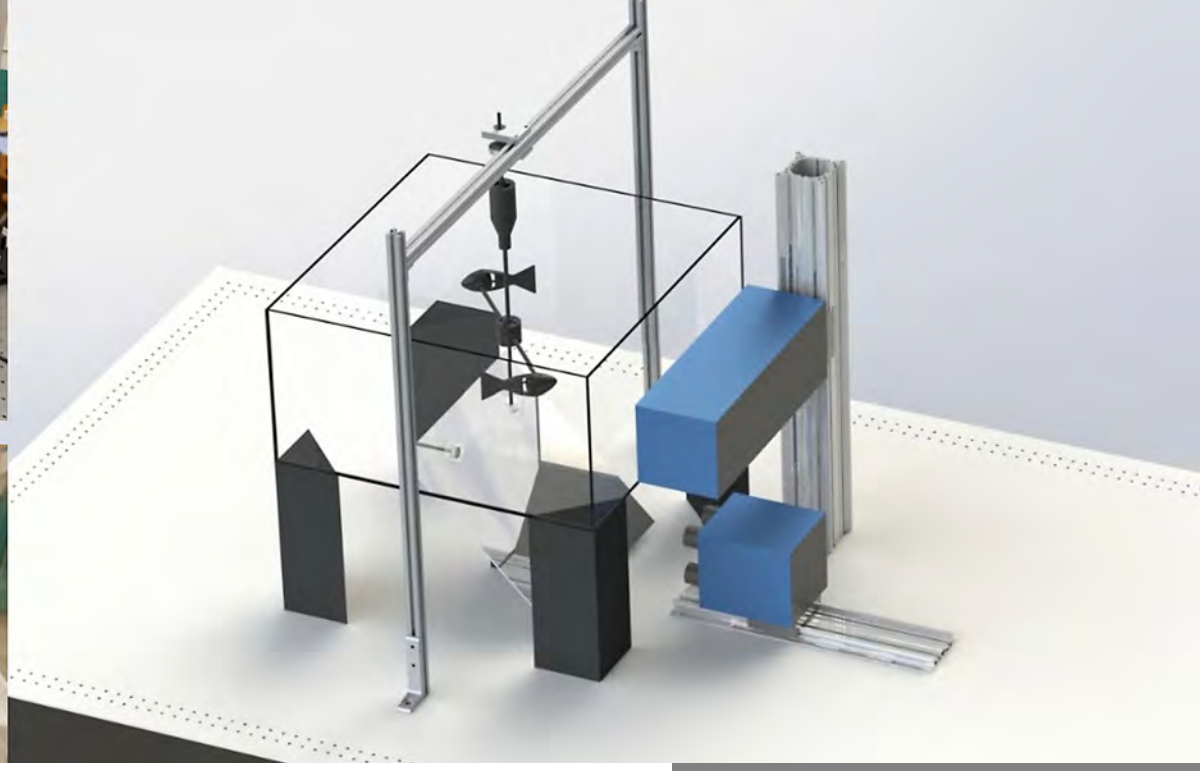
OTHER RESEARCH AREAS

- **NEXT-GENERATION GAS DRIVEN EQUIPMENT -** DOE, ORNL, & Samsung Electronics America
- **HIGH-EFFICIENCY A/C SYSTEM FOR FUTURE EVS AND AVS -** Ford Motor Company



> *"This project will develop HTHP heat exchangers that could reduce energy consumption, system footprint, and emissions in a variety of applications, including electricity generation, nuclear reactors, transportation, and many more."*
>
> –Dr. Sajjad Bigham





With the Flow

DR. HASSAN MASOUD
ASSISTANT PROFESSOR

As wind energy farms and wave energy converters continue to come online, it becomes increasingly important to understand how to maximize energy harvesting opportunities through optimization. To achieve peak performance, Dr. Hassan Masoud is using deep theory, computer simulations, and experimentation to build an understanding of the interaction of fluid flows with dynamic boundaries.

"In fluid flows with dynamic boundaries, the solid surface is also in motion, so we must understand the coupling between the kinematics of the object and the dynamics of the flow," says Masoud, who has studied, among other problems, the aerodynamics of insects' flexible flapping wings. "Insects' wings oscillate up and down through a series of pitching and plunging motions, where lift and thrust is generated. We found that everything is coupled in this problem in that the shape of the wings are determined by the fluid forces which are themselves controlled by the form and motion of the wings."

Using experimental flow visualization and computational fluid dynamics, Masoud is also studying the interaction of robotic fish in a school.

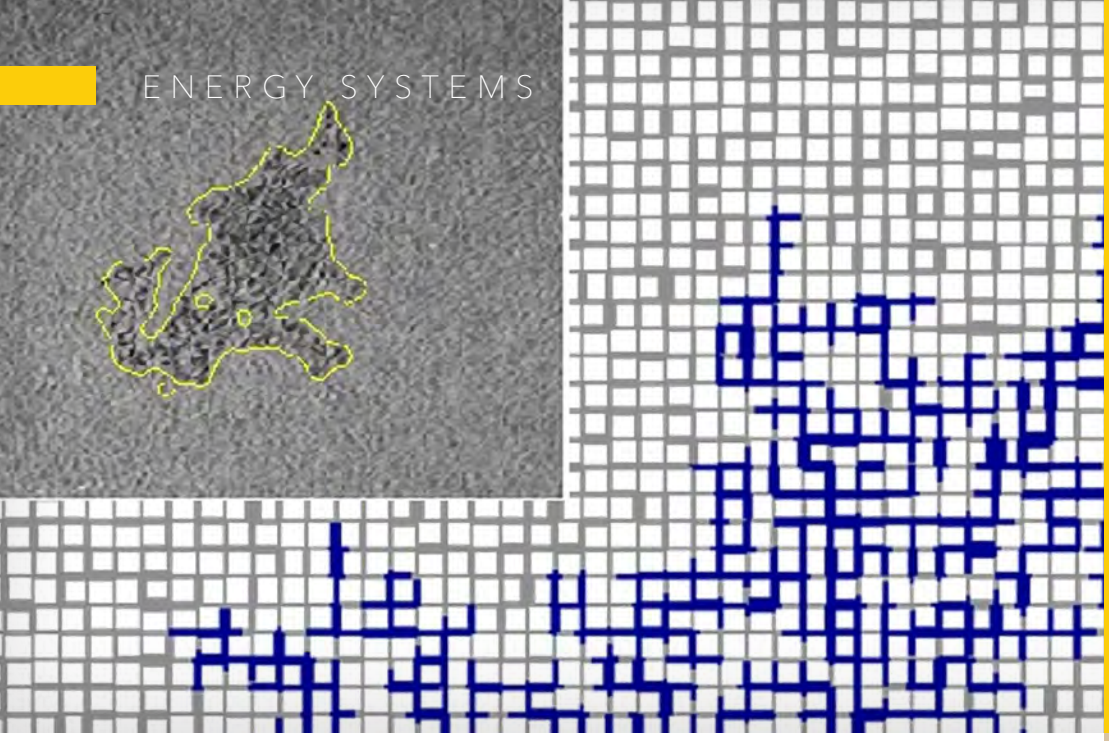
"We seek to find out how the swimming speed of individual fish comes out of their interactions with the immersing fluid and with the neighboring fish in the array," says Masoud.

The schooling behaviors can be considered as an example of multibody fluid-structure interaction. Surprisingly this is essentially the case for arrays of wind turbines and wave energy converters—all of them are focused on extracting maximum energy from their interactions with the surrounding fluid.

> *"Our goal is to integrate the acquired fundamental understanding of fluid flows and dynamically changing boundaries with engineering ideas to address outstanding technological and societal problems."*
>
> —Dr. Hassan Masoud

RESEARCH AREAS

- **INDIVIDUAL AND GROUP DYNAMICS OF MARANGONI SURFERS -** NSF
- **COLLECTIVE HYDRODYNAMICS OF ROBOT FISH -** Michigan Tech
- **PERFORMANCE OPTIMIZATION OF WAVE ENERGY CONVERTERS ARRAYS -** Michigan Tech



RESEARCH AREAS

- **LOW MASS, LOW POWER, NON-MECHANICAL EXCAVATION OF GYPSUM AND OTHER EVAPORITES FOR WATER PRODUCTION ON MARS -** NASA
- **NOVEL IONOMERS AND ELECTRODE STRUCTURES FOR IMPROVED PEMFC ELECTRODE PERFORMANCE AT LOW PGM LOADINGS -** DOE

Chasing Water

DR. EZEQUIEL MEDICI
RESEARCH ASSISTANT PROFESSOR

Validation of predictions by experimentation is critical when working at the micro- and nanoscales. Modeling and simulation techniques are used by Dr. Ezequiel Medici to build an understanding of the way mass and energy move through porous materials from the liquid water state to the heat transfer state.

"I have developed an advanced simulation tool that works in MATLAB that includes all transfer phases and works on small-scale simulation, which is highly detailed and requires a unique set of physics," says Medici. "As part of the work, we've collaborated with several universities and national laboratories, who conduct the large scale modeling with our detailed analysis as an input."

With a focus on fuel cells, he is simulating a combination of oxygen and fuel moving across and through a porous media object, such as a catalyst, that undergoes a surface reaction, creating heat and electric current. This requires simulating the motion of the electrons, liquids, gases, and protons.

"The heart of this work is understanding the exchange of mass and energy at the microscale to explicitly describe and simulate those behaviors," says Medici.

Currently working with funding from the Department of Energy and NASA, he hopes to move his model to other porous materials applications, such as absorbent materials.

"It's fascinating to study the micro- and nanoscale physics that you cannot normally see, but can indirectly observe. When we get the physics and modeling right, our predictions can be validated through experimentation and it's very rewarding."

–Dr. Ezequiel Medici

Bubbling & Boiling to Cool

DR. AMITABH NARAIN
PROFESSOR

Big data and the development of the Internet of Things (IoT) have increased the importance of high power density servers and large data centers around the world. These facilities require high power density chip cooling and generate large amounts of waste heat as a result. Dr. Amitabh Narain is utilizing his work on flow boiling to improve heat sink performance while creating a new generation of server and data center cooling approaches.

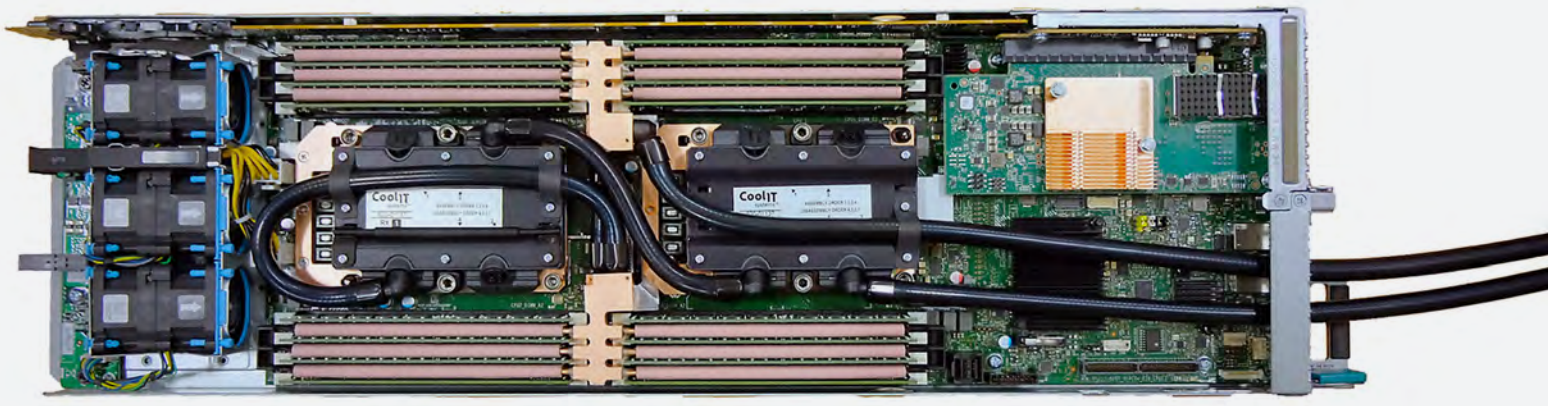
Explosive growth in microscale nucleation rates during flow-boiling of an environment-and-electronics friendly liquid leads to high power density cooling through proposed new heat sinks. With the use of inexpensive meshed-copper for micro-structuring of the boiling surface and in-plane acoustic vibrations from a pair of Piezoelectric-transducers, micro-bubbles are generated and dislodged—driven by a resonance approach from the Piezo-controller.

"The vapor created as a result of the process can be pulled out of the data center racks, condensed, and the low grade waste heat can be recycled and used to generate electricity with the help of higher grade waste heat available from a co-located mini power plant for the data center. Through the use of new heat sink technologies, chips can have higher power density and we can allow more servers in a rack," says Narain.

> *"There is opportunity in recovering the waste heat and converting it to electricity in these facilities, further promoting clean energy and greening of the environment."*
>
> –Dr. Amitabh Narain

RESEARCH AREAS

- **FUNDAMENTAL INVESTIGATIONS FOR VERY HIGH HEAT-FLUX INNOVATIVE OPERATIONS OF MILLI-METER SCALE FLOW BOILERS -** NSF
- **PIEZOS-ENHANCED FLOW-BOILING (PIEZO TRANSDUCER) -** Support from Ahem Group: Ahem Rentals, Ahem Energy LLC



Sample picture of an existing water-cooling technology at server level. Picture shows deployment of two multi-channel water-cooling heat-sinks (with CoolIT logos) that are deployed over Chips. Photo: https://www.coolitsystems.com/coolit-systems-announces-liquid-cooled-intel-buchanan-pass-server/dscf0697/.

Big Turbines, Big Data

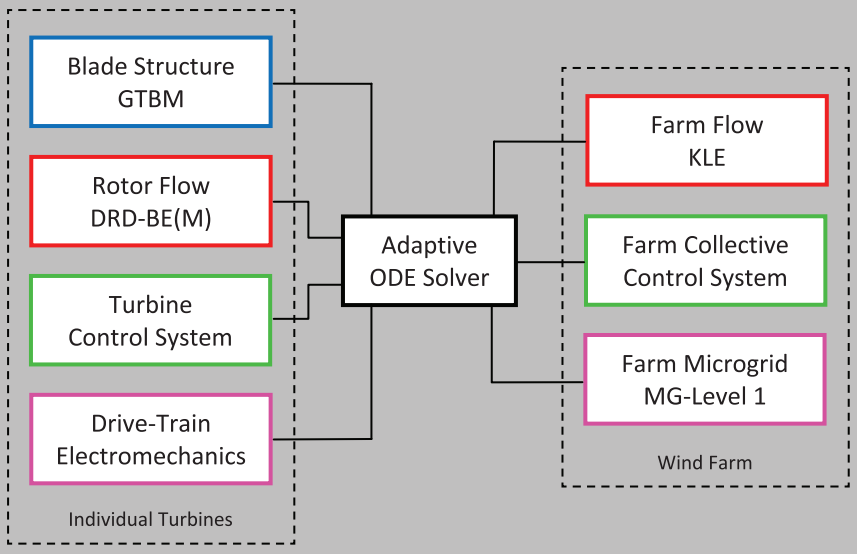
DR. FERNANDO PONTA
RICHARD & ELIZABETH HENES
PROFESSOR IN WIND ENERGY

Wind has already become the major source of renewable energy worldwide. Clean and sustainable, wind shows a clear trend to become the most important among all energy sources in the near future. In order to continue this trend, it is necessary to understand the detailed physics behind the system: from the rotor structure and aerodynamics to turbine control and drivetrain electromechanics.

Over many years, Dr. Fernando Ponta has been refining a multi-physics simulation of the dynamics behind the wind turbine to gain a complete picture of how a wind turbine behaves under various conditions.

"We are integrating the building blocks of the turbine's various models in what we call the Common ODE Framework (CODEF). This is a novel modeling technique based on the use of non-linear adaptive algorithms to gather together the equations associated with different modules modeling rotor flow, blade structure, control system, and electromechanical devices. The common framework keeps the stability of the algorithmic scheme in the time-dependent, evolutionary dynamics," says Ponta.

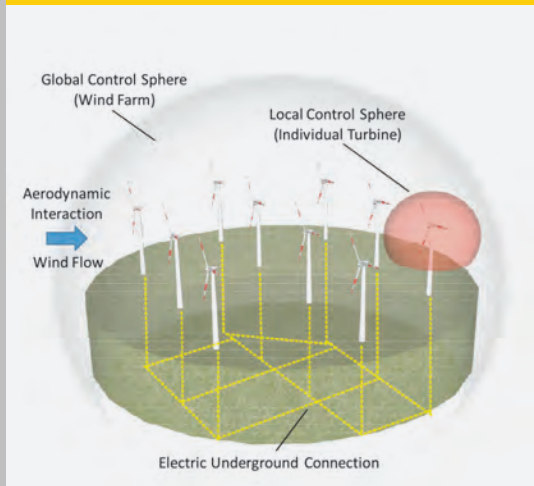
In the upscaled study, Ponta and his team are working to develop an effective model connecting each individual turbine into a high resolution simulation of an entire wind farm.

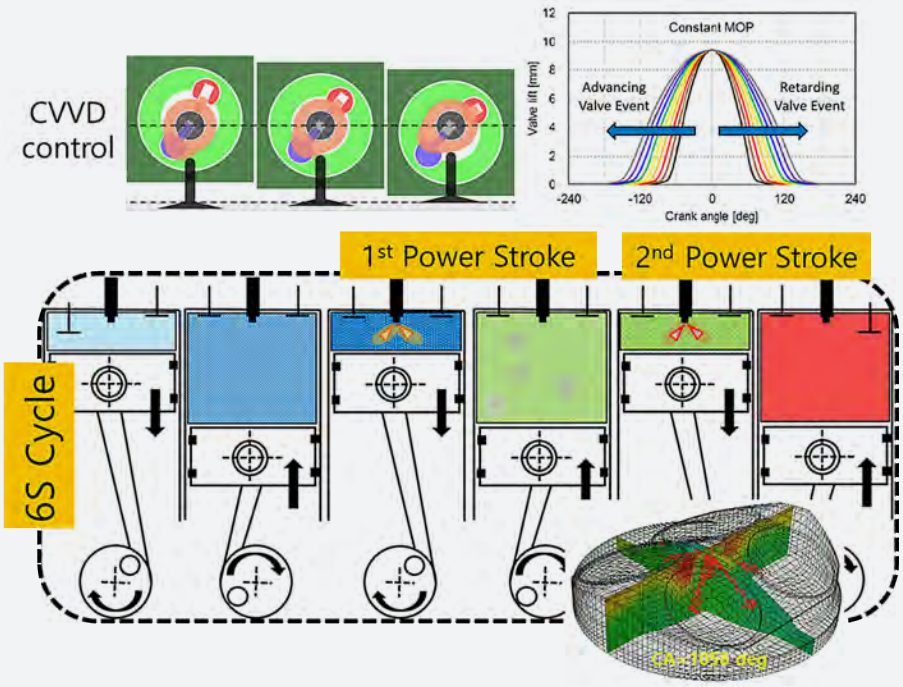


> *"The common framework allows us to work in different scales with enough resolution for global-level flow and control dynamics of the farm. We are capable of reflecting with enough accuracy the multi-physics dynamisms of the turbines."*
>
> –Dr. Fernando Ponta

RESEARCH AREA

DEVELOPMENT OF REDUCED ORDER MODELS (ROMS) FOR WIND TURBINE PLANT, AERODYNAMIC, STRUCTURAL, CONTROL, AND ELECTRICAL GRID INTERACTION -
In Collaboration with Sandia Labs





Gasoline meets Diesel

DR. YOUNGCHUL RA
ASSOCIATE PROFESSOR

Following the trend toward a sustainable, clean, and green ecosystem, consumers are demanding heavy-duty vehicles and machinery follow suit. Through an effort funded by the Department of Energy, Dr. Youngchul Ra is exploring new engine prototypes involving combustion, specifically focused on gasoline spark-ignition engines and compression-ignition engines.

"We see a benefit from each kind of engine. The diesel engine can reach much higher efficiency, however, it is notorious for particulate matter emissions," says Ra. "We want to use low-emissions gasoline as the fuel combined with compression ignition to produce a better, cleaner engine."

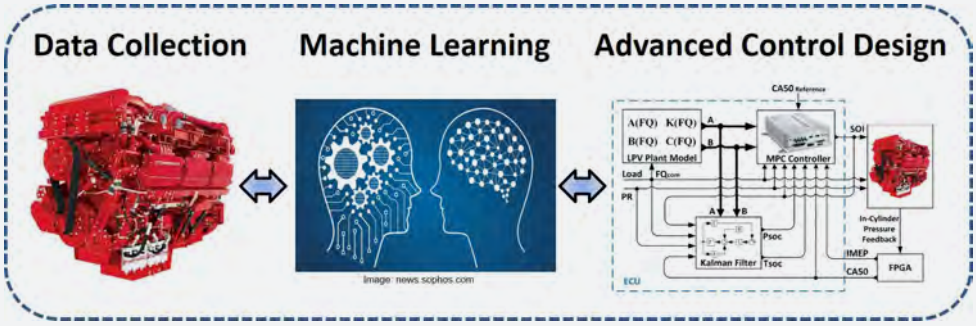
In previous attempts to combine the two engine types, knocking resulted from the mixture of fuel and air prior to combustion. With a novel engine configuration, Ra is conducting computational research to demonstrate feasibility. "We are testing the viability of the control mechanism of a six-stroke gasoline compression ignition (GCI) engine using computational fluid dynamics. Through our partnership with Hyundai Motor Company, and their patented valve drivetrain, we are able to validate our results through dynamometer testing and then feed those results back into our model," says Ra.

Using a full engine geometry grid and modeling the motion of the pistons, Ra is producing promising results. The six-stroke GCI engine, which also can be operated in four-stroke mode, provides greater flexibility, controllability, and can maintain a high thermal efficiency while reducing emissions in a wider operation range.

RESEARCH AREAS

- **CO-OPTIMIZED SI-LTC-PPCI ENGINE SYSTEM DEMONSTRATOR TO IMPROVE FUEL ECONOMY WHILE MEETING LEVIII EMISSIONS -** DOE
- **INVESTIGATION ON ENHANCEMENT OF COMBUSTION PERFORMANCE AND EFFICIENCY OF GCI AND MIXED MODE COMBUSTION IN A 6-STROKE-CYCLE ENGINE WITH CVVD TECHNIQUE -** Hyndai Motor Company
- **DEVELOPMENT AND APPLICATION OF FUEL SURROGATE AND CHEMICAL KINETICS MODEL FOR PACCAR TRUCK ENGINE SIMULATION -** PACCAR

> *"We are able to control the valves in the engine freely, without limitations, to allow a new operating range that could not be achieved before, creating flexibility to expand from four to six strokes."*
>
> –Dr. Youngchul Ra



> *"As opposed to isolating the physics, we store the data and use that to train the machine learning algorithms to parameterize the behavior for model-based control."*
>
> –Dr. Mahdi Shahbakhti

Driving Machine Learning

DR. MAHDI SHAHBAKHTI
ASSOCIATE PROFESSOR

Engine manufacturers strive to release a product that operates in specifics ways under each set of operating conditions and fuel mixtures to optimize performance and reduce emissions. In the past, this has meant relying on the physics-based controls. Using an approach developed by Dr. Mahdi Shahbakhti, engine manufacturers will be able to leverage machine learning with dynamometer data to reach peak performance.

"With the techniques of machine learning and differential geometry, we can develop a data-driven model to use for advanced control of IC engines," says Shahbakhti. "We create the data by operating the engine over a range of conditions and from those input combinations we obtain relationships between load on the engine, the temperature, or the environment."

Data for the National Science Foundation study is being collected using the dynamometers on campus and at Cummins with support from the University of Georgia. The model predictive control developed will be further applied to advanced and complex systems, including dual-fuel advanced engines.

"With this approach, we can reduce the time for developing control models from one to two years to one month. The time to develop models has been substantially reduced and is systematic. This is the engine, put it on the dynamometer, input the conditions, collect the data for machine learning, and develop the model," says Shahbakhti.

RESEARCH AREAS

- **GOALI: COLLABORATIVE RESEARCH: CONTROL-ORIENTED MODELING AND PREDICTIVE CONTROL OF HIGH EFFICIENCY LOW-EMISSION NATURAL GAS ENGINES -** NSF; Partners: Cummins Inc. & Univ. of Georgia
- **CO-OPTIMIZED PPCI-SI ENGINE SYSTEM DEMONSTRATOR TO IMPROVE FUEL ECONOMY WHILE MEETING LEV III EMISSIONS -** DOE; Partners: Hyundai & Philips 66
- **IMPROVED DRIVELINE TORQUE SHAPING: CONTROLS AND CALIBRATION -** Ford Motor Company
- **IMPROVED CLUNK PARAMETERIZATION AND RIG DEVELOPMENT -** Ford Motor Company
- **HIGH ENGINE SPEED CRANKING AND INDIVIDUAL COMBUSTION CONTROL FOR REDUCED COLD START EMISSIONS -** Ford Motor Company
- **NEXTCAR: CONNECTED AND AUTOMATED CONTROL FOR VEHICLE DYNAMICS AND POWERTRAIN OPERATION ON A LIGHT-DUTY MULTI-MODE HYBRID ELECTRIC VEHICLE -** ARPA-E DOE
- **HIGH BMEP AND HIGH EFFICIENCY MICRO-PILOT IGNITION NATURAL GAS ENGINE -** DOE & Westport Inc.

Drips, Drops, & Droplets

DR. KAZUYA TAJIRI
ASSOCIATE PROFESSOR

Fuel cell technology has been in development for many years as a cleaner option for the automotive industry, but has been limited by affordability and longevity. Dr. Kazuya Tajiri is addressing these challenges by characterizing water behavior in proton exchange membrane fuel cells through a project funded by the Department of Energy.

"We are looking at how water moves, where it is generated, and how we can transport the wastewater out," says Tajiri. "We characterize the water transport process in the catalyst layer and optimize the layer structure to improve performance."

In the next phase, Tajiri and his team will investigate the porous structure formation process, using inkjet printing to fabricate catalyst layers.

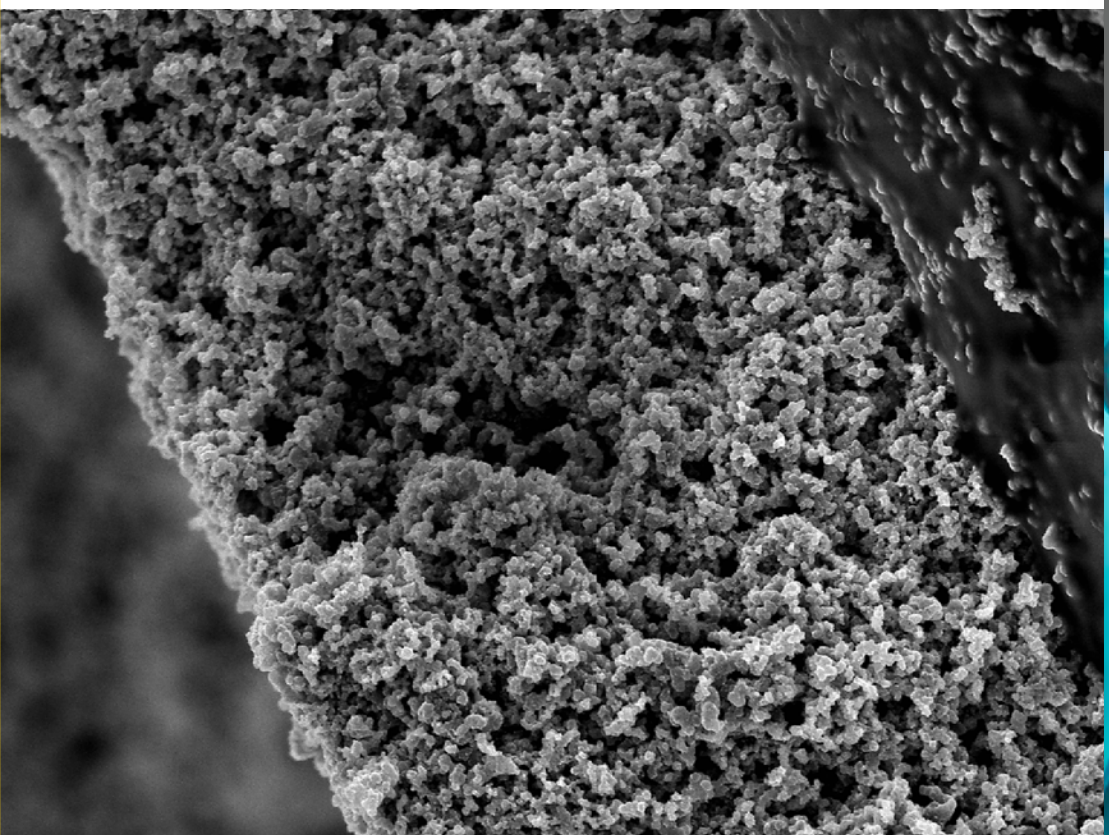
"Through the inkjet printing process, we will find the mechanisms of the droplet interaction and drying," he says. "We will visualize the interaction of the droplets on the surface and the shape changes with a high-speed camera and a scanning electron microscope to build our understanding of the porous structure formation."

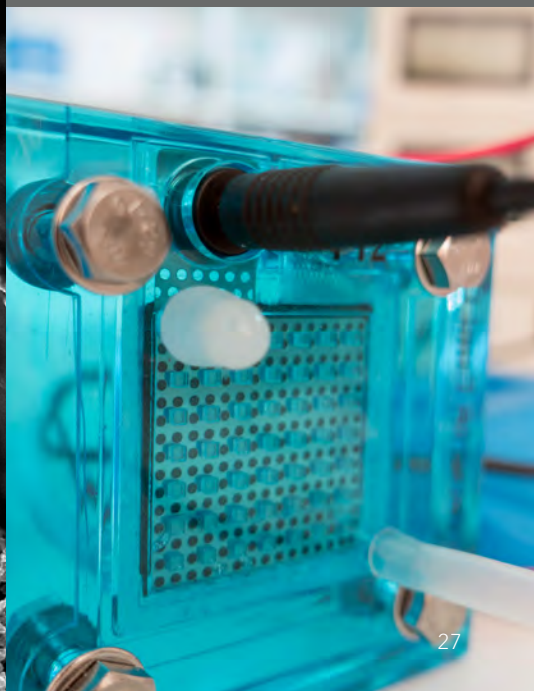
Through the study of the droplet interaction and the final structure, Tajiri hopes to improve fuel cell performance, longevity, and commercial viability.

RESEARCH AREAS

- **NOVEL IONOMERS AND ELECTRODE STRUCTURES FOR IMPROVED PEMFC ELECTRODE PERFORMANCE AT LOW PGM LOADINGS -** DOE & 3M
- **INK DROPLET BEHAVIOR AND 3D STRUCTURE FORMATION IN ELECTRODE FABRICATION WITH INKJET PRINTING AND SPRAY METHODS -** Unfunded
- **IN-SITU TRANSIENT ANALYSIS OF TWO-PHASE FLOW PRESSURE DROP IN PEMFC FLOW CHANNELS -** Industrial Sponsor
- **TECHNOLOGY REVIEW OF PROTON EXCHANGE POLYMER ELECTROLYTE FOR FUEL CELL APPLICATION -** Industrial Sponsor

> *"By building on our understanding of the catalyst layer, we will be able to improve feasibility of fuel cells on the market."*
>
> –Dr. Kazuya Tajiri





BIOMEDICAL SYSTEMS

From nanomaterials novel imaging techniques, the science of human health is stepping forward with our researchers. In some cases, those steps are literal, with orthopedic implants, and new cartilage for osteoarthritis patients.

FACULTY INVOLVED

- DR. PARISA ABADI
- DR. CK CHOI
- DR. CRAIG FRIEDRICH
- DR. SUSANTA GHOSH*
- DR. HASSAN MASOUD*

**These faculty members are featured elsewhere in the Annual Report in a separate research area.*

Guiding Power

DR. PARISA ABADI
ASSISTANT PROFESSOR

Actuators are relied upon in the medical field for a range of procedures, including imaging, by carrying a small camera throughout the body for diagnostic purposes. When working in the body, the accuracy of the actuators is important, as is the adhesion to ensure the materials within the actuator cannot seep into the body. Dr. Parisa Abadi is developing electrochemical actuators based on carbon nanotubes that have high conductivity, work with low voltage, and are safe to be used within the human body.

"When working within the body, it is critical to make sure the materials stay within the device, so we need a good adhesion system to ensure the integrity of the nanomaterials," says Abadi.

Through funding from the American Heart Association, Abadi is using carbon nanotubes and hyaluronic acid to develop a biocompatible actuator with opportunities in 3D printing for biomedical devices.

"The micro actuators we're developing are smaller than 100 microns in diameter and will be integrated into other devices, such as catheters or guide wires for directing them inside of the body," says Abadi. "In these applications, the guide wires are very small, so very thin actuators are required. We've developed the material and the device and now we're working on testing and characterization."

After learning about the problem during her post-doc position in Harvard Medical School, Abadi hopes to improve both system and patient experience when interacting with these applications.

> *"Actuators have many applications. As we develop more advanced actuators with better performance through 3D printing, we can start animal testing and eventually testing in human situations."*
>
> –Dr. Parisa Abadi

RESEARCH AREAS

- **ACTUATORS FOR GUIDANCE OF CATHETERS -** American Heart Association
- **ADDITIVE MANUFACTURING OF NANOCOMPOSITES -** Michigan Tech
- **ADVANCED MATERIALS FOR CARDIAC TISSUE ENGINEERING -** Michigan Tech
- **MECHANICS OF HIERARCHICAL MATERIALS -** Michigan Tech

Advanced Functional Materials 28 (19), 2018 back cover

Visualizing Regeneration

DR. CHANG KYOUNG CHOI
ASSOCIATE PROFESSOR

For people suffering from osteoarthritis, the pain associated with losing cartilage can be debilitating. Grafts used to help osteoarthritis patients today lack biomimetic pericellular matrices (PCM), which leads to reduced cellular function. Dr. Chang Kyoung Choi is dedicated to improving cartilage regeneration by creating a material that mimics the natural condition.

"Using microfabrication techniques, we encapsulate a single cell of the chondrocytes in microbeads, which confines the PCM regeneration," says Choi. "With a polymer-based photocrosslinkable material called oxidized methacrylate alginate (OMA), we are able to create biomimetic PCM for optimal cellular function, which can protect the cell from stress and maintain the chondrocyte's phenotype."

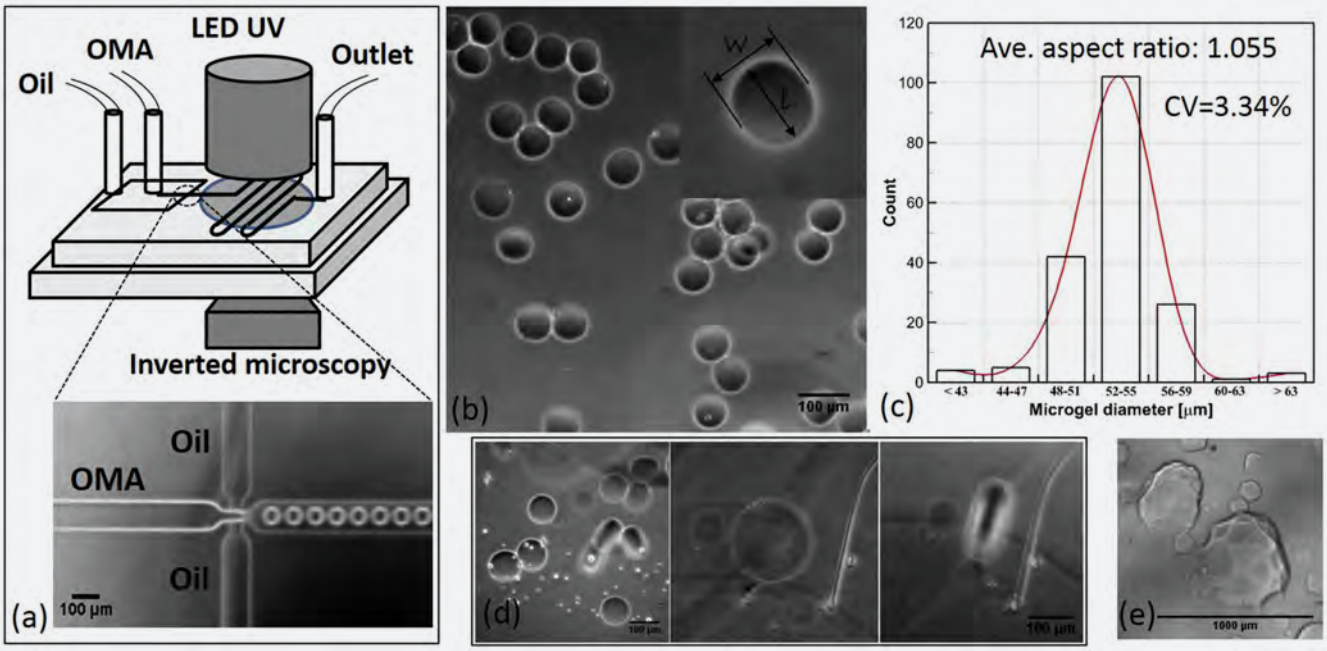
To achieve the natural behavior of the cartilage, Choi has worked to develop the proper mechanical strength surrounding the chondrocyte, as well as the size of the PCM through a unique visualization process. During the encapsulation, he relies on high speed imaging to monitor the process and then embeds it in a single polymer layer to stack them further.

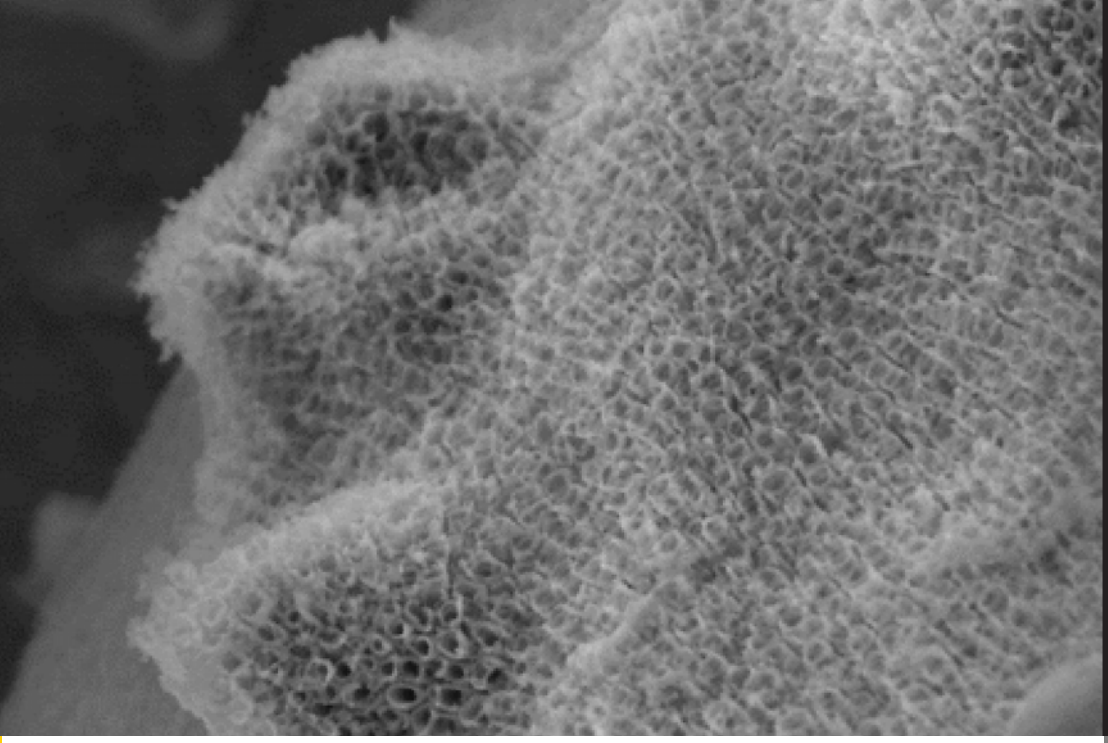
"The resulting chondrons grown into a thin layer of polymer are stacked up to create a 3D cartilage," says Choi. "In current regeneration, cartilage uses a bioreactor, which results in massive chondrons. With our approach, we can control the mechanical strength of the PCM and the overall size, resulting in better control and higher accuracy."

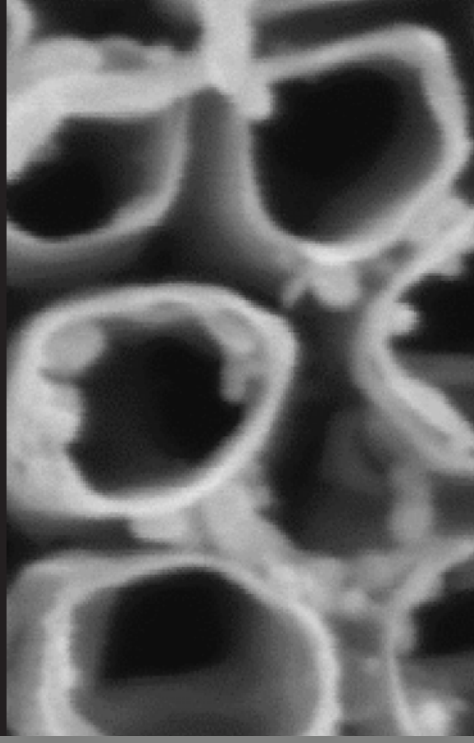
RESEARCH AREAS

- **OPTO-ELECTRIC CELLULAR SENSING**
- **MICROFLUIDICS AND MICROSCALE HEAT TRANSFER**
- **DROPLET IMPINGEMENT ON PATTERNED METAL SURFACES**
- **EVAPORATION OF THIN FILMS AND DROPLETS**
- **MULTISCALE INTERFACE PHENOMENA**
- **NEUTRON IMAGING**
- **FLUID FLOW-INDUCED SHEAR EFFECT ON CHONDRONS; REGENERATION OF PERICELLULAR MATRIX FROM CHONDROCYTES USING MICROENCAPSULATION**

> *"Using my experience in cellular imaging and microfabrication, we have been able to see the cellular reaction in fluid flow shear applications to improve cellular processes."*
>
> –Dr. Chang Kyoung Choi







Improving Motion

DR. CRAIG FRIEDRICH
RICHARD & BONNIE ROBBINS CHAIR

When looking to improve bone-to-bone adhesion properties in orthopaedic implants, Dr. Craig Friedrich and his team not only found a solution to improve the bond, but also discovered a means to reduce the risk of post-operation infection.

"We discovered during our testing processes that the nanotextured implants have inherent antibacterial properties, which could go a long way in reducing the post-operation infections common in orthopaedic surgeries," he said.

Friedrich pushes for research to be commercially viable, so his team developed a unique heat treatment process that has reduced the processing time down from several hours for traditional implants to a matter of 10 minutes for his nanotextured version.

"This breakthrough would make this amenable for implantation in an industrial setting in terms of speed, understanding chemistry of the surfaces, and controlling the surfaces in a way the FDA would require," says Friedrich. "We've done our work to get these features and the time down to make this an attractive option to industry."

Although the implants have been tested in several preclinical models at Beaumont Health in Royal Oak, MI, it has not yet been brought to commercialization. "As a next step, the nanotube implants would have to be tested in a clinical trial setting; however, industry takes time to adapt," says Friedrich. "We work with the goal that anytime we have done something for industry to improve the quality or speed, we have made it more attractive and more likely to be adopted."

> *"Adhesion was our primary focus, but it's been rewarding to see our heat treatment speed and antibacterial properties emerge to make it more attractive to industry."*
>
> –Dr. Craig Friedrich

RESEARCH AREAS

- **TOWARDS COMMERCIALIZATION OF FUNCTIONALLY SMART BONE IMPLANTS -** Michigan Translational Research & Commercialization (MTRAC), Multiscale Technologies Institute, & Beaumont Departments of Orthopaedic Surgery & Research

- **MRSA ANTIBACTERIAL ORTHOPAEDIC IMPLANTS -** University of Michigan MTRAC for Life Sciences Innovation Hub, Michigan Tech Multi-Scale Technologies Institute, Robbins Professorship of Sustainable Manufacturing, and Beaumont Departments of Orthopaedic Surgery and Research

DYNAMIC SYSTEMS

Excitation. Analysis. Additive Manufacturing. By exciting mechanical systems and analyzing acoustic characteristics, our faculty are expanding opportunities for adaptive manufacturing processes and enhancing capabilities in detecting location, path, and sound origin in remote locations.

FACULTY INVOLVED

- DR. ANDREW BARNARD
- DR. JASON BLOUGH

Barrier to Sound

DR. ANDREW BARNARD
ASSOCIATE PROFESSOR

As the Arctic opens up to increased military and commercial exploration, the US Navy is interested in developing situational awareness tools. Through a grant from the Naval Engineering Education Consortium, Dr. Andrew Barnard and Co-PI Dr. Tim Havens, computer science, are collaborating with the Naval Underwater Workforce Center in Rhode Island to identify, classify, localize, and track the activities in the Arctic using undersea acoustics.

Starting with data collected in a previous project in Utqiagvik, Alaska, Barnard's team will explore opportunities to utilize machine learning to identify acoustic signatures of above-ice sources.

"We will characterize the signature, train a learning algorithm to tell what it is, where it is, and where it is moving using full multimodal sensing techniques," says Barnard.

Hydrophones will be used in the water with microphones on land and be enhanced with geophones to detect the motion of the ice to develop a real-time data capture with phase lag. The resulting signals will be piped back via satellite to triangulate a source location. The greatest challenge being in ice variation and discontinuities.

"Ice is chaotic. It moves, fractures, and changes in real-time, creating ridges under water you may not know are there," says Barnard. "This testing is typically done in deep water, but we are completing it in shallow water, where ice may comprise the whole water column."

> *"With data acquisition, sensor suites, and data processing, we are creating our own data algorithm to enhance the current sensing capabilities and lower our tracking error."*
>
> –Dr. Andrew Barnard

RESEARCH AREAS

- **ONR GRADUATE TRAINEESHIP AWARD: MULTI-MODAL, NEAR-SHORE, ICE-COVERED ARCTIC ACOUSTIC PROPAGATION MEASUREMENTS AND ANALYSIS -** Office of Naval Research (ONR)
- **LOCALIZATION, TRACKING, AND CLASSIFICATION OF ON-ICE AND UNDERWATER NOISE SOURCES USING MACHINE LEARNING -** Naval Engineering Education Center
- **USING NANOTECHNOLOGY TO CREATE A PROOF-OF-CONCEPT PROTOTYPE FOR NOISE-CANCELING IN BUILDING VENTILATION SYSTEMS -** NSF
- **ACTIVE NOISE CANCELLATION FOR AUTOMOTIVE HVAC -** Calsonic Kansei
- **HYDRAULIC SOUND CHARACTERIZATION -** Caterpillar
- **HARD DRIVE NOISE TESTING -** Johnson Controls
- **APPLICATION OF CARBON NANOTUBE THERMOPHONE FOR RANGE EXTENDER EXHAUST ACTIVE NOISE CONTROL -** Magna
- **VIBRATION QUALIFICATION TESTING -** Orbion Space Technology
- **OCEAN OF THINGS -** Soartech Industries
- **URBAN RECONNAISSANCE USING SUPERVISED AUTONOMY -** Soartech Industries
- **DEMONSTRATION OF A COAXIAL THERMOPHONE FOR ACTIVE NOISE CONTROL IN VEHICLES -** Michigan Economic Development Corporation MTRAC
- **DEVELOPMENT OF A SWEPT SINE VIBRATION MEASUREMENT SYSTEM -** Wartsila Defense

Generating Excitement

DR. JASON BLOUGH
PROFESSOR

The future of parts manufacturing is in adaptive manufacturing and 3D printing, which means manufacturers must spend time assessing the quality of the parts to ensure there are no voids within the part. Dr. Jason Blough, along with a team of researchers, is working with funding from a sponsor to find a dynamic method to conduct part assessments.

"Currently when building parts, manufacturers use a CT scan to check for changes in the part density, which is expensive and time consuming," says Blough. "We are exploring ways to test batches of parts simultaneously—looking for good parts and those that fall outside the nominal range of variation."

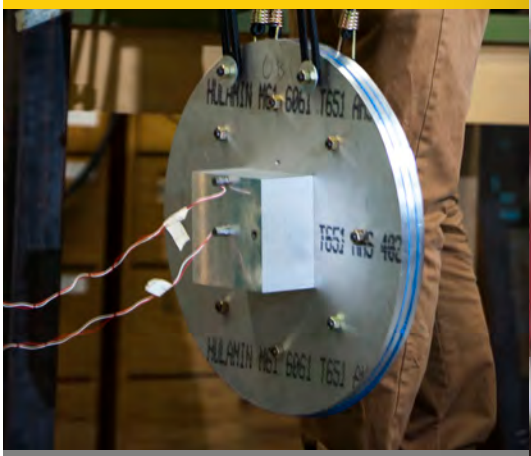
Finite element analysis models are being used to understand the measurements and how they should change based on a fault within the part and that is being combined with physical testing.

"With excitation methods, we are making the part vibrate and seeing its response to loads," he says. "In trying to calculate an accurate and automatic response measurement, we are using a scanning laser to collect response measurements and a digital image correlation to inspect parts en masse."

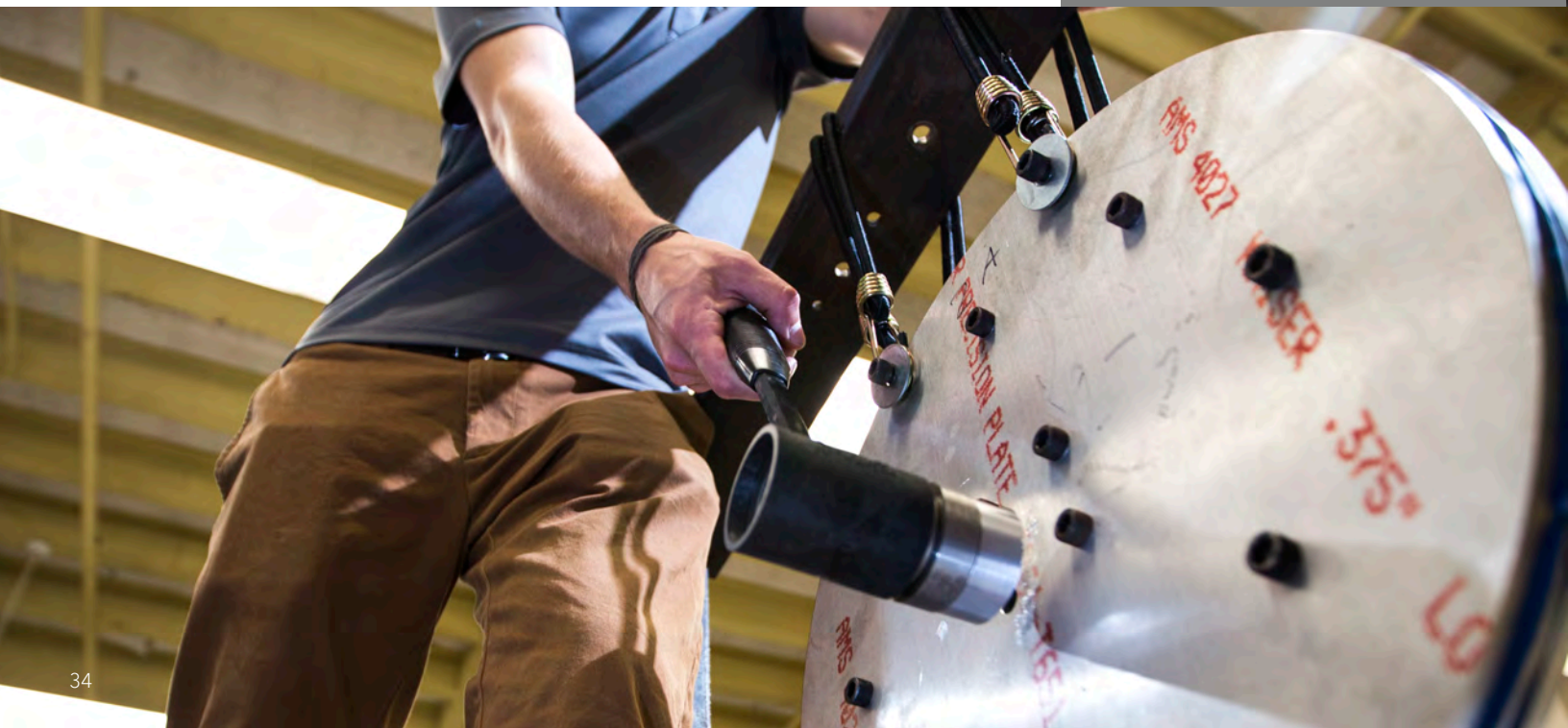
The challenge for the team has been to uncover a solution for exciting the parts in a manner that generates a response, while also developing an affordable and reproducible method for dynamic assessments.

RESEARCH AREAS

- **DYNAMIC MEASUREMENT PROBLEMS**
- **DEVELOPING NEW DIGITAL SIGNAL PROCESSING ALGORITHMS TO UNDERSTAND NVH TYPE PROBLEMS**
- **WAYS TO IMPROVE THE NVH CHARACTERISTICS OF VIRTUALLY ANY MACHINE**



> *"We're looking at a range of methods, but it all comes back to standard health monitoring of the parts in a reliable manner."*
>
> —Dr. Jason Blough



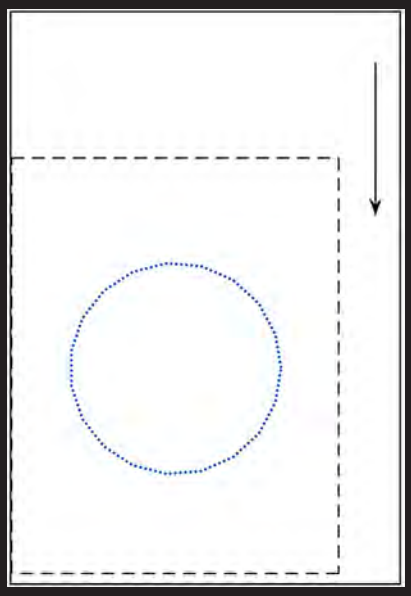
ARTIFICIAL INTELLIGENCE & MACHINE LEARNING

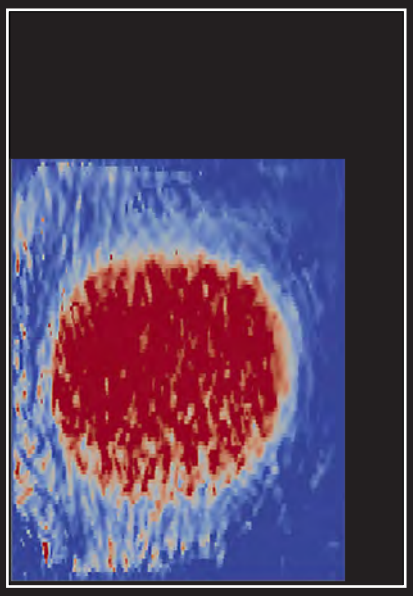
Our research creates opportunities for improved efficiency. Through the development of predictive computational models, we improve diagnostics, manage power, and enhance aid in remote locations. With intelligent systems, our faculty are advancing control systems for improved defense and aid relief efforts.

FACULTY INVOLVED

- DR. SUSANTA GHOSH
- DR. STEVEN GOLDSMITH
- DR. TRISHA SAIN
- DR. WAYNE WEAVER
- DR. GORDON PARKER*

*This faculty member is featured elsewhere in the Annual Report in a separate research area.





LEFT: *Sketch of the experimental and computational (inner rectangle) domains for the tissue mimicking phantom. The circle denotes the actual position of the stiffer inclusion, which mimics tumor. The arrow indicates the location of the acoustic radiation force push.*

RIGHT: *Reconstructed shear modulus distribution for the experiment shown in the left-figure.*

Detecting Tumors

DR. SUSANTA GHOSH
ASSISTANT PROFESSOR

Breast cancer is the second most common form of cancer and the most common in women. Screening and early detection is key for treatment; however, noninvasive detection methods are lagging for women. Dr. Susanta Ghosh is developing an accurate elastography technique to detect tumors. His present work on elastography employs data from impulsive ultrasonic waves, along with machine learning to further enhance detection. Ghosh has worked in collaboration with researchers at Duke University Health and the Mayo Clinic to develop novel ultrasound elastography techniques.

"As the wave moves through the breast tissue, the wave propagation data can be measured. Using an optimization algorithm, we can predict the elasticity map of the breast tissue, which distinguishes healthy tissue from malignant. At present, we are using ultrasound data to train machine learning algorithms to improve the predictive capability. If successful, these techniques should find applications in diagnosis, alongside a medical professional's interpretation," says Ghosh.

Through improving diagnosis of breast cancer, physics-guided machine learning techniques aim to reduce the number of unnecessary biopsies.

"The system has to be accurate so you avoid false negatives, but also ensure no cancer goes undetected," says Ghosh. "Our recent work, in collaboration with researchers at Duke and Mayo, has shown promising results."

RESEARCH AREAS

- **A DEEP LEARNING APPROACH FOR DEFORMATION OF MULTI-WALLED CARBON NANOTUBES**
- **COMPUTATIONAL AND ANALYTICAL MODELING FOR THE INTERFACE-FRACTURE OF MICRO-ARCHITECTURED GLASS**
- **AN ATOMISTIC-CONTINUUM FORMULATION FOR MECHANICS OF MONOLAYER TRANSITION METAL DICHALCOGENIDES**
- **DATA-DRIVEN ULTRASOUND ELASTOGRAPHY: ITS FEASIBILITY IN BREAST CANCER IMAGING**

> *"It's been rewarding to work on ultrasound elastography, which aims to improve the current screening practices for cancer diagnostics through combining computational techniques and biomedical experiments."*
>
> –Dr. Susanta Ghosh

Power Supply & Energy Storage

DR. STEVEN GOLDSMITH
RESEARCH PROFESSOR

Predicting power supply needs as solar and wind energy availability shifts could go a long way in balancing the power grid and preparing for uncertainty. Dr. Steven Goldsmith developed a simulation program in MATLAB with hybrid simulator architecture to understand real-time distributed multi-agent control of distributed resources in a microgrid.

"The simulation consists of 38 asset agents that communicate to a centralized power scheduling agent determining the power balance between sources and loads over a 15 second horizon and adds sources or sheds loads as needed," says Goldsmith.

The generation, load, and storage agents forecast power needs based on a neural network design developed by Dr. Laura Brown, computer science, which does 15 second forecasts. A newer simulation forecasts over a 24 hour horizon using an optimizer, developed by Dr. Gordon Parker and Robert Jane, minimizing fuel consumption in a trade-off with photovoltaic sources and battery storage.

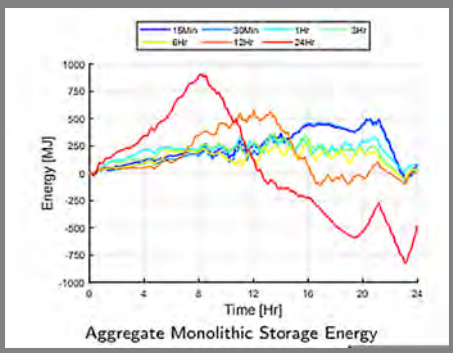
"One major challenge for our system is scalability, which is why we are focused on distributed versus centralized agent. We want to provide a clustered decision making process with redundant overlap and integrate the distributed system with solar, wind, and battery storage."

As interest in autonomous systems increases, Goldsmith is training future engineers for such projects, working with sponsorship of the ME-EM and ECE departments to develop a 15-credit Certificate in Safety and Security of Autonomous Cyber-physical Systems.

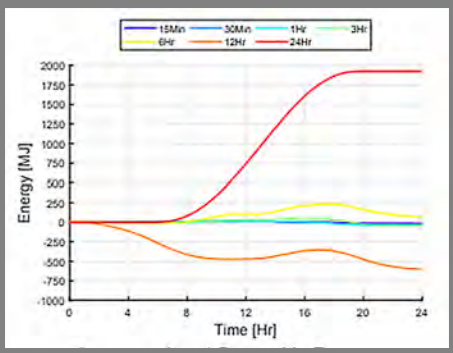
RESEARCH AREAS

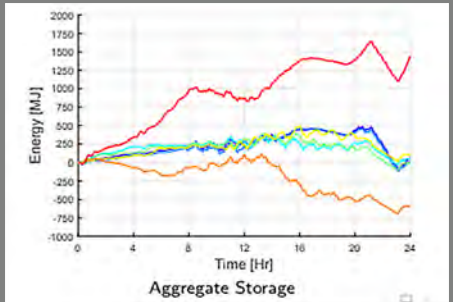
- **INDUSTRIAL AND AUTOMOTIVE CYBER SECURITY**
- **ARTIFICIAL INTELLIGENCE/ AUTONOMOUS SYSTEMS**
- **CYBERWARFARE SIMULATION**
- **AUTOMATED MICROGRID MANAGEMENT**

> *"This work applies to all Distributed Energy Resources and will be impactful for microgrids in forecasting, planning, and control."*
>
> –Dr. Steven Goldsmith



Aggregate Monolithic Storage Energy





Aggregate Storage

Predictive Properties

DR. TRISHA SAIN
ASSISTANT PROFESSOR

Starting out in computational modeling for novel materials, Dr. Trisha Sain quickly realized the omnipresence of polymers. They were everywhere. But she questioned their efficacy and sought to further understand their durability under extreme conditions. These extreme scenarios are something engineers face in aerospace for durability, toughness, and environmental performance, as well as the automotive industry for lightweight material selection of under hood and underbody exhaust, where components experience extreme temperatures.

The level of stress materials undergo in both applications is extreme, so the development of polymer-based materials is critical. Sain is developing a predictive computational tool that will predict the performance of materials in harsh environments.

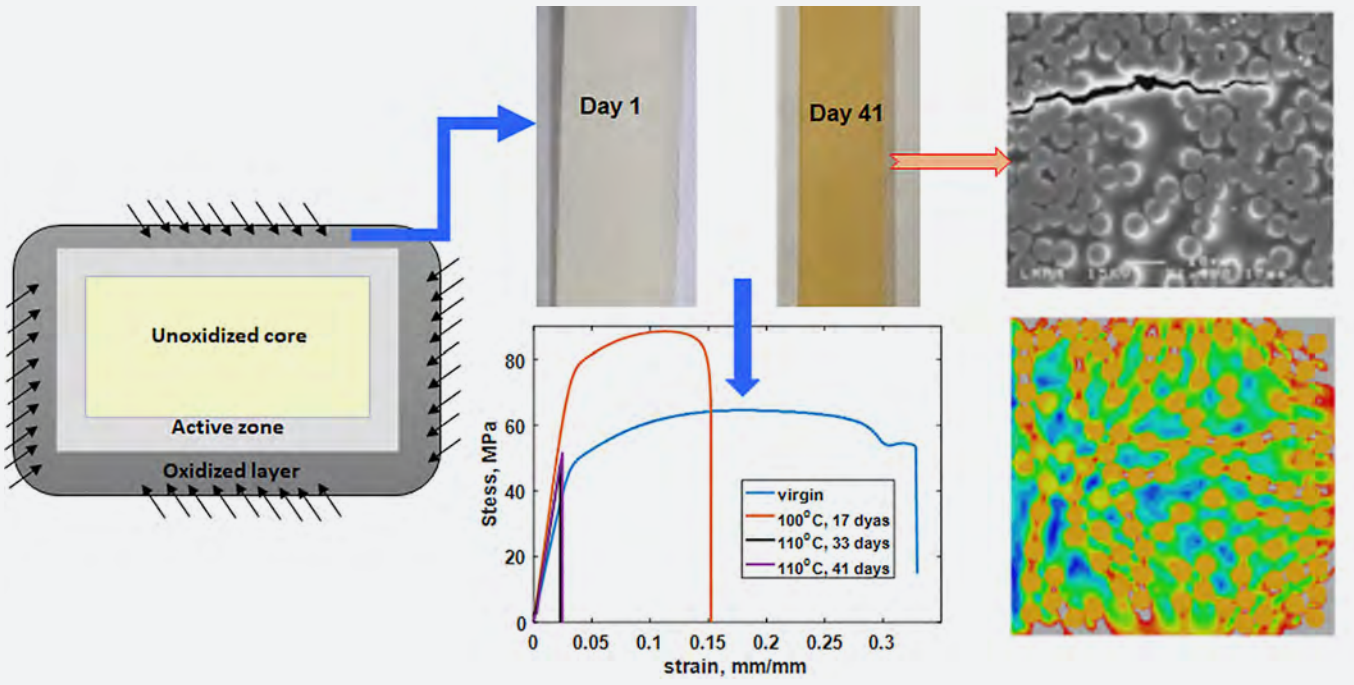
"Existing literature doesn't have the robust data available to validate the research, so I'm working from both modeling and experimental sides," says Sain. "We are keeping materials simulated under environmental conditions and watching how the properties degrade and performance changes over time."

Her multi-physics computational tool takes into account the mechanics, damage, oxidation, degradation factors, and thermal properties. With testing conducted at the Air Force Research Laboratory, the properties of the polymers will help develop a parametric set of relationships that predict performance of materials based on the polymer design.

RESEARCH AREAS

- **EXPERIMENTALLY COUPLED MULTIPHYSICS THEORY AND MODEL DEVELOPMENT FOR POLYMER THERMO-OXIDATION -** Michigan Tech
- **INTERLOCKING MICRO-ARCHITECTURE DESIGN IN BRITTLE MATERIALS FOR TOUGHNESS IMPROVEMENT -** Michigan Tech

> *"We will know we are successful when the computational model predicts the properties of a polymer that was not used in our model mission."*
>
> –Dr. Trisha Sain



Power in Motion

DR. WAYNE WEAVER
DAVE HOUSE ASSOCIATE PROFESSOR

As the reality of power generation and delivery shifts toward microgrid installations, making them resilient and self-assembling is already becoming a reality. Dr. Wayne Weaver and colleagues are developing autonomous grid-managing robots to power base camps for Marines and disaster recovery efforts.

"Right now, most military bases and electric ships that have microgrids have fixed generation and storage, but we're exploring what happens if you put sources on autonomous robots, operating alone or where the people are busy with other tasks," says Weaver.

Through funding from the Office of Naval Research – Marine Logistics Division, Weaver is exploring the broad concept of using autonomous robots to establish these power-managing microgrids with high-level objectives and independent agents responding intelligently to events like generators running out of fuel.

As part of the project, the team intends to demonstrate autonomous robots distributing load connections and power generation in the field with high-level human input into the system, training the robot on the priorities, establishing power, and then reconfiguring as needed if, for example, a battery is depleted.

> *"We are using a hierarchy of controls and automation with varying levels of independence, bringing autonomous behavior together with microgrid power management and ultimately building a useful tool for future military and human disaster relief efforts."*
>
> –Dr. Wayne Weaver

RESEARCH AREAS

- **AUTONOMOUS MICROGRIDS: THEORY, CONTROL, FLEXIBILITY AND SCALABILITY -** ONR
- **REAL-TIME SIMULATOR FOR ADVANCED ENERGY NETWORK PLANNING OPTIMIZATION AND CONTROL -** ONR
- **META-STABILITY OF PULSED LOAD MICROGRIDS -** Sandia National Labs
- **COLLABORATIVE RESEARCH: CRISP TYPE 2: REVOLUTION THROUGH EVOLUTION: A CONTROLS APPROACH TO IMPROVE HOW SOCIETY INTERACTS WITH ELECTRICITY -** NSF
- **POWER ELECTRONICS DESIGN, INTEGRATION AND COMPONENT SELECTION FOR AQUAHARMONICS INC. 1:7 SCALE WAVE ENERGY CONVERTER DEVICE -** AquaHarmonics Inc.

WAVE ENERGY

Located near Lake Superior, our faculty and students use state-of-the art equipment and access to analyze flow patterns and optimize wave energy harvesting opportunities for coastal communities and unmanned underwater vehicles. By analyzing such systems, our faculty are empowering sustainable development.

FACULTY INVOLVED

- DR. LUCIA GAUCHIA
- DR. GUY MEADOWS
- DR. GORDON PARKER

The New Buoys Club

DR. LUCIA GAUCHIA
RICHARD & ELIZABETH HENES
ASSISTANT PROFESSOR OF
ENERGY STORAGE SYSTEMS

Energy harvesting can come from a number of sources; most recently researchers have been analyzing opportunities for harvesting energy from shore waves. Dr. Lucia Gauchia is collaborating with Dr. Ossama Abdelkhalik at Iowa State University to adapt and optimize wave energy converter designs to reflect certain principles of wind energy farm models.

"Waves travel across the converters, so we know when the waves are hitting and can predict the wave arrival down the array," says Gauchia. "Typical systems use a single converter design throughout the array, but we are looking at whether they should be different based on their position– to extract the most energy."

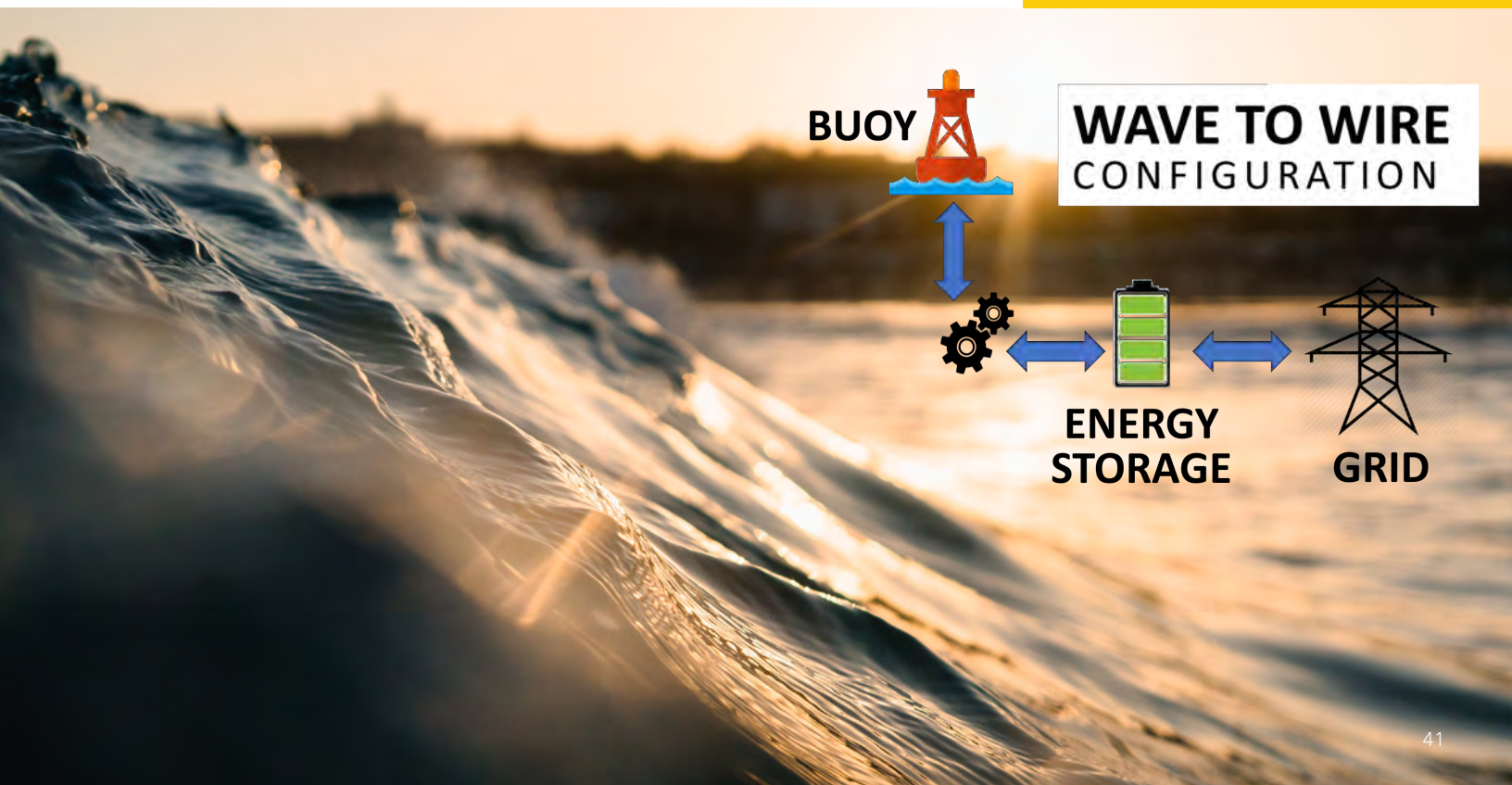
In managing the buoys of the wave energy converter, Gauchia and her team are using simulation to develop a collective behavior system to provide power from one buoy to another as needed. By using an optimal control point and an energy system through batteries in the buoys, an actuator could be used to give an internal force to a buoy. Although this may initially cost some power, it could put the buoy in optimal position to extract more energy.

"The overall benefit of this adjustment is to improve system-level efficiency and cost. Wave energy conversion systems are presently oversized, so this would allow us to have a better design in smaller form, so they're not only more efficient, but they are also able to communicate," says Gauchia.

> *"Ultimately, my interest is in looking at the distribution of energy storage we need with renewable resources to reach optimal performance across all conditions."*
>
> –Dr. Lucia Gauchia

RESEARCH AREAS

- **OPTIMAL RECONFIGURATION AND RESILIENT CONTROL FRAMEWORK FOR REAL-TIME PHOTOVOLTAIC DISPATCH TO MANAGE CRITICAL INFRASTRUCTURE (REDIS-PV) -** DOE
- **CAREER: AN ECOLOGICALLY-INSPIRED APPROACH TO BATTERY LIFETIME ANALYSIS AND TESTING -** NSF (EEUU)



> *"Our research focuses on teaching the human to teach the machine how to survive in big waves."*
>
> –Dr. Guy Meadows

The research speaks for itself:
UGLOS.MTU.EDU

Riding the Waves

DR. GUY MEADOWS
RESEARCH PROFESSOR

As climate variability increases, understanding the Great Lakes' response is critical for all levels of government and society. To prepare coastal properties and to protect coastal infrastructure, Dr. Guy Meadows is using a suite of environmental monitoring platforms, autonomous vehicles, and bottom-mounted cabled observatories to collect data. Meadows' observations are reported publicly in real-time and include a wide range of meteorological and oceanographic parameters. He has identified trends, such as water levels rising and increased wave intensity and frequency, which has agencies across the state of Michigan putting greater focus on coastal community planning.

"We collect data, mostly through buoys, with more than two million data points a year that anyone can access and download," says Guy Meadows. "Everything is lining up with predictions for increased future extremes."

With funding from the State of Michigan, Meadows and his team seek to make coastal communities more resilient, specifically for handling coastal change and management. They also innovate new tools for watercraft to deal with larger waves: the team has developed a jet ski that acts as an autonomous surface vehicle (ASV) to capture motion data.

"Taking advantage of Lake Superior's large waves, we are building an autonomous control system for the jet ski to maneuver through large waves to complete its mission, while making on-board routing decisions," says Meadows. "Waves are steep and come quickly, so autonomous vehicles can get into trouble in a short time, these lessons on maneuvering can enhance other marine applications to improve vessel safety."

RESEARCH AREAS

- **ENVIRONMENTAL MONITORING BUOY FOR THE STRAITS OF MACKINAC**
- **THE UPPER GREAT LAKES OBSERVING SYSTEM -** NOAA-Integrated Ocean Observing System
- **OCEAN SENSORS -** Defense Advanced Research Projects Agency (DARPA)
- **MANEUVERING OF SMALL CRAFT IN LARGE SEAS**
- **GREAT LAKES COASTAL RESILIENCY -** Michigan Department of Environment Great Lakes and Energy
- **ROBOTIC ASSISTED UNDERWATER COMPUTER VISION -** US Geological Survey
- **HIGH FREQUENCY RADAR CURRENT MAPPING FOR THE STRAITS OF MACKINAC -** NOAA-Integrated Ocean Observing System
- **SMART SHIPS COALITION -** Michigan Department of Environment Great Lakes and Energy

Keeping Power Afloat

DR. GORDON PARKER
JOHN & CATHI DRAKE CHAIR

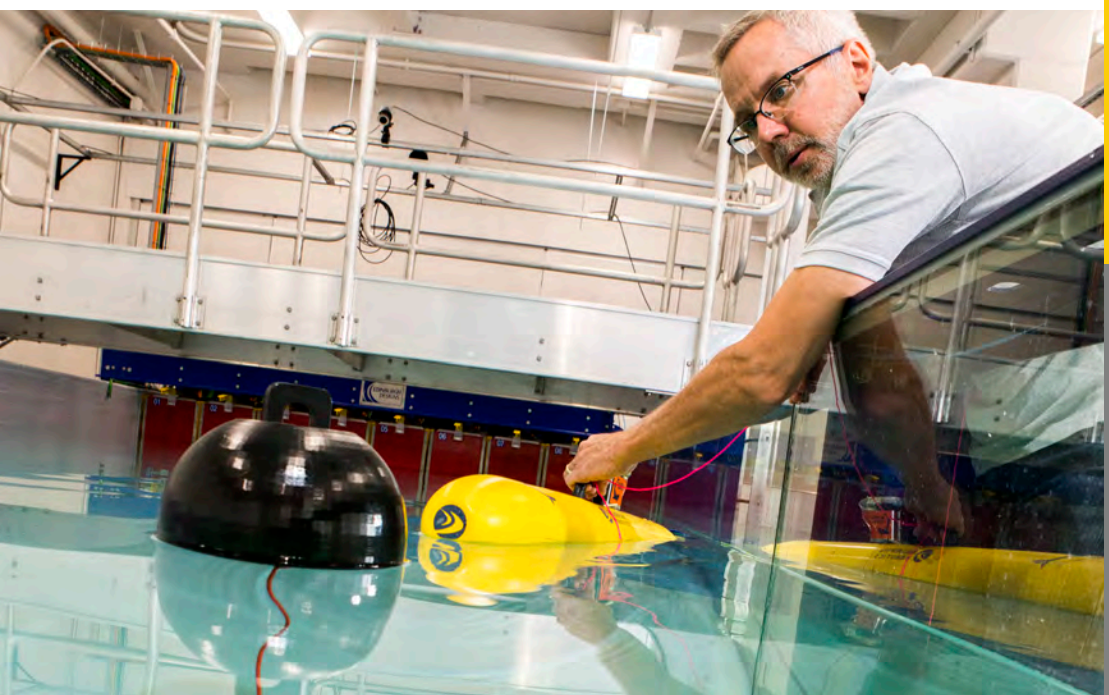
Autonomous underwater vehicles rely on battery power to remain operational. When working in the middle of the ocean or other large body of water, charging sources aren't readily available. Dr. Gordon Parker is developing a solution for this problem with a marine renewable energy microgrid.

"We are looking at providing an energy source for unoccupied, underwater vehicles or surface vessels through a floating microgrid system, or a marine energy grid, by developing control strategies that bridge the gap between the theoretical models and the realistic conditions you find on the ocean," says Parker. The system can include an array of wave energy converters.

Through the use of the wave tank on the Michigan Tech campus, Parker is pairing machine learning with model predictive control to help engineers measure key parameters accurately and predict wave generator behavior into the immediate future.

"In a control scheme, we look up a device, harmonize with the wave field, and resonate. With reinforcement learning, we can look at what is happening in the wave field and other wave energy converters in the array and try different controls. Our system is penalized if it doesn't perform well and rewarded if it does," says Parker.

Students are heavily involved in the research through senior design projects–developing a wave tank testing model of a wireless wave energy converter, as well as a group creating a wave energy converter that extracts maximum power. These control schemes and marine energy grids have applications beyond refueling unoccupied underwater vehicles and can be further applied to environmental sensing.



RESEARCH AREAS

- **INCREASING SHIP POWER SYSTEM CAPABILITY THROUGH EXERGY CONTROL -** ONR
- **REAL-TIME SIMULATOR FOR ADVANCED ENERGY NETWORK PLANNING OPTIMIZATION –** ONR
- **HIGH VOLTAGE DC DISTRIBUTION STUDY OF INTELLIGENT POWER SYSTEMS -** AFRL
- **AGENT-BASED CONTROL OF AGILE ENERGY NETWORKS -** Army Research Laboratory (ARL)
- **CONSORTIUM IN DIESEL ENGINE AFTERTREATMENT RESEARCH -** Various Industry Sponsors
- **SEAWORTHINESS THROUGH INTELLIGENT TRAJECTORY CONTROL AND HIGH-FIDELITY ENVIRONMENTAL SENSING -** DARPA

> *"There is a spectrum of wave energy converter systems in development and there is opportunity in controlling these systems in interesting and sophisticated ways."*
>
> –Dr. Gordon Parker

MANUFACTURING SYSTEMS

Dedicated to education and advancing manufacturing systems, our diverse faculty forge new realities in production. Through adaptations made to the Senior Design curriculum and the research on adaptive manufacturing systems, we prepare students with the skills to be effective on day one.

FACULTY INVOLVED

- DR. ZEQUN WANG
- DR. BILL ENDRES
- DR. CRAIG FRIEDRICH*

**This faculty member is featured elsewhere in the Annual Report in a separate research area.*

Developing the Design Process

DR. BILL ENDRES
ASSOCIATE PROFESSOR

With the adoption of the Mechanical Engineering Practice courses into the ME-EM curriculum, came the drive for change within the Senior Capstone Design Program led by Dr. Bill Endres. While students were receiving greater hands-on experience with physical hardware and modern simulation tools, the design process was partially pushed to the background, so he set to work developing supplemental written guidance. His initial coverage of problem definition to concept generation and assessment has blossomed into a pair of nearly complete books.

"The books look at engineering professionalism and practice from problem understanding and definition to ideation and function-level design, to detail-design engineering, prototyping, testing and even selling," says Endres. "It's about teaching mindset toward delivering value, inspiring students and young engineers to leverage skillsets they have been learning throughout their education and early career."

The Senior Design curriculum has been further transformed from traditional report writing to a series of interactive design reviews supported by technical memos and a technical archival document (TAD) that grows throughout the project.

"They get a template for the TAD week one and carry it through to the end," says Endres. "The entirety of their work-product is recorded to provide their customer with both concise summaries and full details. We are keeping it geared to industry, communicating in a way engineers must when they begin their careers. It's about better training our students for the field."

RESEARCH AREAS

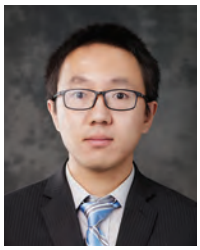
- **MACHINING DYNAMICS**
- **CUTTING MECHANICS**
- **MANUFACTURING PROCESSES**

"The focus is mindset, emphasizing permission to have some failures and make some mistakes, learn from them, and face reality, all the while practicing teaming, communicating, and selling themselves, their ideas, and their solutions."

–Dr. Bill Endres

RESEARCH AREA

PROGNOSTICS AND HEALTH MANAGEMENT -
Michigan Tech



Uncertainly Certain

DR. ZEQUN WANG
ASSISTANT PROFESSOR

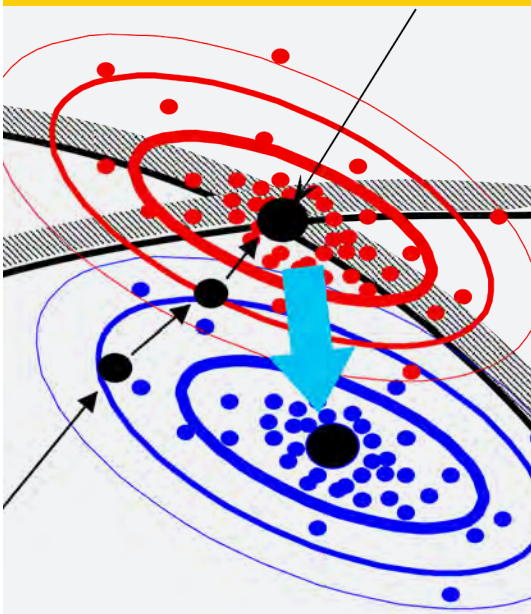
The trend toward adaptive manufacturing processes continues to rise as companies choose 3D printing over traditional manufacturing processes. To increase the viability of adaptive processes, the mechanical, design, and manufacturing parameters need to be optimized. Dr. Zequn Wang is using deep learning methods to maximize system and product performance.

"Exploring design and manufacturing areas under uncertainty, we have access to the measurements of the manufacturing parameters. We take that data and make predictions based on what is known or unknown," says Wang. "In modeling the manufacturing and mechanical systems, we handle the randomness and uncertainty, compensating by optimizing parameters and sensitivity."

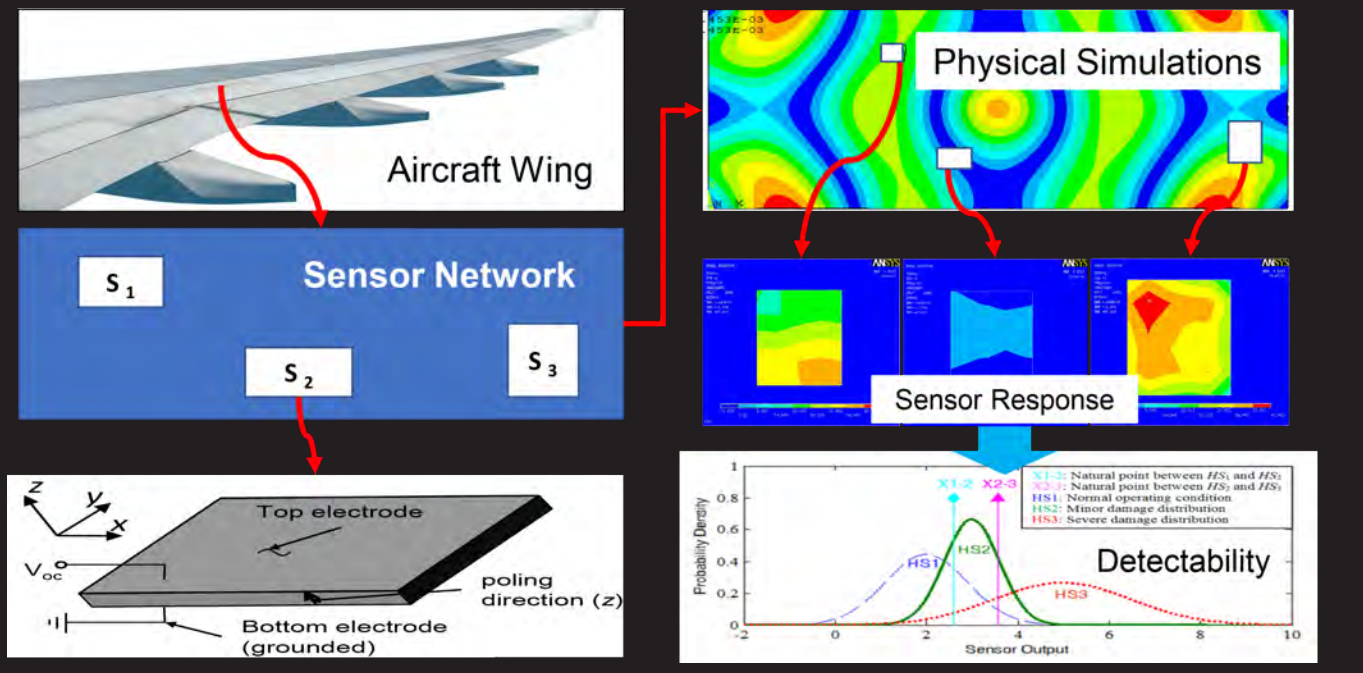
If a product is difficult to manufacture or has sensitive elements, Wang's process can be used to make design changes reliably, while maintaining use of current machinery. In addition, the simulation and experimentation required for the high reliability in considering uncertainties for traditional engineering systems is computationally intensive and expensive.

"Using innovative methods, we generate the data that is used to train the machine learning model and are able to produce a savings on computational efforts," says Wang.

He uses stochastic processes to allow for a greater number of manufacturers to adopt additive manufacturing methods with a high level of success.



> *"With this approach, we are able to create a tool to help manufacturers better design for reliability using adaptive manufacturing processes."*
>
> –Dr. Zequn Wang

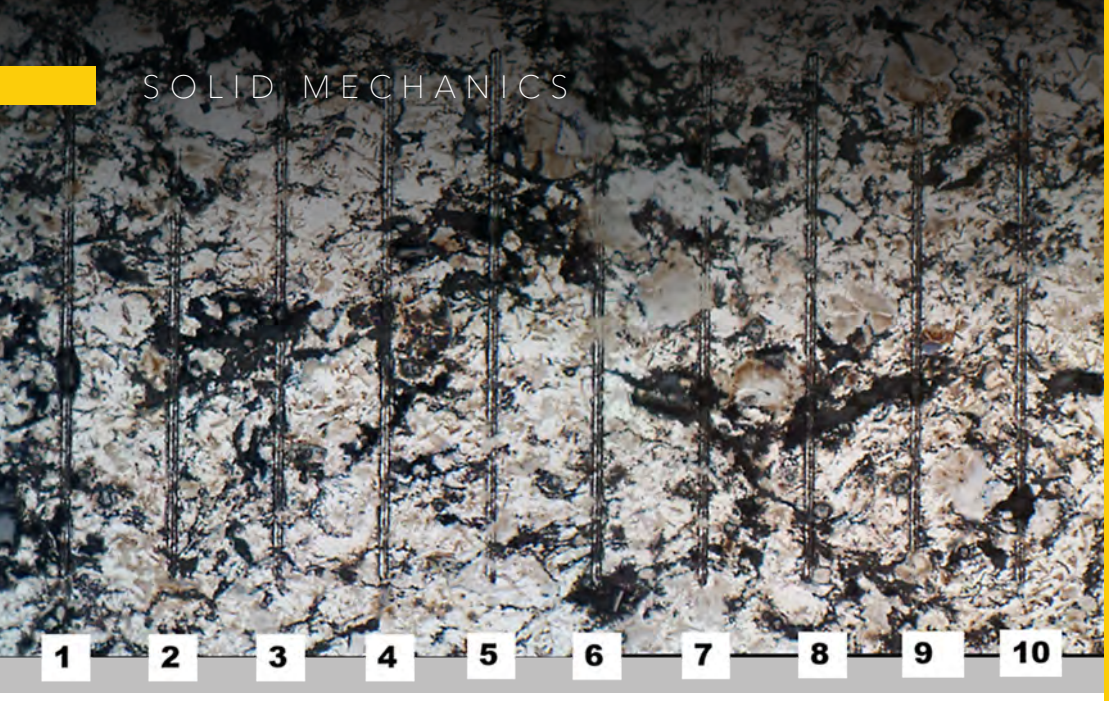


SOLID MECHANICS

By understanding failure. We make success possible. Researching materials in the micro-, nano-, and macro-scales, our faculty members bring stronger, more reliable products to market.

FACULTY INVOLVED

- DR. IBRAHIM MISKIOGLU
- DR. STEPHEN MORSE



RESEARCH AREAS

- **USE OF SEVERE PLASTIC DEFORMATION TO ALTER PROPERTIES OF MATERIALS**
- **FAILURE STUDIES OF RANDOM FIBER COMPOSITES WITH APPLICATIONS TO STRUCTURAL PROBLEMS**
- **FAILURE OF SANDWICH PANELS WITH APPLICATIONS TO STRUCTURAL PROBLEMS**
- **NANOSCALE PROPERTIES OF INTERPHASE IN POLYMER MATRIX COMPOSITES**
- **PHOTOMECHANICS INTEGRATED WITH DIGITAL IMAGE PROCESSING FOR THERMOMECHANICAL STRESS ANALYSIS**

Experimenting with Stress

DR. IBRAHIM MISKIOGLU
ASSOCIATE PROFESSOR

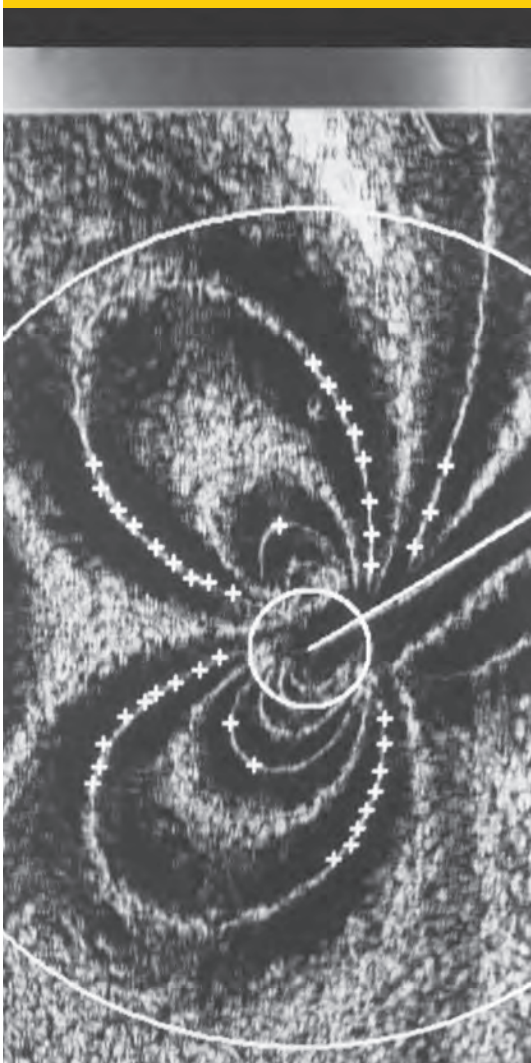
Materials used in the manufacturing processes are constantly changing and shifting to better handle wear, stress, and fatigue. New materials are not commonly released to the market without first undergoing extensive testing. Through his dedication to solid mechanics, Dr. Ibrahim Miskioglu is leaving his mark on the characterization of composite materials at the macro-, micro- and nanoscales.

Working with a partner in France who designs the composite materials, ranging from metal or epoxy/rubber matrix materials, Miskioglu provides testing support to define the creep and wear properties using nanoindentation measurements. Through the project, they have utilized recycled materials in the composites such as rubber from a shoe manufacturer or aluminum chips from the aeronautical industry. To measure the stress and strain of the materials, he takes an experimental approach using tools such as strain gauges, as well as digital image correlation and nanoindentation.

"Over the course of the project, we have seen improvements in wear response, as well as strength through compression testing," says Miskioglu.

> *"Our work will introduce new materials for the transportation industry, specifically aerospace, to hopefully bring composite materials with recycled constituents to market."*

–Dr. Ibrahim Miskioglu



Structurally Sound

DR. STEPHEN MORSE
ASSISTANT PROFESSOR

Building design trends change swiftly and in recent years have shifted toward the use of glass almost exclusively for the facade. This change ramps up the importance of Dr. Stephen Morse's research in glass loads and design safety.

"I am on the committee responsible for the code that engineers use to determine what kinds of glass they need," says Morse. "This allows me to understand where the industry needs are and then in the lab, I explore answers to those questions and integrate them into the standards."

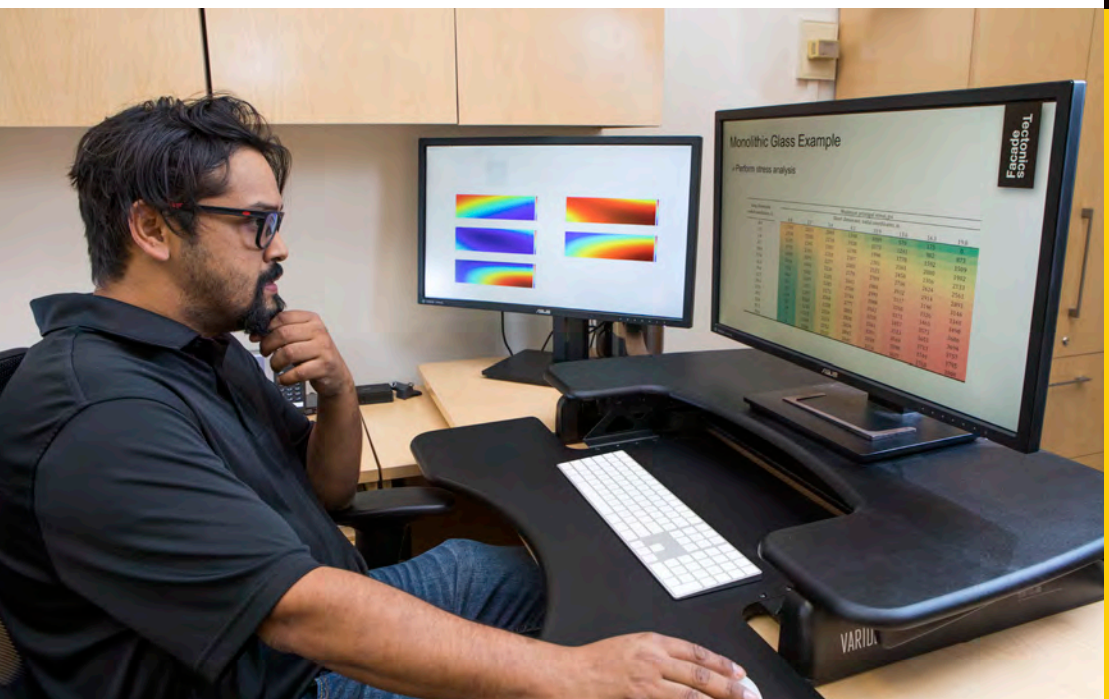
One of his current projects is analyzing the strength of glass edges, specifically for stairway applications.

"We find that glass edges become stressed directly more than the surface glass," says Morse. "When we understand how it has been cut and assembled, we can quantify glass edge conditions for architectural and structural uses."

Working in both full scale and lab scale glass strength, Morse evaluates the glass to find the micro level fracture origin, the stress it was under during fracture, and how surface treatments and coatings impact the strength.

Focused on filling the gaps for all glass types, Morse is working toward a unified model, so testing is not required each time a new coating or glass comes on the market. Morse's research directly feeds into the standards set for glass design and provides a means for engineers to establish new designs safely.

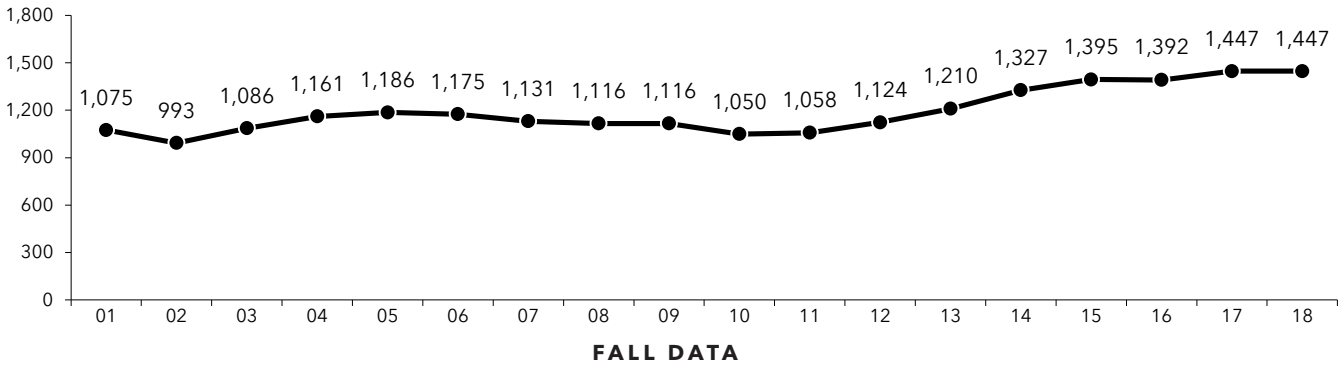
> *"Through our research, we know glass failures originate on the surface and what we do to the surface impacts the strength of the glass."*
>
> –Dr. Stephen Morse



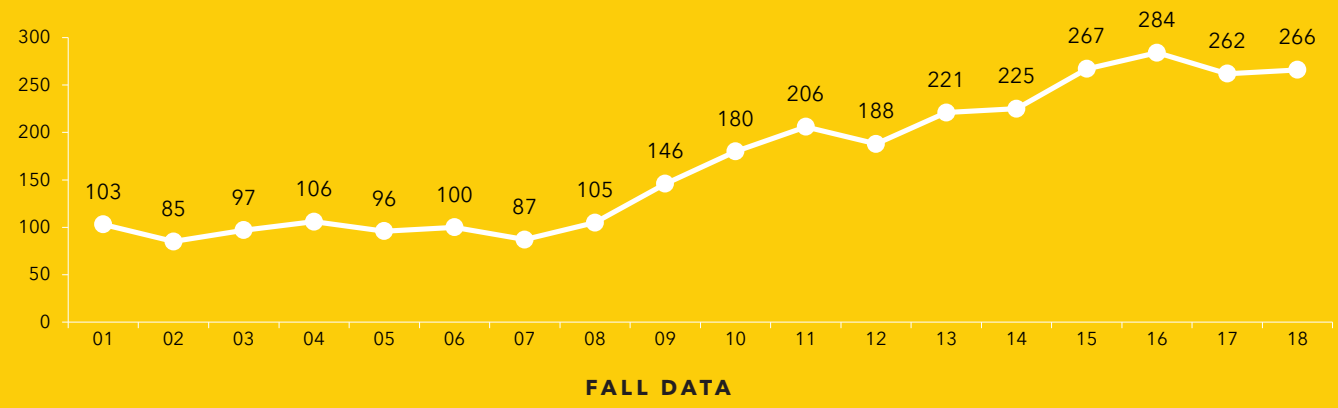
RESEARCH AREAS

- **WINDOW GLASS STRENGTH DESIGN**
- **WIND LOADS ON STRUCTURES**
- **FINITE ELEMENT MODELING OF BRITTLE MATERIALS**
- **LARGE SCALE DATA PROCESSING AND DATA MINING**

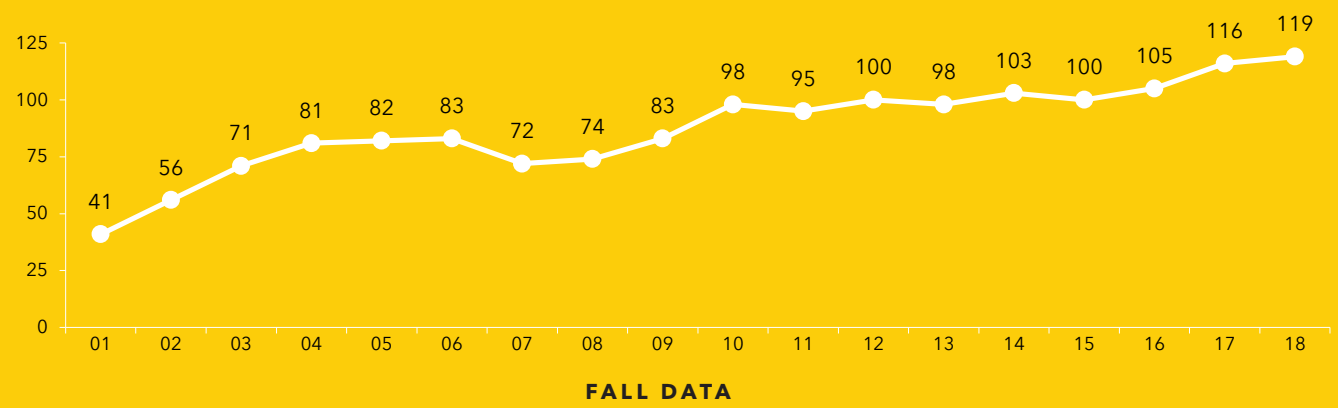
BS ENROLLMENT



MS ENROLLMENT

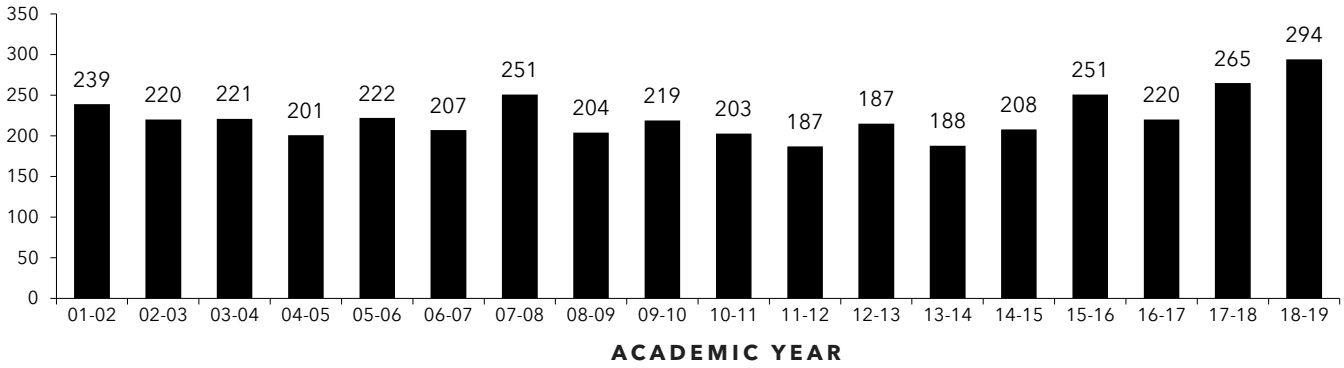


PHD ENROLLMENT

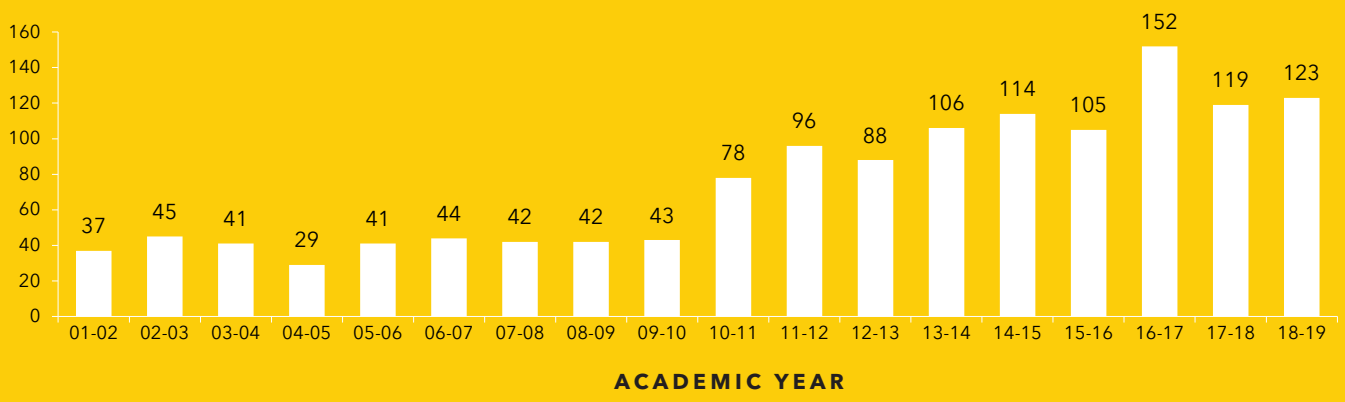


In a few cases, the BS enrollment and degree data shown above may differ from past publications because the official, final enrollment data is only available after this publication goes to press.

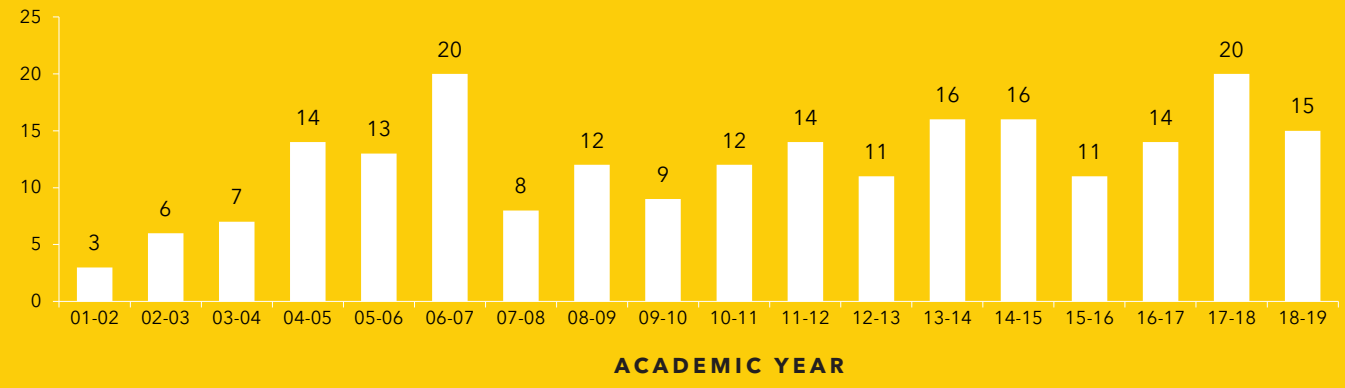
BS DEGREES



MS DEGREES



PHD DEGREES



Driving Tech Forward

ME-EM Department and Michigan Tech leadership maintain steady contact with industry and have been tracking the forces driving the next industrial revolution, also known as Industry 4.0. The administration sought to better prepare students, and campus as a whole, by taking a leadership stance in forging this new era. Five key factors were identified as the driving disruption, including: data sources, networks, big data, machine learning, and people.

President Rick Koubek brought faculty and students together to address the disruptive forces and enhance Michigan Tech's market position. What resulted were nine themes across the following domains: digital, designed and built, human and social, and natural worlds:

1. Advanced Materials & Manufacturing
2. Autonomous & Intelligent Systems
3. Data Revolution & Sensing
4. Diversity & Inclusion
5. Education for the 21st Century
6. Health & Quality of Life
7. Natural Resources, Water, & Energy
8. Policy, Ethics, & Culture
9. Sustainability & Resilience

In January 2019, committees were formed surrounding the nine themes with committee chairs hand selected by Michigan Tech leadership. Two ME-EM faculty were selected to lead committees, in areas where Michigan Tech already has leadership, but where there is opportunity to build on the strength in both education and research.

Dr. Greg Odegard was selected to lead the Advanced Materials & Manufacturing committee, while Dr. Jeff Naber was chosen to chair the Autonomous & Intelligent Systems committee.

ADVANCED MATERIALS & MANUFACTURING

"We started out by assembling a working group to define specifically what we would want to focus on," says Odegard. "After several meetings and research, we decided on a focus of advanced manufacturing for a circular economy–that is products being manufacturing in a way they can be remanufactured and avoiding landfills."

The ME-EM curriculum will be revised to create hands-on Mechanical Engineering Practice-based courses that focus on understanding a product, reverse engineering the product, or redesigning it in a more sustainable manner.

"We will break down standard consumer products to see where in the process the design went down the wrong path. For example, students could look at the concept of adhesives, which is permanent and look at opportunities to use bolts instead of glue, which can be taken off and reused," says Odegard.

Beyond hands-on courses, the committee is exploring the development of a minor in advanced materials and manufacturing at the undergraduate level and adding certificates at the graduate level.

"Now that we have picked a focus, we get to decide where it can have a positive impact on campus and how it can best be developed to strengthen campus educationally and in research," says Odegard.

> *"While we have experts on campus in materials and manufacturing, we are looking for partners to support our endeavors and build on our knowledge of the circular economy."*
>
> –Dr. Greg Odegard

With $70,000 in funding in year one and total funding of one million, the first year and a half will be spent attending conferences, traveling to workshops, and gathering information to build a strong curriculum and research base to leverage partnerships and continue making students ready for industry and desirable to employers.

AUTONOMOUS & INTELLIGENT SYSTEMS

"Our committee will focus on increasing exposure outside of Michigan Tech for our on-going work in autonomous and intelligent systems. We will target research and development in unstructured environments for land and water," says Naber. "A significant part of this effort is bringing the experts and resources together in the Michigan Tech community and developing unique land and water vehicle platforms as a catalyst to move us forward."

OVER THE COURSE OF THE NEXT FIVE YEARS, the Michigan Tech campus community will adapt to align their educational and research focuses with challenges facing the industrial revolution. The adaptations will come in a variety of forms from research programs to coursework additions and to prepare students to 'hit the ground running' as effective and contributing engineers.

Also funded with $70,000 in year one with total funding of one million, the committee will develop the two platforms,working with faculty, instructors, and students across campus to adapt courses at the graduate and undergraduate levels.

Further goals include packaging three smaller certificates together for a master's degree and reintroducing certificates at the undergraduate level.

> *"We want to leverage the expertise and resources we already have in place and use those to supply data for courses in vehicle dynamics, sensing, and controls, both in physical and virtual lab spaces."*

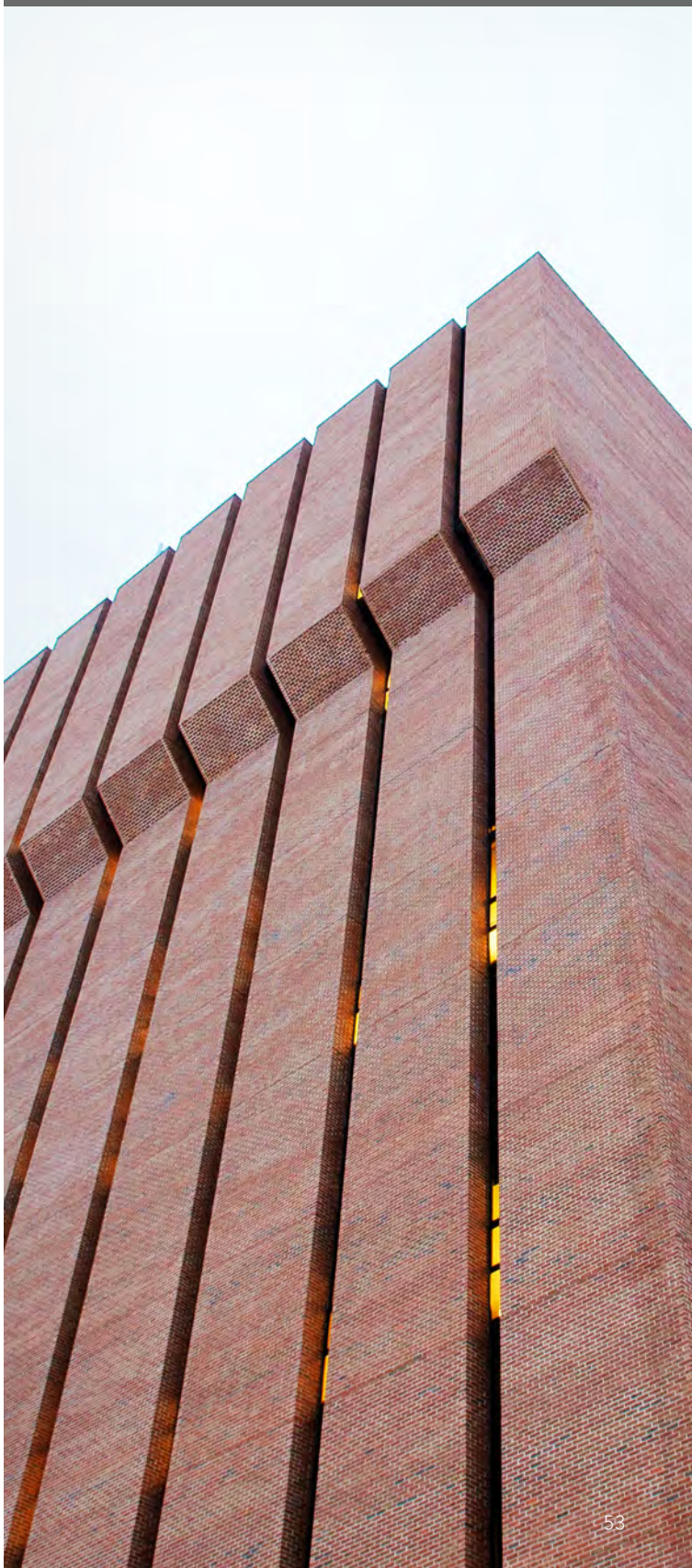
–Dr. Jeff Naber

"We have numerous physical test courses and labs in place, but through this funding; we can also create virtual labs to be used across courses with detailed models of vehicle dynamics and terrain. With a virtual vehicle using virtual sensors, we can drive on virtual terrain and back that up with data from the physical assets," says Naber.

This year, the committee will focus on land-based vehicles and aligning with partners to get a fully instrumented vehicle with remote control. In year two, the instrumented vehicle will be adapted to an autonomous system to collect data and enhance classroom support with water-based vehicle support beginning in year three.

"With current on-road technology, we find that LIDAR fails in the rain and snow. The vehicles are not able to deal with real-world weather outside of optimal conditions. These are all challenges in path planning and navigation. When you're on a road, you know where you will go, but in unstructured environments, we need to first decide what is passable and achievable considering vehicle dynamics and terrain," says Naber. "This introduces new obstacles and terrain assessments that need to be addressed."

Michigan Tech is well suited to handle the challenges of the unstructured environment at both the land and water levels through experience at the Keweenaw Research Center, Great Lakes Research Center, APS LABS, and the Michigan Tech Research Institute.



GRADUATE SEMINAR SERIES

EXTERNAL SPEAKERS

Dr. Iman Afzal
Gwangiu Institute of Science and Technology
Overcoming the Bottleneck of State of the Art Fabrication and Manufacturing Processes

Darwin Baas
Director of Public Works for Kent County
Kent County Sustainable Business Park: Our Journey to Zero

Dr. Robert Baldwin
National Bioenergy Center
Co-processing of Bio-oil and Fossil Crude Oil in Conventional Petroleum Refineries

Dr. David Biggs
Ricardo strategic Consulting
Introduction to Ricardo Strategic Consulting

Dr. Jill Blecke
Sandia National Laboratories
Off-Axis Input Characterization of Random Vibration Laboratory Data for Model Credibility

Dr. Sonjoy Das
SUNY Buffalo State
Effective and Efficient Semi-Analysis Finite Element Modelling of Lubrication Flows in 3D Printing and Brain Mechanics

Dr. Eric Eddings
University of Utah
Numerical and Physical Modelling of Joints and Deformation Wave Energy Converters

Dr. David Forehand
University of Edinburgh, Scotland, UK
Numerical and Physical Modelling of Joints and Deformation Wave Energy Converters

Kerrianne Hobbs
Air Force Research Laboratory
Verification and Validation of Complex and Autonomous Systems

Dr. Peter Ifju
University of Florida
Unmanned Hydrofoil Watercraft

Rajesh Jha
CEO of SimInsights Inc.
VR/AR Based personalized Learning

Dr. Stephen Kelley
North Carolina State University
System-wide Considerations for the Production of Hydrocarbon Fuels from Biomass

Dr. Chang-Wook Lee
PACCAR Technical Center
Computational Analyses in HD Truck Industry

Dr. Sungyon Lee
University of Minnesota
Interfacial Dynamics: Droplets and Suspensions

Dr. Armando McDonald
University of Ohio
The Effect of Biochar as Reinforcing Filler on the Properties of Wood Plastic Composites

Dr. Marianna Maiaru
University of Massachusetts
A new class of Metal-Graphene Composites

Dr. Reza Mirzaeifar
Virginia Tech
A New Class of Metal-Graphene Composites

Dr. Shima Shahab
Virginia Tech
An Ultrasonic Solution for Wireless Powering of Biomedical Implants

Dr. Kendra Sharp
Oregon State University
To Be of Use: Humanitarian Engineering at Oregon State University

Dr. Arend Van der Zande
University of Illinois Urbana-Champaign
Atomic Membranes and Controlled Interfaces from 2D Materials

Dr. Alan Zehnder
Cornell University
Mechanics of a Self-Healing Hydrogel: Deformation, Thermal Effects and Fracture

MICHIGAN TECH SPEAKERS

Dr. Parisa Abadi
Department of Mechanical Engineering–Engineering Mechanics
Materials with Multi-Scale Structure for Biomedical applications

Dr. Nancy Barr
Department of Mechanical Engineering–Engineering Mechanics
Timing is Everything: Strategies for Avoiding the Temptation to Plagiarize

Robert Bishop
Department of Academic Integrity
Academic & Community Conduct

Dr. Kathleen Feigl
Department of Mathematical Sciences
Investigations of the Formation, Deformation and Breakup of Liquid Drops using CFD

Dr. Raymond Shaw
Department of Physics
What I've learned about Turbulence and Clouds: An Interdisciplinary Atmospheric and Engineering Romance for Valentine's Day

ORDER OF THE ENGINEER

FALL 2018
Heidi A. Mueller '93
Supervisor – 2.3L GTDI Engine
Calibration, Ford Motor Company

SPRING 2019
Jennifer Trice '87
Associate Corporate Engineer
3M – Engineering Systems & Technology

GRADUATE STUDENT FELLOWSHIPS

SUMMER 2018-SPRING 2019

Winnikow Fellowship
Akshay Vikram Netke
Xiucheng Zhu

Doctoral Finishing Fellowships
Soroush Sepahyar
Xin He
Saeed Jafari Kang
Xian Li
Niranjan Miganakallu Narasimhamurthy
Zhuyong Yang
Kai Zhang
Hui Huang
Behdad Afkami

Outstanding Graduate Student Teaching Award
Ahammad Basha Dudekula
Siddharth Bharat Gopujkar
Cameron Hansel
Erica Jacobson
Luke Jurmu
Mingyang Li
Niranjan Miganakallu Narasimhamurthy
William Pisani
Samantha Swartzmiller
Upendra Yadav
Zhuyong Yang

Dean's Award for Outstanding Scholarship
Sampath Kumar Reddy Boyapally
Hui Huang
Miles Penhale
FNU Rahul Jitendra Thakkar
Nikhil Appasaheb Shinde
Mitchel Timm
ZXiucheng Zhu

BS GRADUATES (294)

SUMMER 2018 (10)

Ethan Beavers
Justin Boogaart - Summa Cum Laude
Kendra Gburek
Cody Goodreau
Drew Hanover - Magna Cum Laude
Preston Hogue
Kevin Kyle
Christopher Lake
Davis Russcher
Tony Sharp

FALL 2018 (97)

Aimee Allen - Magna Cum Laude
Roberto Araujo Ferreira - Cum Laude
Joe Axberg
Zach Bauman
Jalen Beck
Jeremy Bell
Kaleb Bergman
Tim Billman
Taylor Bischof
Logan Brueck
Weston Butler
DJ Byard - Cum Laude
Greta Colford - Cum Laude
Marlena Daniels - Cum Laude
Aaron Dean
Stephen Dietrich
Austin Dohse
Matthew Erickson
Doug Fabry
Conner Ford - Summa Cum Laude
Josh Gentner
Josh Gerez
Jessica Geroux
Cassie Gietek
Steven Golm - Magna Cum Laude
Alex Gorcyca
Ryan Groves
Nick Harmsen - Summa Cum Laude
Matthew Hays
Jake Herzog
Dustin Hitchings
John Hoffman
Joe Hurford
Victor Lerulli
Todd Impola - Magna Cum Laude
Nicholas Irwin
Michael James
Chenguang Jin
Brandon Johnson
Andrew Johnson - Cum Laude
Clark Kangas
Michael Kennedy
Leroy Kincannon - Summa Cum Laude
Rachel Kolb
Chip Koszewski
Alexandra Krisztian
Daniel LaCroix - Summa Cum Laude
Scott Laiho
Brandt Lanser
Brendan Lefebvre
Justin Lerma
Andrew Luchenbach - Summa Cum Laude
Matt McInerney
Mendel Meister
Lucas Meyer - Cum Laude
Adam Michaud
Robert Mikula-Malstrom
Tyler Miller
Alex Miller
Adam Mitchell
Jeffrey Mott
Armand Mucci - Cum Laude
Brandon Narodzonek
Hannah Nelson
Jake Noble
Ben Palmer
Justin Pearl
Shawn Peterson
Sabrina Pflanzer
Brian Piechocki - Cum Laude
Levi Pietila
Carson Price - Cum Laude
Spencer Reames
Taylor Reed - Cum Laude
Tom Richter
Brian Roman
Bryant Rowe
Marshall Sayles
Laura Schimmel - Cum Laude
Alec Schmoll
Chris Schultz
Brady Severt - Cum Laude
Devon Smith
Max Smith
Dan Stapley - Cum Laude
Cora Taylor
Matthew Thompson - Magna Cum Laude
Collin Triick
Jackson Troin
Courtney VanWagoner
Mike Vennard - Cum Laude
Sivakumar Vigneshwar
Julia Vu
Alan Wilson - Summa Cum Laude
Andrew Wunderlin
Gabriel Wykle
Duo Zhang

SPRING 2019 (187)

Quintin Abel
David Adamovicz - Cum Laude
Alex Akermann
David Anna - Summa Cum Laude
Kevin Anthony
Nick Anzalone
Jacob Ashley
John Bailey - Summa Cum Laude
Ryan Baumann
Jacob Bennett
Liz Bergh - Summa Cum Laude
Brody Berry
Austin Bittner - Summa Cum Laude
John Blanchard
Trevor Boal - Cum Laude
Monica Brechting - Cum Laude
Gordon Brinkman
Nick Brodowski - Magna Cum Laude
Logan Brunette - Cum Laude
Dakota Carpenter - Cum Laude
Max Casler
Cody Chartier
Yuxin Chen
Austin Chmura - Summa Cum Laude
Ryan Connolly
Ray Coyle - Summa Cum Laude
Trevor Cretney - Cum Laude

Aaron Curtiss
Adam Daavettila
Tania Demonte Gonzalez - Magna Cum Laude
Aaron Dene
Noah Dobrzelewski - Magna Cum Laude
Riley Dolan
Jason Dvorscak
Mitch Dzikowicz - Magna Cum Laude
Kevin Edlebeck
Dan Ellsworth
Christian Elsesser
Alex Emmes
Jacob Erickson
Emeka Esemonu - Cum Laude
Juan Espinoza-Birruete
Jake Evilsizer
Daniel Faber
Rob Falzon
Mike Ferron
Andrew Fischer
Alex Flory - Cum Laude
Krista Fog - Cum Laude
Patrick Free
Carl Fruncek - Magna Cum Laude
Gabrielle Fung
Jess Gering
Patrick Gilland - Magna Cum Laude
Kaleb Glowacki
Wesley Gratz
Paul Hanafin
Dan Heckman - Magna Cum Laude
Gabby Heinz - Magna Cum Laude
Jacob Hendrickson
Jacob Hubert - Magna Cum Laude
Paul Jacks
Tim Jackson - Cum Laude
Landon Jakubos
Joe Jarvi
Emil Johnson - Cum Laude
Ethan Johnson
Sarah Jones
Ben Judd - Summa Cum Laude
Jesse Justice - Magna Cum Laude
Jacob Kaisler - Magna Cum Laude
Quinn Kaspriak
Kathryn Keen - Magna Cum Laude
Alex Keit - Cum Laude
Joshua Kemppainen
Zack Kendziorski - Cum Laude
Matthew Kenney
Colton Kettelhut
Ethan Klein
Ben Klinter - Cum Laude
Christian Kniat - Cum Laude
Alyssa Knoester - Magna Cum Laude
Eric Kostreva
Lily Kraft
Ted Kretzmann
Tony Lackey
Jacob Laidlaw - Magna Cum Laude
Bradley Larson
Dylan Lauscher
Alex Lautenbach
Erik Lemmen
Richard Li
Jonathon Lindfors - Magna Cum Laude
Josh Loiselle
Sean Lusk - Magna Cum Laude
Andre Makela
Alex Malliett - Cum Laude
Anson Mannes
Trevor Marvin
John Matcheck
Sean McCann
Cal McCarty
Jared McDowell - Magna Cum Laude
Patrick Mcfall - Summa Cum Laude
John Medley
Brian Messman
Jared Meyer - Cum Laude
Adam Miller
Vince Mills
Nick Minarich
Jaime Modolo
Clay Nadolsky - Summa Cum Laude
Wes Nelson
Justin Niemi
Matthew Norton
Thomas O'Hotzke
Peter O'Mara - Cum Laude
Luke Olari - Cum Laude
Matt Olson
Michael Ostlund
Collin Overlock
Rachel Palen
Stanley Peterson
Bryce Potok
Ethan Prehoda
Alex Prucha
Austin Putnam-Johnson
Ryan Quigg - Magna Cum Laude
Jon Quinn
Steve Ramfjord - Cum Laude
Jacob Ramos
Becca Ratkowski
Colin Redner - Cum Laude
Nathaniel Regan
Aaron Richard
Thomas Richards
Josiah Richards - Summa Cum Laude
Gunnar Rogers
Rachel Savat
Zack Schultz
Andrew Schunter - Summa Cum Laude
Daniel Scsavnicki - Cum Laude
Brandon Seitz
Caleb Shear
Congtao Shen
Michael Sinclair - Cum Laude
Olivia Smith
Tanner Smith
Owen Soulliere
Rebecca Spencer
Alex Spiess
Nate Stancroff
Hugh Stanton
Logan Stetsko - Summa Cum Laude
Alec Stilwell - Magna Cum Laude
Alex Stine
Hannah Stoll
Cole Stout
Vilnis Stumbris
Alex Sutton
Dakota Sweeney
Max Tervo
Traven Thai
Wiley Thomas
Ryan Thompson
Chris Thompson
Christopher Thormodson - Cum Laude
Robbie Tian - Cum Laude
Zach Tibbits
Blake Tiber - Cum Laude
Kyle Tolman
Alex Voigt - Cum Laude
Taylor Warren - Cum Laude
Ryan Washington
Tyler Wells
Mark Wenzel - Cum Laude
Jacob Wenzlick
Mike Werthman - Cum Laude
Anna Wheatley
Jason Whitler - Magna Cum Laude
Jeremy Whitman
Davin Wiitanen
Sean Wilde
Aubrey Woern
Danny Woodall
Jason Worful
Travis Zuleger - Cum Laude

MS GRADUATES (123)

SUMMER 2018 (20)

Agarwal, Rohan Bipin
Advisor: Craig Friedrich
Course work only

Bharadwaj, Abhilash Muralidhar
Advisor: Craig Friedrich
Course work only

Bulusu Surya Naga, Praveen
Advisor: Greg Odegard
Design Optimization and High Cycle Fatigue Analysis and of a Differential Case

Johnson, Kevin M.
Advisor: Craig Friedrich
Course work only

Khopkar, Nikhil Charuhas
Advisor: Craig Friedrich
Course work only

Kolapkar, Shreyas Sunil
Advisor: Ezra Bar-Ziv
Pyrolysis of Fiber-Plastic Waste Blends

Larsen, William S.
Advisor: Jason Blough
Analysis of the Shock Response Spectrum and Resonant Plate Testing Methods

Mishra, Soumil Shreya
Advisor: Craig Friedrich
Course work only

Nayak, Shyam Vaman
Advisor: Craig Friedrich
Course work only

Pandya, Joy Kalpeshbhai
Advisor: Craig Friedrich
Course work only

Pawar, Ashray
Advisor: Craig Friedrich
Course work only

Pendse, Pratik Vivek
Advisor: Craig Friedrich
Course work only

Reddy, Gurijala Venkat Prithvi
Advisor: Darrell Robinette
Control Oriented Modeling of an Automotive Drivetrain for Anti-Jerk Control

Sheffield, Logan M.
Advisor: Craig Friedrich
Course work only

Shinde, Omkar Uday
Advisor: Gregory Odegard
Fractography of As-Cast Ductile Iron Samples and Analyzing the Effect of Skin Roughness on its Fatigue Properties Using Fracture Mechanics Approach

Surresh, Kaushik
Advisor: Mahdi Shahbakhti and Darrell Robinette
Modeling and Analysis of Chevy Volt Gen II Hybrid Vehicle in Electric Mode

Thakkar, Utkarsh Kamlesh
Advisor: Craig Friedrich
Course work only

Trivedi, Saumya Kamlesh
Advisor: Craig Friedrich
Course work only

Vanheusden, Elizabeth M.
Advisor: Lyon King
Thermomagnetic Convective Cooling of Hall Effect Thruster

Wang, Huanqing
Advisor: Bo Chen
Development of Dynamic Programming and Receding Horizon Control Strategies for GM Volt II Multi-Mode Hybrid Electric Vehicle

FALL 2018 (27)

Ahuja, Nitisha
Advisor: Seong-Young Lee
Experimental Investigation of Impinged Droplet Dynamics

Bonfochi Vinhaes, Vinicius
Advisor: Jeff Naber and Mahdi Shahbakhti
Combustion Development of a High Efficiency Diesel Micro Pilot Natural Gas Engine

Boyapally, Sampath Kumar Reddy
Advisor: Craig Friedrich
Course work only

Bruck, Daniel S.
Advsior: Craig Friedrich
Course work only

Dasari, Surya Prakash Reddy
Advisor: Craig Friedrich
Course work only

Gowdelli, Baleshwar
Advisor: Craig Friedrich
Course work only

Heilman, Michael T.
Advisor: Craig Friedrich
Course work only

Jadav, Abhishek K.
Advisor: Jeff Naber and John Johnson
Experimental and Modeling Study of Particulate Matter Oxidation Under Loading Conditions for a SCR Catalyst on a Diesel Particulate Filter

Kamal, Anurag
Advisor: Lucia Gauchia
Course work only

Khoshbakht Irdmousa, Behrouz
Advisor: Craig Friedrich
Course work only

Lyu, Jianyang
Advisor: Ossama Abdelkhalik and Lucia Gauchia
Optimization and Control of an Array of Wave Energy Converters

Mitchell, Byrel R.
Advisor: Craig Friedrich
Course work only

Murali, Balaji
Advisor: Craig Friedrich
Course work only

Naglak, John E.
Advisor: Nina Mahmoudian
Applications of Robot Operating System (ROS) to Mobile Microgrid Formation Outdoors

Patel, Divykumar Chandrakant
Advisor: Craig Friedrich
Course work only

Patil, Aishwary Sharad
Advisor: Craig Friedrich
Course work only

Patil, Devyani B.
Advisor: Youngchul Ra
Analysis of Injection Parameters Influencing Gasoline Direct Injection Compression Ignition (GDICI) Engine Operation in LTC using Naphtha

Pinto, Clive Nelson
Advisor: Craig Friedrich
Course work only

Pourhasanzadehsharifi, Maryam
Advisor: Jeffrey Naber
Course work only

Rahul Jitendra Thakkar, FNU
Advisor: Craig Friedrich
Course work only

Sandugula, Sai Charan
Advisor: Craig Friedrich
Course work only

Shinde, Nikhil Appasaheb
Advisor: Amitabh Narain
Innovative Fin-Tubes for a Standard Staggered Bundle Leading to Significant Reductions in Air-Side Thermal and Pressure-Drop Resistances for a Popular Heat-Exchanger

Surve, Shubhada Satishraje
Advisor: Craig Friedrich
Course work only

Timm, Mitchel L.
Advisor: Hassan Masoud
Evaporation of a Sessile Droplet on a Slope

Tushar Khanna, FNU
Advisor: Craig Friedrich
Course work only

Vojini, Amit Dev
Advisor: Amitabh Narain
Innovative Fin-Tubes for a Standard Staggered Bundle Family Leading to Significant Reductions in Air-Side Thermal and Pressure-Drop Resistances for a Popular Heat-Exchanger - Modeling and Analysis in the Context of its Deployment...

SPRING (76)

Anand, Anupam
Advisor: Craig Friedrich
Course work only

Bagaria, Mayank Kumar
Advisor: Gregory Odegard
Experimental and Numerical Simulation of Split Hopkinson Pressure Bar Test on Borosilicate Glass

Bandi, Tanmay
Advisor: Craig Friedrich
Course work only

Bansal, Aayush
Advisor: Craig Friedrich
Course work only

Basugade, Akshay Arun
Advisor: Craig Friedrich
Course work only

Beavers, Ethan J.
Advisor: Craig Friedrich
Course work only

Bhasme, Saurabh Sudhakar
Advisor: Mahdi Shahbakhti and Darrell Robinette
Modeling Chevy Volt Gen II Supervisory Controller in Charge Sustaining Operation

Bhattacharjya, Shuvodeep
Advisor: Jeffrey Naber
Effect of Sensor Errors on Autonomous Steering Control and Application of Sensor Fusion for Robust Navigation

Birhade, Amol Rajendra
Advisor: Craig Friedrich
Course work only

Chakravarthi Dwarakanathan, Vishal Jagannathan
Advisor: Craig Friedrich
Course work only

Chavan, Jaideep Singh
Advisor: Craig Friedrich
Course work only

Chutani, Ayush
Advisor: Craig Friedrich
Course work only

Couture, Claire M.
Advisor: Craig Friedrich
Course work only

D Souza, Minorka
Advisor: Craig Friedrich
Course work only

Darokar, Kaushal Kumar
Advisor: Mahdi Shahbakhti and Darrell Robinette
Automotive Driveline Backlash State and Size Estimator Design for Anti-Jerk Control

Devaragudi, Sai Rajeev
Advisor: Bo Chen
MPC-Based Autonomous Driving Control with Localized Path Planning for Obstacle Avoidance and Navigating Signalized Intersections

MS GRADUATES (CONT.)

Dhawad, Aishwarya Surendra
Advisor: Craig Friedrich
Course work only

Dhongre, Fauzan Ayyaz
Advisor: Craig Friedrich
Course work only

Doshi, Rumit Rakeshbhai
Advisor: Craig Friedrich
Course work only

Dulong, Cameron R.
Advisor: Craig Friedrich
Course work only

Fata, Zachary C.
Advisor: Craig Friedrich
Course work only

Francis, Adam D.
Advisor: Craig Friedrich
Course work only

Ghate, Atharva Pravin
Advisor: Craig Friedrich
Course work only

Girdhar, Sunit
Advisor: Craig Friedrich
Course work only

Gundre, Karan
Advisor: Craig Friedrich
Course work only

Gupta, Ishan
Advisor: Craig Friedrich
Course work only

Hansel, Cameron
Advisor: Craig Friedrich
Course work only

Hiray, Sanket Rajendra
Advisor: Craig Friedrich
Course work only

Jadhav, Aniket Maruti
Advisor: Craig Friedrich
Course work only

Jain, Ojus Suresh
Advisor: Craig Friedrich
Course work only

Jain, Shubham Ramesh
Advisor: Gregory Odegard
Design Optimization of Brake Rotor Using CFD Techniques

Jain, Swejal
Advisor: Craig Friedrich
Course work only

Joshi, Chaitanya Vilas
Advisor: Craig Friedrich
Course work only

Kalinkar, Ashutosh Anil
Advisor: Craig Friedrich
Course work only

Kange, Mayuresh Pandharinath
Advisor: Craig Friedrich
Course work only

Kolb, Benjamin S.
Advisor: Andrew Barnard
Experimental Characterization of Hydraulic System Sound

Kulkarni, Aditya Dattatraya
Advisor: Craig Friedrich
Course work only

Kumar, Gaurav
Advisor: Craig Friedrich
Course work only

Kumbhalkar, Konark Dhananjay
Advisor: Gregory Odegard
Weight Reduction of a Differential Case and Its Static Structural Analysis

Lokhande, Tejas
Advisor: Craig Friedrich
Course work only

Luchenbach, Andrew S.
Advisor: Craig Friedrich
Course work only

Mahapatra, Ajitesh
Advisor: Craig Friedrich
Course work only

Mehandi Ratta, Prince Kumar
Advisor: Craig Friedrich and Aleksandr Sergeyev
Remotely Controlled Industrial Robotic Arm and Simulation of Automated Thermal Furnace

Mehta, Shardool Raju
Advisor: Craig Friedrich
Course work only

Mistry, Jinitkumar Nirajkumar
Advisor: Craig Friedrich
Course work only

Mohd Yaqzan, FNU
Advisor: Gordon Parker
Closed Loop Energy Maximizing Control of a Wave Energy Converter Using an Estimated Linear Model that Approximates the Nonlinear Froude-Krylov Force

More, Kuldeep Popat
Advisor: Craig Friedrich
Course work only

Muralidhar Nischal, FNU
Advisor: Jeffrey Naber and Jason Blough. *Application of Sensor Fusion for SI Engine Diagnostics and Combustion Feedback*

Patel, Meet Naimeshbhai
Advisor: Craig Friedrich
Course work only

Patil, Ajay Jangonda
Advisor: Craig Friedrich
Course work only

Patil, Chinmay Vishwas
Advisor: Craig Friedrich
Course work only

Pochettino, Andrew
Advisor: Jeffrey Naber and John Johnson
Course work only

Pratapa, Vinaykrishna
Advisor: Craig Friedrich
Course work only

Premchandani, Siddharth
Advisor: Craig Friedrich
Course work only

Raghupathy, Vishnu Prasaad
Advisor: Craig Friedrich
Course work only

Rama, Neeraj
Advisor: Darrell Robinette
Route-Optimized Energy Management of Connected and Automated Multi-mode Plug-in Hybrid Electric Vehicle using Reduced-order Powertrain Modeling and Dynamic Programming

Rana, Sachin
Advisor: Craig Friedrich
Course work only

Ravi, Vijayanand
Advisor: Craig Friedrich
Course work only

Ravindran, Arvind
Advisor: Craig Friedrich
Course work only

Sarkar, Animesh
Advisor: Craig Friedrich
Course work only

Sathi, Harsha Reddy
Advisor: Craig Friedrich
Course work only

Shah, Deep Dirgesh
Advisor: Craig Friedrich
Course work only

Sharma, Palash
Advisor: Craig Friedrich
Course work only

Singh, Vishavjit
Advisor: Craig Friedrich
Course work only

Sista, Venkatmayur
Advisor: Craig Friedrich
Course work only

Somasundaram, Ajay
Advisor: Craig Friedrich
Course work only

Spike, Nathan D.
Advisor: Darrell Robinette and Jeremy Bos
Course work only

Sullivan, Mary C.
Advisor: Craig Friedrich
Course work only

Tamhankar, Nikhil Keshav
Advisor: Craig Friedrich
Course work only

Thakur, Ritesh Rajendra
Advisor: Craig Friedrich
Course work only

Tilgule, Harshal Vinod
Advisor: Craig Friedrich
Course work only

Tiwari, Pranay
Advisor: Craig Friedrich
Course work only

Vigil, Emily A.
Advisor: Craig Friedrich
Course work only

Visal, Saleel Milind
Advisor: Craig Friedrich
Course work only

Weisend, Logan A.
Advisor: Craig Friedrich
Course work only

Woodland, Mark T.
Advisor: Craig Friedrich
Course work only

PHD GRADUATES (15)

SUMMER 2018 (6)

Ahmadi Darani, Shadi
Advisor: Ossama Abdelkhalik
System Architecture Optimization Using Hidden Genes Genetic Algorithms with Applications in Space Trajectory Optimization

Bellur, Kishan S.
Advisor: Jeffrey Allen and Chang Kyoung Choi
A New Technique to Determine Accommodation Coefficients of Cryogenic Propellants

Tang, Meng
Advisor: Jeffrey Naber and Seong-Young Lee
A Spray and Combustion Studies of High Reactivity Gasoline in Comparison to Diesel under Advanced Compression Ignition Engine Conditions

Wang, Luting
Advisor: Bo Chen
Study of Modeling and Optimal Control of Plug-In Electric Vehicles and the Integration with Smart Grid

Yao, Wentao
Advisor: Reza Shahbazian-Yassar
Interplay of Ionic Transport and Crystal Facets in Lithium-Ion Battery Cathodes

Zou, Shangyan
Advisor: Ossama Abdelkhalik
Optimal Control of Wave Energy Converters

FALL 2018 (6)

Dahodwala, Mufaddel Z.
Advisor: Jeffrey Naber
Experimental and Computational Investigation of Dual Fuel Diesel-Natural Gas RCCI Combustion in a Heavy-Duty Diesel Engine

De Jesus Rivera, Edward
Advisor: Darrell Robinette
Pressure Measurements Inside Multiple Cavities of a Torque Converter and CFD Model Correlation

Imam, Muhammed Rifat
Advisor: Trisha Sain
Design, Deformation Mechanics, and Failure of Architectured Polymeric Materials

Li, Bingxi
Advisor: Nina Mahmoudian
Multi-Robot Mission Planning with Energy Replenishment

Moser, Trevor H.
Advisor: Tolou Shokuhfar and Craig Friedrich
A Journey Towards Understanding Biology Holistically at the Nanoscale

Salvato, John J.
Advisor: Zequn Wang and John Gershenson
Agile-Stage Gate Management (ASGM): NPD Implementation Practices from Global Firms Developing Complex, Physical Products

SPRING 2019 (3)

Li, Xian
Advisor: Ye Sun
A Hybrid-Powered Wireless System for Multiple Biopotential Monitoring

Sepahyar, Soroush
Advisor: Amitabh Narain
Influence of Micro-Nucleate Boiling on Annular Flow Regime Heat Transfer Coefficient and Flow Parameters - for High Heat-Flux Flow Boiling of Water

Trinklein, Eddy H.
Advisor: Gordon Parker
Optimal Power Flow Control of Networked DC Microgrids

Kautzer Named 2019 Academic All-American

Michigan Tech Nordic skier, **Amanda Kautzer** was named a 2019 Academic All-American, selected by the members of the College Sports Information Directors of America (CoSIDA). She was also honored on the Google Cloud Academic All-America® Division II Women's At-Large Team.

Kautzer finished the 2018-19 Nordic ski season with a 4.0 grade-point average as a mechanical engineering and biomedical engineering dual major, now entering her fourth year at Michigan Tech.

This summer Kautzer worked as an undergraduate researcher in the Engineered Biomaterials Lab of Dr. Rupak Rajachar in the Department of Biomedical Engineering at Michigan Tech. She has also worked as an engineering intern at RTI Surgical.

Kautzer was the champion in the 15k classic at the 2019 NCAA Central Region Skiing Championships and competed for Michigan Tech at the 2019 NCAA Skiing Championships, where she finished in the top 20 in the 15k classic.

Her stellar season earned her a pair of All-Region honors and a First Team All-CCSA accolade. In addition, Kautzer received the team's Scholastic Achievement Award and was also named Most Improved Skier.

She is also a member of two consecutive United States Collegiate Ski Association (USCSCA) All-Academic Teams. And that's not all. Kautzer has qualified for the US women's team in the Biathlon Junior World Championship four years in a row.

Kautzer grew up in Plymouth, Minnesota, attending Benilde-St. Margaret's High School. She enjoys adventuring, canoeing, reading, knitting, and photography.

LECTURERS (L - R): **Steven Ma,** Professor of Practice; **Aneet Narendranath,** Senior Lecturer; **Jim De Clerck,** Professor of Practice; **Cameron Hadden,** Lecturer; **Jaclyn Johnson,** Senior Lecturer; **Radheshyam Tewari,** Senior Lecturer; **Nancy Barr,** Professor of Practice. **NOT PICTURED: Rao Komaravolu,** Principal Lecturer.

ADVICE TO STUDENTS

"Build your interpersonal communication skills. They are necessary for professional and personal success."
NANCY BARR

"Learn actively, with dedication. Seek help from instructors and peers."
STEVEN MA

"Get a good night's sleep on exam day."
CAMERON HADDEN

"Slow down and really absorb the material from each class, even if that means longer to graduate. Seriously consider graduate school."
JEREMY WORM

"Even if you've never done it before, it doesn't mean you'll do it wrong."
JOEL DUNCAN

"Learn to manage your time."
ALEX NORMAND

"Don't limit yourself to one textbook for a course. Instead, use our brilliant campus library to review the same material through the voice of several different authors."
ANEET NARENDRANATH

"Go to class, study hard, and have a little fun along the way!"
DEBRA LINN

"Hard work pays off! Believe!"
CINDY WADAGA

"Cope with failure by learning from your mistakes."
TRICIA STEIN

"Get involved in undergraduate research!"
STEVEN SENCZYSZYN

"Don't be afraid to make a mistake. Try something... evaluate what was good and not so good. Make improvements and keep moving forward."
STEVEN LEHMANN

"Focus on your priorities first!"
CHRISTOPHER MORGAN

"Don't let not knowing something stop you from making progress. The information is out there, talk to people, research, collect information and never stop learning new skills."
RACHEL HOOK

"Aim sky high and never stop improving."
RADHESHYAM TEWARI

BEST PART OF MY JOB

"Interacting with students and seeing their achievements, knowing I've played a small role in it."
JACLYN JOHNSON

"Working with the students, staff, and faculty."
MARTIN TOTH

"The people."
CONNIE TUOHIMAA

"Being involved with teams of researchers who are developing exciting new technologies for bettering the human condition, the environment—even outer space!"
MARLENE LAPPEUS

"The moment a student recognizes they just accomplished something they thought they couldn't."
JONATHAN LUND

"The people I work with every day, and the students I am able to help."
PAULA FEIRA ZENNER

STAFF (L - R): Tricia Stein, Engineering Academic Advisor I; **Marlene Lappeus,** Assistant Director of Research & Graduate Online Programs; **Debra Linn,** Office Assistant; **Alexander Normand,** Office Assistant - APSRC; **Cindy Wadaga,** Graduate Program Assistant; **Ryan Towles,** Academic Advisor; **Karen Bess,** Executive Assistant; **Connie Tuohimaa,** Manager of Finance & Accounting.

NOT PICTURED: Robert DeJonge, Senior Research Engineer II; **Dale Kero,** Senior Major Gift Officer; **Kristi Kesti-Pieti,** Administrative Aide; **Christina Sarazin,** APSRC Office Assistant; **Mark Somero,** Senior Capstone Design Training Specialist; **Paula Zenner,** Director of Operations & Finance.

APSRC STAFF (L - R): **Jeremy Worm,** Associate Director; **Bill Atkinson,** Research Engineer; **Brian Eggart,** Research Engineer; **Tucker Alsup,** Assistant Research Engineer; **Paul Dice,** Manager; **Rachel Hook,** Research Engineer Scientist I; **Christopher Morgan,** Operations Manager; **Joel Duncan,** Research Associate; **Henry Schmidt,** Research Engineer; **Steven Senczyszyn,** Research Engineer.

NOT PICTURED: **Ed Trinklein,** Research Engineer & Instructor; **Steve Lehmann,** Research Associate.

ROLE MODEL(S)

"Chris Passerello and Harold Evensen (ME-EM professors, now retired). Both had systematic approaches that worked to determine solutions to any problem."

JIM DE CLERCK

"Dr. Bill Predebon, a champion of this department for over 40 years with great passion and strong work ethic."

KRISTI KESTI-PIETI

STAFF (L - R): **Martin Toth,** Shop Supervisor; **Robert Page,** Laboratory Facilities Manager; **Jonathan Lund,** Senior Design Training Specialist.

TOUGHEST PART OF MY JOB

"Juggling and mind-reading."

KAREN BESS

"The sheer number of ME undergrads."

RYAN TOWLES

"The breadth of projects. Each requires its own set of skills which take time to acquire and master."

ED TRINKLEIN

Distinguished Teaching Award

"Teaching is fun for me. For me it's more about giving back. I had a lot of really great teachers who gave me a lot and I feel like I owe it to the students to give that back to them."

Dr. Andrew Barnard knows what it's like to be a Michigan Tech student; he earned both his bachelor's (2002) and master's (2004) degrees in mechanical engineering at Tech before heading to Penn State for a PhD in acoustics, work he completed in 2010.

Barnard spent eight years as a research associate in the Applied Research Laboratory at Penn State before returning to the ME-EM Department as an assistant professor in 2014. He was recently promoted to associate professor with tenure. Along with his promotion in early May 2019, Barnard was named the director of the Great Lakes Research Center.

"This award means a lot to me, especially because it's based on student evaluations," says Barnard. "Because they're really the customer, that's who I'm here to help. To me it means they think I'm doing a good job delivering my content to them, which is really what professors are: content providers. And there are a lot of content providers out there, so it's nice to know I can compete."

> *"Andrew is highly regarded by his students. His teaching evaluations have consistently been in the top 10% of faculty teaching evaluations since he started at Michigan Tech. He is able to bring his excitement for his research into the classroom in a way that resonates with his students. This recognition by students is very well deserved."*
>
> –Dr. William Predebon, Chair, ME-EM Department

AWARDS

Dr. Andrew Barnard was promoted from assistant professor without tenure to associate professor with tenure.

Dr. Nancy Barr was elected to the IEEE Professional Communication Society's (PCS) board of governors.

Dr. John E. Beard was granted professor emeritus status. He will continue to work with his students and the Department as a research professor.

Dr. James De Clerck received the Student Organization Advisor of the Year award at the 25th Annual ME-EM Student Leadership Awards Banquet.

Dr. Lucia Gauchia has been promoted from assistant professor without tenure to associate professor with tenure.

Dr. Cameron Hadden (lecturer) received the 2019 Mechanical Engineering Teacher of the Year Award by the ME Student Advisory Council.

Marlene Lappeus, assistant director, research and graduate on-line program, celebrated 15 years of service to Michigan Tech.

Dr. Stephen Morse received an American Society for Testing and Materials (ASTM) International Committee Award of Appreciation for his outstanding contributions to the Standard Practice for Determining Load Resistance of Glass in Buildings, and Glass Use in Buildings.

Dr. Gregory Odegard was elected a fellow of ASME in recognition of his significant impact and outstanding contributions in the field of composite materials research. He pioneered computational modeling techniques to predict the influence of molecular structure on bulk-level properties of composite materials.

Dr. William (Bill) Predebon, department chair and professor (ME-EM) received a Certificate of Recognition for his commitment to engineering education and continuous service to the society at the ASME International ME Education Leadership Summit in New Orleans.

Dr. Younchul Ra was promoted from associate professor without tenure to associate professor with tenure.

Dr. Darrell Robinette received the 2019 Forest R. McFarland Award from SAE Engineering.

Dr. Sheryl Sorby (professor emerita) was elected president-elect of the American Society for Engineering Education (ASEE), a term she will hold one year before assuming the presidency in 2020.

Martin Toth, training specialist supervisor, celebrated 20 years of service to Michigan Tech.

Charles Van Karsen was granted professor emeritus status. He will continue to work with his students and the Department as a research professor.

Dr. Paul van Susante received the 2018 Outstanding Professional Service Award by the Aerospace Division of the American Society of Civil Engineers.

Dr. Jeremy Worm was appointed to the Michigan Truck Safety Commission by Michigan Governor Gretchen Whitmer.

JOHN JOHNSON AWARD

The SAE John Johnson Award for Outstanding Research in Diesel Engines goes to **Dr. David Foster**, an internationally-renowned consultant on engine combustion processes, emissions control, and efficiency improvements at the University of Wisconsin-Madison.

The award is funded through contributions by ME-EM Professor Emeritus John Johnson. Nominations can be made online at SAE.org.

New Professor of Practice

Dr. Nancy Barr has accepted an appointment as Professor of Practice. As director of the ME-EM Engineering Communications Program, she delivers embedded communication instruction to undergraduate students, teaches graduate engineering communication courses, assists faculty in crafting critical thinking/communication assignments, and trains faculty in best practices for evaluating student communication.

Barr currently serves as secretary of the IEEE Professional Communication Society Board of Governors. She is a member of the American Society of Engineering Education, National Council of Teachers of English, and the Consortium for Graduate Communication. She has a PhD in Rhetoric, Theory, and Culture from Michigan Tech. She is also the author of three mystery novels. Read more on her blog, stemcommunications.wordpress.com.

Best part about my job?
Teaching, cross-disciplinary projects, and curriculum development.

Advice to students?
Build your interpersonal communication skills. Those skills are necessary for professional and personal success.

MISSION

PREPARE ENGINEERING STUDENTS FOR SUCCESSFUL CAREERS.

VISION

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2018 ME-EM ACADEMY INDUCTEES

DR. TONY ALTOBELLI BSME '86

Tony Altobelli has served as Assistant Treasurer at Google for 11 years since joining the company in 2007. In his role as head of the investment portfolio management group, Altobelli designed and established Google's investment management platform to manage the company's worldwide cash portfolio that presently exceeds $100 billion.

Altobelli is now the head of Risk and Strategy at Google Treasury, responsible for investment and hedging strategies and risk management activities.

During his tenure at Google, Altobelli has also held several other treasury leadership positions in the areas of corporate finance and capital markets, managing the company's liquidity and financing activities, financial derivatives strategies, foreign exchange risk management, capital structure, and strategic corporate initiatives, including investments in renewable energy and affordable housing projects. He has served as a member of the Google 401(K) advisory committee.

Prior to joining Google, he spent 11 years serving in various quantitative and leadership roles within the treasury department at Hewlett-Packard Company in Palo Alto, Calif. At HP, he led the corporate finance and capital markets functions, capital structure initiatives, derivatives and interest rate risk management activities, and served as Foreign Exchange Manager. While at HP, Altobelli was recognized by a number of Wall Street publications for his innovative work on risk management and derivatives strategies for managing financial risk.

His first job after graduating from Michigan Tech with a BS in mechanical engineering was as a design engineer at the General Electric Company Medical Systems Group in Milwaukee, WI. He worked on the development of innovative diagnostic imaging systems such as CAT scanners, MRI, and X-ray systems used in healthcare.

BRIAN J. KRINOCK BSME '85

Brian Krinock is Senior Vice President, Manufacturing & Engineering - Vehicle Plants for Toyota Motor North America (TMNA). In his role, Krinock is responsible for Toyota's eight vehicle assembly plants that produce over two million vehicles annually with over 30,000 team members.

Prior to his current role, he served as President of Toyota Motor Manufacturing Canada, Inc. (TMMC) for five years. TMMC assembles over 550,000 Corolla, RAV4, and Lexus RX series vehicles yearly.

During his time in Canada, the plant won seven consecutive global JD Power Awards while undergoing significant plant expansions and model changes doubling capacity.

Prior roles within Toyota include serving as the North American leader for the Toyota/Subaru manufacturing joint agreement in Lafayette, Ind.; Solara Chief Manufacturing Engineer; general manager of Purchasing Division; and numerous positions within the Production Engineering Division.

Krinock began his Toyota career in 1991 after working for the Chrysler Corporation for six years. He is a Chrysler Institute of Engineering graduate and holds a Master of Engineering from Oakland University. He graduated from Michigan Technological University in 1985 with two Bachelor of Science degrees in Mining and Mechanical Engineering.

Krinock is a strong supporter of a private Christian summer camp for inner-city children and has had leadership positions for various community organizations. He resides in the state of Kentucky with his wife, Julie, and three children. He enjoys skiing, camping, biking, and boating.

The purpose of the Academy is to honor outstanding graduates of the Michigan Technological University Department of Mechanical Engineering - Engineering Mechanics. Selection into the Academy recognizes excellence and leadership in engineering and civic affairs.

This induction honors some of the most successful of the more than thirteen thousand alumni of Michigan Tech's Department of Mechanical Engineering - Engineering Mechanics. Portraits and a brief biography of Academy members are prominently displayed in the lobby of the ME-EM building to serve as inspirational role models for future mechanical engineering and engineering mechanics students.

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SERVING OTHERS: MICHIGAN TECH HONORS KARL ('85 BSME) & CHRISTINE LAPEER ('85 BSMT)

The Michigan Tech Humanitarian Award is presented to those alumni and friends who, through their outstanding involvement and dedication, have made a significant contribution of volunteer leadership or service which has improved or enriched the lives of others and the welfare of humanity.

Karl and Chris LaPeers practice their humanitarian efforts at Michigan Tech (funding seven, four-year scholarships) and also around the world. The couple were honored at the Michigan Tech Alumni Reunion on August 2.

During his time at Tech, Karl vividly remembers the second day of classes. "I met my future bride (now wife of 32 years) in a calculus class—the best thing that ever happened to me at Michigan Tech."

After graduation, Karl joined Fanuc Robotics to design industrial robots for the automotive industry. He returned to his studies, in business this time, at the University of Michigan where he became a Henry Ford Scholar, graduated first in his class, and earned his MBA in 1993. Karl helped start Peninsula Capital Partners, an investment company, where he works to this day.

Over the course of the last decade Karl and Chris have helped fund one of the largest mission movements in history, and funded ministries ranging from Christian bands to missionaries and evangelists.

In 2013, the LaPeers and their children, working through the Angel House initiative, funded the building of three Angel House Orphanages (25 children each) and two freshwater wells in India.

The LaPeers joined the massive 1Nation1Day (1N1D) mission outreach in the Dominican Republic in 2015, and then again, in Nicaragua in 2017. Most recently, last June, the LaPeers traveled to Peru for 1N1D, working in Taropoto, in the Amazon region of Peru, co-leading the efforts of 150 foreign missionaries. Chris, a medical technologist, ran a medical clinic with over 30 medical professionals that treated, at no cost, nearly 1,500 patients in five days. Karl gave lectures at universities, spoke at leadership and business conferences, churches, and press conferences.

Their son, Nate (25), daughter-in-law Elizabeth (25), and two daughters, Heather (29) and Elayna (12) made the trip to Peru, too, teaching children in local schools. The family also helped fund clean water projects in Tarapoto and Cusco that are now providing clean, safe water to people—many for the first time in their lives.

Their goal now, as a family, says Karl, is to "dig deeper to reach more people with a message of hope, purpose, and eternity—not just on foreign mission trips, but each day where we live and work."

2018-19 PCA MEMBERS

The Presidential Council of Alumnae (PCA) at Michigan Tech, recognizes successful Michigan Tech women graduates for their educational excellence, past student service, professional accomplishments, and community contributions.

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EXTERNAL ADVISORY BOARD

The External Advisory Board (EAB) is a select group of corporate, university, and government leaders, many of whom are alumni. EAB members share their expertise and provide assistance with curriculum direction, research topics, resource development, and education-industry partnership.

They offer professional insight and provide valuable input, shaping the state-of-the art engineering education that takes place in the ME-EM Department. Members can serve a maximum of two four-year terms.

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Donors are critical to the success of the Department of Mechanical Engineering-Engineering Mechanics. Please consider directing your donation to the ME-EM Department Building for the Future, Phase II, Endowing Excellence Fund using the enclosed self-addressed envelope. Every gift counts and will be used to make a difference in the education of our students.

The following list encompasses the many people who have generously shared their treasure to create an outstanding ME-EM Department. We are extremely grateful for their ongoing support.

Those contributing directly to the ME-EM Department from **June 1, 2018 to May 31, 2019** are listed below. Note: Employee matching gifts are listed among individuals, below.

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ADVANCED POWER SYSTEMS $6,316,856

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Co-Optimized PPCI-SI Engine System Demonstrator to Improve Fuel Economy while Meeting LEVIII Emissions	PI: Jeffrey Naber Co-PI: Youngchul Ra, Seong-Young Lee, Mahdi Shahbakhti, Jeremy Worm, Henry Schmidt	Hyundai-kia America Technical Center, Inc (HATCI)	$1,161,130	2019-2021	$1,161,130
Proof-of-Concept and a Prototype of an Integrated Torrefaction-Extrusion Unit for Organic Wastes Streams	PI: Ezra Bar-Ziv	National Science Foundation	$750,000	2018-2021	$750,000
Next-Generation Desiccant-Based Gas Clothes Dryer System	PI: Sajjad Bigham	US Department of Energy	$718,288	2019-2022	$718,288
Torrefaction of Sorted MSW Pellets to Produce a Uniform Feedstock for Biopower	PI: Ezra Bar-Ziv	Battelle Energy Alliance - Idaho National Laboratory	$700,213	2018-2020	$700,213
Control-oriented Modeling and Predictive Control of Advanced Dual Fuel Natural Gas Engines	PI: Mahdi Shahbakhti Co-PI: Jeffrey Naber	National Science Foundation	$331,422	2018-2021	$331,422
MTU Consortium in Diesel Engine Aftertreatment Research Phase II	PI: John Johnson Co-PI: Jeffrey Naber, Gordon Parker	Various Sponsors: Isuzu, Cummins	$229,127	2016-2019	$169,639
Alternative Fuels Research with Argonne National Laboratory	PI: Scott Miers	Argonne National Laboratory	$185,836	2019-2020	$92,219
Post Doctoral Research Fellow Studies	PI: Jeffrey Naber	Aramco Services Company	$167,126	2018-2019	$167,126
Snowmobile Mini-PEMs	PI: Scott Miers Co-PI: Brian Eggart	Environment and Climate Change Canada	$165,381	2018-2019	$165,381
Ford Sensor Fusion	PI: Jeffrey Naber Co-PI: Jason Blough, Paul Dice, Joel Duncan	Ford Motor Company	$160,000	2019	$160,000
Investigation on Enhancement of Combustion Performance and Efficiency of GCI and Mixed Mode Combustion in a 6-Stroke-Cycle Engine with CVVD Technique	PI: Youngchul Ra	Hyundai Motor Company	$160,000	2019-2021	$160,000
Nostrum Stationary Power with NG/Diesel Pilot Injection	PI: Jeffrey Naber Co-PI: Joel Duncan, Tucker Alsup, Paul Dice	Nostrum Energy, LLC	$150,000	2019-2020	$150,000
Multi-Axis Resonant Fixture Shock	PI: Jason Blough Co-PI: Charles Van Karsen, James De Clerck	Honeywell Federal Manufacturing & Technologies, LLC	$149,000	2018	$25,000
Investigation of Injection Spray Characteristics	PI: Henry Schmidt Co-PI: Bill Atkinson, Jeffrey Naber	Aramco Services Company	$124,636	2019	$124,636

ADVANCED POWER SYSTEMS (CONT.) $6,316,856

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Tailorable Resonant Plate Shock	PI: Jason Blough Co-PI: Charles Van Karsen, James De Clerck	Honeywell Federal Manufacturing & Technologies, LLC	$120,000	2018-2019	$120,000
Frequency Response Inspection of AM Parts	PI: Jason Blough Co-PI: Andrew Barnard, Kevin Johnson	Honeywell Federal Manufacturing & Technologies, LLC	$100,000	2018-2019	$100,000
Ford Ignition Studies	PI: Jeffrey Naber Co-PI: Paul Dice, Bill Atkinson	Ford Motor Company	$100,000	2019	$100,000
Nostrum SI DI Methanol/ Water Injection Optimization	PI: Jeremy Worm Co-PI: Jeffrey Naber	Nostrum Energy, LLC	$100,000	2019-2020	$100,000
Demonstration of a Coaxil Thermophone for Active Noise Control in Vehicles	PI: Andrew Barnard	University of Michigan	$99,608	2018-2019	$99,608
Spark Plug Electrode Erosion in a Heavy Duty Natural Gas Application	PI: Jeremy Worm	E3 Spark Plugs	$87,228	2018-2023	$87,228
Fixture Design and Damage Potential	PI: Jason Blough Co-PI: Charles Van Karsen, James De Clerck	Honeywell Federal Manufacturing & Technologies, LLC	$70,000	2019	$70,000
Nostrum High Brake Mean Effective Pressure	PI: Jeremy Worm Co-PI: Tucker Alsup, Joel Duncan	Nostrum Energy, LLC	$65,947	2019-2020	$65,947
Investigation of Injection Spray Characteristics for One HD Single-Hole Injector	PI: Henry Schmidt Co-PI: Jeffrey Naber, Bill Atkinson, Seong-Young Lee	Aramco Services Company	$55,219	2018-2019	$55,219
Investigation of Injection and Spray Characteristics for Two HD Diesel Injectors	PI: Jeffrey Naber Co-PI: Henry Schmidt, Bill Atkinson, Seong-Young Lee	PACCAR, Inc	$49,756	2018-2019	$49,756
Development and Application of Fuel Surrogate and Chemical Kinetics Model for PACCAR Truck Engine Simulation	PI: Youngchul Ra	PACCAR, Inc	$49,000	2018-2019	$49,000
Delivery of Hands-on Professional Development Modules in Diesel Engine Calibration and Powertrain Instrumentation	PI: Jeremy Worm Co-PI: Chris Morgan, Jeffrey Naber	US Department of Defense: Army Tank Automotive Research, Development, and Engineering Center	$47,000	2018	$47,000
Catalytic Combustion Diesel Oxidation Trap Catalyst Study	PI: Jeffrey Naber Co-PI: Paul Dice, Tucker Alsup, Joel Duncan	Catalytic Combustion Corporation	$42,940	2018-2019	$42,940
Hitachi Active Thermal Management Project Phase II	PI: Jeffrey Naber Co-PI: Chris Morgan, Tucker Alsup	Hitachi America, LTD	$35,000	2019	$35,000
Ford Combustion Sensing Control	PI: Jeffrey Naber Co-PI: Bo Chen	Ford Motor Company	$30,000	2019	$30,000

ADVANCED POWER SYSTEMS (CONT.) $6,316,856

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Delivery of Hands-on Professional Development Modules	PI: Chris Morgan Co-PI: Jeremy Worm	Dana Corporation	$24,657	2018	$24,657
Exhaust Emissions Analysis	PI: Scott Miers	Arctic Cat, Inc.	$19,639	2018	$19,639
Delivery of Hands-on Professional Development Modules in Propulsion Systems	PI: Chris Morgan	Dana Corporation	$16,124	2018	$16,124
Nostrum Condenbine Concept	PI: Jeffrey Naber	Nostrum Energy, LLC	$15,000	2019-2020	$15,000
Hitachi Active Thermal Management Project	PI: Jeffrey Naber Co-PI: Chris Morgan, Tucker Alsup	Hitachi Automotive Systems Americas, Inc	$14,000	2019	$14,000
Delivery of Hands-On Professional Development Modules in Electrified Propulsion Systems	PI: Chris Morgan Co-PI: Jeremy Worm, Darrell Robinette	AVL Powertrain Engineering, Inc.	$8,577	2019	$8,577
Investigation of Droplet Size of PFI Injectors	PI: William Atkinson Co-PI: Henry Schmidt, Jeffrey Naber	Nostrum Energy, LLC	$6,253	2019-2020	$6,253
Investigation of Injection Spray Opening and Closing Characteristics for HD Diesel Injector	PI: Henry Schmidt Co-PI: Jeffrey Naber, Bill Atkinson	PACCAR, Inc	$4,717	2019	$4,717
Automotive Electrification Controls Engineering Professional Development	PI: Darrell Robinette Co-PI: Chris Morgan	Borg Warner	$4,032	2018	$4,032

AGILE INTERCONNECTED MICROGRIDS $2,952,390

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Agent-Based Control of Agile Energy Networks	PI: Gordon Parker Co-PI: Wayne Weaver (Electrical & Computer Engineering), Laura Brown (Computer Science), Steve Goldsmith	US Department of Defense, Army Research Laboratory	$900,000	2017-2020	$99,743
Autonomous Microgrids: Theory, Control, Flexibility and Scalability	PI: Wayne Weaver (Electrical & Computer Engineering) Co-PI: Rush Robinett, Nina Mahmoudian	US Department of Defense: Office of Naval Research	$869,980	2016-2020	$250,045
Toward Undersea Persistence	PI: Nina Mahmoudian	US Department of Defense: Office of Naval Research	$672,349	2015-2018	$104,677
HVDC Distribution Study of Intelligent Power System	PI: Wayne Weaver (Electrical & Computer Engineering) Co-PI: Gordon Parker	University of Dayton Research Institute	$220,244	2016-2018	$12,000
Real-time Simulator for Advanced Energy Network Planning Optimization	PI: Wayne Weaver (Electrical & Computer Engineering) Co-PI: Gordon Parker	US Department of Defense, Office of Naval Research	$200,000	2018-2019	$200,000
Magnetic Sensor Suite for Remotely Operated Vehicles for Littoral Threat Characterization in Complex Seabed Environments	PI: Nina Mahmoudian	Twinleaf, LLC	$89,817	2017-2019	$39,351

ENGINEERING EDUCATION INNOVATION $216,595

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Senior Design: Air Force University Engineering Design Challenge	PI: William Endres	Technology Service Coproration	$37,000	2018-2019	$37,000
Senior Design: Advanced Vehicle Hood Architecture and Design	PI: William Endres	FCA US, LLC	$26,640	2018-2019	$26,640
Senior Design: Air Cooled Inverter Heatsink	PI: William Endres	National Center for the Advancement of STEM Education (nCASE)	$25,530	2018-2019	$25,530
Senior Design: Gator XUV835 Exhaust System	PI: William Endres	John Deere	$25,530	2018-2019	$25,530
Senior Design: Laser Welding of Carbide-Tipped Saw Blade	PI: William Endres	Milwaukee Tool	$20,424	2019	$20,424
Senior Design: Auto Reciprocating Blade - Test Rig Improvement	PI: William Endres	Milwaukee Tool	$20,424	2019	$20,424
Senior Design: Variable Geometry Gerotor Pump Design	PI: William Endres	GHSP, Inc.	$12,765	2019	$12,765
Senior Design: Ball Piston Pump Design	PI: William Endres	GHSP, Inc.	$12,765	2019	$12,765
Senior Design: Surgical Instrument Life Cycle Test System	PI: William Endres	Thompson Surgical Instruments	$11,839	2019	$11,839
Senior Design: Improved Kerrison Rongeur Design	PI: William Endres	Thompson Surgical Instruments	$11,839	2019	$11,839
Senior Design: Surgical Instrument Direct Lighting Design	PI: William Endres	Thompson Surgical Instruments	$11,839	2019	$11,839

MULTISCALE TECHNOLOGIES INSTITUTE $2,081,591

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Novel Ionomers and Electrode Structures for Improved PEMFC Electrode Performance at Low PGM Loadings	PI: Jeffrey Allen Co-PI: Kazuya Tajiri, Ezequiel Medici	3M Corporation	$813,960	2016-2019	$257,376
NRI: INT: COLLAB: Anthropomorphic Robotic Ankle Prosthesis with Programmable Materials	PI: Mo Rastgaar	National Science Foundation	$680,182	2018-2022	$680,182
Hydraulic Sound Characterization	PI: Andrew Barnard	Caterpillar, Inc.	$216,960	2019	$70,000
Conductive Cell Imprinted Polymers for Mature Induced Pluripotent Stem Cell Derived Cardiomyocytes	PI: Michael Hill (Post Doctoral) Co-PI: Parisa Abadi	American Heart Association	$159,211	2019-2020	$159,211
I/UCRC: Novel High Voltage/ Temperature Materials and Structures	PI: Gregory Odegard Co-PI: Paul Sanders (Materials Science), Julia King (Chemical Engineerging)	Colorado Seminary - University of Denver	$102,350	2016-2019	$26,491
Automotive Noise Cancellation-Automotive HVAC	PI: Andrew Barnard	Calsonic Kansei North America	$99,112	2019	$99,112
Technology Review of Proton Exchange Polymer Electrolyte for Fuel Cell Application	PI: Kazuya Tajiri	Tosoh Corporation	$6,379	2019	$6,379
Vibrator Acceptance Testing	PI: Andrew Barnard	Orbion Space Technology Incorporated	$3,437	2019	$3,437

SPACE SYSTEMS $16,058,933

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
Institute for Ultra-Strong Composites by Computational Design (US-COMP)	PI: Greg Odegard Co-PI: Ravi Pandey, (Physics), Julia King, (Chemical Engineering), Trisha Sain	National Aeronautics and Space Administration	$14,999,995	2017-2022	$5,000,000
Low Mass, Low Power, Non-Mechanical Excavation of Gypsum and Other Evaporites and Water Production on Mars	PI: Jeffrey Allen Co-PI: Paulus van Susante, Timothy Eisele (Chemical Engineering), Ezequiel Medici	National Aeronautics and Space Administration	$520,481	2018-2021	$201,433
Testing the Equivalence of Evaporation and Condensation Coefficients using the Constrained Vapor Bubble (CVB) Data from ISS Experiments	PI: Jeffrey Allen	National Aeronautics and Space Administration	$238,544	2018-2020	$88,350
Auris: A Cubesat to Characterize and Locate Geostationary Communications Emitters	PI: Lyon (Brad) King	Utah State University Space Dynamics Laboratory	$165,000	2019	$165,000
Performance Characterization of a Low-Power Hall-Effect Thruster	PI: William Predebon	Orbion Space Technology Incorporated	$134,913	2018-2019	$134,913

ADDITIONAL RESEARCH TOPICS $1,107,596

TITLE	NAME	SPONSOR	TOTAL	PERIOD	FY 19
CAREER: System-on-Cloth: A Cloud Manufacturing Framework for Embroidered Wearable Electronics	PI: Ye (Sarah) Sun, in conjunction with the Institute of Computing and Cybersystems (ICC)	National Science Foundation	$602,410	2018-2023	$60,241
PFI-TT: Using Nanotechnology to Create a Proof-of-concept Prototype for Noise-Cancelling in Building Ventilation Systems	PI: Andrew Barnard, in conjunction with the Great Lakes Research Center (GLRC)	National Science Foundation	$200,000	2018-2020	$200,000
Application of the Carbon Nanotube (CNT) Thermophone for Range Extender Exhaust Active Noise Control	PI: Andrew Barnard, in conjunction with the Great Lakes Research Center (GLRC)	Magna International, Inc.	$150,099	2019-2020	$150,099
Robust Terrain Identification and Path Planning	PI: Jeremy Bos (Electrical & Computer Engineering), in conjunction with the Institute of Computing and Cybersystems (ICC) Co-PI: Darrell Robinette	University of Michigan	$112,346	2018	$65,619
Enterprise: Gen 2/3 AHSS Bicycle Frame Development	PI: Steve Lehmann Co-PI: Joseph Thompson (Pavlis Honors College), Richard Berkey (Pavlis Honors College), Zack Fredin (Pavlis Honors College)	AK Tube, LLC	$25,899	2018-2019	$25,899
Enterprise: SERC 2018 NSW 12 Vision Undersea	PI: Andrew Barnard, in conjunction with the Center for Leadership and Innovation for Transformation (LIFT) Co-PI: Richard Berkey (Pavlis Honors College), Zack Fredin (Pavlis Honors College), Joseph Thompson (Pavlis Honors College)	Stevens Institute of Technology	$7,400	2018-2019	$7,400
Enterprise: SERC 2018 USCG 01 Mass Rescue Devices	PI: Andrew Barnard, in conjunction with the Center for Leadership and Innovation for Transformation (LIFT) Co-PI: Rickey Berkey (Pavlis Honors College), Zack Fredin (Pavlis Honors College), Joseph Thompson (Pavlis Honors College)	Stevens Institute of Technology	$7,400	2018-2019	$7,400
Hard Drive Noise Testing	PI: Andrew Barnard, in conjunction with the Great Lakes Research Center (GLRC)	Johnson Controls	$2,042	2019-2020	$2,042

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AEROSPACE PROGRAM SKYROCKETS TO SUCCESS

"I never had a doubt that Michigan Tech would eventually launch a satellite. We knew we had a lot to learn our first couple years as a new satellite design team, but we also saw the enthusiasm from students across departments on campus. It was clear we were laying the foundation for a strong program."

—Casie (Applin) Wolak '04, US Air Force

Student-built Nanosatellite Oculus-ASR Successfully Launched

June 2019—Launched from Pad 39A at NASA's Kennedy Space Center, student-built nanosatellite Oculus-ASR rode the SpaceX Falcon Heavy rocket into a nine-month mission to assist the US Department of Defense (DoD) in more efficient and accurate monitoring of the myriad of objects circling the globe.

Many of the 800 students who have been Michigan Tech Aerospace Enterprise team members, and other Michigan Tech alumni and friends, watched the livestream of what SpaceX founder Elon Musk described as "our most difficult launch ever." The mission, Falcon Heavy's first night launch, involved four upper-stage engine burns and three separate deployments.

It's been roughly 18 years since the Aerospace Enterprise began, 15 years since Michigan Tech began participating in the University Nanosatellite Program, and nine years since Huskies won the competition.

Dr. Brad King, Richard & Elizabeth Henes Professor of Space Systems Engineering and Aerospace Enterprise Faculty Advisor, said he can't take credit for the idea to start an Enterprise focused on spacecraft design, testing, and integration. Students John Verville and Casie Applin asked for it.

"These were two students who liked space and said, 'Hey, there's this new faculty member who's into space. Let's get him to start an Enterprise.' That was the nucleus of it," said King. "Its roots are in students who love space and wanted something more on campus."

Verville, a 2004 electrical engineering graduate, is currently Windchill Technical Lead at NASA Goddard Space Flight Center. "I brought Aerospace Enterprise up during my interview and it got NASA's attention," said Verville.

Casie (Applin) Wolak, who also graduated in 2004, is active duty Air Force and continues to pursue her goal to be accepted into the astronaut program. "I definitely did want to be an astronaut and still do," she said. "I was a finalist for the current astronaut candidate class and hope for a better outcome next application cycle."

As Huskies from across the nation and the aerospace industry continue to celebrate, they're expressing gratitude for the new heights reached by the Oculus-ASR project, successfully launched and deployed from the SpaceX Falcon Heavy.

> *"The real mission was training a new generation of satellite and rocket engineers and no matter what happens from here on out it was a success. I owe my career and my best friends to this mission and will always be honored to have contributed to it."*
>
> —Aaron Wendzel '11 EE, SpaceX Rocket Dev. Facility

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MTU.EDU/MECHANICAL CONNECT WITH US:

MICHIGAN TECH'S STUDENT-BUILT NANOSATELLITE, OCULUS-ASR, WAS A PART OF THE SPACEX FALCON HEAVY LAUNCH ON JUNE 25.

It was designed and built by students in the Aerospace Enterprise under faculty advisor, Dr. Brad King—a project begun at the team's inception in 2004. The dream of the over 800 students involved was realized when the Falcon Heavy deployed Oculus-ASR as its first payload. The nanosatellite is now on a nine-month mission to efficiently and accurately monitor the myriad of objects circling the globe for the US Department of Defense.