

# MECHANICAL ENGINEERING



UNIVERSITY OF WISCONSIN-MADISON



ENHANCING THE STUDENT EXPERIENCE

Historic endowed chair honors John Bollinger



# CHAIR'S MESSAGE



Usually, I use this space to highlight some of the great things that are happening in the department—and there are many. But this time I would like to fill this space with my remembrances of Professor Robert (Bob) Lorenz, who sadly passed away in January 2019. Bob could best be described as what you get

when you try to compress lots of springs between two not-perfectly-parallel surfaces—there is an excess of energy that is going to be released! Nothing can contain it. To our great fortune, when the stored potential energy was converted to work in Bob's case, it was useful work that advanced the field of electric machine control. The details of Bob's prolific output can be seen elsewhere in this newsletter. From my point of view, I never considered Bob to be a colleague. Not that he was not collegial—he definitely was. But by every metric Bob was doing so much more than me that it seemed somewhat incongruous that we would both hold the title of professor.

Over the course of his career, Bob received many gifts to support his research and earned royalties from his many patents. These funds were kept in an account at the UW Foundation that he used as a rainy day fund. The rapid advance of Bob's illness, however, prevented him from drawing on these funds. As a final bequest to the department, Bob repurposed those funds to establish the Robert Lorenz Professorship, which will be given to a faculty member with expertise in physics-based controls—Bob's specialty. Bob understood the importance of recognizing high-quality faculty through endowed professorships and the positive impact this has on a department. We are grateful that Bob chose to establish this professorship and are eager to find its first worthy recipient.

I have spent my career studying combustion phenomena in internal combustion engines and am a staunch believer in that technology for the future. Last summer I bought a new car—a plug-in hybrid vehicle that can go about 25 miles on electric power and has a fully capable gasoline engine for long-range operation. For reasons that I am happy to discuss (in another venue), it is the optimal solution for my transportation needs. The electric half of my car's powertrain uses the products of Bob's research work. Every day when I drive to and from work, with the hum of the electric motor in my ears, I will think about my colleague Bob Lorenz.

ON, WISCONSIN!

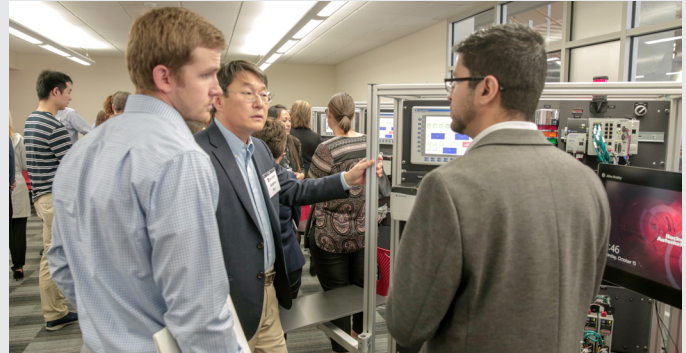
**Jaal Ghandhi**

John Bollinger Chair of Mechanical Engineering and  
Grainger Professor of Sustainable Energy  
ghandhi@engr.wisc.edu • (608) 263-1684

## Support Mechanical Engineering!

To make a gift to the department, go to:  
[allwaysforward.org/giveto/me](http://allwaysforward.org/giveto/me)

**Brad Green, Director of Development**  
(608) 308-5354  
[brad.green@supportuw.org](mailto:brad.green@supportuw.org)



In the Rockwell Automation Industrial Connected Enterprise Laboratory, students can get their hands on today's most advanced industrial manufacturing technologies. The new lab will support undergraduate coursework as well as faculty, staff and student research projects.

Read more: [www.engr.wisc.edu/automatic-anything-ordinary-partnership-rockwell-prepares-engineers-excel/](http://www.engr.wisc.edu/automatic-anything-ordinary-partnership-rockwell-prepares-engineers-excel/)



## Accelerated Master's Programs

An engineering master's degree from UW-Madison gives you the credentials to get ahead. Find a program that fits your goals and lifestyle.

- 21 flexible online and accelerated programs
- Degrees in multiple disciplines, including seven within ME
- World-renowned faculty
- Individual attention
- Innovative partners
- Dedicated fellow students
- Rigorous courses that address real-world problems
- Ideas, inspiration and tools to apply immediately on the job

**Earn the recognition you deserve, and prepare yourself today to meet tomorrow's engineering challenges.**

[advanceyourcareer.wisc.edu/engineering](http://advanceyourcareer.wisc.edu/engineering)

# HONORING JOHN BOLLINGER

## Endowed chair will take department to next level

The experiences John Bollinger (BSME '57, PhDME '61) enjoyed as a student in the department set him on a path to a distinguished career in which he made a difference in the lives of thousands of engineering students at UW-Madison.

As a standout professor and mechanical engineering department chair, and later as dean of the College of Engineering, Bollinger was especially passionate about creating opportunities for students to engage in hands-on learning and entrepreneurial activities.

Now, a major new gift to the department in honor of Bollinger will open up even more opportunities for students to enrich their educations.

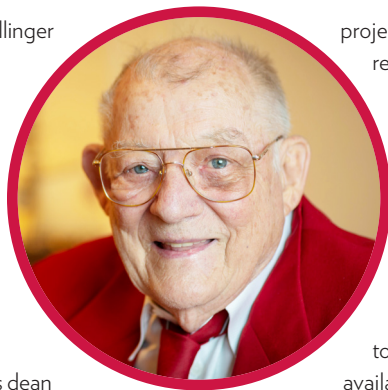
Herbert V. Kohler Jr., executive chairman of the Kohler Company, and other donors are endowing the department's chair position with \$5 million as a way to pay tribute to Bollinger and elevate the department.

It is the largest gift in the department's history and is one of just three endowed department chair positions in the College of Engineering, all of which have been established in 2019.

"This endowed chair will be a catalyst for many new opportunities benefiting our students and will be instrumental in taking the department to the next level," says Jaal Ghandhi, the first department chair to hold the John Bollinger Chair of Mechanical Engineering. "It's a very fitting honor for John, given his long and illustrious career devoted to the college and the department."

The endowed chair provides flexible funding that Ghandhi says will enable the department to purchase state-of-the-art lab equipment to educate undergraduate and graduate students using the latest technology, akin to what they will encounter in industry.

And while the department currently helps support student travel to various national competitions, Ghandhi is excited that funds from the endowed chair would allow the department to expand its support for student organizations and teams working on ambitious



projects. "There are times when relatively modest amounts of money will give students the tools and ability to be better prepared for competitions," Ghandhi says. "These competitions are highly valuable learning opportunities for our students, so it's great to have this flexible funding available to help students get the most out of their experience."

Ghandhi says the department could create additional opportunities to foster entrepreneurial skills in students through a "maker fund." Students would be encouraged to pitch their innovative ideas to the department chair and promising ideas would receive startup funds to move them from concept to reality.

In addition to helping support the department chair's research program while leading the department, the endowed fund will help other faculty kickstart high-risk, high-reward research projects.

For example, it could provide faculty members with some resources to demonstrate that a novel idea shows promise—and that greatly increases their chances of securing external grants to pursue the research.

"Money from this endowed chair offers a way to seed research in the department," Ghandhi says. "Then if that faculty member's external grant proposal is really successful, it's a huge win for the department and the college."

Bollinger says learning about the endowed chair was a great surprise for him, and he's excited about the department's future and the far-reaching impact this gift will have.

"I consider it an honor to have my friends and colleagues decide to remember me in this very meaningful way," Bollinger says.

Bollinger served as dean of the college from 1981 to 1999, and presided over the \$16 million college expansion to Engineering Hall in 1993.

During his 18-year tenure as dean, he created a new aesthetic environment for the college campus. He oversaw the creation of well-known landmarks such as the *Máquina* sculpture and fountain and new building architecture that transformed a group of buildings into an identifiable engineering campus, complete with a main street renamed "Engineering Drive." Bollinger was also instrumental in planning the Engineering Centers Building and raising the needed funds. Completed in 2002, it was the first new building on the engineering campus in 40 years.

Always committed to providing meaningful learning experiences, Bollinger established a new freshman course in the college that assigned a real-world engineering project from design to final product. In addition to fostering the activities of student organizations, he championed efforts to recruit more women and students from underrepresented minority groups to enter engineering.

He received numerous accolades over his renowned career, and is a fellow of the National Academy of Engineering, the American Society of Mechanical Engineers, and the American Society for Engineering Education.

From 1984 to 2003, Bollinger served on the Kohler Company's board of directors, where his tenure mirrored a period of expansion with several strategic acquisitions and new

markets. His contributions inspired Kohler Jr., to make a \$1 million gift to the endowed chair fund in Bollinger's honor.

"John was a stalwart in driving innovation at Kohler, providing our associates with entrepreneurial freedom and the necessary tools for them to excel," he says. "In his role as dean, John was influential in helping to match engineering students with Kohler through internships and co-op programs. Many of these individuals became full-time associates, who have contributed to our mission of improving the level of gracious living for those touched by our products and services."

**"This endowed chair will be a catalyst for many new opportunities benefiting our students."**

**— Jaal Ghandhi, Department Chair**

# ADVANCING ADDITIVE MANUFACTURING BY SLASHING SUPPORT

3D printing opens up design possibilities that engineers could once only dream of.

The technology allows manufacturers to create parts with unique and complex shapes—parts that conventional manufacturing methods such as die casting or injection molding can't produce.

With 3D printing, also known as additive manufacturing, a machine creates a part by adding material in layers, building the object from the ground up. Because each new layer needs to be supported by the layer below it, there's a limit to how much one layer in a complex part can jut out over the next. As a result, manufacturers often need to build structures to support a part as it's being printed.

To address these issues, Qian has devised a method that significantly reduces the amount of support material needed to build components with 3D printing—and, in some cases, can even eliminate the need for support structures altogether.

"Traditionally, the support structure is created by simply considering the geometry of the part, and then creating the columns needed for support," Qian says. "But this isn't optimized."

His method streamlines the support structure using computational modeling tools.



In one project, he used his techniques to design a part that required 43-percent less supporting material than would be used in the traditional additive manufacturing process relying on standard commercial design software. A 3D-printed part generally

needs support if there are areas where its surface is sloped facing downward.

However, in the topology optimization process, engineers first provide requirements for the part and overall design goals—and then a computer program performs analyses and generates ideal component topologies.

"So the challenge is, if you don't know the geometry of the part in advance, then how would you know the surface slope and whether you would need support or not?" Qian says.

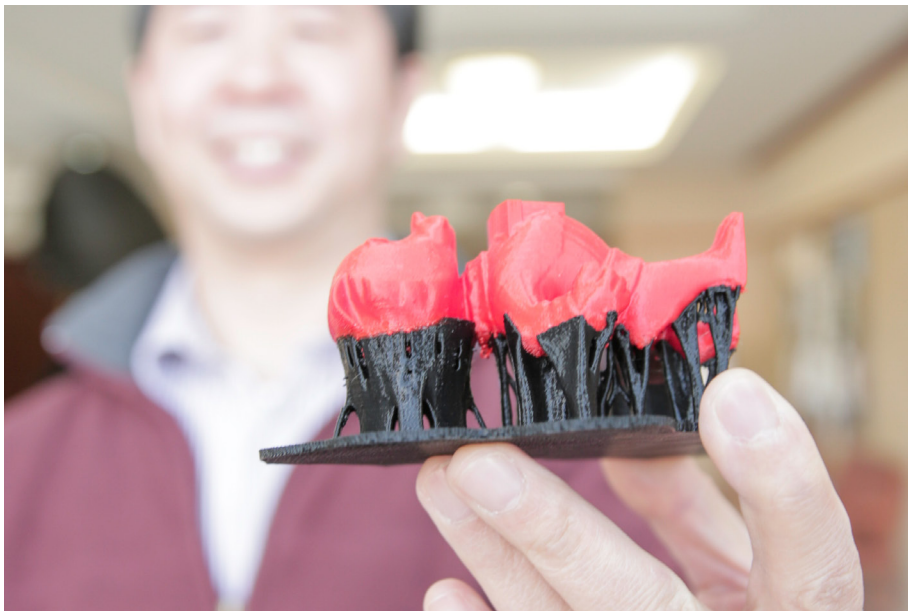
That's where his breakthrough comes in—in a way that's somewhat like predicting the future.

Qian developed a method for calculating the amount of surface area on a component that needs support—without knowing the part's final geometry ahead of time. He says the key was defining a new measurement called the projected undercut perimeter. "When you calculate this new measurement, it essentially corresponds to the area that needs support," he says.

By incorporating the new measure into his computer models, Qian is able to control the amount and angle of overhang—thus minimizing or even eliminating the support structure—when designing a part.

As a result, for example, he can design a component that's optimized to dissipate as much heat as possible without needing any support structure to manufacture.

**Read more:** [www.engr.wisc.edu/advancing-additive-manufacturing-slashing-support/](http://www.engr.wisc.edu/advancing-additive-manufacturing-slashing-support/)



Qian's new method reduces the amount of support material (black plastic) needed to allow the red material (Bucky) to be 3D-printed. Photos: Sarah Page.

"But after the part is completed, removing that supporting material can be costly," says Professor Xiaoping Qian. "These support structures are sometimes referred to as sacrificial structures, because they are discarded in the end, which wastes material and build time."

Furthermore, it can be difficult to access and remove the support structure without risking damage to the finished part.

By enabling manufacturers to use the minimum amount of support material, the approach delivers faster build times as well as cost savings on material.

Qian's techniques are broadly applicable for a wide variety of additive manufacturing technologies. So far, he has demonstrated the benefits of his approach using fused deposition modeling and 3D-printed metal parts using a laser powder bed fusion process.



# REVOLUTIONARY ENGINEERED BLOOD VESSELS BEHAVE LIKE THE REAL THING

Tom Turng envisions a future in which surgeons can order mass-produced artificial blood vessels that arrive ready to use in bypass surgeries.

“Kind of like when you order something from Amazon and it ships right away; we want to do the same thing—but instead, the off-the-shelf product is artificial blood vessels that doctors can implant into a patient,” says Turng, Kuo K. and Cindy F. Wang Professor and Vilas Distinguished Achievement Professor.

A pioneer in bio-based materials for use in the body, Turng has developed a way to consistently create small-diameter artificial vascular grafts that mimic the mechanical performance of native blood vessels.

Currently, artificial blood vessels with diameters smaller than 6 millimeters—the kind needed for bypass surgeries—are not commercially available. However, such a product could transform treatment for cardiovascular diseases, which are the leading cause of death globally.

Turng’s invention, which promises to eliminate the need to harvest vessels from the patient, addresses this major medical need. Each year, for example, more than 500,000 bypass surgeries are performed in the United States alone.

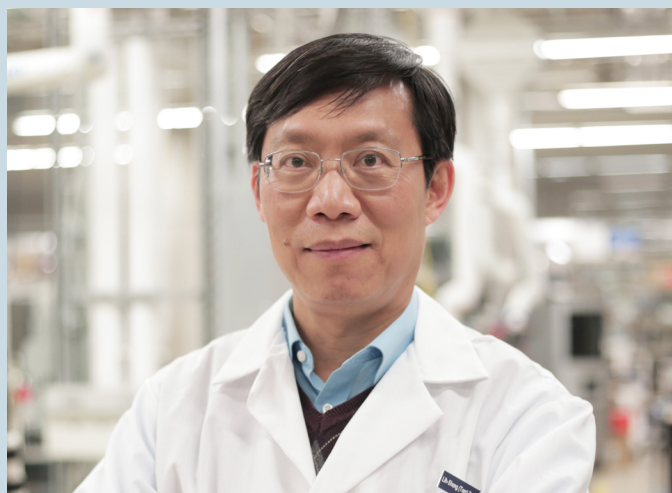
Today, surgeons performing bypass procedures must remove veins or arteries from another part of the patient’s body. Then, they implant those vessels to create a new route for blood flow that bypasses a blocked or diseased vessel.

“However, suitable tissue isn’t often available due to prior harvesting or a patient’s health, so in those cases we need to have an artificial blood vessel to complete the bypass,” Turng says.

But not just any artificial blood vessel will do.

Turng says it’s crucial for these artificial blood vessels to emulate the mechanical properties and performance of natural blood vessels. “In the small-diameter blood vessels that we’re working with, even a slight mismatch in mechanical properties will lead to the formations of blood clots and other complications that can be deadly,” he says.

When we engage in physical activity, our blood vessels can easily expand to allow extra blood flow and oxygen to sustain that activity. But when a vessel reaches a certain expansion, it also stiffens to maintain its



integrity for blood circulation. This type of behavior—initially soft and subsequently stiff—is challenging to replicate with artificial blood vessels.

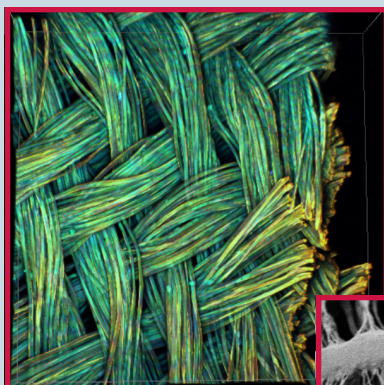
Turng and his collaborators drew on their extensive experience in polymer processing and materials selection in their quest to find the optimal combination of materials and fabrication methods—including braiding, electro-spinning, thermal-induce phase separation, and extrusion—to produce an artificial vessel with lifelike mechanical properties.

In the end, their winning combination included using a stretchy plastic material along with stiffer biomaterials that emulate the elastin and collagen fibers in a blood vessel, respectively. Turng found that creating wavy structures with the stronger biomaterials caused the vessel to toughen once it reached full expansion, mimicking the behavior of the real thing.

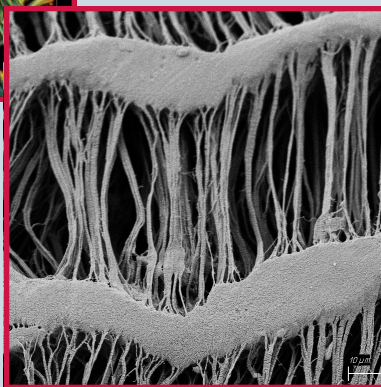
This ambitious ongoing research project involves close collaboration with stem-cell pioneer James Thomson, director of regenerative biology at the Morgridge Institute for Research at UW-Madison. Thomson’s research group is using induced pluripotent stem cells to engineer the endothelial cells that make up the cellular lining of the vessel.

Meanwhile, Turng has also developed sophisticated methods for modifying the surface of the vessels. These modifications allow the vessel to function as the scaffolding upon which the endothelial cells will adhere and grow outside of a patient’s body.

“Right now, we’re conducting cell culture experiments, and we’re striving toward the critical phase of proving that we can grow the endothelial cells inside the fabricated tube,” says Turng. “Once that’s accomplished, I think we’re pretty close to achieving our mission.”



The first generation of the researchers’ artificial blood vessel used braided silk fibroin.



An image of the microstructure of an expanded artificial blood vessel. The wavy structures of the second-generation vessel allow it to mimic the mechanical performance of native blood vessels. Image courtesy of Tom Turng.

Read more: [www.engr.wisc.edu/revolutionary-engineered-blood-vessels-behave-like-real-thing/](http://www.engr.wisc.edu/revolutionary-engineered-blood-vessels-behave-like-real-thing/)

# NEWS FROM OUR STUDENT ORGANIZATIONS

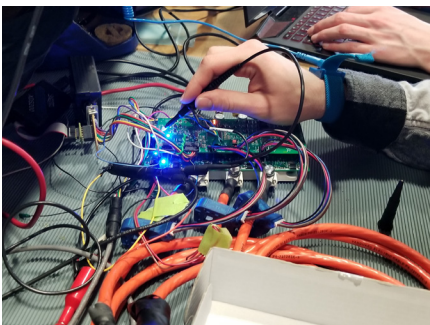


## SWE ▲

Over the fall 2018 semester, the Society of Women Engineers has expanded on professional development, personal development and outreach events, including founding an international outreach committee, which sent 11 members to run STEM workshops in India. The organization also hosted a SWE week to welcome students to campus. And it sent 30 members to the SWE National Conference in Minneapolis, where the chapter received the Gold Outstanding Collegiate Section Award and a best practice award for partnerships with collegiates, professionals, industry, and academia. In the spring 2019 semester, SWE introduced a one-on-one mentoring program in addition to its mentoring families to provide another way for younger members to more formally seek advice and community from older members. In 2019, SWE is also expanding its outreach to local schools and continuing to provide new leadership opportunities for its members.

## Pi Tau Sigma

In the 2018-19 academic year, Pi Tau Sigma, an international honor society of top juniors and seniors in mechanical engineering, is focused on revitalizing the organization and increasing membership. The organization has begun diversifying its activities, and members are looking forward to working on exciting projects with the department, doing gratifying community service outreach, entering design competitions, and more.



## Wisconsin Racing ▲

The Wisconsin Racing electric team participated in the Formula SAE Electric competition in Lincoln, Nebraska, in June 2018, where it won fourth place overall and took first place for the best designed car for the second year in a row. The fall 2018 testing season was cut short due to mechanical failures on the car, and students spent most of the fall making improvements to the 2018 design for the 2019 design. The team is working on assembling the car in anticipation of testing it in the spring before the Formula SAE Electric competition in June 2019.



## SAE ▲

The Clean Snowmobile team, which won third place overall in the highly competitive gasoline category at the 2018 SAE International Clean Snowmobile Challenge, is gearing up for the 2019 competition. The Clean Snowmobile Challenge is an engineering design competition that challenges college students to reengineer an existing snowmobile to reduce emissions and noise. Their modified snowmobiles compete in a variety of events including emissions, noise, fuel economy/endurance, acceleration, handling, static display, cold start and design. For 2019, the team has been busy working on implementing a new independent engine controller. The students have also increased the compression ratio of their engine and added more control to the spark timing.

The UW-Madison Baja SAE team is preparing for the Baja SAE California competition in May 2019, and the team is learning from a few failures its car experienced in the Kansas competition in 2018. In Kansas, the team placed 15th out of 100 teams from across the United States as well as from India, Brazil and Mexico.

The team is focused on building and testing an improved car for the 2019 competition.



## ASME

ASME had an exciting and busy 2018. In February, the group organized a mock interview event where representatives from six companies came to conduct practice interviews and résumé reviews with ASME members. The group held its annual golf outing in September 2018. With industry professionals from companies including Epic, Milwaukee Tool, Greenheck, Subzero, GE, and Enerpac in attendance, the event gave ASME members a valuable opportunity to network with potential employers before the fall career fair. ASME ended 2018 with an event focused on exploring undergraduate research. Researchers from 10 labs gave presentations and highlighted opportunities for undergraduates to get involved with research.

Fall 2018 was the first semester since ASHRAE merged with ASME, and it was very successful. Some highlights included the ASHRAE/ASME general meeting in October with Trane, a tour of the Charter Street Power Plant, and monthly meetings with the ASHRAE Madison chapter.

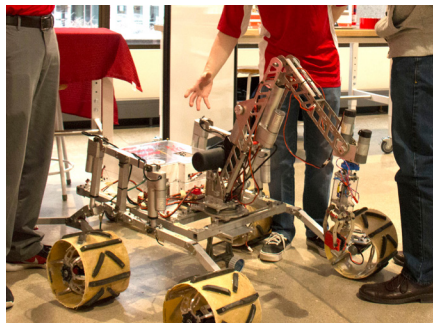
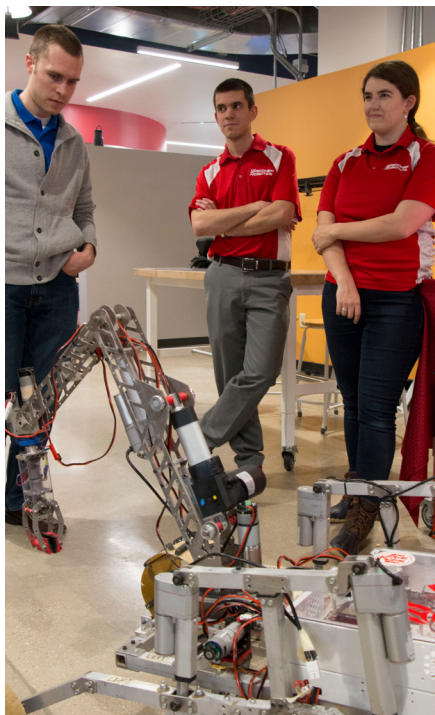


## Badgerloop ▲

In July 2018, Badgerloop traveled to Hawthorne, California, for the third SpaceX Hyperloop Pod Competition, where the team had a strong showing among the 18 teams from around the world. The competition challenges student teams to design and build pods for an ultrafast, futuristic form of transportation.

Even though Badgerloop's sleek teardrop-shaped red-and-black pod did not take top prize, its pod passed the majority of the competition's rigorous technical tests, while the students wowed the judges with their work ethic and resourceful creativity. Badgerloop was one of three teams selected to present their designs on competition day.

Since the new academic year began in fall 2018, the team has been hard at work fundraising for and designing its fourth pod for the 2019 competition. This new pod is similar in design to the team's previous one, allowing the students to apply lessons they learned last year and improve upon their previous iterations. To keep up with the team's progress, check out its monthly updates at [Badgerloop.com](http://Badgerloop.com) or on social media (Facebook @BadgerloopTeam and Twitter @badger\_loop).



## Wisconsin Robotics ▲

Wisconsin Robotics participated in the University Rover Challenge, an international competition based in Hanksville, Utah, in June 2018. The competition challenges students to build the world's best student-designed Mars rover. Wisconsin Robotics placed 16<sup>th</sup> overall out of 95 teams coming from 13 countries. The team is working on improving its rover system for the 2019 competition. In February 2019, members of the team showed off its Mars rover to representatives of eight Wisconsin companies during an event held at the college's makerspace. The event was dubbed a "reverse career fair" because it inverted the usual relationship, where potential employees wander past employer booths.

# SENSING AND CONTROLS PIONEER BOB LORENZ PASSES AWAY



College of Engineering  
UNIVERSITY OF WISCONSIN-MADISON

[www.engr.wisc.edu/me](http://www.engr.wisc.edu/me)

Mechanical Engineering  
1513 University Avenue, Madison, WI 53706



Nonprofit Org.  
U.S. Postage  
PAID  
Madison, WI  
Permit No. 658

Professor Robert Lorenz passed away on Jan. 27, 2019, at age 72, following a fight with metastatic prostate cancer.

Lorenz was internationally renowned as the world's leading authority in the field of physics-based control of electric motors and adjustable-speed drives. In February 2019, the National Academy of Engineering (NAE) posthumously named Lorenz to its 2019 class of fellows, which is among the highest professional honors accorded to an engineer. The NAE recognized Lorenz's contributions to modeling and control of cross-coupled electromechanical systems for high-performance electric machines and drives.

After joining the UW-Madison engineering faculty in 1984, he immediately got involved with the then-new Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC), an academic-industry partnership he helped to grow into one of the largest and best-known university consortia in its field today, with more than 85 company sponsors. He co-directed WEMPEC for 22 years.

Lorenz received his bachelor's, master's and PhD in mechanical engineering from UW-Madison. Before beginning his PhD program, Lorenz worked in industry for 10 years at Gleason Works in Rochester, New York, where he honed his engineering skills by developing high-performance motor controls for machine tools that were ahead of their time. He also served two years in the U.S. Army during the Vietnam War, developing new gun-aiming controls at the Aberdeen Proving Ground in Maryland.

Always known for his infectious enthusiasm and high energy level, he passionately pursued his unique research vision for 34 years at UW-Madison, where he supervised more than 200 graduate students, authored more than 400 technical papers with his students that resulted in 34 IEEE prize paper awards, and earned more than 40 U.S. patents.



Lorenz's many original contributions have significantly improved the performance of electric motors in nearly every conceivable application ranging from paper mills to electric vehicles. He was globally recognized as a pioneer in the development of robust "self-sensing" control algorithms that eliminate fragile rotor position sensors from electric motors in many high-performance applications, making the motors smaller, less expensive and more reliable. He also invented a new motor control scheme that makes motors respond more rapidly and accurately to commands while simultaneously improving their efficiency. These valuable features are highly appealing to motor drive manufacturers who are

now adopting this breakthrough control scheme in their newest generation of high-performance factory automation drive products.

Lorenz earned numerous prestigious awards during his academic career, including the IEEE Richard Kaufmann Technical Field Award in 2014, and was named an IEEE fellow in 1998. He was very active in IEEE, including service as president of the IEEE Industry Applications Society during 2001 and an elected member of the IEEE Board of Directors from 2005 to 2006. He also held the Elmer and Janet Kaiser Chair and was Consolidated Papers Professor of Controls Engineering at UW-Madison.

In addition to his impressive academic achievements, Lorenz always reserved time to be actively involved in a wide range of civic and humanitarian volunteer service activities that included the Madison Rotary Club, Habitat for Humanity of Dane County, and international medical mission work in several parts of the world extending from Africa to Guatemala. Lorenz received the College of Engineering Ragnar E. Onstad Service to Society Award in 2002 in recognition of his many years of dedicated public service.