McCormick School of Engineering and Applied Science

NORTHWESTERN ENGINEERING

FALL 2019

BUILT TO COLLABORATE

ADVANCING THE HUMAN-ROBOT PARTNERSHIP


Northwestern
Peter
Olivia
Northwestern | McCORMICK SCHOOL OF ENGINEERING
Class of 2023
WHOLE-BRAIN

WILDCAT WELCOME

In mid-September before classes started, the newest Northwestern engineers gathered on the Technological Institute plaza for "An Afternoon with McCormick." There, they learned about programs and interacted with student group members who showed off projects ranging from racecars to rockets. The event, held during the weeklong Wildcat Welcome orientation, allows students to meet their class of 2023 peers as well as members of the Northwestern Engineering faculty and administration.

Photography by Joel Wintermantle

"Collaboration with technology unlocks new possibilities, and at Northwestern Engineering, we are driving this evolution. However, it is also critical that we understand the positive and negative impacts that technology can have in our lives and in society at large."

GREETINGS FROM NORTHWESTERN ENGINEERING

We live surrounded by technology. It can help us work more efficiently, explore new environments, and overcome physical challenges. Collaboration with technology unlocks new possibilities, and at Northwestern Engineering, we are driving this evolution. However, it is also critical that we understand the positive and negative impacts that technology can have in our lives and in society at large.

Our new Center for Robotics and Biosystems envisions a future where humans and robotics work seamlessly together. We can trace this thinking to the 1990s when our faculty invented "cobots" that were used in a General Motors assembly line, not to replace human workers, but to help them. This type of research continues today with projects like partially autonomous wheelchairs that interact in specific ways with patients with different medical conditions.

One of the ways that we are looking to develop the tools needed to manage the impact of technologies is through our growing collaboration with colleagues at the Pritzker School of Law. As artificial intelligence becomes integrated with the justice system, and with it the potential to guide litigation and legislation, it is a critical time to join forces to understand and guide these implications. From courses that bring together law and computer science students to a cross-disciplinary project that enables artificially intelligent access to court records, the initiative aims to spark innovation and drive positive change in the justice system.

Another way to think about the implications of technology, both now and far into the future, is to curate dialogues with people with widely different viewpoints. An example of this is our partnership with the Mary and Leigh Block Museum of Art. Dario Robleto serves as our inaugural Artist-at-Large, instigating conversations among researchers in areas such as synthetic biology who are eager to consider the potential implications of their ground-breaking research.

In this issue we also celebrate the election of Professors Wei Chen and Linda Broadbelt to the National Academy of Engineering, one of our field's highest honors. Not only are each of these women renowned engineers, both are also accomplished educators and mentors. We are lucky to call them our colleagues.

These are just some of the stories about pathbreaking research and achievements from faculty and students that I am delighted to share with you in this issue. It is a truly exciting time to be at Northwestern Engineering.

As always, I welcome your feedback.

JULIO M. OTTINO
Dean, McCormick School of Engineering and Applied Science

On the Cover At the Center for Robotics and Biosystems, a swarm of 100 ground robots can self-assemble into specific shapes.

Photography by Justin Barbin

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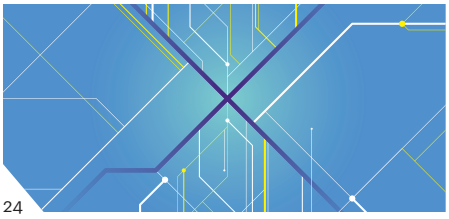
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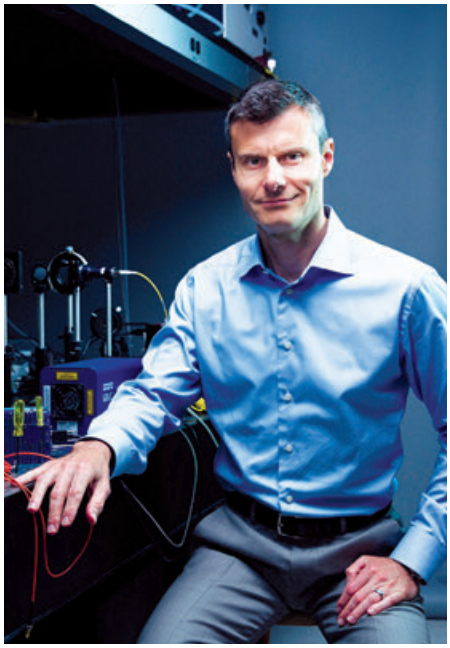
NORTHWESTERN ENGINEERING
FALL 2019

NEWS



Center for Physical Genomics and Engineering Launches

The Center for Physical Genomics and Engineering officially launched May 31 with a symposium that brought together the field's top faculty, students, researchers, and industry members. Led by Professor Vadim Backman, the center uses breakthrough optical imaging and computational genomics to reprogram the genome's chromatin, which regulates gene expression, in order to treat disease and to engineer living systems to overcome environmental challenges.

At the symposium on Northwestern's Chicago campus, Backman and other researchers shared their latest insights and offered thoughts on where the field should focus going forward via eight scientific presentations and a poster session. The center is working to develop physics-based approaches to addressing diseases in which global genomic reprogramming plays a role, including Alzheimer's disease, atherosclerosis, and developmental diseases.

MSIA HACKATHON EXPLORES BUSINESS OPPORTUNITIES USING CREDIT DATA

Joseph Cook and Nuo Xu, both Master of Science in Analytics (MSiA) students, won MSiA's sixth annual Hackathon. The team analyzed credit and data revenue from ABC Supply Co. to help the wholesale materials distributor expand future credit opportunities with customers and monitor operations more wisely. Their analysis could enable the company's operations team to better pinpoint branches in need of credit support, as well as branches that could offer more aggressive credit.

Nearly two dozen teams presented at the Hackathon, a collaboration between the MSiA program and ABC Supply. The day-long competition challenged students to use skills developed in the program to analyze large datasets in hopes of making meaningful discoveries.

120

Number of students prototyping climate change solutions at the 2019 Design for America Leadership Studio

30

Percentage of computer science majors who are women

"It's been a wonderful experience for city staff, nonprofit partners, businesses, and residents who interacted with the students. I really appreciate the thorough and empathetic approach the Northwestern students bring."

JASON KUNESH Design Director, City of Chicago

CITY OF CHICAGO PARTNERS WITH NORTHWESTERN ENGINEERING TO EXPLORE CIVIC SERVICE DESIGN

Eighteen students in the Segal Design Institute's Master of Science in Engineering Design Innovation (EDI) program presented designs for service discovery tools to City of Chicago officials, marking the first time a Northwestern Engineering class partnered with the city on a collaborative design project.

During the class, Human-Centered Design Studio 3, Service Design, students developed digital and interactive resource ideas for Chicago residents to better understand, access, and interact with city services. Students worked to understand how citizens discover existing city services and designed ways to reach more citizens. The course teaches service design, which is the process of understanding ecologies of stakeholders and iteratively designing and testing solutions to meet different needs.

NORTHWESTERN HOSTS SIXTH INTERNATIONAL MAMMALIAN SYNTHETIC BIOLOGY WORKSHOP

Northwestern University and the Center for Synthetic Biology hosted more than 150 attendees from institutions across the globe at the Sixth International Mammalian Synthetic Biology Workshop on the Evanston campus.

The workshop has grown into the premier gathering for the community dedicated to harnessing the power of synthetic biology for medical applications. This year's gathering focused on engineering immunity, building multicellular systems, and emerging technologies.

"We're increasingly able to engineer individual cells to perform custom functions," says Professor Josh Leonard, chair of the meeting. "Our key challenges now include trying to figure out how to engineer a collection of cells to cooperate in a desired way."

The workshop featured plenary talks from University of Chicago and Massachusetts Institute of Technology faculty, a panel discussing the broader considerations necessary to ensure that synthetic biology technologies are developed in ways that benefit all, and a presentation by Northwestern Engineering's Artist-at-Large Dario Robleto.

4

Number of Northwestern researchers who contributed to the EBRC Roadmap for engineering biology

4.2 MILLION

Number of people dying annually from air pollution, which Ken Park is addressing through smog extraction

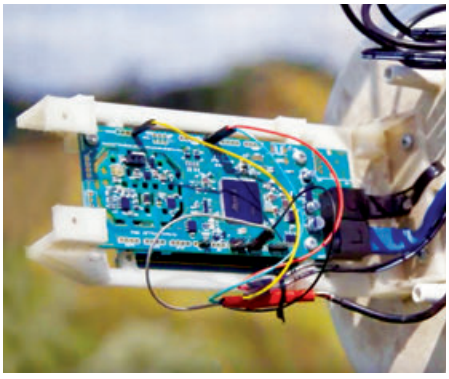
SOLAR CAR TEAM UNVEILS REIMAGINED VEHICLE AT FORMULA SUN GRAND PRIX

Featuring a reimagined car designed for reliability and structural stability, 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 with its new car, "Seven," at the Circuit of the Americas track in Austin, Texas. Following a close technical inspection of the vehicles' electrical and mechanical systems, teams spent up to three days on the 3.5-mile track to see how many laps their cars could complete using only power from the sun. NUsolar finished fifth in the Single Occupant Vehicle Class category during its only full day of racing.

"To be successful, you need to optimize your power intake from your solar array and your power outtake to your motor sticks, so you can keep the vehicle driving for eight hours a day."

IEVA STAKVILEVICIUTE Senior, Mechanical Engineering and Manufacturing and Design Engineering and Project Manager, NUsolar



"Our team's job was to design an off-the-grid, environmentally friendly power system able to provide all the energy needed for these nodes."

WILLIAM WHITTENBURY
Senior, Manufacturing and Design Engineering

Design Students Create Remote Power System for Prairie Sensor Network

Students in the Segal Design Institute's Interdisciplinary Design Projects course collaborated with Professor Bill Miller to expand the Array of Things sensor network, which uses the Waggle technology developed by Argonne National Laboratory, into a prairie environment to collect environmental data. Their final prototype for powering the nodes incorporated a wind turbine, solar panel, battery, and charge controllers on a reduced-size pole.

The sensors measure environmental factors in the prairie, such as temperature, air pollutants, and humidity. However, powering the nodes challenged students to consider environmental restrictions such as fire hazards and wildlife safety.

The class involves students spending two quarters on interdisciplinary projects focused on designing a solution to a problem posed by a client partner. Array of Things is a collaborative effort, including scientists, universities, local government, and communities to collect real-time data on urban environments, infrastructure, and activity for research and public use.

Hackathon Explores Trends in Reported Red Cross Incidents

After years of increasing steadily, the number of reported incidents—most of which were house fires—in the Chicago and Northern Illinois Region of the American Red Cross decreased more than 10 percent over eight months.

During a 48-hour hackathon, students in Analytics for Social Good, taught by Professor Karen Smilowitz, worked to apply quantitative and qualitative analysis to datasets, searching for an explanation. They also interviewed members of the Red Cross and the Evanston Fire Department.

The data revealed that a boost in the economy had caused a decrease in space heater use and that there were fewer serious fires where the Red Cross had installed smoke alarms.

3.3

Terahertz coverage of a new chip-based frequency comb developed by Manijeh Razeghi

46

Number of Energy Frontier Research Centers, two of which are co-led by Northwestern and recognized with Ten at Ten awards

50

Percentage that Luís Amaral and researchers slowed mutant fruit flies' metabolic rate, preventing harmful genetic mutations

"This class has real-world challenges that no other class deals with. The whole idea is that the world is dirty. The world is messy. Out in the world, the answer to a problem is not found on page 52 in a textbook. You've got to chase down the solution."

MARK WERWATH Clinical Associate Professor, Industrial Engineering

INDUSTRIAL ENGINEERING STUDENTS PARTNER WITH HIGH-PROFILE ORGANIZATIONS THROUGH IE CLIENT PROJECT CHALLENGE

This spring, industrial engineering students in IE Client Project Challenge teamed up with 15 client partners—including United Airlines and the Chicago Cubs, as well as nonprofits such as Ann and Robert H. Lurie Children's Hospital of Chicago—to work on large-scale, open-ended challenges.

One team made several site visits while working with the Chicago Cubs to improve the fan experience at Wrigley Field during renovations of the ballpark's upper deck. Another team helped United develop strategies to respond more quickly to customers who reach out via Facebook and Twitter.

Formerly called Senior Design, the IE Client Project Challenge course is now offered to industrial engineering juniors to help them leverage the experience in their job searches.

ADVANCING RESEARCH THROUGH THE ROBOT DESIGN STUDIO

Northwestern Engineering students studying to be mechanical, computer, and electrical engineers—both undergraduate and graduate students—came together to build robots that advance research through the class Robot Design Studio.

The multidisciplinary course challenged students to take specifications for robot systems proposed by project partners and produce robust, working robot prototypes over the course of two quarters.

First, the students built motors. Then, one team worked with Professor Ping Guo on technology that could enable large-scale 3D printing. A second team worked with Professor Kevin Lynch to build an inexpensive high-precision robot with six degrees of freedom.

LOCAL STUDENTS EXPLORE CAMPUS DURING ANNUAL CAREER DAY FOR GIRLS

More than 160 Chicago-area middle school and high school girls performed hands-on experiments and toured Evanston campus laboratories during Northwestern University's 48th annual Career Day for Girls.

The program supports sixth- through 12th-grade girls interested in science and mathematics by sharing information about educational and career opportunities in engineering and applied science. "Dream it. Do it." was the theme for this year's workshop sponsored by Northwestern Engineering's chapter of the Society of Women Engineers.

The event included an engineering design competition, laboratory tours, hands-on experiments, and a coding workshop. The students participated in activities ranging from building floating concrete figurines to observing the creation of liquid nitrogen ice cream to learning about robotics, prosthetics, and bioelectronic devices.

AS DESIGN FOR AMERICA TURNS 10, ANNUAL SUMMIT SPOTLIGHTS LOCAL CLIMATE CHANGE

At this year's four-day Design for America (DFA) Summit, more than 120 students from 36 colleges across the country honed their design and leadership skills while developing solutions to tackle climate change in local communities during the DFA Design Sprint. The undergraduates worked with several community organizations, including Chicago Youth Alliance for Climate Action and Sierra Club Chicago.

The summit marked the 10th anniversary of DFA, a student-led, grassroots network that assesses social challenges using human-centered design and works with communities to implement solutions. Founded by Professor Liz Gerber and three Northwestern undergraduates in 2009, DFA has quickly taken hold at colleges across the country, with chapters at more than 40 universities.

"I especially enjoyed the chance to interact with teams of enthusiastic and highly engaged students from across the US as part of a 'speed-dating' sprint on building collaborative relationships."

BILL MILLER Professor, Chemical and Biological Engineering

17

Number of times safer the anti-cancer delivery system created by Nathan Gianneschi is compared to other paclitaxel-based drugs

8

Number of teams who brought semi-autonomous robots to the 28th annual Design Competition

MSE Faculty and PhD Students Teach in Uganda

Materials scientists from Northwestern Engineering and universities around the world came together for a two-week immersive experience in East Africa to share knowledge about sustainable energy materials. The Joint Undertaking for an African Materials Institute presented its third workshop at Makerere University in Kampala, Uganda, for more than 60 students from universities worldwide.

The program included seminars, poster sessions, hands-on labs, and collaborative projects on topics such as photovoltaics, thermoelectrics, and nanoparticles. It included a plenary talk by Sir David King, senior strategy adviser to the president of Rwanda, who discussed the impending challenges of climate change.

STUDENT-DESIGNED "BOSCHMAN" SAILS TO VICTORY AT 2019 DESIGN COMPETITION

Boschman, a student-designed robot, sunk the competition and won a $1,000 award at "Battleship," the 28th annual Design Competition at Northwestern Engineering. Eight teams brought semi-autonomous robots to compete in a round-robin style tournament based on the classic board game.

A platform divided into two six-foot by six-foot squares with a barrier between provided the arena. The first team that sunk all its opponents' ships by pushing them off the platform—or that sunk more of them within the allotted three minutes—won the round.

LAB NOTES

Great Lakes Health and Economy Endangered, Report Warns

A new report from Professor Aaron Packman and more than a dozen experts provides an updated picture of how climate change is significantly affecting the Great Lakes and how it threatens public health, infrastructure, wildlife, and the regional economy.

The first-of-its-kind report, commissioned pro bono by the Environmental Law & Policy Center in concert with the Chicago Council on Global Affairs, aims to educate policymakers and the public about the vital importance of acting now to protect natural resources. Among the warnings: Great Lakes states should brace for more extreme weather, lower quality drinking water, agricultural losses, and deteriorating coast lines.

Meanwhile, Packman's laboratory continues the search for solutions. With funding from the National Science Foundation, he leads a multidisciplinary team from Northwestern, University of Illinois, and Argonne National Laboratory called Systems Approaches for Vulnerability Evaluation and Urban Resilience (SAVEUR).

The project combines social science, data science, and engineering to more accurately predict extreme events. The research will help inform proposed sustainable and adaptive infrastructure changes.

"We are already seeing the effects of climate change on Great Lakes cities. One example is the recent severe flooding, which is associated with changing weather patterns in the winter and early spring."

AARON PACKMAN
Professor,
Civil and
Environmental
Engineering

ANTIMICROBIAL PAINTS HAVE A BLIND SPOT

Antimicrobial paints promise to protect against bacteria, but they might do more harm than good. In a study led by Professor Erica Hartmann, researchers tested bacteria commonly found inside homes on samples of drywall coated with antimicrobial, synthetic latex paints. Within 24 hours, all bacteria died except for Bacillus timonensis, a spore-forming bacterium.

"If you attack bacteria with antimicrobial chemicals, they will mount a defense," Hartmann says. "Bacillus is typically innocuous, but by attacking it, you might prompt it to develop more antibiotic resistance."

Bacteria thrive in warm, moist environments, so most die on dry, cold indoor surfaces. This makes Hartmann question the need for antimicrobial paints, which may only cause bacteria to become stronger.

ARTIFICIAL INTELLIGENCE SYSTEM SPOTS LUNG CANCER BEFORE RADIOLOGISTS

Deep learning—a form of artificial intelligence that teaches computers to learn by example—has detected malignant lung nodules on low-dose computed tomography scans of the chest with a performance meeting or exceeding that of expert radiologists, according to a study from Northwestern Engineering, Google, and Northwestern Medicine.

The system provides an automated image evaluation system to enhance the accuracy of early lung cancer diagnoses that could lead to earlier treatment. When tested, the system also produced fewer false positives and fewer false negatives, which could lead to fewer follow-up procedures and fewer missed tumors.

"AI IN 3D CAN BE MUCH MORE SENSITIVE IN ITS ABILITY TO DETECT EARLY LUNG CANCER THAN THE HUMAN EYE LOOKING AT 2D IMAGES."

MOZZIYAR ETEMADI
Research Assistant Professor, Biomedical Engineering

800

Number of unique reaction conditions mapped through new approaches to engineer metabolic pathways

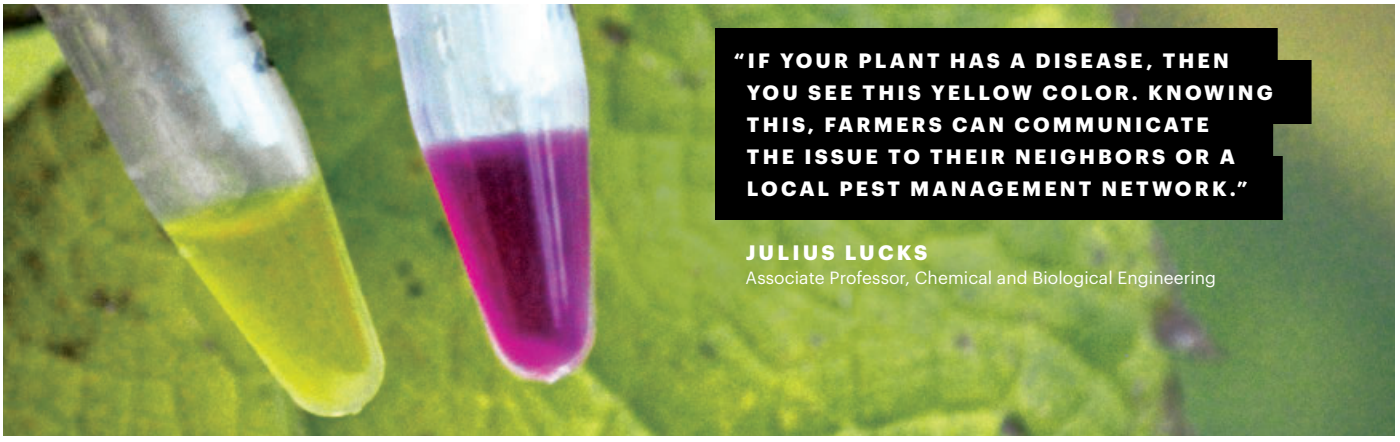
14

Number of compounds Chris Wolverton identified with potential for high-temperature superconductivity

Researchers Offer New Insight on Citations

While most researchers cite older, well-established papers in their field, Professor Luís Amaral and Northwestern Engineering researchers found that highly cited papers—papers that other published papers cite most often and, therefore, are considered successful—also cite more work that has been published relatively recently.

After analyzing nearly 6 million citations among more than 156,000 scientific papers published between 2005 and 2016, the researchers found that cited work goes on to become highly cited itself, showing that top researchers are adept at betting on good prospects.



"IF YOUR PLANT HAS A DISEASE, THEN YOU SEE THIS YELLOW COLOR. KNOWING THIS, FARMERS CAN COMMUNICATE THE ISSUE TO THEIR NEIGHBORS OR A LOCAL PEST MANAGEMENT NETWORK."

JULIUS LUCKS
Associate Professor, Chemical and Biological Engineering

POINT-OF-USE DIAGNOSTICS MIGHT DETECT PLANT DISEASE AND MORE

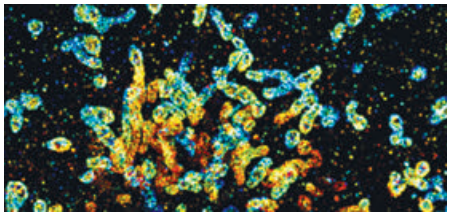
Current methods for detecting diseased crops require expensive lab equipment located far from the field. New point-of-use diagnostics technology under development by Professor Julius Lucks will help farmers test crops for disease using only their own body heat to activate the portable technology, called PLANT-Dx.

Its developers aim to equip low-income farmers around the world with a low-cost field test to improve detection of viruses and bacteria in their crops. "These farmers don't really have an avenue to do crop testing," Lucks says. "They don't have access to laboratory testing, or if they do, it's too expensive."

All a farmer must do is place a sample of ground-up plant material in a PLANT-Dx test tube. Molecular sensors, using body heat or ambient heat, will then trigger a change in color within a few hours if bacteria or a virus is present.

The next steps for PLANT-Dx involve further field testing and adjusting the technology to detect multiple viruses. Lucks and his researchers are also looking at ways to connect the technology to an electronic data collection infrastructure.

The research is supported by a $100,000 grant from Grand Challenges Explorations, an initiative funded by the Bill & Melinda Gates Foundation to encourage research that can break the mold for solving persistent global health and development challenges.



Imaging Single Molecules in 3D

Northwestern Engineering researchers developed a new platform that can image single molecules in 3D, allowing deeper probes into the inner workings of cells. The platform uses spectroscopic single-molecule localization microscopy (sSMLM), a tool that can capture simultaneously the spatial information of a single molecule and its spectroscopic signature.

Researchers improved the tool by combining existing sSMLM technology with a two-mirror system, allowing it to image molecules in 3D at much greater depths. This new tool could have profound implications in molecular biology by helping researchers understand complex processes inside cells.

"Our design is relatively easy to implement and will allow us to study molecular interactions much better than before," says Professor Hao Zhang, who developed the technology with Professor Cheng Sun. "Now we can see not only where molecules are, but also what they are."

20

Range of nanometer resolution for a new technique using single-molecule super-resolution optical microscopy

208

Percent increase in overall expression of target protein through Ribo-T, a new artificial ribosome created by Michael Jewett

SOLVING THE LONGSTANDING MYSTERY OF HOW FRICTION LEADS TO STATIC ELECTRICITY

What causes that hair-raising effect when an inflated balloon passes over a person's head or the subtle spark when someone slides across the carpet in socked feet? Most people have had such experiences, but why they happen has long remained a mystery.

A Northwestern Engineering team led by Professor Laurence Marks developed a new model that shows how rubbing two objects together bends tiny protrusions on the surface of materials and produces static electricity, or triboelectricity.

This new understanding has potentially important implications for existing electrostatic applications, such as energy harvesting and printing, and for avoiding possible danger, including fires started by sparks from static electricity.

"This provides much insight into tailoring triboelectric performance for current applications and expanding functionality to new technologies."

LAURENCE MARKS Professor, Materials Science and Engineering

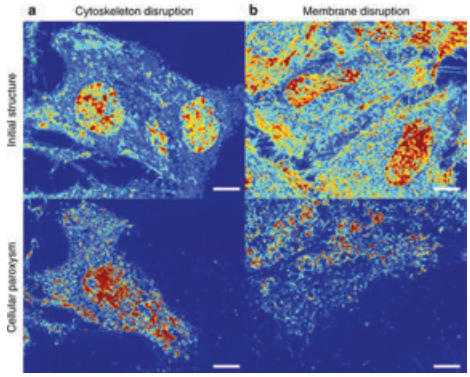
NORTHWESTERN STUDY OF ANALOG CREWS IN ISOLATION REVEALS WEAK SPOTS FOR MISSION TO MARS

Northwestern University researchers are developing a predictive model to help NASA anticipate conflicts and communication breakdowns among crew members and head off problems that could undermine the mission to Mars.

In multiphase research conducted in two analog environments—the Human Exploration Research Analog in the Johnson Space Center in Houston and the SIRIUS mission in the NEK analog located at the Institute for Bio-Medical Problems in Russia—Northwestern Engineering Professor Noshir Contractor and Northwestern University Professor Leslie DeChurch are studying the behavior of analog astronaut crews on mock missions. These missions include isolation, sleep deprivation, specially designed tasks, and mission control that mimics real space travel with delayed communication.

The threefold goal is to establish the effects of isolation and confinement on team functioning, identify methods to improve team performance, and develop a predictive model that NASA could use to assemble the ideal team and identify potential issues with teams before and during the mission.

"A lot of past efforts to create models that simulate the future have run into the criticism that they were not really grounded in good data," Contractor says. "What we have here is unprecedented good data. We aren't talking about intuition and expert views. This model is based on real data."



New Imaging Technique Reveals Burst of Activity Before Cell Death

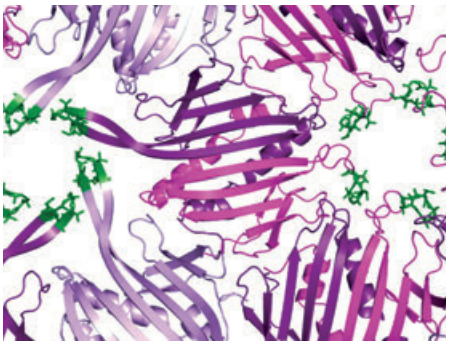
For chromatin, the group of DNA, RNA, and protein macromolecules packed within the human genome, motion is integral to its role as a regulator of how genes get expressed or repressed.

A research team led by Professor Vadim Backman along with Professors Guillermo Ameer and Igal Szleifer has developed a new optical technique to study the movement of cells without using cumbersome labels or toxic dyes to track them. Researchers applied the new technique, called dual-PWS, by studying the nanoscale structural and dynamic changes of chromatin in eukaryotic cells in vitro. Using ultraviolet light to induce cellular death, the team measured how the movement of the cells' chromatin changed.

The researchers also found that prior to a cell reaching its "point of no return" during decay, the cells' genomes burst with fast, instantaneous motion with different parts of the cell moving seemingly at random. The phenomenon, called cellular paroxysm, is a mystery, but Backman says the more researchers learn about chromatin, the more likely they can one day regulate gene expression, which could change treatments for diseases like cancer and Alzheimer's.

"Every single biological process you can imagine involves some sort of macromolecular rearrangement. As we expand our research, I can't help but wonder, 'What will we find next?'"

VADIM BACKMAN
Walter Dill Scott Professor of Biomedical Engineering



REVEALING THE RULES BEHIND VIRUS SCAFFOLD CONSTRUCTION

A research team led by Professor Danielle Tullman-Ercek has expanded the understanding of how virus shells self-assemble, an important step toward developing techniques that use viruses to deliver targeted therapeutics throughout the body.

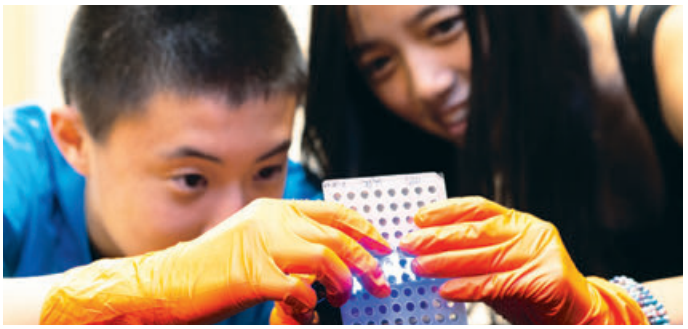
By performing multiple amino acid substitutions on a bacterial virus called the MS2 bacteriophage, researchers discovered instances of epistasis, a phenomenon in which two changes produce a behavior different from the behavior that each change causes individually. The work builds on Tullman-Ercek's earlier work to develop SyMAPS, a technique to test single variations of the MS2 particle. The team plans to expand testing to determine if the behaviors apply to similar viruses.

6

Degrees of freedom of the ABB robot in James Hambleton's Soil-Structure and Soil-Machine Interaction Lab

82

Number of young engineers—including Brenna Argall—selected by the National Academy of Engineering to participate in the Frontiers of Engineering Symposium



EXPANDED BIOBITS TEACHES CRISPR AND ANTIBIOTIC RESISTANCE TO HIGH SCHOOLERS

A Northwestern University-led team has expanded its BioBits Health educational kit to include modules for CRISPR and antibiotic resistance. The team wrapped its first pilot study, which tested the kit with a group of Chicago-area teachers and high school students.

Launched in 2018 with the Massachusetts Institute of Technology, BioBits is a suite of hands-on educational kits that enable students to perform a range of biological experiments by adding water and simple reagents to activate freeze-dried cell-free reactions. The kits link complex biological concepts to visual, fluorescent readouts so students know the results after a few hours in a single glance.

"There is a lot of excitement about being able to edit genomes with these technologies. BioBits Health calls attention to a lot of important questions—not only about how CRISPR technology works but about ethics society should be thinking about."

MICHAEL JEWETT Professor, Chemical and Biological Engineering and Codirector, Center for Synthetic Biology

NEW RESEARCH USES BAYESIAN COGNITION APPROACH TO IMPROVE DATA VISUALIZATION

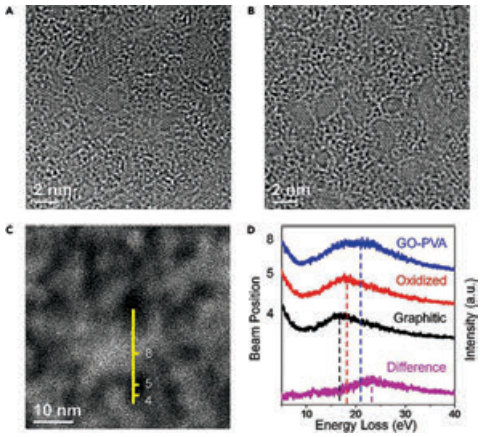
Consumers of news often encounter data visualizations relating to topics like climate change or election results—topics where personal biases affect how data is interpreted and how existing beliefs change based on new information. Yet, designers of data visualizations typically don't consider these factors.

A study from Professor Jessica Hullman and collaborators at the University of Washington used Bayesian models of cognition to elicit people's beliefs before and after showing them data. The researchers then examined how much beliefs actually changed based on seeing data compared to the predictions made by the Bayesian model, which treats subjects as rational processors of information.

Beyond helping data journalists better convey data visualizations, these models could also apply to human-in-the-loop artificial intelligence or data analysis systems, which aim to combine the knowledge of humans and systems to enable forms of reasoning that neither could do alone.

"We can learn more from such a model about how people interpret data visualizations relative to other ways of evaluating visualization interpretation, and we can use a model like this to better evaluate and design visualizations."

JESSICA HULLMAN Breed Junior Professor of Design and Assistant Professor, Computer Science and Journalism



TOUGHENING UP GRAPHENE OXIDE SHEETS WITH POLYMER

While graphene and graphene oxide have been touted as the building blocks of next-generation sensors and wearable electronics, the substances themselves are usually brittle despite their strength and high surface-to-volume ratio.

Professors Horacio Espinosa and Jiaxing Huang have developed a way to toughen up graphene oxide by layering it with polyvinyl alcohol, a synthetic polymer. In doing so, they created a material two times tougher and, because of the way the two materials bind, much less prone to failures due to cracks and piercings.

"The polymer bridges the cracks and makes the material much tougher and potentially self-healing," says Espinosa, who believes the work could serve as a model for two-dimensional materials going forward.

14

Number of MS EDI students who collaborated with Kraft Heinz, Lurie Children's Hospital, and Actualize Therapy during Design Sprints course

18

Number of MS in Biotechnology students who traveled to San Diego to connect with industry leaders

SCIENTISTS PROVE A MEDIEVAL WEST AFRICAN GOLD PURIFYING PROCESS WORKS

A team of Northwestern materials scientists led by Professor Marc Walton have experimentally replicated a gold purification method practiced in the 10th and 11th centuries in Tadmekka, Mali, using similar material resources, and found the process works incredibly well.

The team used gold dust, recycled glass, and sand from nearby Lake Michigan to conduct a reduced version of the original process. Team members melted the gold dust and filtered it through crushed glass to purify. They then used copies of the original clay thumbprint molds to cast replica blank coins in bronze instead of gold.

Making Glass Even Clearer

Professor Sinan Keten and a team of other researchers from North Dakota State University and the National Institute of Standards and Technology have designed an algorithm with the goal of giving polymeric glasses more clarity. The algorithm makes possible the creation of 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 the mechanical behavior of glass at different temperatures and could result in the fast discovery of new materials with optimal properties.

Luís Amaral

Harold Kung

Yonggang Huang

Linda Broadbelt

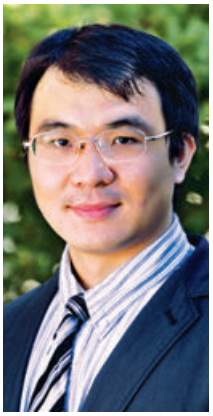
Jie Gu

Chad Mirkin

Richard Lieber

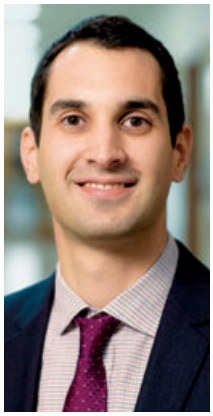
Jian Cao

Barry Nelson



Han Liu

Kimberly Gray



Sinan Keten

Faculty Awards

Luís Amaral, Linda Broadbelt, and Richard Lieber Elected to AIMBE's College of Fellows

The American Institute for Medical and Biological Engineering's College of Fellows comprises the top 2 percent of medical and biological engineers in the country.

Han Liu Earns Presidential Early Career Award for Scientists and Engineers

PECASE is the highest honor bestowed by the US government on young science and engineering professionals.

Harold Kung Receives American Chemical Society Award

The George A. Olah Award in Hydrocarbon or Petroleum Chemistry recognizes outstanding research achievements.

Jie Gu Recognized with NSF CAREER Award

The Faculty Early Career Development Program awards from the National Science Foundation are the most prestigious honor for junior faculty. He will receive $500,000 over five years.

Jian Cao Named Vannevar Bush Faculty Fellow

The highly competitive honor from the US Department of Defense includes a $3 million, five-year research grant.

Kimberly Gray Earns LEAP-HI Award

The National Science Foundation award will support research of resilient urban infrastructure systems. She will receive $2 million over five years.

Yonggang Huang Receives Theodore von Karman Medal

This award is the American Society of Civil Engineers' highest honor in mechanics.

Chad Mirkin Awarded Perkin Medal

The prestigious award is the highest honor in the US for achievement in industrial chemistry.

Barry Nelson Earns Two IISE Awards

The Institute of Industrial and Systems Engineers recognized Nelson with the David F. Baker Distinguished Research Award and the Modeling and Simulation Division Teaching Award.

Sinan Keten Earns Walter L. Huber Civil Engineering Research Prize

The award from the American Society of Civil Engineers is the highest-level mid-career research award in civil engineering.

CONNECTING ART + ENGINEERING

Three years ago, leaders at Northwestern Engineering and the Mary and Leigh Block Museum of Art had an idea—to directly engage artists with engineers by embedding an Artist-at-Large with the McCormick School of Engineering. The goal was broad— to spark vital conversations between members of two highly creative, cutting-edge fields and then wait to see what happened.

As curator of the program, I worked with Dean Julio M. Ottino and Lisa Corrin, director of the Block, to bring five contemporary artists to campus over the course of a year to discover intersections between their work and what's happening at Northwestern Engineering. The artists lectured on their work and met with faculty in areas ranging from robotics, computer science, and nanotechnology to political science, sociology, poetry, and art history.

Among those notable artists, we found Dario Robleto uniquely positioned to serve as the first artist for this initiative. A transdisciplinary artist, researcher, and writer based in Houston, his exploration of music, popular culture, science, war, and history has often resulted in intricately handcrafted objects.

Focused on the creative response to loss, he draws on wide-ranging, unconventional materials from meteorites to lost recordings of heartbeats from the 19th century. What underpins all of Robleto's projects is his humanism—a bridge connecting necessary and important conversations that, until his arrival, had gone unspoken.

Early on, we connected Robleto with Megan Crowley-Matoka, associate professor of medical education and anthropology at Northwestern University Feinberg School of Medicine, and with Julius Lucks, associate chair and associate professor of chemical and biological engineering. Soon, we realized that Robleto needed to connect with Lucks's colleagues at the Center for Synthetic Biology—where ethics and societal impact form one of the program's four pillars.

Since then, their conversations have ranged from the limits of life at a cellular level to how ideas around altruism and generosity have real-life repercussions for our health. Naturally, big questions have emerged:

- How do ethical considerations impact decisions that scientists and researchers make every day?
- How can engineers, as socially conscious humans, adapt science to social needs?
- And, importantly, what is our responsibility to take a stake in technologies that redefine fundamental aspects of life itself?

These conversations, initiated by Robleto's curiosity and humanism, have the power to alter the course of Northwestern engineers' research—and to shape the future. Thank you, Dario, for embarking on this journey with us, sharing your insight, capaciousness, and boundless curiosity.

Susy Bielak served as the Susan and Stephen Wilson Associate Director of Engagement and Curator of Public Practice at the Mary and Leigh Block Museum of Art and curated the inaugural Artist-at-Large Program at Northwestern Engineering.

ARTIST-AT-LARGE DARIO ROBLETO MAKES THE CASE FOR MULTIDISCIPLINARY COLLABORATION TO ADDRESS CRITICAL SOCIAL AND ETHICAL ISSUES.

EXPLORING ETHICS ACROSS FIELDS

IN THE SPRING OF 2018, I was appointed Artist-at-Large in an ambitious cross-disciplinary initiative between Northwestern Engineering and the Mary and Leigh Block Museum of Art. Under the visionary leadership of Dean Julio M. Ottino and Lisa Corrin, director of the museum, I have been afforded incredible access to various brain trusts in one of the country's premier universities.

The question at the heart of this initiative could not be more timely and relevant: What constitutes meaningful collaboration among people from different disciplines and disparate fields?

Artist-at-Large Dario Robleto provokes conversations with Northwestern researchers including Josh Leonard, Megan Crowley-Matoka, Julius Lucks, and Danielle Tullman-Ercek.

A new paradigm with far-reaching impact

On this vital point, the challenges between the arts and humanities on one end and the sciences and engineering on the other are significant. There is a perception that we do not have much in common in how we formulate questions and methodological approaches; how we navigate the differences between the objective and subjective; how we determine "results;" and what the broader impacts of such transdisciplinary collaboration would entail.

In the context of limited time and resources, for an outcomes-oriented engineering school of Northwestern's caliber to give a contemporary artist a "hall pass" to wander through departments and classes based purely on curiosity and undefined possibilities could not be riskier. Creating the infrastructure for such work to occur is to value process as much as the product and intellectual patience across disciplines more than suspicion and competition.

These are not trivial details. Artists like me, who advocate for this disciplinary patience and integration, mostly operate independently with little sustained support. What the dean and director are building together is not only a commitment to intellectual diversity among students and faculty, but also a program with, potentially, broader societal impact.

The disciplinary distinctions between the arts and sciences of today were not always necessary. For complex historical reasons, the arts, humanities, engineering, and sciences split in such ways that we often forget what we have in common. This, I feel, has come with a significant loss to society as a whole. Specialization within academic fields has accelerated to such an extent that, at least on paper, it seems hard to argue what meaningful dialogue an artist could have with a theoretical physicist, a heart surgeon, or an astrobiologist. Equally, it is quite a stretch to imagine how a biologist may challenge a sculptor or a performance artist.

Increasingly, though, the complexity of our inquiries into nature through one domain are so expansive that they transcend their field of origin and require multiple disciplines to address them adequately. After several months of research in various departments at Northwestern, it became clear to me that one field in particular demanded the effort of such multidisciplinary attention: synthetic biology.

Scientific advancement raises new moral questions

Synthetic biology's radical advancement—human control and design of the human genome—is not only a technical feat, but also falls into that rare classification of scientific advancements that are existential, extending far beyond the laboratory. Like all forms of power, especially one that harnesses the mechanisms of biological life, synthetic biology is now susceptible to the full range of competing human needs and desires: access and control, self-interest and the greater good, well-being and abuse.

As synthetic biology's potential unfolds—curing all genetic diseases to its inevitable weaponization—its impact will stretch across cultural and social dynamics, religious thought, philosophical inquiry, global economics, artistic representation, and ethical norms. But it is this last consideration—ethics—that makes an urgent case for the reintegration of the arts, humanities, and sciences. For it is through ethics, and the social engagement it requires, that complex, laboratory-based science, such as synthetic biology, can embrace its connection to the humanity and public responsibility underlying the work.

As an artist, but also as a citizen with a deep appreciation for science, something that deeply concerns me is the growing public divide and mistrust about scientific investigation and its perceived, but perhaps very real, lack of ethical and moral oversight. Increasingly, many scientific and medical fields are not just operating within existing, well-trodden ethical terrain—the Hippocratic oath or patient consent, for example—they also are inventing new ethical questions no one ever thought to ask. (Perhaps most provocatively, should we take the reins of evolution into our own hands?) When all the public sees are headlines about science moving forward because it *can*, before ever asking if it *should*, it damages the kind of public dialogue we need to be having about issues that will affect us all.

But what does it mean to create work that outpaces ethical deliberation and public understanding? Are there sufficient pathways for scientists to consult with ethicists, moral philosophers, and artists or even to consider perspectives entirely outside academia, like economically or racially marginalized groups, people with disabilities, patients and their families, or religious groups?

What does it mean if, partly through the breakdown between the arts, humanities, and sciences, a generation of scientists is unequipped to think through the social and ethical consequences of their work? Essentially, how do we draw on the full range of humanity's creative and moral imagination when dealing with groundbreaking scientific developments?

As an artist, I feel I have a responsibility to remain informed and to utilize the incredible power of the arts as a type of poetic checks and balances to the sciences, poking and prodding with questions different from those my scientific counterparts may ask. Further, the arts are uniquely designed to aid with the translational work to the public through building the metaphors, symbols, allegories, public programs, or whatever form is necessary to communicate clearly.

Interdisciplinary reflection and introspection

It is within this confluence of cutting-edge science, ethics, social responsibility, and the critical and translational power of the arts that, with the generous participation of colleagues from the synthetic biology and bioethics departments, I was able to moderate a public event addressing many of the concerns I have laid out.

As I learned from observing and listening in on numerous conversations, my colleagues—synthetic biologists Josh Leonard, Danielle Tullman-Ercek, and Julius Lucks; and medical anthropologist Megan Crowley-Matoka—are driven not only by their individual research goals, but by the fact that they are socially conscious humans who care about the broader consequences of their work.

To honor the on-the-ground complexity of these scientists' experiences, it was crucial not to focus just on the worst-case scenarios of science run amok. Instead, I wanted to highlight the many inventive and nimble ways these scientists do rise to the ethical responsibilities their fields require, even while they reflect that the systems of ethical dialogue and oversight are far from adequate moving forward.

The format was designed for each of us to share an experience within our fields where an ethical conundrum unexpectedly appeared. At that moment, we had a choice: ignore it, work around it, let others worry about it, or challenge ourselves to embrace the problem and perhaps even let it determine how we move forward.

Not only did we lay out clear examples of ethical conundrums within our fields ("dual-use" technology, the limitations of existing patent structures for the common good, the problems of self-regulation, the ethical responsibility of art-science collaborations, etc.), we also designed the evening to put our disciplines' modes of inquiry and problem-solving in comparison, alignment, or misalignment, revealing aspects that surprised us in our commonalities or challenged us in our differences.

Collaboration for the common good

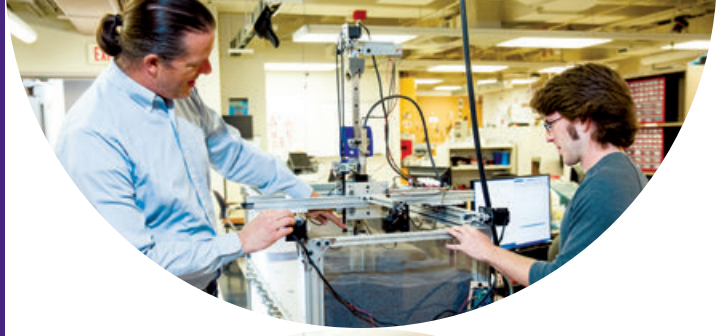
As I have observed over many years, the vast majority of the public never interacts directly with scientists or artists. Equally rare is for scientists and artists to publicly or privately speak face to face. Our processes and motivations remain obscured, often filtered through various popular culture media that usually operate within clichés.

But, in an era where scientific advancements will increasingly complicate a wide range of cultural and social issues, it is irresponsible for the arts, humanities, and sciences to remain in their status quo—comfortable in disciplinary silos. Further, in the current climate of distrust and polarization of thought, with growing public skepticism of the sciences and arts in particular, having a public and civil discussion amongst ourselves about ethics is itself a statement about our responsibility to work together for the greater social good. It is through initiatives such as Northwestern's Artist-at-Large Program that we can build a new model for how this work is accomplished.

I want to thank Julio and Lisa for their visionary leadership and long-term commitment to intellectual diversity and dialogue between the arts and sciences; Susy Bielak, former curator of public practice and associate director of engagement at the Block Museum of Art; and Kyle Delaney, executive director of strategic initiatives and marketing at the McCormick School of Engineering, for their expert guidance, management, and patience as we discovered the possibilities of this program together.

DARIO ROBLETO

Photography by Sean Su



ROBOTS ARE COLLABORATORS, NOT COMPETITION

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

ROBOTS ARE NOT COMING TO TAKE OUR JOBS, CONTROL OUR LIVES, OR MAKE HUMAN BEINGS OBSOLETE.

They're here to work with us and to help us be our best selves—at work and at home—whether we'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 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," says 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."

A COLLABORATIVE FUTURE

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 (see sidebar).

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 faculty and research scope continuing to grow, the Center for Robotics and Biosystems launched this fall. Faculty 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," says Lynch, also the editor-in-chief of leading robotics academic journal *IEEE Transactions on Robotics*. "We design robots that augment human abilities."

A SPACE FOR HUMAN-HUMAN AND HUMAN-ROBOT COLLABORATION

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 work side-by-side with students in the popular Master of Science in Robotics program. This encourages the cross-pollination of ideas by students and faculty with different backgrounds, and accommodates visitors from the the center's many collaborators.

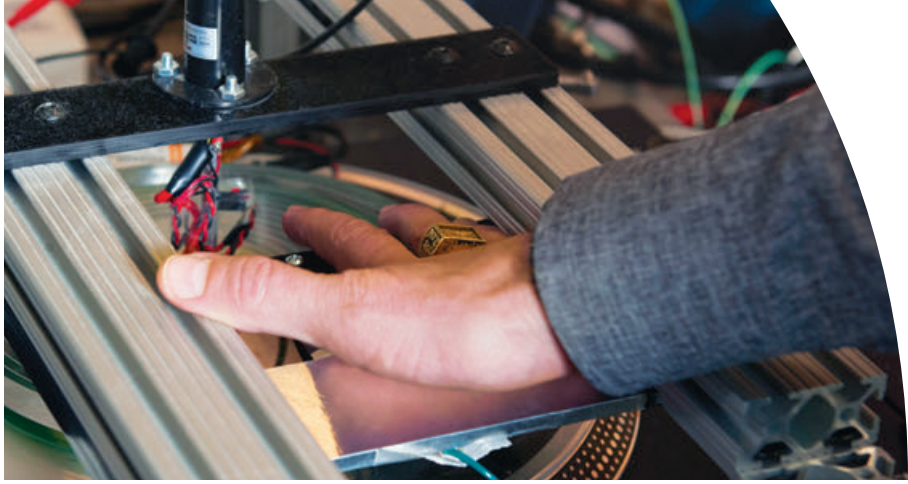
The new space, says Lynch, chair of the mechanical engineering department, "will hopefully catalyze even more partnerships at Northwestern." That in turn should expedite realization of the vision where humans and machines integrate seamlessly in both work and life.

Northwestern Engineering's legacy in robotics started in the 1950s when Dick Hartenberg, a professor, and Jacques Denavit, a PhD student, developed a way to represent mathematically how mechanisms move.

At the time, there was no agreement on how to describe the kinematics—the geometry of motion—of mechanisms consisting of links (rigid bodies, like bones) and joints (parts that allow motion between rigid bodies, like a shoulder joint). The duo showed that the position of one link connected to another by a joint could be represented minimally using only four numbers, or "parameters." These came to be known as the Denavit-Hartenberg parameters, the standard description of the kinematics of robots for decades to come.

Thirty years later, when Michael Peshkin arrived at the McCormick School of Engineering as an assistant professor, the field of robotics was focused on trying to develop fully autonomous robots.

"Everyone thought robots would become more and more capable until they could walk among us, and step in for human workers," says Peshkin, now professor of mechanical engineering. "Nobody had much of an idea how to make that happen, but the goal was always autonomy."



"We realized that autonomy for robots wasn't the right goal. Instead, we could combine the strengths of people in intelligence, perception, and dexterity, with the strengths of robots in persistence, accuracy, and interface to computer systems."

MICHAEL PESHKIN
Professor, Mechanical Engineering

A PROGRESSION OF PARTNERSHIPS

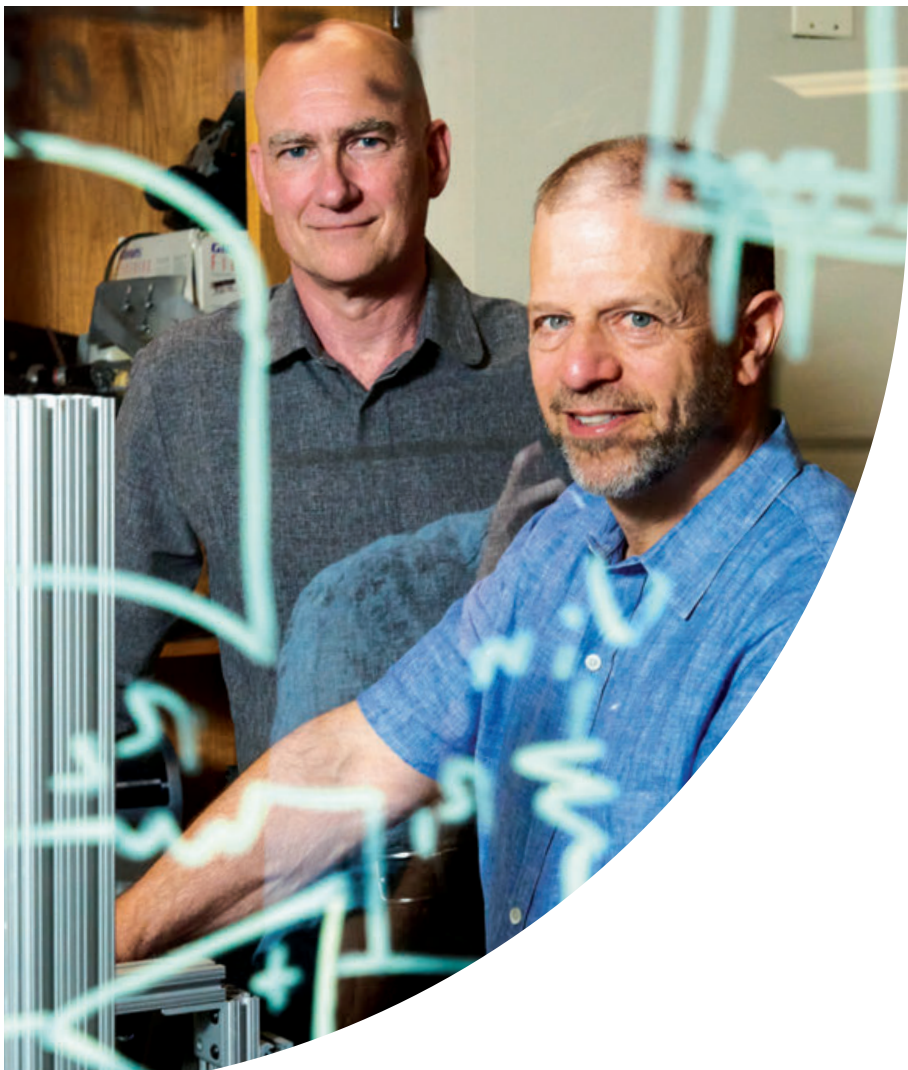
In the early 1990s, a grant from the General Motors Foundation prompted Peshkin and collaborator Ed Colgate, now Breed Senior Professor of Design, to talk to GM assembly line workers. Though humans and robots shared the floor, they couldn't work together physically, for safety reasons. Robotic systems had to remain behind a fence, creating a mindset that robot jobs and human jobs were completely distinct.

At the same time, the human workers were using machines to help move heavy parts for assembly, such as hoists. Peshkin and Colgate learned, however, that GM's workers valued a certain level of independence. Workers got satisfaction from lifting parts with their own muscles, and the fast, smooth motion as they moved parts into place. This joy of free motion was lost when they had the assistance of machines.

"We realized that autonomy for robots wasn't the right goal," Peshkin says. "Instead, we could combine the strengths of people in intelligence, perception, and dexterity, with the strengths of robots in persistence, accuracy, and interface to computer systems."

Inspired, the researchers designed and built cobots—a portmanteau of the term collaborative robots—that physically cooperate with workers to manipulate heavy items. The low-power robots helped guide the workers. When installing an automobile seat, for example, the worker initiated the motion and controlled the action while the cobot guided the seat to its exact position.

"It still gave workers the pleasure of motion that they wanted to retain," Peshkin says. "The robot became a collaborator, not a replacement."



HUMAN-ROBOT TEAMS DETECT DANGER

Combat soldiers trying to secure dense, urban areas often face dangerous levels of uncertainty. Will the next alley contain a potential threat, or just kids playing soccer? Northwestern Engineering's Todd Murphey is developing a way to mitigate the danger—drones that can fly ahead of the troops, sense the environment, and report back what they see to the squad.

Murphey, professor of mechanical engineering, is finding ways to help humans interact and collaborate with autonomous systems. With funding from the Defense Advanced Research Projects Agency, he is developing algorithms and software that allow drones to perceive the environment, then determine which information should be transmitted to humans, and which should be ignored.

"Having some representation of what you're about to encounter will lead to better decision making," says Murphey, director of the Master of Science in Robotics program. He and his group are currently determining the best way for drones to relay information and are testing the system in virtual reality environments this fall.

"This sort of feedback loop—modeling perception, making decisions, and then feeding that information back to a person—has implications in everything from manufacturing to driverless cars," Murphey says. "There's definitely a role for autonomy to help keep people safer."

"This sort of feedback loop—modeling perception, making decisions, and then feeding that information back to a person—has implications in everything from manufacturing to driverless cars."

TODD MURPHEY
Professor, Mechanical Engineering

ROBOTS INSPIRED BY BIOLOGY

"We take a bio-inspired approach, but we don't just blindly mimic biology. To engineer the best system possible, we need to determine which specific features of the biology are most important."

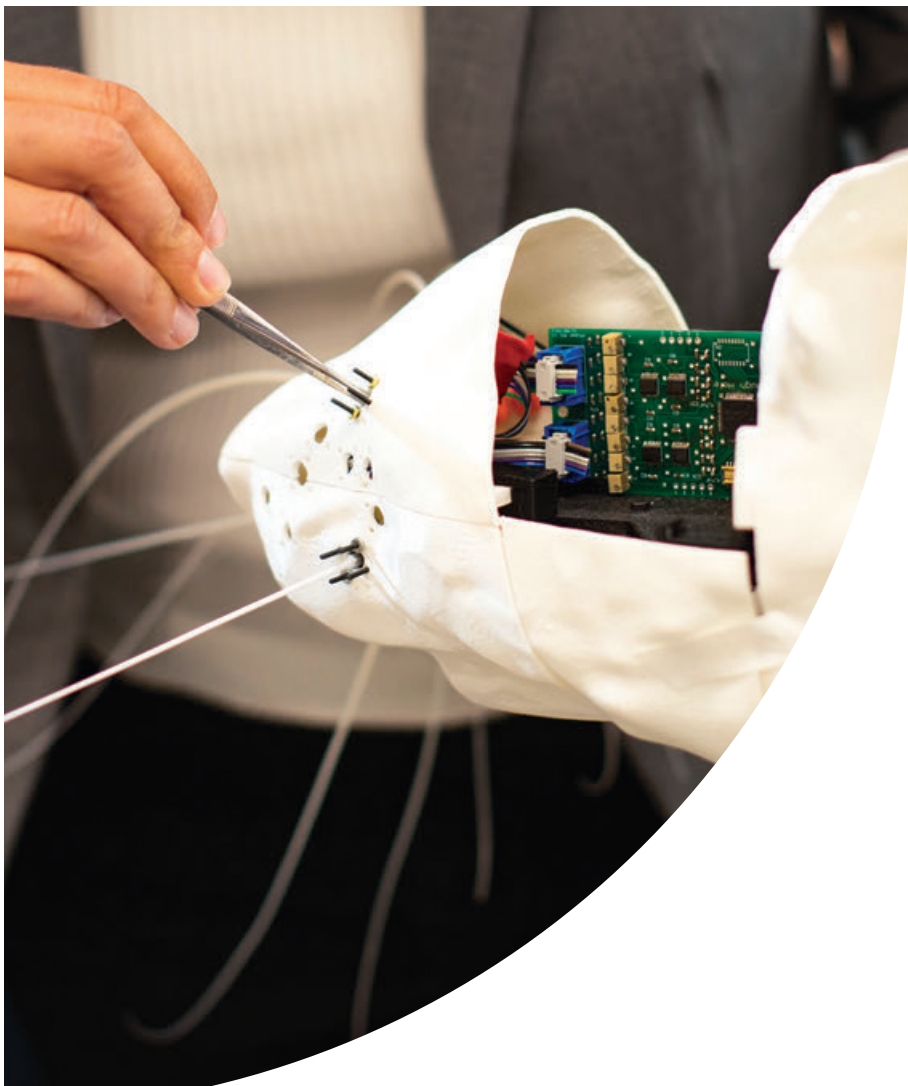
MITRA HARTMANN
Charles Deering McCormick Professor of Teaching Excellence and Professor, Biomedical Engineering and Mechanical Engineering

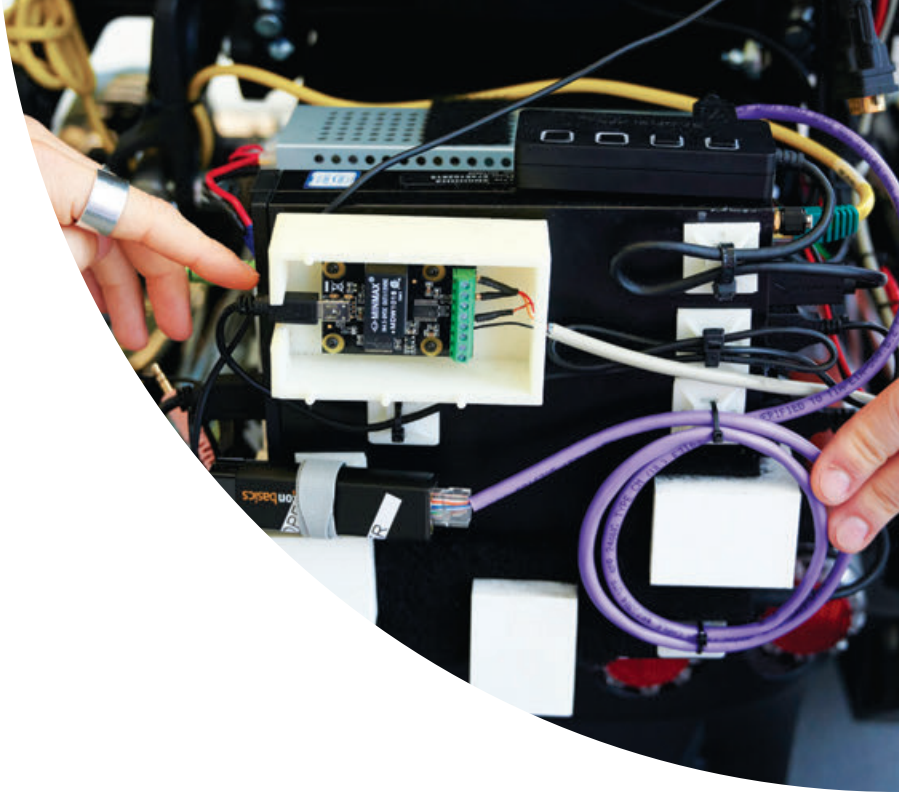
Nearly all mammals use whiskers to explore and sense the environment. Rats, for example, use their whiskers to determine an object's location, shape, and texture. Seals and sea lions use their whiskers to hunt fish.

Mitra Hartmann, Northwestern Engineering's Charles Deering McCormick Professor of Teaching Excellence and professor of biomedical engineering and mechanical engineering, is leading an effort to develop robotic whiskers that can imitate these capabilities. The work could help develop robots that can perform touch-based sensing in dark, murky, or dusty environments (like pipes and tunnels), as well as robots that can sense the flow of air and water.

Each robotic whisker—a long, thin, plastic cone attached to an artificial follicle—can sense an object's location and texture just as a rat's whisker does. The team is currently constructing an entire array of whiskers for more precise measurements.

"We take a bio-inspired approach, but we don't just blindly mimic biology," Hartmann says. "To engineer the best system possible, we need to determine which specific features of the biology are most important."





Humans navigating the world in wheelchairs face obstacles in and out of the chair, but Northwestern Engineering's Brenna Argall aims to help through autonomy.

Argall, associate professor of computer science, mechanical engineering, and physical medicine and rehabilitation, is working to create partially autonomous wheelchairs that can help their users avoid obstacles, plan and navigate routes, and maneuver in tricky spaces. "We want to build a system that can pay attention and help with certain tasks," Argall says.

She and her lab are currently working to characterize just how people drive their powered wheelchairs. They built a course in her lab at the Shirley Ryan AbilityLab—complete with doors, ramps, and sidewalks—and are developing datasets of how patients with spinal cord injuries, cerebral palsy, and ALS use different wheelchair interfaces.

HUMANS GUIDED BY ROBOTS

"If we know how people operate these machines, we can design autonomy that knows how that operation happens and expects certain signals to create a more fluid symbiosis between human and machine," Argall says.

She also works with Sandro Mussa-Ivaldi, professor of biomedical engineering, physiology, and physical medicine and rehabilitation, to investigate how a quadriplegic patient could use a system of sensors on their upper body to control a complex system, like a robotic arm. "This system could help with functional tasks and help the body improve and gain strength," she says. "That's the gold standard of rehabilitative robotics."

EMILY AYSHFORD

"This system could help with functional tasks and help the body improve and gain strength. That's the gold standard of rehabilitative robotics."

BRENNA ARGALL
Associate Professor, Computer Science, Mechanical Engineering, and Physical Medicine and Rehabilitation

WHERE TECH CROSSES PATHS WITH THE LAW

Northwestern's schools of engineering and law join forces to refine and preserve the rule of law worldwide.

> "We want interdisciplinary teams both to create new tools and to understand how the other side thinks and works. With that understanding comes a new way of collaborating that will lead not only to innovation but also to leadership in artificial intelligence and the law. It's a space that's primed for guiding principles."
>
> **JULIO M. OTTINO** Dean, McCormick School of Engineering

Though judges and juries strive to be impartial, a deep look at macro-level patterns found in data calls into question whether this is actually the case.

Take the death penalty, for example. Only after researchers began to study who was sentenced to death rather than to life in prison did patterns related to ethnicity emerge. A 1990 US General Accounting Office report combined 28 different studies of homicide cases to find that, among defendants with similar criminal histories, those whose victims were white were several times more likely to receive the death penalty than those whose victims were African American.

Nearly 30 years later, advances in artificial intelligence (AI) and machine learning enhance our ability to understand other important insights in legal proceedings previously hidden in large datasets. These tools give rise to many other opportunities—and challenges.

On one hand, software can help lawyers prepare for litigation. On the other, it might give them an unfavorable advantage.

If attorneys can identify a pattern of words or terms in documents that can be used to guide judges to rule in their favor, should they be able to use them? Because these tools are so new, should legislation govern their use? How can lawyers and engineers work together to make these tools not only useful but also fair by design?

These are the questions Northwestern Engineering and Northwestern Pritzker School of Law faculty and students hope to answer through new courses, research projects, and joint initiatives at the intersection of technology and law to help shape the future of legal services, judicial systems, and the law itself.

"We want interdisciplinary teams both to create new tools and to understand how the other side thinks and works," says Julio M. Ottino, dean of the McCormick School of Engineering. "With that understanding comes a new way of collaborating that will lead not only to innovation but also to leadership in artificial intelligence and the law. It's a space that's primed for guiding principles."

Those working in law must understand AI technologies to help regulate and use them to make legal systems more efficient and fair, says Kimberly Yuracko, dean of Northwestern Law.

"We want to leverage these technologies to create the kind of society we want to live in. Together we can use technology to better realize our foundational principles of justice."

FORGING NEW LAW AND TECH PARTNERSHIPS

Both computer science and law faculty approach this partnership with caution because of the widespread use of AI systems in media for the dissemination of "fake news." As algorithms play a heavy hand in offerings to readers, false information can be presented to reinforce a reader's point of view.

"Now we have news filter bubbles and weaponization of information," says Kris Hammond, Bill and Cathy Osborn Professor of Computer Science. "Unless someone is at the wheel, bad things like this can happen. But if the right people are making decisions, these advanced technologies can be magnificent."

"We can collaborate to create law and technologies that promote human rights and expand and preserve the rule of law around the globe."

DAN LINNA Director of Law and Technology Initiatives

This fall, Northwestern Engineering and Northwestern Law enhanced their collaboration by appointing Dan Linna as the director of law and technology initiatives, the first joint position in law and engineering. With his background as an IT consultant and as an attorney representing international corporations and technology clients, Linna has experience on both sides of the equation. At Michigan State University, he founded LegalRnD–the Center for Legal Services Innovation. At Northwestern, he aims to work with faculty and teach students at both the law and engineering schools to improve legal services and determine the best path for regulation of emerging technologies.

"Technology is already changing the delivery of legal services," he says. For example, some legal search services use natural language processing and semantic analysis in their retrieval processes, while others provide text analytics and machine learning to support the discovery process. Emerging products include AI software that can learn from the decision history of a court or judge to predict outcomes or provide insights into the opposing counsel.

"We want to work with big law firms, legal aid groups, and within the legal ecosystem overall to improve access to the law and help improve legal systems," he says. Also, lawyers could help lead how AI regulations are structured. "We want to be proactive, and ask how law and regulation can facilitate innovation that seizes opportunities to improve society for everyone."

ENGINEERING AND LAW STUDENTS WORKING TOGETHER

Linna teaches at both Northwestern Law and Northwestern Engineering. In law, he teaches Artificial Intelligence and Legal Reasoning, helping to demystify the technology and motivate students to consider how to use data and technology to improve the delivery of legal services. In engineering, he instructs Master of Science in Artificial Intelligence students about law and the governance of AI. "I want computer scientists not only to understand regulation, but also to shape it and create an environment where these tools will be used for good," he says.

This past winter and spring, students from both schools came together in CS+X Innovation Lab: Building Technologies for the Law. Thirty-two engineering and law students were divided into six teams and charged with designing, developing, and testing innovative products in the legal space. The course was taught by Linna, Hammond, and Dave Schwartz, Stanford Clinton Sr. and Zylpha Kilbride Clinton Research Professor of Law.

"We wanted to teach law and computer science students to work together," Hammond says. "We wanted to develop a real partnership to solve these problems. The results were breathtakingly successful."

One team developed a system that uses AI to check a set of clauses in a contract during negotiation in a fraction of the time an associate normally takes to complete. "Humans are still involved in the process—this just takes one part of the problem off somebody's plate," Hammond says.

Another group developed an application related to telemedicine, where doctors provide consultations remotely. While this technology provides quick and easy diagnoses, it raises legal questions for doctors, in-house counsel, and insurers. The team's application allows these stakeholders to ensure a doctor is compliant in providing telemedical care in any of the 50 states by answering a series of questions.

CREATING SYSTEMS GUIDED BY DEMOCRATIC PRINCIPLES

Initiatives like these will help lead the way to a future that isn't mired in the legal equivalent of "fake news."

"We can build a road to a future where the use of these technologies aligns with the goals and values of the law: fairness, transparency, responsibility, culpability, and liability," Hammond says. "If we're going to use these technologies well and correctly, we have to have this convergence."

That will help both those in the legal system and those who find themselves caught within it. "What if we were proactive and created a world where the law was embedded in systems to respect human rights and democratic principles from the beginning by design?" Linna says.

"We can collaborate to create law and technologies that promote human rights and expand and preserve the rule of law around the globe."

EMILY AYSHFORD

FINDING A BETTER WAY TO STUDY FEDERAL COURT RECORDS

Northwestern researchers and students have launched a cross-disciplinary pilot project that could put the University at the forefront of enabling artificially intelligent access to federal court records. Accessing those records through the current online PACER (Public Access to Court Electronic Records) system is onerous. Not only is the interface not intuitive, but the federal government charges 10 cents per page downloaded.

For researchers who want to look for patterns among the records, that's no small fee. In 2018 alone, the federal court system handled approximately 300,000 new civil cases and 75,000 criminal cases generating millions of content pages.

"It makes no sense," says Luís Amaral, Erastus Otis Haven Professor of Chemical and Biological Engineering at Northwestern Engineering. One of Amaral's specialties is finding new patterns among large data sets. So when he heard Dave Schwartz, Stanford Clinton Sr. and Zylpha Kilbride Clinton Research Professor of Law at Northwestern Pritzker School of Law, give a presentation about this problem, Amaral started thinking about solutions.

"If we can't see or measure what's happening in the judicial system, how can we know what's going well, or what needs improvement?" he says. Amaral, who also codirects the Northwestern Institute on Complex Systems, got together with a group of computer science and law school faculty members to consider the problem.

What made most sense was to download all the federal court records and create their own open and searchable database. A great idea, but such an endeavor could cost $100 million. Problem solvers by trade, the group members found that if they downloaded only the table of contents for each case, they would have enough information about the judge, attorneys, litigants, and cases to create a useful database.

INCREASING OPENNESS AND FAIRNESS

The group launched the Northwestern Open Access to Court Records Initiative to prove the concept. The first step was to download information from all federal civil and criminal lawsuits brought in the years 2010 and 2015 for the US District Court for the Northern District of Illinois (covering Chicago) and the Northern District of Georgia (covering Atlanta). They also downloaded biographical information on all active judges in the two districts and identified all publicly traded corporations named in a case.

Last winter quarter, as part of the initiative, a group of students in CS+X Innovation Lab: Building Technologies for the Law, was charged with creating a pilot system through which potential users could ask questions like: How does the ethnicity of judges correlate with their caseloads? Does litigation involving large publicly traded companies differ from other litigation in terms of duration, litigation intensity, settlement rates, and case outcomes? Does litigation involving minority-owned companies differ from other litigation?

"It's a fundamental artificial intelligence and computer science problem," says Kris Hammond, Bill and Cathy Osborn Professor of Computer Science. "How do you give people access to complex analytics when they don't know how to describe exactly what they need? The answer—by employing natural language to drive search and analytics."

The pilot was so successful that the initiative received funding from the National Science Foundation. The Northwestern team is working with Solstice, a Chicago-based digital strategy and user experience firm, to design and deploy the first version of this system.

"We hope to create an ecosystem of applications and tools that will enable reporters, lawyers, economists, political scientists, and the public to study this system," Amaral says. "The courts system should be a paragon of openness and transparency. This system will help with that."

EMILY AYSHFORD

"We hope to create an ecosystem of applications and tools that will enable reporters, lawyers, economists, political scientists, and the public to study this system. The courts system should be a paragon of openness and transparency. This system will help with that."

LUÍS AMARAL Erastus Otis Haven Professor of Chemical and Biological Engineering

INVESTIGATING BIG IDEAS AT THE SMALLEST SCALE

Linda Broadbelt's award-winning work in complex kinetic modeling has spurred diverse collaborations to solve practical problems.

"I feed off the special environment here at Northwestern—inquisitive, collaborative, and ambitious. That's what allows different kinds of interactions to flourish."

LINDA BROADBELT Sarah Rebecca Roland Professor and Professor, Chemical and Biological Engineering

WITH AN OPEN MIND AND COLLABORATIVE SPIRIT, Northwestern Engineering's Linda Broadbelt works on big ideas at a small scale, bringing her computational analysis work to fields as diverse as biomass conversion, artwork degradation, shale gas conversion, and polymer recycling.

"These problems are all compelling and intellectually engaging, and I've been comfortable to pursue them because I've had some world-class partners," says Broadbelt, Sarah Rebecca Roland Professor in the Department of Chemical and Biological Engineering.

Her lab tackles global issues like energy and the environment by investigating chemical reactions at the atomic scale, working with partners from around the world, in industry as well as in academia.

"It's not trivial to dive into new areas where you're collaborating with people at a pharmaceutical company one day and with researchers from the Rijksmuseum in Amsterdam the next," says Randall Snurr, John G. Searle Professor and chair of the Department of Chemical and Biological Engineering. "Linda is fearless in jumping into new fields and showing the impact of kinetic modeling and quantitative engineering tools."

This year, Broadbelt was named a member of the National Academy of Engineering, among the highest honors in engineering. In recognizing her accomplishments as a McCormick School of Engineering faculty member over the past 25 years, the NAE cited her "contributions to complex kinetic modeling" and impact on industry.

A PROMINENT PARTNER

A member of the elite American Institute for Medical and Biological Engineering College of Fellows and honored by the American Institute of Chemical Engineers, Broadbelt is internationally recognized for her ability to assemble quantitative descriptions of complex systems characterized by thousands of reactions and molecules. This expertise has made her a much sought-after partner.

During one prominent research project with Dow Chemical, for example, Broadbelt and her team developed methods for predicting the backbone composition and arrangements of monomers in polymers. In another collaboration with ExxonMobil, Broadbelt's group constructed the most detailed models of biomass conversion.

"These opportunities allow our group to have an impact on addressing real-world problems," Broadbelt says.

Most recently, she has been investigating hydrocarbon conversion, specifically shale gas's potential as a bridge fuel, while she and others continue to explore other innovative renewable technologies. In addition, Broadbelt's team is examining polymer recycling, aiming to create strong and resilient plastics that nevertheless can break down easily after use, thereby minimizing environmental impact.

"We still care about making real materials, real chemicals, things that are at the highest production scale," says Broadbelt, whose honors include the Fulbright Distinguished Scholar Award and the National Science Foundation's Faculty Early Career Development (CAREER) Award.

CONTRIBUTING TO A VIBRANT ENVIRONMENT

A past recipient of Northwestern's Dorothy Ann and Clarence L. Ver Steeg Distinguished Research Fellowship Award that recognizes research and scholarship that enhances the University's reputation, Broadbelt's contributions also include educating the next generation of engineers.

As chair of the Department of Chemical and Biological Engineering from 2009 to 2017, Broadbelt led the department's growth in both performance and reputation, including its emergence as a world leader in synthetic biology. Since 2017, she has served on Northwestern Engineering's senior leadership team as associate dean for research.

"Linda is a wonderful role model for many of us in her teaching and mentoring of students, top-level research, and service to the department and the University," Snurr says.

For Broadbelt, it's been a joy. "I feed off the special environment here at Northwestern—inquisitive, collaborative, and ambitious," she says. "That's what allows different kinds of interactions to flourish."

DANIEL P. SMITH

Photography by Justin Barbin

DESIGNING BETTER DESIGNS

By creating algorithms that account for physical uncertainties and human nature, Wei Chen increases the efficiency and effectiveness of engineering complex systems.

"I'm grateful to be at a place where the culture is so collaborative. Our goal is to create data-driven methods that can predict how changes in design will affect design performance and find means to reduce the risk of undesirable outcomes."

WEI CHEN Wilson-Cook Professor in Engineering Design and Professor, Mechanical Engineering

Humans have been designing mechanical solutions for their problems since ancient times, but the study of the design process itself—engineering design—came into its own as a research discipline only in the 1980s.

Wei Chen, Northwestern Engineering's Wilson-Cook Professor of Engineering Design and professor of mechanical engineering, has stood at the forefront since the field's early days with her groundbreaking work focused on uncertainty.

This year, Chen received one of the highest honors in engineering—election to the National Academy of Engineering—for her "contributions to design under uncertainty in products and systems, and leadership in the engineering design community."

Chen, who serves as director of the Integrated Design Automation Lab and the Predictive Science and Engineering Design Cluster, is admired as a passionate educator, a respected editor of leading academic journals, and a tireless supporter of the University and the engineering community at large. She holds two patents, has written or edited more than 280 publications, and is one of the most cited researchers in engineering design.

"Professor Chen is a model of excellence in everything she does," says Kevin Lynch, chair and professor of mechanical engineering. "She is a truly devoted leader who commits countless hours to her research and students."

Modeling uncertainty

Chen's work uses modern computing power to assess sources of uncertainty and incorporate them into engineers' decisions, especially in the design of complex systems like aircraft and automobiles.

Designing a car, for example, encompasses many sources of uncertainty. The variables involved in assessing safety during a crash include the materials a car is made of, its speed on impact, and the angle at which it is struck. "We model and quantify those uncertainties," says Chen, "to help designers make rational, optimal, and robust design decisions."

Without such algorithms, she says, a design engineer might make heuristic-based decisions that could deliver less-than-optimal solutions. For example, such decisions might result in a car that's heavier than required to ensure safety and could waste materials, money, time, and effort.

Manufacturing giants, including Boeing and Ford, use software programs, such as Isight and Altair HyperWorks™, that employ her methods. "It's satisfying to know that people aren't just reading my papers, but also using my work," says Chen.

The human factor

Her contributions to new research topics have influenced how the broader community understands design. This includes recognizing the role of humans throughout the design process—the engineer who designs a product, the corporate executive who markets it, and the consumer who ultimately uses it.

Crucial to her success are her collaborations with researchers from an extraordinarily wide array of fields, including decision theory, social network modeling, statistical inference, computer science, transportation, mechanics, manufacturing, and materials. Citing more than two dozen coauthors from Northwestern, she credits the University's interdisciplinary programs for inspiring her students to become catalysts for several fruitful projects.

"I'm grateful to be at a place where the culture is so collaborative," she says. "Our goal is to create data-driven methods that can predict how changes in design will affect design performance and find means to reduce the risk of undesirable outcomes."

Giving back

Chen has a long record of service on editorial boards and professional societies, currently contributing as editor-in-chief of *ASME Journal of Mechanical Design*, president of the International Society of Structural and Multidisciplinary Design, and review editor of *Structural and Multidisciplinary Optimization* and *Design Science*. And she has an equally stellar track record as an educator.

For five years, she served as director of graduate studies in the Department of Mechanical Engineering. At the end of her tenure, she received the first-ever, University-wide Ver Steeg Award, which recognized her success in the demanding work of recruiting, onboarding, and mentoring diverse, top-rate graduate students. Lynch notes, "We're lucky to have her."

Though Chen stepped down two years ago, her example still influences recruitment efforts, Lynch adds. In fact, more than half of the department's newly matriculated graduate students are female, nearly double the percentage of female students pursuing a doctorate of engineering nationwide.

In all endeavors, Chen moves beyond uncertainty. As she puts it, "You have to go beyond your traditional domain to break new ground."

CATHERINE GARA

Photography by C. Jason Brown

LEARNING WHEN TO *FOLLOW THE CROWD*

NORTHWESTERN ENGINEERING'S SEYED IRAVANI BLENDS ECONOMIC MODELING WITH BEHAVIORAL EXPERIMENTS TO HELP BUSINESSES BETTER UNDERSTAND THEIR CUSTOMERS.

Imagine you want to buy a camera. Scrolling through your phone, you find a wealth of options available at your favorite e-commerce store.

Now, imagine narrowing your choices down to two models. They both are respected brands, enjoy similarly positive reviews, and are priced nearly the same. Yet, there's one difference: one camera's product page notes it has sold 20 units. The other has sold 4,000 units.

Which would you choose?

If you'd opt for the camera backed by thousands of previous purchases, you're not alone. The phenomenon of the "peer effect" has been studied for years in the social sciences and is now catching the attention of engineers. When non-experts approach a decision with incomplete information, they look to other sources for help. In today's consumer landscape, where abundant choice often leads to overwhelming confusion, customers turn to fellow shoppers for guidance.

"A professional photographer understands exactly what brands and features are better. Knowing how items sell doesn't matter," says Northwestern Engineering's Seyed Iravani. "Yet, if you aren't confident that you understand the difference in choices, should you choose the one everyone buys or the one fewer people buy?"

AN ANALYTICAL APPROACH

Iravani, a professor of industrial engineering and management sciences at the McCormick School of Engineering, is exploring a growing field called behavioral operations management, which seeks to better understand how decision-making theory and human behavior can help companies learn about their customers and optimize their business.

ACCOUNTING FOR HUMAN BEHAVIOR

Analytical models assume decision makers are rational thinkers unaffected by emotion or behavioral bias. To investigate how human decision-making differs from his analytical models, Iravani and collaborators recruited undergraduates for an experiment to account for the role of peer influence. The students were asked to choose one of four boxes (shown on a computer screen), each of which, they were told, had a 20 percent chance of containing a $20 bill—analogous to a higher-quality product—and an 80 percent chance of being empty. Ten percent of the participants, acting as "informed customers," were told ahead of time the correct box to choose.

Iravani and his team watched the queues form as participants—who could observe which box others chose—made their decisions. "We found that people followed the crowd all the time," Iravani says. "Even when the software provided hints on how to think analytically to find the correct box, or we told them some participants knew the right choice, they still did so. The urge to follow the crowd was even stronger than we thought."

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SEYED IRAVANI Professor, Industrial Engineering and Management Sciences

At the heart of his work is how the length of queues—or the number of products sold—affects the perceived value of products. Supported by a National Science Foundation grant, Iravani has developed analytical models that examine the relationship between queue length and "informed customers" in a market.

"If you have a large number of informed customers who know the best product choice, the longer queue—with more sales—likely includes more informed customers, so following the crowd is the right thing to do," says Iravani, who over the years has collaborated with researchers from University of Chicago, Dartmouth College, and Penn State University.

When there are fewer informed customers, however, following the crowd may not be the optimal decision. "When customers don't know what to choose and there are fewer informed customers in the market, our game theoretical models show that one should follow the minority, not the crowd," Iravani says. "With a high probability, the minority group is formed by informed customers who know the better product."

So what should a rational decision maker do when others act irrationally and follow the crowd when they shouldn't? "In those circumstances, we found you should also follow the crowd, since it increases your chance of getting the better product," Iravani says. "It sounds counterintuitive, but if others act irrationally, you should too."

A COMBINED APPROACH

Currently, Iravani is refining a predictive behavioral queuing model that combines the analytical theory with the peer-influenced results of his experiment. He hopes to partner soon with companies to test the system.

"Companies will learn how publicizing the number of products sold can help boost sales for more profitable products," Iravani says. "That will impact how they advertise, how they adjust prices, and how many types of products to offer."

He adds, "Today's consumers are offered a lot of variety, which means more choice, but also more difficult decisions. Companies know that, and they are studying customer behavior and using psychological factors to influence purchasing and increase revenues."

ALEX GERAGE

DESIGNING A MEASURE OF SUCCESS

Segal Design Institute's Pam Daniels cooks up an innovative design now sold at New York's Museum of Modern Art.

Daydreaming during a project management class in 2014, Pam Daniels (mpd² '15) started wondering why every size measuring cup had the same shape—a full circle instead of its corresponding dimension on a pie chart. Would it be possible to make them look like the shape they represented, so a half just looked like half? Where would the handles go if you did that?

Based on the skills she was learning from spending time in class and building things in the shop while pursuing a Master of Product Design and Development Management (mpd²) degree, the former advertising executive began exploring the possibilities: Could she actually make a half cup in the shape of a half circle, a quarter cup in the shape of a quarter circle, nest them, and keep them volumetrically accurate?

After initial rough sketches, Daniels jumped into CAD and modeled her designs. She then 3D printed them on a Makerbot—skills learned at the Segal Design Institute. Within a week, she had in hand a prototype to show her friends and fellow Segal students, including Brandon Williams ('13, EDI '14), whose viewpoint she trusted.

They all agreed—she was onto something.

Motivated by the positive feedback, Daniels refined the prototype and began a five-year, up-and-down journey accompanied by Williams and the Segal community to create the visually intuitive measuring cups now sold in New York's Museum of Modern Art Design Stores and catalog.

Born designer

As a child, Daniels explored creative design, building furniture and sewing clothes. One winter, she even created a backyard forest out of discarded Christmas trees.

"I'd been passionate about my creativity long before I knew there was a container for all the things I enjoy doing the most," she says. "That container is called design."

As an undergraduate at Tufts University, Daniels majored in French but spent time working on design projects, including making curtains for her dorm room. Even while serving as senior vice president of global operations for Starcom MediaVest Group/Leo Burnett, she designed and installed her own kitchen cabinets and earned certification in landscape design for fun.

Photography by Justin Barbin

Kid in a candy store

In 2013, Daniels stopped by the Ford Motor Company Engineering Design Center—and the visit changed her life.

"When I walked through the front doors and saw the lofted two-story machine shop, my jaw dropped. For me, it was a candy store," she says. Realizing that as a McCormick School of Engineering student she could play with all the tools in the Ford shop, she applied to the mpd² program.

"I knew Northwestern was not going to call and ask if I'd ever thought about applying to the program," she says. "I would have to have the audacity to apply and see if I could get in."

Indeed, Daniels did just that. She enrolled in the mpd² program as a part-time student that fall, honing her product design skills in classes while pursuing outside entrepreneurial projects. She embraced all Segal had to offer, even joining the bootcamp for the Master of Science in Engineering Design Innovation students to gain more hands-on experience.

"As a student, Pam brought such enthusiasm and creative ideas—she dedicated herself to becoming a well-rounded designer," says Greg Holderfield, Segal director and Pentair - D. Eugene and Bonnie L. Nugent Clinical Professor of Mechanical Engineering.

Walter Herbst, mpd² program director and clinical professor of mechanical engineering, guided her independent study projects, including flat-pack furniture and home storage design concepts. "She used the tools we teach in the mpd² program, which includes creating multiple mockups of user-centered research, to transform an everyday product into a delight," he says.

Move to the front of the class

After graduation, Daniels's career took an unexpected detour—teaching.

In 2015, she accepted a post at Segal as one of the first-ever design innovators in residence alongside classmate Williams, with whom she would cofound a design practice, Welcome Industries. Together, the team transformed a Ford conference room into Studio5, an open space where they showcased innovative design work while guiding students.

"We loved being a source of creativity and energy right outside the classrooms on the ground floor," she says.

Daniels, now a clinical associate professor, teaches classes ranging from user experience to digital fabrication techniques, human-centered design, and entrepreneurship. She also cotaught Design Thinking and Doing with Williams. A passionate learner, Daniels audited Williams's class on visual communications—skills that came in handy when designing the visual measuring cups' packaging.

Keeping the entrepreneurial spirit alive

With the Segal community's support, Daniels continued to develop the design. Williams helped with materials selection, polished 3D printed prototypes, and met with prospective manufacturing partners.

"We were committed to bringing the measuring cups to market," Daniels says. Williams had previously licensed a product. With the cups, however, they wanted to manage the entire process themselves, from patenting to manufacturing to marketing. "That way we could remain the decision makers on everything from the materials used to where it was manufactured."

Happy with their design, they decided to raise money through crowdfunding to support manufacturing in early 2018. More than 500 backers pledged a total of more than $22,000, yet the campaign ultimately fell short of its $65,000 goal.

Following their own advice to design students, Daniels and Williams used the setback to regroup. "We learned that a lot more setup was needed before launching the product," Williams says. "We didn't get the attention of the right people."

Determined, Daniels and her husband, Mark Daniels, decided to self-fund the tooling and start manufacturing. Their goal: to exhibit the visual measuring cups at the International Home + Housewares Show in Chicago in March 2019.

It worked: Welcome Industries was offered a spot in the Design Debut section for first-time exhibitors. In the three months before the housewares show, Daniels partnered with Chicago-based Janler Corporation, run by Northwestern alum Carol Klingler Ebel (KSM '88), to create the tooling and manufacture the measuring cups in time.

Show time

At the show, Daniels solicited feedback from buyers on topics ranging from the product design to the packaging, and the cups were recognized as one of the finalists for the 2019 IHA Global Innovation Awards. But the biggest thrill for Daniels was making a dream connection with representatives from the Museum of Modern Art in New York.

"I've gone to the MoMA store every trip I've taken to New York over the past 20 years," Daniels says. "I would land at LaGuardia Airport, look at my watch, and tell my cab driver, 'I have 45 minutes before the meeting, take me to the MoMA store.'"

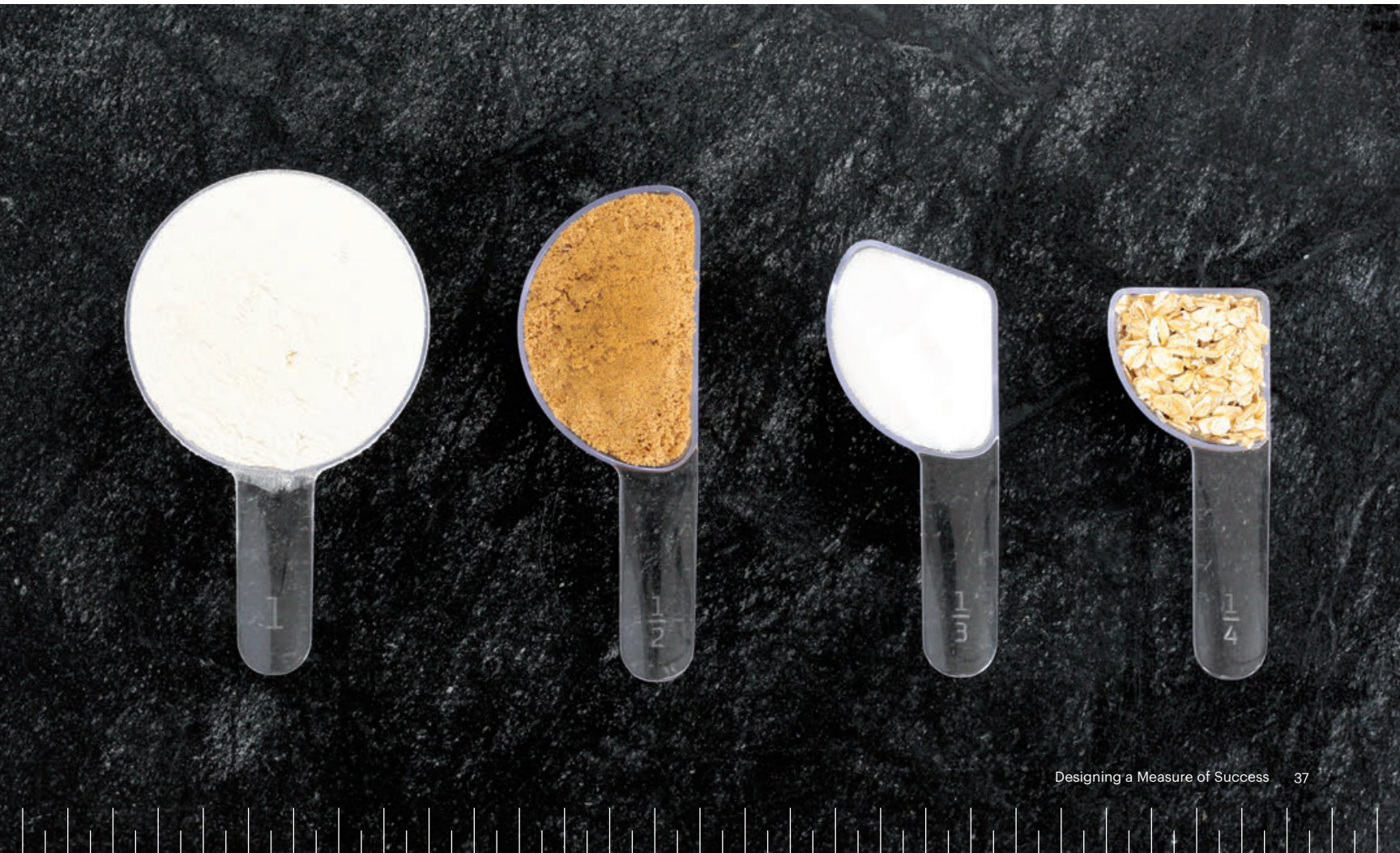
MoMA was the first retail partner for the visual measuring cups and began selling them in its stores and catalog this fall. More than 2,000 units shipped in the first two months of production. By August 2019, Welcome Industries already had shipped the measuring cups to all 50 states and is now working to produce corresponding visual measuring spoons.

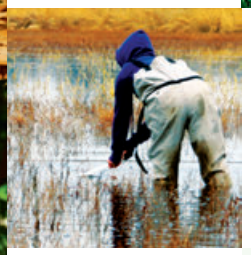
"It's been a marvelous journey. Northwestern has helped me be the person I want to be," she says. "It's helped me develop the skills and the relationships I needed to turn my ideas into reality."

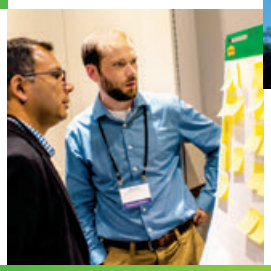
ALEXANDRIA JACOBSON

"It's been a marvelous journey. Northwestern has helped me be the person I want to be. It's helped me develop the skills and the relationships I needed to turn my ideas into reality."

PAM DANIELS Clinical Associate Professor, Segal Design Institute

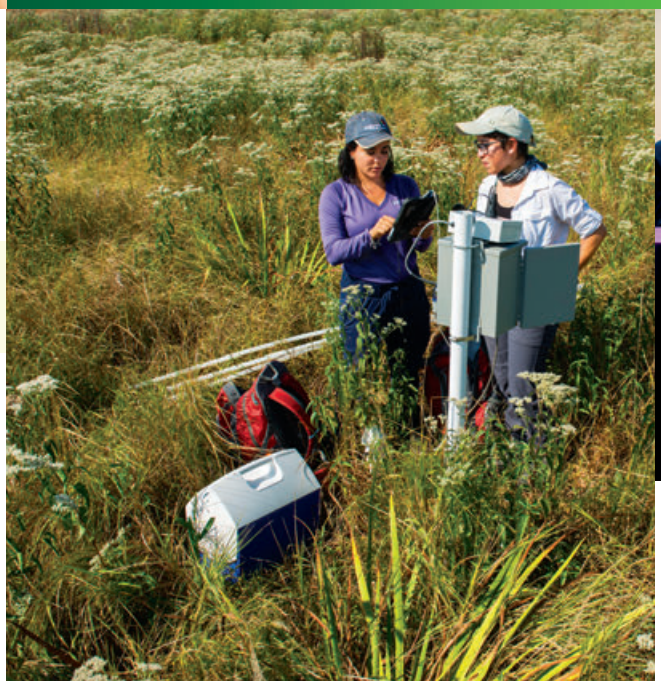


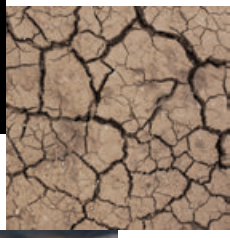




ENGINEERING A SUSTAINABLE FUTURE

New Center for Engineering Sustainability and Resilience sparks interdisciplinary collaboration to solve some of the world's most pressing environmental issues





"Connecting and leveraging everyone's knowledge is important, and the center will encourage that even more strongly going forward."

JENNIFER DUNN
Research Associate Professor, Associate Director of CESR, and Director of Northwestern Argonne Institute of Science and Engineering

From technology that harvests water from air to a blueprint for a modern and resilient "living city," researchers at Northwestern Engineering are taking the lead on our planet's most challenging environmental issues.

These researchers now have a strong ally in their fight: Northwestern's Center for Engineering Sustainability and Resilience (CESR). This new interdisciplinary center brings together engineers and researchers from across the University and beyond to jumpstart research and innovative technologies that tackle complex sustainability challenges like climate change, water quality, clean energy, and pollution.

"There's already a lot going on in sustainability research and education at Northwestern," says Bill Miller, professor of chemical and biological engineering and director of the center. "We can help coordinate and promote that work within our school and connect it to our partners."

Already, the University has more than a dozen organizations studying sustainability-related issues, from the Institute for Sustainability and Energy at Northwestern to the Northwestern Center for Water Research to the Northwestern University Transportation Center. CESR will play a unique role.

"We're going to be facilitators and enablers," says Miller. "We don't want to subsume the great centers that already exist. We want to illuminate how they connect while looking to contribute in ways that will benefit everyone."

Boasting more than 50 affiliated faculty members from nearly every academic discipline at the McCormick School of Engineering, the new center propels collaboration by connecting faculty and students with related research interests in areas like climate change mitigation, water systems and reuse, and sustainable manufacturing.

Earlier this year, Miller worked with students in a Segal Design Institute course to adapt an urban environmental monitoring system developed by Argonne National Laboratory for use at Gensburg-Markham Prairie, located 25 miles south of downtown Chicago. The collaboration produced designs for an off-the-grid, environmentally friendly system to power monitoring nodes in the prairie nature preserve that measure air quality, environmental parameters, and light intensity.

"Students are interested in exploring sustainability as part of their undergraduate or graduate work," says Jennifer Dunn, associate director of CESR, research associate professor at Northwestern Engineering, and director of research at Northwestern Argonne Institute of Science and Engineering. "There's a hunger there that we want to feed with new opportunities to learn and explore."

CESR will also host interactive workshops and symposia, welcoming sustainability leaders from academia, government, nonprofits, and industry to foster dialogue and spark new collaborations with Northwestern Engineering. As Miller points out, "We don't want to just study sustainability, we want to actively promote it."

WORKSHOPPING A SUSTAINABLE CHICAGO

In July, CESR held its inaugural event spotlighting a core research area: sustainable urban systems. Leaders from Northwestern, Argonne, the Field Museum, the Nature Conservancy, and others convened to discuss and adopt short-term initiatives that could improve the sustainability and quality of life in communities around Chicago, as well as identify multidisciplinary long-term research needs for developing more sustainable urban systems.

The two-day event embodied Miller and Dunn's vision: engineers, scientists, journalists, lawyers, architects, social scientists, and industry professionals working together with representatives from community organizations and regional governments, bridging expertise, and approaching major environmental and societal challenges holistically.

"If you think about how to mitigate urban flooding, for example, you need people who understand water quality impacts, hydrology impacts, and green infrastructure," Miller says. "It was important that we left the discussion with actionable takeaways that work for the people who will be responsible for implementing them."

"You want to avoid fixing one problem while creating another," Dunn adds. "Connecting and leveraging everyone's knowledge is important, and the center will encourage that even more strongly going forward."

BRINGING CONCEPT TO LIFE THROUGH COLLABORATION

Looking ahead, Miller and Dunn hope CESR will help spur blue-sky research and education initiatives by supporting faculty and students seeking funding opportunities or by cultivating industry and nonprofit partnerships. Dunn already sees tangible evidence of the new center's impact on collaboration.

"It's exciting to see the new ideas that arise when you bring people together," Dunn says. "There's an enthusiasm from the connections people have made and the ideas that have bubbled up. We're excited to help make those ideas a reality."

ALEX GERAGE

FROM GOOD TO GREAT TO EXTRAORDINARY

KEISHA SLAUGHTER USES PROBLEM-SOLVING SKILLS ACQUIRED AT NORTHWESTERN ENGINEERING TO STREAMLINE PROCESS IMPROVEMENT AT JPMORGAN CHASE.

"From the moment I first arrived, I loved the campus, the architecture, the lake, and the warm feeling that I felt from everyone I met."

KEISHA SLAUGHTER

When JPMorgan Chase & Co. reached out to Keisha Slaughter ('00) with a job opportunity in 2013, she had a hard time envisioning how to apply her engineering skills in the financial space. Up to that point, the industrial and civil engineer had worked primarily with tangibles—from boxes at UPS to missiles at Boeing.

So, she did what any logical person would do when faced with a major career decision—she called her mom. While Slaughter was growing up in Memphis, Tennessee, her mother, Connie Thompson, built a career in the financial industry working with a regional bank. After reading the Chase job description, Thompson said it was just the kind of thing her own bank needed.

"She got excited and started listing all these ways she thought I could lend my skills. At that point I got excited, too," Slaughter says. "I never thought about electronic processes as needing improvements and efficiencies."

Today, as head of process improvement with Chase in Columbus, Ohio, Slaughter works with management operations to set company strategy for driving efficiencies, reducing costs, and improving the products and services Chase offers.

"We always look for ways we can better serve our clients," she says. "I appreciate being at a company where my skills are celebrated and I can help set the strategy by saying, 'Yes, we're doing good, but how do we get to great? How do we get to extraordinary?' That's very fulfilling."

Working in the financial services industry felt like coming home. It sparked memories of visiting her mother at the bank as a child. "It felt very natural being here," she says. "There are so many ways to problem solve and drive efficiencies that I didn't even know existed. For me, it's been a playground of intellectual curiosity and challenges because there are so many different opportunities to flex that muscle."

Slaughter began her career as an industrial engineering project manager with UPS in the Dallas–Fort Worth area after earning a civil engineering master's degree in transportation engineering from the University of Texas at Austin. Later, she held similar positions with Anderson Merchandisers in Denton, Texas, and West Monroe Partners in Columbus, Ohio.

She also served as project manager with the Ohio STEM Learning Network, focusing on a topic close to her heart. She still volunteers to help kids fall in love with math, which she calls the language of problem solving. Immediately prior to her current role, she worked as an industrial engineer with Boeing in Heath, Ohio.

While her career spans industries, there's a common thread running through each experience. "I need a fair amount of intellectual challenge, so I'm always seeking that next problem to solve," she explains. "With my diversity of experience in logistics, distribution, and education, I've developed skills that I can apply to any industry to create efficiencies and process improvements."

Slaughter discovered her love of problem solving at Northwestern. "From the moment I first arrived, I loved the campus, the architecture, the lake, and the warm feeling that I felt from everyone I met," she says. "I immediately accepted the admission offer, and I never regretted that decision, not one day of my life."

She stays in touch with Northwestern through the National Society of Black Engineers, Northwestern University Black Alumni Association, and Northwestern Alumni Association. "It's a way to stay connected to a university that gave me so much," she says. "I want to pay it forward."

SARA LANGEN

From the Ford Shop to SparkShop

Shonali Ditz and **Tiernan Murrell** launch a nonprofit to inspire Chicago-area fourth and fifth graders with hands-on engineering learning.

Northwestern Engineering alumnae Shonali Ditz ('13) and Tiernan Murrell ('16) first met in 2013 through the Formula SAE student group where they spent much of their time in the shop at the Ford Motor Company Engineering Design Center, designing and building formula-style race cars. Both became project managers for the team, and after graduation, both found jobs in the automotive industry in Illinois.

Given their common interests, the two eventually became roommates and, in 2017, quit their jobs to found SparkShop. The Chicago-based nonprofit aims to inspire and mobilize the next generation of engineers and innovators through hands-on STEM workshops in fourth- and fifth-grade classrooms throughout the Chicago area.

Since founding SparkShop, Ditz, who earned a manufacturing and design engineering (MaDE) degree, and Murrell, who studied biomedical engineering, have visited 15 schools where they taught more than 1,300 students.

"We wanted to use our engineering degrees to do something good and make an impact in our community," Ditz says. "We wanted to build a program that would bring engineering and all the opportunities in our field to young kids."

SparkShop offers three courses: innovation and entrepreneurship, applied engineering, and materials and manufacturing. "Research shows that fourth and fifth graders are at a developmental sweet spot to pick up new interests, develop new strengths, and form new ideas about themselves," Ditz notes.

The team also provides supplementary lesson plans for educators to continue teaching engineering concepts in their regular curriculum in four other subjects: science, social studies, arts, and language arts. Explains Ditz, "We want to really lift up the teachers we work with to keep the momentum going for their students."

The team provides three hours of hands-on engineering content in each classroom, bringing along machinery like a 3D printer and laser cutter. Their work is gaining attention. In 2018, SparkShop received a grant from the Motorola Solutions Foundation to provide free and discounted programs to six low-income classrooms in Chicago's Hermosa and Austin neighborhoods.

"We want kids to realize that even if you're a really phenomenal communicator or artist, there's also a place for you in the technical fields. Historically, that's not been shared," Murrell says.

The McCormick School of Engineering's whole-brain engineering philosophy inspired their work. Their interdisciplinary experiences—leading student groups and taking a variety of classes—prepared them for the many challenges of running a nonprofit, from grant writing to facilities management and relationship building.

"Those soft skills, which are intrinsic to Northwestern's engineering program, gave me the capabilities and confidence I needed to start a business," Murrell says.

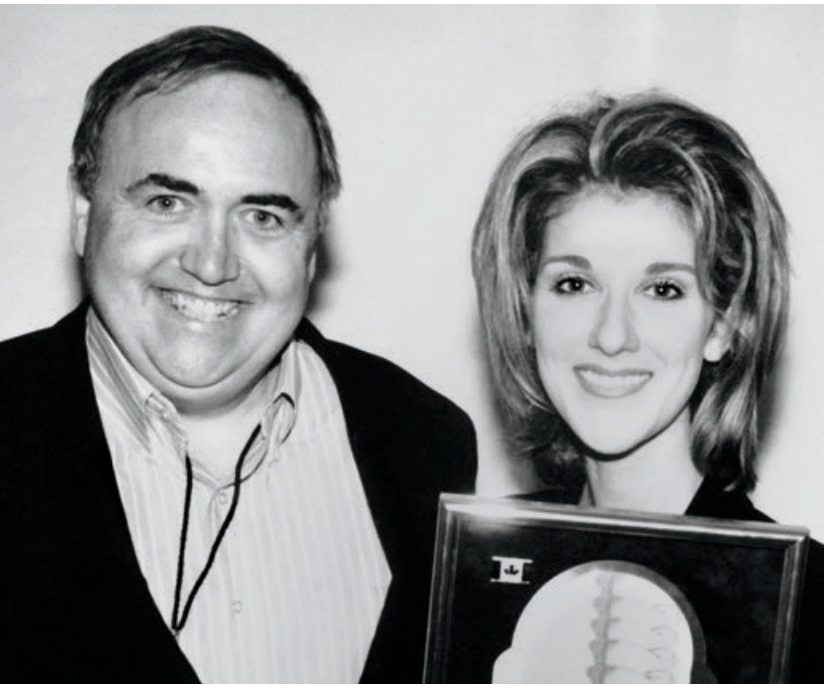
Murrell says SparkShop shares the whole-brain engineering mindset with the fourth and fifth graders in hopes of inspiring them to pursue STEM education through after-school and summer programs, and to eventually seek engineering-related careers.

"We are carrying that philosophy forward as we teach this next generation of engineers," Murrell says.

ALEXANDRIA JACOBSON

"We wanted to build a program that would bring engineering and all the opportunities in our field to young kids."

SHONALI DITZ



ENGINEERING THINKING HELPED **THOMAS TYRRELL** SHAPE ARTISTS' CONTRACT NEGOTIATIONS AND INTELLECTUAL PROPERTY ISSUES IN THE MUSIC INDUSTRY.

YOU'RE NEVER TOO OLD TO ROCK AND ROLL

Thomas Tyrrell ('67) always loved music. As a Northwestern Engineering student, he quickly fell into the 1960s music subculture on campus. Every Friday afternoon, he and his friends went to Chicago, first combing through the vinyl at Rose Records, then taking in a classical music concert at Orchestra Hall.

He and seven roommates were even evicted during winter finals for playing music in their off-campus apartment. "We got into a thing with the owner downstairs that we shouldn't play our records so loud," he says. "My roommate was a bit of a hothead, so that night he put the stereo on the floor with the speakers face down and played the *1812 Overture*. When we came back from class the next day, we had our eviction notice."

Quickly, Tyrrell moved to Sargent Hall. He has a prescient photo of himself there listening to his latest purchase—the CBS/Columbia Records LP of Pablo Casals and the Marlboro Festival Orchestra's *Six Brandenburg Concerti of Johann Sebastian Bach*. "Little did I know that I would spend most of my career at CBS Records and its successor, Sony Music," he says.

After more than 30 years in the music industry, the now-retired general counsel for CBS Records and Sony Music and executive vice president of Sony Music International looks back over an exciting career spent negotiating artist contracts for superstars like the Rolling Stones, Freddie Mercury, Michael Jackson, Leonard Cohen, Vladimir Horowitz, and Julio Iglesias. And he supervised a network of international music companies to help lead the industry's fight to stop the nearly fatal attack of Internet digital piracy.

READY FOR ANYTHING

Things change fast in the music business. Thankfully, Tyrrell says, Northwestern taught him how to think on his feet.

"We learned how to search for practical, workable solutions in changing situations of uncertainty and complexity," says the former Industrial Engineering and Management Sciences Advisory Board member. "You've got to keep an open mind and be ready for anything."

That flexibility helped Tyrrell transition to New York University's School of Law. Although he grew up in Calumet City, Illinois, he felt at home in New York, where he has lived ever since. "I had my first pastrami sandwich and said, 'Where has this been all my life?'" he laughs. "From that moment, I was a New Yorker."

He spent three years as a litigator on Wall Street, but everything changed at a farewell lunch when he learned his colleague was moving to RCA Records' law department. "A light went on—I never thought you could work for a record company," he says. "I told him to give me a call when something opened up. He did, and that was the rest of my career."

In 1974, Tyrrell began work as a contract specialist in RCA's law department. Soon, he was working on contracts for young artists about his age—David Bowie, John Denver, Lou Reed, and Jefferson Starship. But, in 1977, he read in *Billboard* that RCA was moving the department he worked closely with to Los Angeles. Not wanting to leave New York City, he sent his resume out immediately. "Within a couple of months, I was working at CBS Records in New York," he says. "I knew the business, and they were able to just drop me on big contracts immediately."

NEVER STARSTRUCK

The first big deal Tyrrell worked on at CBS was with Spanish singer Julio Iglesias, now considered the world's most commercially successful Latin artist.

One of Tyrrell's funniest memories happened at a reception for Iglesias during the peak of his fame. As Tyrrell talked with the singer's manager, they couldn't find Iglesias anywhere. Then they spotted him in a corner chatting with Tyrrell's wife, Lani. On the way home, Tyrrell asked her about the conversation. Lani said Iglesias told her, "When you go to bed with your husband tonight, whisper in his ear, 'Julio wants more money,'" Tyrrell laughs.

Never starstruck, Tyrrell focused on the deals. Still, he has many fond memories of artists, including negotiating the first English-language contract for teenager Celine Dion.

Once, when Dion was in New York to launch an international tour, he escorted her to an industry dinner in a limo with his daughter. "Celine gave her an autographed photo that said, 'Elly, good luck next year in high school!' Well, Elly is 40 now, works as a lawyer in New York, and still has that photo."

A CAUTIONARY TALE

Tyrrell loved his work, but it wasn't always fun. He faced a huge challenge in 1982 when Sony Corporation convinced CBS Records to switch from records and cassette tapes to compact discs. At the time, CD players were priced at $1,000, and factories and record stores were configured to the older formats. The daunting problem became Tyrrell's to solve globally.

"You can't push a button and next Monday everybody goes to CDs," he says. "So, we started in the United States and rolled it out one step at a time."

It took nearly 10 years before CDs outsold vinyl records and cassettes. Sony Music ended up buying CBS Records, where Tyrrell spent the rest of his career.

The transition to CDs tells a cautionary tale. When CBS executives considered the switch, concerns that CDs could be copied were brushed off, thinking the technology was too expensive to tempt music pirates. But technology evolved, and duplicating CDs became easy. "We did not anticipate the Internet, and we certainly didn't anticipate the delivery of albums over the Internet," Tyrrell says.

> "We learned how to search for practical, workable solutions in changing situations of uncertainty and complexity. You've got to keep an open mind and be ready for anything."
>
> **THOMAS TYRRELL**

Soon pirated digital copies of Sony's albums appeared on file-sharing platforms like Napster, Grokster, and LimeWire. Tyrrell testified at multiple Congressional hearings. "The Congressional committee members said we were burying our heads in the sand and asking the government to protect us," he remembers. "I said to them, 'We're talking about a delivery system that is all the music you want, anytime you want it, for free. How do we compete with free?'"

A DIFFERENT BUSINESS

During the next several years, numerous music-industry lawsuits against illegal file-sharing companies proved successful in essentially killing most pirating companies. Over time, the industry developed legal subscription services and other digital platforms, now the major methods for selling and distributing music.

Today's music business is much different than the one Tyrrell remembers. He mourns the loss of record stores he haunted as a student. Still, he had a great time working in the industry he loved.

Now 14 years retired, the Northwestern Alumni Merit Award winner says he was fortunate to be there. "There were Sunday nights I would have paid money to come in Monday morning to find out what was going to happen next."

SARA LANGEN

An Engineer's Mind with an Artist's Eye

Jim Krebs reflects on a rich, full life of serving his country, designing airplane engines, collecting art, and giving back to Northwestern Engineering.

THE WAY JIM KREBS ('45) FIGURES IT, an airplane fitted with an engine he helped design takes off or lands somewhere in the world every two seconds.

Considering he worked nearly 40 years at General Electric on 18 different engines for 30 different airplane models—and originated the high-bypass turbofan, which became industry standard—he's probably right.

But he couldn't have imagined such a career growing up in Minnesota and northern Illinois during the 1930s. He was interested in sketching airplanes, rocket ships, and cars, but never considered himself a handy guy. "But I did like the idea of making things, and I thought engineering sounded sensible," he says. As a high school senior in 1942 he was attracted to Northwestern's then brand-new Technological Institute and decided to pursue a degree in mechanical engineering. Northwestern was the only school he applied to.

"Jim is the quintessential whole-brain engineer. We have had many long conversations about art, engineering, and innovation, and his success reflects that sort of thinking. It is impressive how far ahead of the curve Jim has been."

JULIO M. OTTINO Dean, McCormick School of Engineering

He was awarded a full scholarship, enrolled in the Naval ROTC program, joined a fraternity, and most importantly, met his future wife Margie (SESP '52) in their first-year English class.

"I learned the basics of engineering—math, statistics, dynamics," he says. "I also improved in reading and writing, which I was already pretty good at, but I also really learned how to learn. I used that skill throughout my career."

After graduating in 1945, he began active duty on the destroyer USS *Dunlap*, but luckily he never saw battle. While located on patrol duty off Iwo Jima, he watched P-51 fighters cavort off the island and fleets of B-29 bombers fly over each night, and began to think about getting involved in the aviation business.

After he was discharged, a Northwestern connection led to a job offer (delivered to his Quincy, Illinois, home via telegram) in General Electric's Aircraft Gas Turbine business in the company's Test Engineering Program. Within his first few years on the job he designed an experimental compressor. Later, he worked for many years as a component designer covering most engine sections, then as project manager of new engines.

Krebs's real break came when he began work as general manager of Advanced Product Planning. He chose to concentrate first on the commercial transport market. At the time, commercial airplanes all used a competitor's low-bypass turbofans, but Krebs and his team believed that making a turbofan with six times higher bypass ratio and much higher pressure ratio—which offered twice the thrust and 20 percent less fuel consumption—was possible.

"We ran the first demonstration of the high-bypass engine for a large military transport in 1964, and now everything that flies commercially has high bypass ratio," he says. "The fact that we decided to try it and then made it work was thrilling."

Krebs rose to the position of vice president of military engine operations in 1978. For his commercial and military successes, he was elected to the National Academy of Engineering in 1982.

"GE was a terrific company to work for," he says. "It was exciting, and I was eager to go to work every day. There were ups and downs, but engineering is about problem solving, and I relished that."

Still an active thinker at age 95, Krebs recently published an opinion piece in *Aviation Week & Space Technology* titled "How the Air Travel Industry Can Wage War on Climate Change." He argues that airlines should eliminate premium-class seating over the next five years. Single-class operations, using the full capacity designed into airplanes, would be more efficient per seat mile, reducing greenhouse gas emissions while using many fewer airplanes.

Though he considered himself an engineer by trade, Krebs always loved art and collected contemporary American prints. After retiring, he and his wife bought a second home in Santa Fe, New Mexico, and began collecting Native American contemporary art. Lately he has been distributing the collections to museums in the Boston area and is donating a number of works to Northwestern's Mary and Leigh Block Museum of Art. He's also a lifelong photographer with many carousels of 35mm slides from his travels, and he has digitized and converted the best of his China photographs into self-published books.

"Jim is the quintessential whole-brain engineer," says Julio M. Ottino, dean of Northwestern Engineering. "We have had many long conversations about art, engineering, and innovation, and his success reflects that sort of thinking. It is impressive how far ahead of the curve Jim has been."

Krebs has stayed in touch with Northwestern over the years, serving on the McCormick Advisory Council and funding both the James N. and Margie M. Krebs professorships and a named lecture hall in the McCormick Education Center.

"I was one very lucky person, looking back on it," he says. "Everything just happened at the right time and right place with the right people. Northwestern certainly got me started on that in many important ways."

EMILY AYSHFORD

WITH GRADUATION COMES ADVICE.

High-achieving alumni offered the class of 2019 expert tips on how to make the most of the greatest gift that comes with a Northwestern Engineering education: whole-brain thinking.

When alumni Yie-Hsin Hung, Warren Haug, and Carolyn Duran donned their purple robes to address the assembled undergraduate, master's, and PhD degree candidates, some priceless themes emerged—keep learning, seek out opportunities, connect with others, and most importantly, stay flexible.

As those three speakers—the CEO of New York Life Investment Management, a retired vice president of Procter & Gamble Company, and a vice president of Intel Corporation—exemplify: your engineering career doesn't always turn out to be what you might have expected on graduation day—it's likely to get even better.

"Our world is changing around us, and you can sit and let it pass you by, or you can choose to adapt and grow and learn with it. Chart your own path."

Warren Haug (MS '63, PhD '65),
Vice President (retired), Procter & Gamble Company

"Solve fully. Don't take things at face value. Keep asking why."

Carolyn Duran (PhD '98),
Vice President, Intel Corporation

"HAVE NO DOUBT, FROM THIS DAY FORWARD, SOLVING PROBLEMS AS A TEAM WILL BE YOUR COLLECTIVE SUPERPOWER."

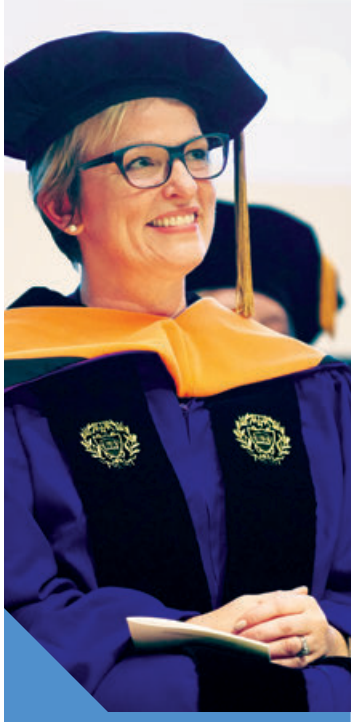
Yie-Hsin Hung ('84), CEO, New York Life Investment Management

"By integrating left-brain and right-brain thinking, what you have received is a world-class education in becoming a first-class problem solver."

Yie-Hsin Hung ('84), CEO, New York Life Investment Management

"What impossible challenge will you take on to change the world for the better?"

Yie-Hsin Hung ('84), CEO, New York Life Investment Management

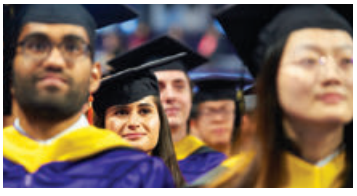


"KEEP YOUR INTELLECTUAL CURIOSITY. GROW IT."

Carolyn Duran (PhD '98), Vice President, Intel Corporation

"WHAT YOU START OUT DOING WILL NOT BE WHAT YOU END UP DOING."

Warren Haug (MS '63, PhD '65), Vice President (retired), Procter & Gamble Company



"Your success will not come from expecting someone to tap you on the shoulder and hand it to you. You need to seek it out."

Carolyn Duran (PhD '98), Vice President, Intel Corporation

IN MEMORIAM

Alan Kistler

Richard P. Van Duyne

Professor Emeritus Alan Kistler

Alan Kistler, professor emeritus of mechanical engineering, passed away on April 1, 2019, at age 90. He was a member of Northwestern's faculty for 30 years.

Kistler earned his bachelor's, master's, and PhD degrees in aeronautics from Johns Hopkins University. After serving in the US Army, he worked in industry exploring aeronautics and gas dynamics, including serving as section chief at the California Institute of Technology's Jet Propulsion Laboratory. In 1969, he joined Northwestern Engineering's Department of Mechanical Engineering and Astronautical Sciences as a professor.

Kistler was best known for his work on turbulence, particularly the development of the Corrsin-Kistler equation, which relates stresses between turbulent and nonturbulent regimes. His other research explorations included the effect of lake breezes on pollutant dispersion, and the effects of cavitation on face seals. He also studied the practical limits of solar and wind energy applications, which resulted in the installation of a wind turbine at the Evanston Ecology Center.

Kistler's honors include membership in the American Institute of Aeronautics and Astronautics, American Physical Society, and American Geophysical Union. He was also part of a NASA committee that evaluated fluid mechanics experiments in space.

Professor Richard P. Van Duyne

Richard P. Van Duyne, the Charles E. and Emma H. Morrison Professor of Chemistry at Weinberg College and a professor of biomedical engineering at Northwestern Engineering, died July 28, 2019. He joined Northwestern in 1971 as an assistant professor after earning a bachelor's degree from Rensselaer Polytechnic Institute and a PhD from the University of North Carolina.

Van Duyne was a trailblazer in the field of plasmonics and was known for his advancement of nanosphere lithography, transforming the field of nanoparticle optics and of localized surface plasmon resonance spectroscopy.

His discovery of surface-enhanced Raman spectroscopy (SERS)—which is capable of both detecting and identifying single molecules—has had a huge effect on chemistry, physics, materials science, and medicine.

Van Duyne was listed among the world's top 100 chemists by Thomson Reuters between 2000 and 2010. He was elected to the American Academy of Arts and Sciences in 2004 and the National Academy of Sciences in 2010. He was a fellow of the American Institute for Medical and Biological Engineering.

Leroy Neuberg '36
Richard Keith Kerr '39
James Geppert '42
Richard D. Harza '44, '47
Raymond L. Benson '45
Philip D. Stokes Jr. '45
Hollen E. Valkenaar '45
Dean G. Van Nest '45
Walden P. Weaver '45
John R. Eshbach '46, '47
Archibald MacLean Jr. '46
Charles C. Swanke '46
Jack H. Bornhoeft '47
Adam G. Kegel '47
John J. Unger '48
Maurice F. Dunne Jr. '49, '80
Vernon H. Siegel '49
John H. Burlingame '50
Stuart R. Wright '50
A. Charles Alexander '51, '55
R. Lee Davis '51
Kenneth L. Lawson '51
Wardwell M. Montgomery '51
Eugene L. Simpson '51, '61
Robert C. Brandquist '52
Roger R. Ellefson '52
William L. Firestone '52
Lyman S. King '52
George E. Tillquist '52
James I. Webb '53
Charles E. Bading '54
Kenneth H. Beeber '54
James A. Geppert '55
Darold W. Jackson '58
Sheldon Pringle '58
Charles P. Schovain '58
Wallace C. Solberg '58
James P. Irving '59
Clarence E. Riser '59
James L. Stokes Sr. '59
Richard L. White '59
Roger L. Peterson '60
Donald F. Grubb '61
Walter A. Michel '63
John F. Carney III '64, '66
John W. Dickey '65, '67
James M. Redmond '65
Bruce A. Townsend '65
Herbert B. Fox '68
Dusan Krajcinovic '68
E. Glenn Holmwall '69
Howard E. Woodward Jr. '69
Melvin A. Schechtman '71, '73
Richard L. Crawley '74, '76
Dwight Grimestad '74
Gordon F. Robinson '74
Mark E. Franklin '77
Donald J. Martin '79
Lee H. Wilson '80
Raymond C. Hauge '81
William H. Cork '82
Paul D. Driscoll '82
Leonora J. Stevens-Beck '82
Debasis Baral '83
Franklin J. Verbos Jr. '85
Jong-Her Shen '94
Jennifer E. Salem '98
Michael Thuma '05

BIG IDEA

GEMLIKE NANOPARTICLES SHINE AS CATALYSTS

Northwestern researchers, including Professors Chad A. Mirkin, Chris Wolverton, and Vinayak Dravid, developed a new method for making highly desirable catalysts from metal nanoparticles, potentially leading to better fuel cells. The researchers also discovered that the method can take spent catalysts and recycle them into active catalysts.

These coveted catalysts are gem-shaped, and each particle has 24 different faces presenting atoms at the surface in ways that make them more catalytically active than those available commercially.

Image by Liliang Huang

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HARNESSING THE SPEED OF LIGHT

Members of Northwestern University Solar Car Team pose with their new car, "Seven," at the Formula Sun Grand Prix in Austin, Texas. The team spent three years building the solar car, which features a new volumetric steel chassis, an aerodynamic carbon fiber aeroshell to house its solar array, and a second rear wheel for improved stability on turns. During an eight-hour race on the track, the car completed 160 miles without any critical mechanical or electrical system failures.