Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2019

MECHANICAL ENGINEERING

DEPARTMENT LAUNCHES CENTER FOR ROBOTICS

New Center for Robotics and Biosystems builds on and strengthens Northwestern's longstanding leadership in collaborative robotics

PhD student Ola Kalinowska tests a flying robot with Professor Michael Rubenstein.

Robots are here to work with humans and to help them be their best selves — at work and at home — whether they're assembling an automobile or recovering from a severe injury.

That vision of a future where humans and robots work seamlessly together is the goal of the new Center for Robotics and Biosystems, Northwestern Engineering's hub for robotics research.

Within a newly expanded 12,000-square-foot space in the Technological Institute that opened this fall, faculty from across disciplines will study the science and engineering of embodied intelligence and how it can advance efforts in everything from space exploration to medicine.

"Some people worry about our future with robots," said **Kevin Lynch**, professor of mechanical engineering and director of the center. "Certainly there will be a changing employment landscape and the potential for misuse of the technology. But advanced robotics will bring countless benefits to our economy, health, and quality of life. Our future is one of human-robot co-evolution, and the center is working to make that future as beneficial to humanity as possible."

Collaborative robots have deep roots at the McCormick School of Engineering. In fact, professors **Michael Peshkin** and **Ed Colgate** coined the term "cobots" in the mid-1990s.

Peshkin and Colgate joined their research labs in 1989, creating the Laboratory for Intelligent Mechanical Systems (LIMS). In 2012, as new faculty members joined and topics expanded to include neuromechanics and bio-inspired robotics, LIMS became the Neuroscience and Robotics Lab.

With an expanding research scope, the center's faculty will have appointments in mechanical engineering, biomedical engineering, computer science, the Feinberg School of Medicine, and the Shirley Ryan AbilityLab.

Research topics include haptic (touch) interfaces, motion planning and control for autonomous robots, swarm robotics, exploration in uncertain environments, robot learning, bio-inspired robots, and the sensorimotor systems of animals.

Still, collaborative human-robot systems remains a key theme across the research of many of the faculty. "We envision a future where humans and robots work together seamlessly," said Lynch. "We design robots that augment human abilities."

The new space — a wide-open collaboration area with smaller, specialized laboratories — includes a prototyping "makerspace" and an area called the "robot zoo," a place to test the latest research on drones, wheeled and legged mobile robots, and robot arms and hands.

Undergraduates and PhD students from different departments will work side-by-side with students in the popular Master of Science in Robotics program, encouraging the cross-pollination of ideas with the center's many collaborators.

The new space, said Lynch, "will hopefully catalyze even more partnerships at Northwestern."

FROM THE CHAIR

Dear friends and colleagues,

Fall quarter is always an exciting time, with the fresh energy of new undergraduate and graduate students arriving on campus. I am thankful every day to have a job where I am able to absorb, and hopefully contribute to, the enthusiasm of our eager young students.

Speaking of new students, thanks to the strong recruiting efforts of our director of graduate studies (**Sinan Keten**) and the ME Graduate Student Society (MEGSS), half of our incoming PhD class is female for the second year in a row. This kind of gender diversity is quite unusual in mechanical engineering, but it is reflective of the strong female leadership in our department. In this newsletter, for example, you can find big news for Professors **Jian Cao**, **Wei Chen**, and **Mitra Hartmann** on pages three and six.

Jian Cao was selected as a 2019 Vannevar Bush Faculty Fellow (page six). This is a highly prestigious award that supports bold and ambitious "blue sky" research that can revolutionize disciplines, create new research fields, or disrupt accepted theories. The award brings a large grant, $3 million over five years, which Jian will use for her long-term vision of how to automate the design of manufacturing processes.

Wei Chen was elected to the National Academy of Engineering in recognition of her research and leadership in the field of design and optimization (page six). In addition to being an outstanding researcher, Wei was a highly effective director of graduate studies for several years during my term as chair. In recognition of her impact on the graduate student experience, she won The Graduate School's inaugural Ver Steeg award in 2017. I am very grateful for her contributions to the department.

Mitra Hartmann was recognized with Northwestern's Charles Deering McCormick Professorship of Teaching Excellence, the top teaching award that the University bestows (page three). She becomes the eighth tenure-track member of our department to be honored at this level (in addition to **Ed Colgate**, **Liz Gerber**, **Rich Lueptow**, **Todd Murphey**, **Neelesh Patankar**, **Michael Peshkin**, and myself), making the Department of Mechanical Engineering the most awarded department at Northwestern.

I am pleased to present this newsletter highlighting some of the major news coming out of the department. Thank you for taking the time to look through it, and I wish you a healthy and fruitful 2019-20.

Kevin Lynch
Department Chair

Undergraduate Curriculum Update

Department introduces flexible course concentrations plus new scientific and embedded Python course

The Department of Mechanical Engineering faculty have approved multiple seven-course concentrations that replace the previous curriculum composed of four-course concentrations plus three required courses outside the concentrations. The update recognizes the need for a flexible curriculum that reflects the constantly evolving nature of the field, as well as the fact that mechanical engineering is increasingly becoming interdisciplinary, as evidenced by recent faculty hires and the industries students work in after graduation.

The curriculum has also been updated to reflect the importance of computing. Professors **Malcolm MacIver** and **Michael Peshkin** designed a new course, Scientific and Embedded Programming in Python, that is now required for all mechanical engineering undergraduates. The class is taught active-classroom style, with students, teaching assistants, and instructors working together. It includes embedded computing in which computers become part of machines or experiments. Student ratings during the course's pilot year were high, with many sharing that they had a new-found confidence in taking on projects with a significant programming component.

Teaching Assistant Chen Chen teaches a module on Big Data.

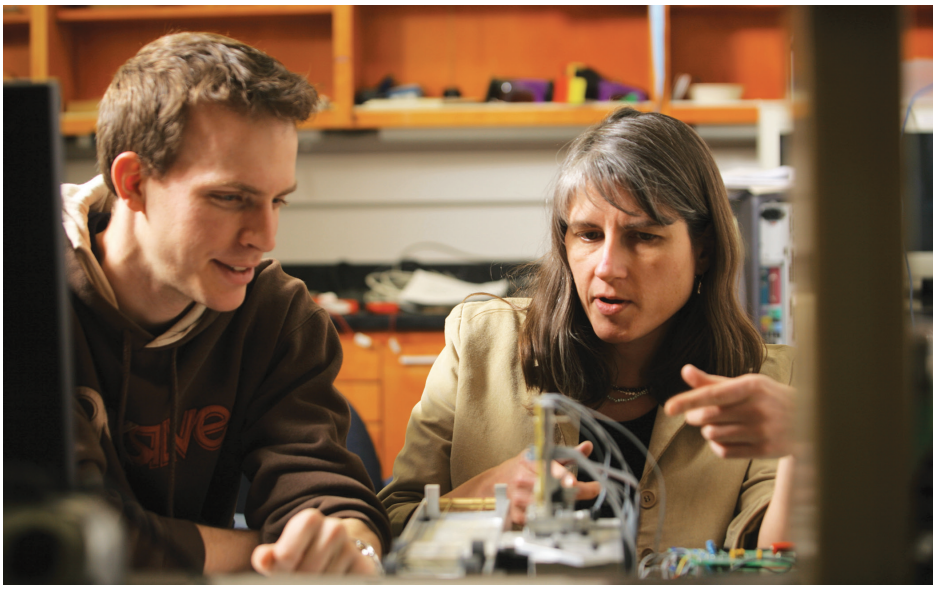
MITRA HARTMANN HONORED WITH UNIVERSITY TEACHING AWARD

Professor recognized for exhibiting excellence and innovation in classroom teaching

Professor **Mitra J. Hartmann** received a 2019 Charles Deering McCormick Professor of Teaching Excellence Award for outstanding performance and dedication to undergraduate education at Northwestern University.

"It is my great honor to recognize this year's McCormick Award recipients," Provost Jonathan Holloway said. "Together, they exemplify Northwestern's commitment to clear and substantive pedagogical practice. The recipients' passion for their respective areas of expertise is ably met by their enthusiasm for sharing their ideas with undergraduates. They are setting the standard by which our very best teachers should be judged."

Hartmann is a professor with a joint appointment in mechanical engineering and biomedical engineering. She received her bachelor's in applied and engineering physics from Cornell University and her PhD in integrative neuroscience from the California Institute of Technology.



Professor Mitra Hartmann was cited for helping students "develop a passion for dispassionate scientific research."

Hartmann's intent is to provide the foundations that allow students to "develop a passion for dispassionate scientific research." Her lectures include both historical perspectives as well as examples of cutting-edge research on topics from astrophysics to biomedical devices. This combination, Hartmann's nominator wrote, "situate the knowledge (students) are gaining in a societal context."

The Charles Deering McCormick Professorship, Lectureship, and Clinical Professorship Awards have a three-year term. A one-time award is also given to the recipient's home department to support activities that enhance undergraduate education. Hartmann accepted her award at a ceremony in Scott Hall on the Evanston campus.

ME Special Lectures

The Department of Mechanical Engineering would like to thank the speakers of its named lectures in 2018-19, and to welcome its speakers for 2019-20.

Belytschko Lecture:

Bruce Engelmann
Dassault Systèmes
November 29, 2018

Cristina Amon
University of Toronto
November 8, 2019

Achenbach Lecture:

Howard Stone
Princeton University
March 11, 2019

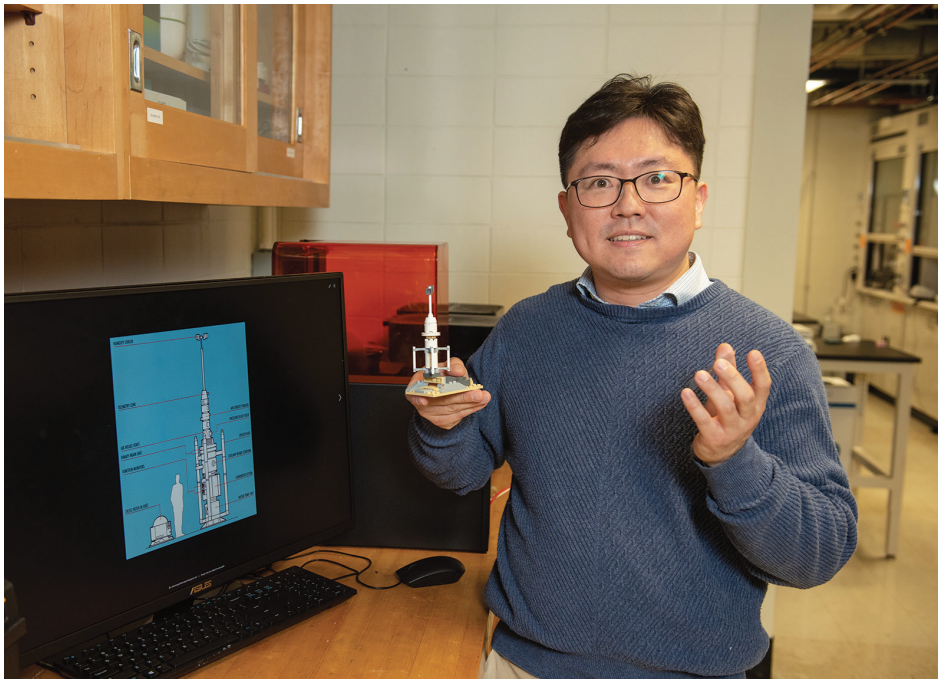
Jennifer Lewis
Harvard University
April 6, 2020

Simpson Lecture:

Lex Smits
Princeton University
May 6, 2019

MAY THE FOG BE WITH YOU

Ken Park seeks to unlock the potential of fog harvesting through bio-inspired surface engineering



Professor Ken Park holds a Lego model of a moisture vaporator from Star Wars, which inspired his research in fog harvesting.

As a self-professed fan of *Star Wars*, Northwestern Engineering's Ken Park is all too happy to bridge his love of a galaxy far, far away to his research on the Evanston campus.

A close scan of items in his office hint at the connection: on his desk sits a Lego model of a moisture vaporator, the cylindrical water harvesting device famously seen in the beginning of the 1977 film.

"I always wondered how Luke Skywalker could run his family's moisture farm on a desert planet like Tatooine, which I assumed had few sources of water," said Park, assistant professor of mechanical engineering. "I later learned it was based on the idea of harvesting the moisture in the air."

> "SO MUCH ATTENTION IS PAID TO HUMANITY'S RELATIONSHIP WITH OUR PLANET, AND WATER IS ESSENTIAL TO ENSURE BOTH HAVE A BETTER FUTURE"
>
> KEN PARK

While *Star Wars* fans are familiar with the moisture vaporator's cone-shaped humidity sensors and cooling vents, Park is more interested in how they work. Park is exploring how harvesting water from air — in the form of fog — using energy-efficient technologies could help tackle growing global concerns of water scarcity.

"So much attention is paid to humanity's relationship with our planet, and water is essential to ensure both have a better future," Park said. "Learning to harvest water more effectively is one way to do so."

Park and his lab take a bio-inspired surface engineering approach, looking to nature for clues for maximizing both the capture of fog and the drainage of water after its collected. This includes studying the optimal aerodynamic design of fog collectors, which recently led to new research providing guidelines on the best wire diameters and surface wettability for given wind speeds to maximize water collection efficiency.

Park also wants to apply his work to a new frontier — smog harvesting. With 4.2 million people dying each year from outdoor air pollution, according to the World Health Organization, extracting the smog in major cities could help tackle growing health and environmental challenges.

The issue lies in what Park refers to as "separation science." Capturing smog is currently a far more difficult process than extracting water from fog, much like a vacuum cleaner is harder to use in humid places due to clogging of air filters by liquid in the air.

Park and his team are now exploring how to use smog harvesting technology to reduce the discharge of brine into the ocean by desalination plants, as well as recapturing water used in cooling towers of thermal power plants.

"I've always wanted to help solve a world problem," Park said. "My research started with how to harvest fog water, but it has quickly evolved to possibly impacting energy and the environment."

Making Glass More Clear

New approach predicts glass' always-evolving behaviors at different temperatures

A multi-institutional team including Northwestern University, North Dakota State University, and the National Institute of Standards and Technology (NIST) has designed an algorithm with the goal of giving polymeric glasses a little more clarity. The algorithm makes it possible for researchers to create coarse-grained models to design materials with dynamic properties and predict their continually changing behaviors.

Called the "energy renormalization algorithm," it is the first to accurately predict glass's mechanical behavior at different temperatures and could result

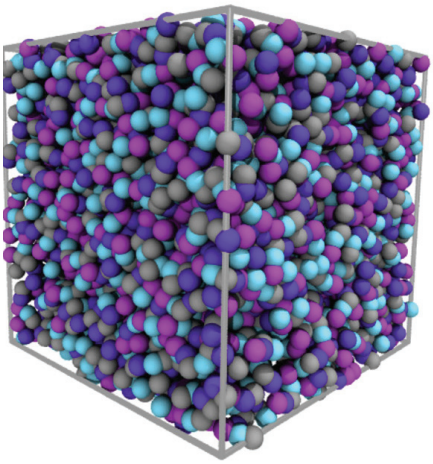
Sinan Keten

in the fast discovery of new materials, designed with optimal properties.

"Our approach scales molecular simulations up by roughly a thousand times, so we can design materials faster and examine their behavior," said **Sinan Keten**, associate professor of mechanical engineering and civil and environmental engineering, who co-led the research, which was published in the journal *Science Advances*.

Glass' structure is in stark contrast to a crystalline solid, in which atoms are arranged in an ordered, predictable, and symmetrical manner. To address this challenge, Keten and collaborators designed their algorithm to factor in the many ways glass molecules would move or not move depending on varying temperatures over time.

To calculate the position of each atom within glass would be painstakingly slow and tedious to compute, even for a high-powered computer. So, the team used "coarse-grained modeling," a simplified approach that looks at clusters of atoms rather than single atoms. Their new methodology efficiently creates parameters for the interactions among these coarser particles so that the model can capture the dramatic slow-down in molecular motion as the glassy material cools down.



Multiscale modeling of a polymer glass to predict its temperature-dependent properties. Credit: Wenjie Xia

Harnessing Nonlinear Vibrations in a Monolayer of Atoms for Force Sensing

Nonlinear effects come into play with extremely thin NEMS device

Horacio Espinosa

Nanoelectromechanical systems (NEMS) are devices with many practical applications, such as fast electronic switches, ultra-sensitive force, and mass sensors.

Though these devices are typically made using silicon, researchers at Northwestern Engineering fabricated a NEMS resonator using tungsten disulfide in just a monolayer of atoms — the ultimate thickness miniaturization limit in such devices. This takes advantage of qualities, such as intrinsic piezoelectricity, found in tungsten disulfide but not in graphene, another commonly studied two-dimensional material.

"As the NEMS device fabricated in our study is extremely thin, nonlinear effects come into play at relatively very small forces. The key is to harness such nonlinear mechanical response into a sensing modality," said **Horacio D. Espinosa**, James N. and Nancy J. Farley Professor in Manufacturing and Entrepreneurship and professor of mechanical engineering, who led the study published in *Nano Letters*.

Most NEMS devices and mass sensors are operated in the linear regime, where the mechanical behavior is composed of independent modes of vibration. However, if the displacement is sufficiently large, nonlinear geometric effects become more important.

The study, a collaboration between Espinosa and Lincoln J. Lauhon, professor and associate chair of Northwestern Engineering's Department of Materials Science and Engineering, exploited the nonlinear behavior in NEMS based on two-dimensional materials for practical applications. NEMS resonators, for instance, are used for signal filtering and logical operations.

FACULTY NEWS

Brenna Argall was selected to attend the 2019 National Academy of Engineering's Frontiers of Engineering Symposium.

Wei Chen was elected president of the International Society of Structural and Multidisciplinary Optimization.

Kornel Ehmann received the Society of Manufacturing Engineers Education Award.

Horacio Espinosa was selected to receive the Prager Medal from the Society of Engineering Science. He was also elected to Academia Europaea.

Liz Gerber received the 2018 Masahiro and Eiko Meshii Award given by the Segal Design Institute.

Ping Guo was awarded the Young Investigator Award at the 2018 International Symposium on Flexible Automation.

Yonggang Huang received the 2019 Theodore von Karman Medal from the American Society of Civil Engineers. He also received ASCE's Zdeněk P. Bažant Medal for Failure and Damage Prevention.

Sinan Keten received the 2019 Sia Nemat-Nasser Early Career Award from the American Society of Mechanical Engineers and the 2019 Walter L. Huber Civil Engineering Research Prize from the American Society of Civil Engineers.

Victor Lefèvre received a 2018 Haythornthwaite Foundation Research Initiation Grant.

Todd Murphey was appointed to the Air Force Scientific Advisory Board.

Emeritus Professor **Alan Kistler,** an expert in aerodynamics and turbulence, passed away on April 1, 2019, at age 90.

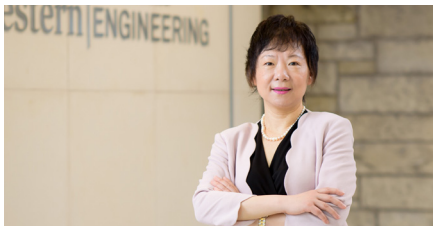
Wei Chen Elected to NAE

Professor **Wei Chen** has been elected to the National Academy of Engineering (NAE), one of the highest professional distinctions awarded to an engineer.

Chen, Wilson-Cook Professor in Engineering Design and professor of mechanical engineering, stands among the 86 new members and 18 new foreign members announced by the NAE in February.

Chen, who serves as director of the Integrated DEsign Automation Laboratory (IDEAL) as well as the Predictive Science and Engineering Design (PSED) Cluster, and the codirector of the Design Cluster, has made important contributions to design under uncertainty and decision-based design.

Her research aims to develop rational and computationally efficient design methods based on data science, optimization, statistical inference, and decision analysis for use in engineering design and manufacturing problems. Currently, Chen's research involves close collaborations with experts in mechanics, manufacturing, materials science and engineering, social science, and computer science.



Wei Chen

She was cited for "contributions to design under uncertainty in products and systems, and leadership in the engineering design community."

Jian Cao Named Vannevar Bush Fellow, AAAS Fellow

Professor **Jian Cao** has been chosen by the US Department of Defense (DoD) as a 2019 Vannevar Bush Faculty Fellow, a highly competitive award supporting transformative, university-based research.

Cao is the Cardiss Collins Professor of Mechanical Engineering and associate vice president for research. She also serves as the director of the Northwestern Initiative for Manufacturing Science and Innovation.

Jian Cao

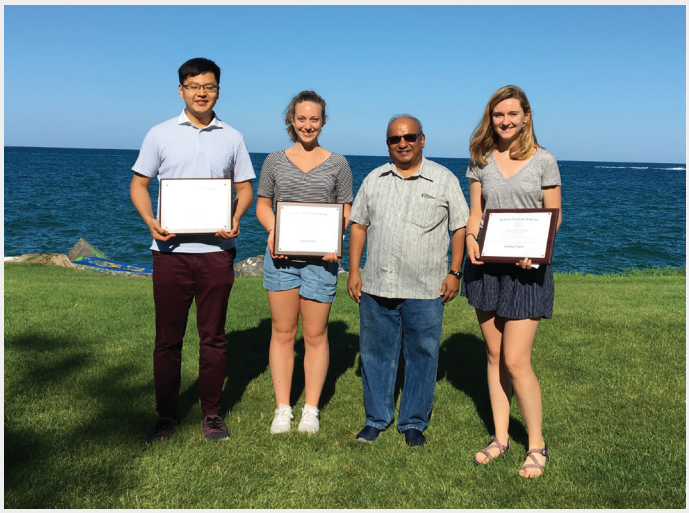
The DoD's Basic Research Office received more than 250 white papers, from which 10 fellows were selected for 2019. This single investigator award includes a $3 million, five-year grant to fund cutting-edge research.

The award follows Cao being named a 2018 American Association for the Advancement of Science fellow. Cao, whose research includes innovative manufacturing processes and systems, was recognized for her distinguished efforts to advance science and its applications.

Matthew Elwin Joins ME Faculty

Matthew Elwin has joined the Department of Mechanical Engineering as an assistant professor of instruction. During his PhD work at Northwestern, he developed distributed estimation algorithms for multirobot systems and coauthored a mechatronics textbook. Elwin will work closely with the Master of Science in Robotics program, mentoring student projects and teaching courses in robotics.

Department Awards Celebrate Graduates



(From left) Haiwen Luan, Milli Schlafly, Assistant Department Chair Manohar Kulkarni, and Annalisa Taylor

Benjamen Lim, who will work for the Singapore government's Government Technology Agency, received the Academic Achievement Award, given to the graduating senior with the highest GPA.

Allison O'Donnell, who will continue her PhD working with Professor Ken Park on bio-inspired atmospheric water collection, received the Undergraduate Research and Innovation Award. She also received the Undergraduate Leadership and Service Award.

Haiwen Luan received the Ted Belytschko Outstanding Research Award, honoring a graduating PhD student.

Milli Schlafly and **Annalisa Taylor** jointly received the Graduate Leadership and Service Award, which recognizes service to fellow mechanical engineering graduate students and the department.

STUDENT NEWS

PhD student **Marisa Bisram** received a Journeyman Fellowship from the Army Research Laboratory.

Incoming PhD student **Emek Barış Küçüktabak** received a Fulbright scholarship.

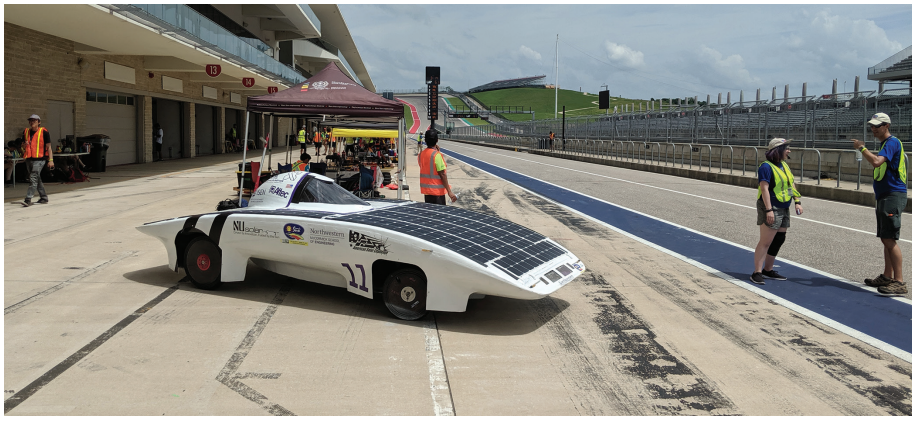
PhD student **Jenny Liu** received a 2019 Paul and Daisy Soros Fellowship.

PhD students **Chris Miller**, **Milli Schlafly**, Sanjana Subramaniam, and **Samantha Ann Webster** each received an NSF Graduate Research Fellowship. Miller was also awarded an NDSEG fellowship.

PhD student **David B. Pickens** was named a Society of Tribologists and Lubrication Engineers Fellow.

For the second consecutive year, the Department of Mechanical Engineering's incoming PhD class comprises 50 percent female students.

Solar Car Team Unveils Reimagined Vehicle



During an eight-hour race on the track, the NUsolar car completed 160 miles without any critical mechanical or electrical system failures.

The Northwestern University Solar Car Team (NUSolar) hit the track during the annual Formula Sun Grand Prix in July. Northwestern's team competed against 20 other university teams at the Circuit of the Americas track in Austin, Texas.

The race was the culmination of three years of hard work developing "Seven," the newest addition to the NUSolar fleet that features a new volumetric steel chassis, an aerodynamic carbon fiber aeroshell and a second rear wheel.

"While our previous car was lighter, it was much harder to service," said **Ieva Stakvileviciute**, NUSolar's project manager and a senior studying mechanical engineering and manufacturing and design engineering. "We decided as a team to go with a steel design that we expect to perform more reliably in competitions."

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Mechanical Engineering Collaborations in 2018

The Department of Mechanical Engineering prides itself on interdisciplinary research with other departments and academic units within Northwestern Engineering. Mechanical engineering faculty also enjoy strong collaborations with other schools at Northwestern University, including the Weinberg College of Arts and Sciences, Kellogg School of Management, School of Communication, and the Feinberg School of Medicine.

The graphic to the right illustrates the department's collaborative publishing in 2018. The area of each circle is proportional to the number of publications per faculty member within a department, and the thickness of each link is proportional to the number of jointly authored publications between departments.