McCormick School of Engineering and Applied Science

NORTHWESTERN ENGINEERING

FALL 2017

RESEARCHERS OF THE FUTURE

Undergraduate Students Spend Summer Break Making New Discoveries

This year's Design for America Leadership Studio welcomed 105 students from 33 universities to learn about design, social innovation, and creative leadership. The event challenged students to use human-centered design to develop solutions to improve accessibility in urban areas. Read more on page 32.


DESIGN for AMERICA

That is why we focus on lifelong skills—a problem-solving toolkit—as well as a whole-brain way of thinking. We want our students and faculty not only to solve the problems we see, but to envision a future no one has thought of yet.

GREETINGS FROM NORTHWESTERN ENGINEERING

We live in a time of great challenges, which, to engineers, means we live in a time of great opportunity. This issue of the magazine is proof of that.

Our faculty members are not only looking to harness new energy sources—they are finding ways to make current energy sources more efficient, often in unexpected places. New materials for airplane turbines and oil lubricants could mean a big reduction in carbon emissions, and advances like these are needed now as we continue to transition to a sustainable future.

Our undergraduate students are looking at new ways to frame and solve problems right from the start. They are conducting research in energy conversion, sustainable cities, and synthetic biology. Our Design for America students are designing ways to make cities more accessible for everyone. And our Engineers Without Borders students are traveling the globe, putting their engineering skills to use, and learning through practice that the first idea isn't always the best.

One of our goals is to teach students to "think like an engineer." There is no better example of this than Professor Luís Amaral. He has the ability to look at one system—for example, cells—and find the patterns that relate to another seemingly unrelated system—say, airports. More than that, Luís has the ability to connect with faculty across disciplines to look at old problems in new ways. The result is a new understanding of complex systems that could transform, in one sweeping move, a number of disciplines.

We are living in the period of fastest change in human history. Undoubtedly, once one problem is solved, another one will arise. No one has figured out how to predict the future or anticipate unintended consequences. That is why we focus on lifelong skills—a problem-solving toolkit—as well as a whole-brain way of thinking. We want our students and faculty not only to solve the problems we see, but to envision a future no one has thought of yet. We do that by creating a space that embraces a diversity of viewpoints and ideas. By connecting different fields and views, one can create something new.

That, ultimately, is our goal: to encourage the people and ideas that will bring us beyond the horizon and put us into a future we cannot yet imagine.

As always, I welcome your feedback.

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

On the Cover

Loren Ayala ('17) adjusts a Waggle node, a system of sensors that monitor the environment. See more on page 26.

Photograph by Chris Strong

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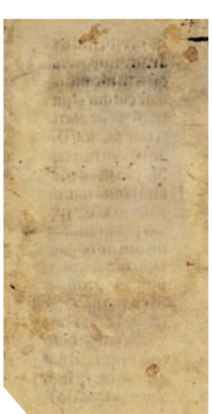

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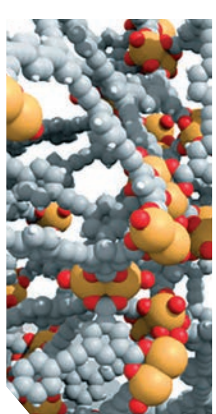

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NEWS

The Networked Body: The Future of Bio-Integrated Technology

Northwestern Engineering co-hosted a public symposium, "The Networked Body: How Wearables and Bio-Integrated Electronics Will Impact Our Future," with the National Academy of Engineering on May 16, 2017. The event welcomed researchers from academia, athletics, and industry to discuss advances in wearable and bio-integrated technologies that promise to impact sports, health, and wellness.

Professor John Rogers, a pioneer in the field of wearable electronics, discussed his work at the intersection of science, engineering, and medicine. His epidermal electronics are ultra-thin, ultra-soft, and waterproof. Placed directly on the skin and comfortable to wear, these wireless electronic "temporary tattoos" produce clinically relevant measurements. For example, by placing tattoos on a prematurely born baby's chest and foot, doctors can monitor functions throughout the body without using wires or interfering with the baby's natural movement and valuable mother-child interactions.

"WE WANT TO GET RID OF THE WIRES."

JOHN ROGERS LOUIS SIMPSON AND KIMBERLY QUERREY PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING

GE AVIATION SELECTS STUDENT PROJECT FOR PROTOTYPING

Airplane inspectors have used an optical device called a borescope to inspect turbine engines for the past 70 years. The time-consuming technique requires inspectors to position the device manually and eyeball the engine to evaluate it.

Aiming to improve and expedite inspections, GE Aviation challenged engineers around the world to design a better system. From more than 150 entries, GE Aviation selected a project submitted by Northwestern Engineering students enrolled in the ME 398 capstone course, and now plans to prototype and test it.

The members of the team, Zachary Fenske, John Harris, Jonathan Hoffman, Elizabeth McTighe, Matthew O'Hagan, Jacob Schneider-Martin, and Jay Welch, call their solution "SearchEYE." The segmented device enters an aircraft engine's combustion chamber, conforms to the chamber's interior geometry, then collects visual inspection data for use by aircraft technicians.

NEW MS IN ARTIFICIAL INTELLIGENCE TO PREPARE LEADERS IN EMERGING TECHNOLOGY

Northwestern Engineering is launching a new Master of Science in Artificial Intelligence program to develop leaders who can create powerful AI systems. This 15-month, full-time program was developed in response to increased demand from industry for computer scientists who understand AI systems and the problems they can potentially solve.

The curriculum will focus on essential AI skills—machine learning, natural language understanding, and automated decision-making—but will also include coursework in the psychology of human interaction with intelligent systems, business and workflow needs, design thinking, and cognitive modeling.

Applications are being accepted now for fall 2018. Applicants should have a computer science degree and at least two years of professional experience.

"RECEIVING THIS AWARD IS A GREAT HONOR, AND I SHARE IT WITH MANY, MANY PEOPLE. NORTHWESTERN IS A PLACE THAT IS FULL OF GOOD PARTNERS WHO HAVE STRETCHED MY THINKING IN MANY DIRECTIONS."

DEAN JULIO M. OTTINO

DEAN JULIO M. OTTINO RECEIVES PRESTIGIOUS GORDON PRIZE

In honor of developing Whole-Brain Engineering, Northwestern Engineering's principal guiding strategy for more than a decade, the National Academy of Engineering presented Dean Julio M. Ottino with the 2017 Bernard M. Gordon Prize for Innovation in Engineering and Technology Education during an award ceremony on May 30. Established in 2001, the Gordon Prize is the nation's highest honor for engineering education.

Whole-Brain Engineering is a reimagining of engineering education; it merges the analytical and technical components of engineering (left brain) with creativity, design, and divergent thinking (right brain). This interdisciplinary approach for developing leaders has led to new Northwestern programs and initiatives for engineers and non-engineers alike. It has dramatically increased connections between Northwestern Engineering and the rest of the University and outside partners, including Northwestern Medicine, the Block Museum of Art, the School of the Art Institute of Chicago, Shirley Ryan AbilityLab, Shedd Aquarium, and more.

MATERIALS RESEARCH CENTER RECEIVES $15.6 MILLION GRANT

The Northwestern University Materials Research Science and Engineering Center received a six-year, $15.6 million grant from the National Science Foundation. One of eight Materials Research and Engineering Centers in the nation funded by NSF this year, the Center is among the longest continually funded materials research centers in the country. Directed by Professor Mark Hersam, it advances world-class materials research, education, and outreach through active interdisciplinary collaborations with academia, industry, national laboratories, and museums, both domestically and abroad. The Center's intellectual merit resides primarily within its two complementary interdisciplinary research groups: one that explores reconfigurable nanoelectronic materials systems and another that aims to discover new inorganic materials with unconventional combinations of properties.

12

Amount in millions of dollars of a new grant from the US DOE to lead a new initiative dedicated to accelerating the production of sustainable, low-cost bio-fuels and chemicals

CONFERENCE PLAYS OUT ISSUES FACING VIDEO GAMING

Amid growing student interest in the burgeoning video game industry, Northwestern hosted "Progression Mechanics," a conference that brought together developers, publishers, commentators, academics, and students for a weekend of presentations, conversations, and gaming. Sponsored by Northwestern Engineering and The Garage, the mid-September 2017 conference welcomed speakers from Chicago and beyond to address issues facing the gaming industry. Presenters tackled topics including experimental games and design, frontiers of game AI, the changing business of game development, eSports, issues in video game culture, and research and industry collaboration.

60

Number of companies recruiting on campus at the annual Industry Day

NEW NSF CENTER TO PRODUCE FUELS AND CHEMICALS

Northwestern is a key partner in the new Center for Innovative and Strategic Transformation of Alkane Resources. Funded by the National Science Foundation and led by Purdue University, the engineering research center will develop new technologies to produce fuels from US shale-gas deposits, an initiative that could inject $20 billion annually into the economy. The new approach proposes to convert light hydrocarbons from shale gas into chemicals and transportation fuels using a network of portable, modular processing plants. Estimates say shale has enough energy to meet all of the nation's transportation fuel needs for 100 years.

75

Number of Northwestern students who attended the annual Grace Hopper Celebration, the world's largest gathering of women technologists

SCHOOLS PROPOSE NEW NAME FOR INTEGRATED DESIGN INNOVATION

A multi-school consortium of engineering design programs has proposed a new, unified category name for the combined design, engineering, and business degree programs each offers.

After multiple meetings and co-hosted student design challenges, Northwestern, Carnegie Mellon, Massachusetts Institute of Technology, Stanford, and University of Pennsylvania recognized that their programs share similar philosophies and student outcomes, but each has its own unique name. The five schools united to create the Integrated Design Innovation Consortium, which suggested a unified category name: Integrated Design Innovation.

"Together we can establish a shared language and set of expectations for our students while allowing each school the flexibility to customize its curriculum to suit its own strengths," says Amy O'Keefe, associate director of Northwestern's Master of Science in Engineering Design Innovation program, which unites engineering, technology, and business through human-centered design. "Our students' shared reach and positive impact are greater than if any of our institutions were to proceed alone." Next, consortium members will connect with industry partners to explore expanding the unified category further.

MIDWEST MUSIC AND AUDIO DAY UNITES ENGINEERS AND MUSICIANS

In June, Northwestern Engineering's 2017 Midwest Music and Audio Day welcomed 50 artists and audio processing researchers who work at the intersection of music and computer science.

Supported by the Barry and Mary Ann MacLean Fund for Art and Engineering, the event featured presentations of CS+Music innovations, such as new apps to search sounds and tools to "de-noise" speech, by artists and engineers from 20 universities and companies.

"I want to see artists and researchers from around the Midwest actually get to know each other," says event organizer Bryan Pardo. "It takes work for academics to reach out to industry or for artists to reach out to academics. Sometimes they don't even know who to reach out to. This event connects people from different fields and helps them start conversations that they otherwise might not have."

Pardo runs Northwestern Engineering's Interactive Audio Lab, which uses machine learning, signal processing, natural language processing, and database search techniques to make new auditory tools and interfaces.

Student-Built House Competes in Solar Decathlon

A student team worked around the clock for three months to complete Northwestern's first-ever entry into the US Department of Energy Solar Decathlon in October 2017, a competition that showcases innovative solar-powered houses designed, built, and operated by collegiate teams from around the world.

Named "Enable," the small house features a roof lined with solar cells that harvest enough energy to power the entire house and an electric car with energy to spare. The house also has self-cleaning windows and walls that break down air pollutants.

"We wanted to make downsizing exciting," says Northwestern Engineering senior Stephen Staley, the team's construction manager. "It's technologically advanced, inexpensive to maintain, and multifunctional. People shouldn't have to downsize to a boring ranch home."

Soccer Could Have a New Way to Practice Passing

An undergraduate team at the Segal Design Institute has developed a portable, cost-effective passing trainer that may soon become a common part of training for Northwestern's soccer program. As part of the Institute's Design 384: Interdisciplinary Design Projects course, the team collaborated with men's soccer assistant coach Rich Nassif to design and prototype a trainer that players could set up easily and use on their own. Their solution, called Assists, provides analytical feedback about the speed and accuracy of passes in non-practice settings. Costing less than $500 to produce, a fraction of the cost of professional trainers, the system combines four small soccer-style goals, LED lights, and an electronics system to create a 360-degree training environment.

NORTHWESTERN RACE CAR TEAMS COMPETE IN INTERNATIONAL COMPETITIONS

With newly redesigned cars, Northwestern's Baja and Formula SAE (Society of Automotive Engineers) teams took part in three competitions in spring 2017: The Baja team in Baja SAE Kansas, an international competition in Pittsburg, Kansas; and the Formula team at Formula SAE at Michigan International Speedway and at Formula SAE Lincoln in Lincoln, Nebraska.

In the past year, the Formula team either upgraded or completely redesigned every system on the car to make it even faster and more aerodynamic. The Baja crew also optimized and improved elements of its car. Built for off-roading, Baja cars navigate rough terrain, such as snow, mud, and rocks, and compete in dynamic events that feature hill climbs, rock crawls, and maneuverability challenges.

7

Number of Maker facilities on campus

30

Number of rockets launched by the Northwestern University Space Technology and Rocketry Society (NUSTARS) over the past year

NSF GRANT TO STIMULATE MATERIALS SCIENCE INNOVATION IN THE MIDWEST

A $700,000 grant from the National Science Foundation will fund a new consortium of five Midwestern universities, including Northwestern, to stimulate innovative materials science research and enable future technological advancement. The Midwest Big Data Spoke for Integrative Materials Design connects experimental and simulation results from several research groups to broaden access to data and computational tools, encourage discovery and collaboration, and extract valuable new insights from materials science data.

The effort supports the mission of the Materials Genome Initiative, launched in 2011 to accelerate the pace of discovery, deployment, and manufacture of advanced materials to improve clean energy, national security, and human welfare.

"DISINFORMATION IS A MAJOR THREAT TO DEMOCRACY. IF WE CAN'T AGREE ON BASIC FACTS, THEN DEMOCRACY SUFFERS."

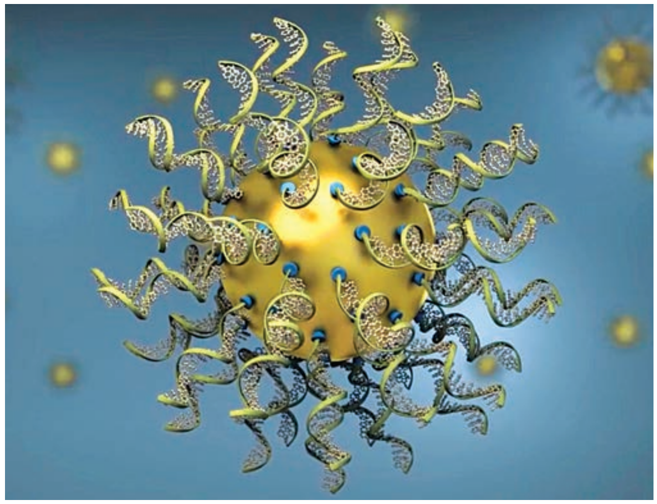
BROOKE BINKOWSKI MANAGING EDITOR OF SNOPES

Northwestern Hosts Computation + Journalism Symposium on Fake News

Northwestern hosted the sixth Computation + Journalism Symposium in mid-October 2017. The event brought together journalists, technologists, academics, and practitioners to share research and explore the ways that computation is transforming key functions of journalism, including reporting, analysis, verification, storytelling, publishing, distribution, and audience engagement.

The symposium focused on fake news and tackled journalists' increasing use of tools and approaches from academia, including statistics, network analysis, natural language processing, and data visualization. Participants also explored scholars' growing understanding of the fundamental importance of key technical challenges posed by journalism as an application area, including social implications. Presentations during the symposium highlighted a variety of core topics, including misinformation and fact-checking.

LAB NOTES



First Spherical Nucleic Acid Drug Injected into Humans Targets Brain Cancer

Northwestern Medicine and the Robert H. Lurie Comprehensive Cancer Center of Northwestern University launched an early-stage clinical trial in May 2017 for the first drug using spherical nucleic acids to be systematically given to humans. Developed by Northwestern Professors Chad Mirkin and Alexander Stegh and approved by the Food and Drug Administration, the investigational drug could treat glioblastoma multiforme, a deadly type of brain cancer.

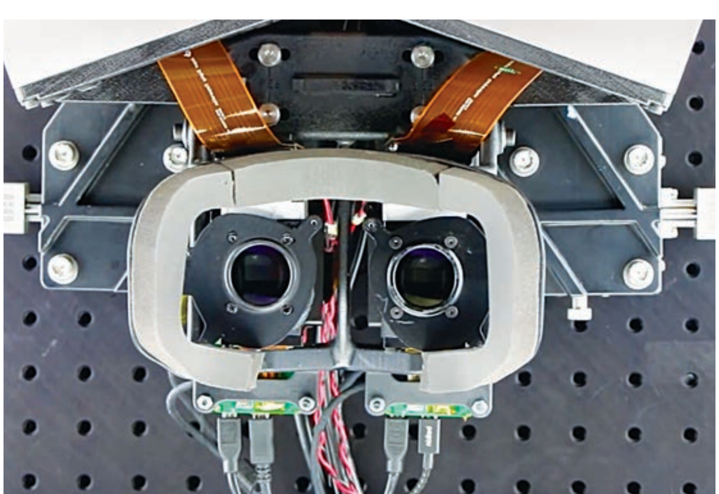
The new drug, NU-0129, consists of short snippets of RNA densely arranged on the surface of spherical gold nanoparticles, which change the genetic makeup of the tumor cells and dampen their ability to divide. It can cross the challenging blood-brain barrier to reach tumors in animals, where it turns down a critical cancer-causing gene. Now, the Phase 0 clinical trial will investigate the drug's ability to reach tumors in humans.

NEW TECHNOLOGY TO MANIPULATE CELLS COULD TREAT PARKINSON'S, ARTHRITIS, OTHER DISEASES

Professor Samuel I. Stupp and his team developed the first synthetic material that has the capability to trigger dynamic signaling among cells, proteins, and other molecules. Such signals can cue cells to express specific genes so they can proliferate or differentiate into several types of cells, leading to growth or regeneration of tissues. Stupp found that synthetic materials—chemically decorated with different strands of DNA designed to display a different signal to cells—potentially could be used to signal neural stem cells to proliferate, differentiate into neurons, and then return to stem cells on demand.

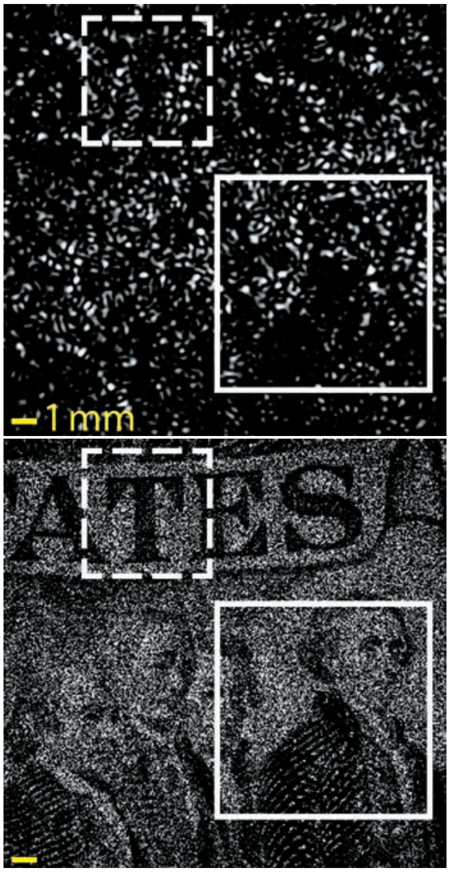
"IT'S IMPORTANT IN THE CONTEXT OF CELL THERAPIES FOR PEOPLE TO CURE THESE DISEASES OR REGENERATE TISSUES THAT ARE NO LONGER FUNCTIONAL."

SAMUEL I. STUPP
PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING, CHEMISTRY, MEDICINE, AND BIOMEDICAL ENGINEERING



VIRTUAL REALITY BROUGHT INTO FOCUS

As one's eyes gaze around a scene, they seamlessly switch focus from one object to the next—regardless of whether the objects are near or far away. Virtual reality (VR) systems, however, have been unable to switch their focus as effortlessly. PhD student Nathan Matsuda, who is advised by Professor Oliver Cossairt, has used custom-designed algorithms and warped focus screens in VR systems to bring objects at different depths into focus. Working with colleagues at Oculus, Matsuda discovered that warping the focus of the screen to conform to the 3D content allows users' eyes to follow the contour of the scene in a natural way, pulling sharp details into focus.



SAVI CAMERA DITCHES LONG LENS FOR DISTANT IMAGES

A camera system known as SAVI (synthetic apertures for long-range, subdiffraction-limited visible imaging) doesn't need a long lens to take a picture of a faraway object. Instead, it can read a laser-projected speckled pattern, interpret it, and construct a high-resolution image. Co-developed by Professor Oliver Cossairt, the technology could eliminate the need for costly telephoto lenses and moving cameras.

Labs at Northwestern and Rice University built and tested the SAVI device, which compares interference patterns among multiple speckled images. The images are taken from slightly different angles but with one camera, which is moved between shots. The speckles serve as reference beams and essentially replace one of the two beams used to create holograms. When a laser illuminates a rough surface, the viewer sees grain-like speckles in the dot because some of the returning light scattered from points on the surface has farther to go, throwing the collective wave out of phase. A computer program then resolves the speckle data into a high-resolution image.

"BY MOVING ABERRATION ESTIMATION AND CORRECTION OUT TO COMPUTATION, WE CAN CREATE A COMPACT DEVICE THAT GIVES US THE SAME SURFACE AREA AS THE LENS WE WANT WITHOUT THE SIZE, WEIGHT, VOLUME, AND COST."

OLIVER COSSAIRT ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

FINDING A NEW WAY TO COMMERCIALIZE BATTERIES

Although more efficient and effective batteries are constantly in development, very few ever make it to the marketplace. Professor Vinayak Dravid and collaborators are solving this problem by proposing an updated model of battery commercialization in the United States. The model incorporates strategies used in the pharmaceutical industry, which boasts a long history of successful market debuts. With SiNode Systems co-founder and CEO Samir Mayekar, Dravid and his graduate student created a series of tailored proposals for entrepreneurs, investors, manufacturers, and policy makers to fuel battery commercialization, including pursuing niche applications, developing strategic partnerships and joint development agreements with large manufacturing companies, targeting capital raises to specific exit scenarios, and focusing on customer-led performance metrics to more fully understand market opportunity.

17

Number of rare-earth elements that can be more easily extracted with Monica Olvera de la Cruz's system

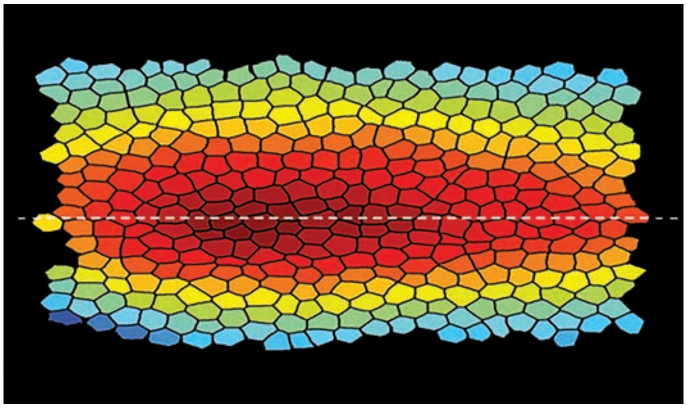
100

Number of seismic stations researchers studied to find evidence of "deep tremor"

THE RISKY BUSINESS OF SELF-PRESERVATION

All animals make critical decisions when faced with when, where, and how to escape from a looming threat. A Northwestern research team using multi-neuron imaging has learned that the escape response for prey is more nuanced than previously thought.

In a study of larval zebrafish, Professor Malcolm MacIver and collaborators were the first to find that the animal's innate escape response incorporates the speed of the approaching predator and not just the proximity of the predator in its calculation of how best to flee. Prior to this research, the escape behavior was thought to be driven by a proximity threshold where anything that gets within a certain distance triggers an escape. The Northwestern team, however, found that at slower approach rates by a predator, the larval zebrafish's fastest escape circuit is not deployed; instead, a different circuit produces a more delayed and variable escape behavior.



Cells' Collective Behavior Determines Tissue Shapes

Professor Madhav Mani and collaborators have brought the world closer to understanding how living tissues and cells arrive at their physical forms. Studying a developing fruit fly embryo, the team identified a collective mode that provides a quantitative description of the deforming epithelial tissue. Such deformation, coupled with the mechanics of growth, defines the shape of the developing tissues.

To better understand the mechanical interactions at play in epithelial morphogenesis, the team formulated and analyzed a model of epithelial tissue, which assumes that the outer layer of tissue determines the mechanical balance within its cells. The model showed a dynamic relationship between cells and their neighbors.

"If you watch people at a busy crosswalk, you will notice that individuals don't appear to walk independently," Mani says. "They constantly watch each other, move in response to others' movements, and thereby move as a whole with certain collective traits. Cells behave similarly when entire tissues flow in an embryo."

471,857

Number of compounds in Christopher Wolverton's Open Quantum Materials Database

150%

Percentage increase in the number of lives that could be saved with Sanjay Mehrotra's optimization model for liver transplant allocation

97

Number of engineering students who received their PhD in June

BREAKING THE PROTEIN-DNA BOND

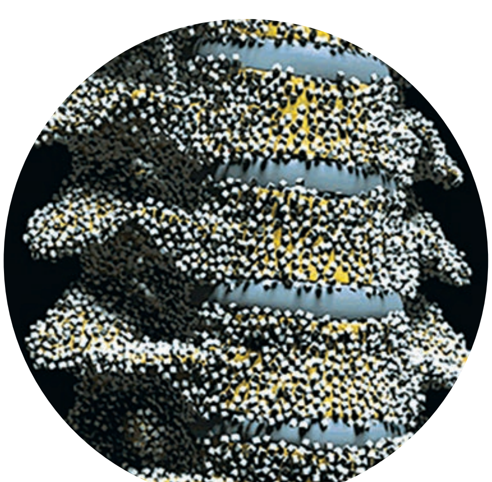
An interdisciplinary Northwestern study reports that the important protein-DNA bond can be broken by unbound proteins floating around in the cell. This discovery sheds light on how molecules self-organize and how gene expression is dynamically controlled.

Professor Monica Olvera de la Cruz led the development of a theoretical model and performed molecular dynamics simulations to show the prevalence of the protein-DNA break-up at the single-binding site due to the competitor proteins. This disproves former beliefs that protein-DNA bonds were unaffected by unbound proteins and instead resulted from more "cooperative" interactions among many molecules, large protein clusters, or long DNA segments.

"Our results suggest that protein-DNA dissociation could have a profound effect on the dynamics of biological processes that depend on protein binding in vivo. This may be an important factor to take into account when modeling gene expression in living cells."

MONICA OLVERA DE LA CRUZ
LAWYER TAYLOR PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING

Sugar-coated Nanomaterial Excels at Promoting Bone Growth



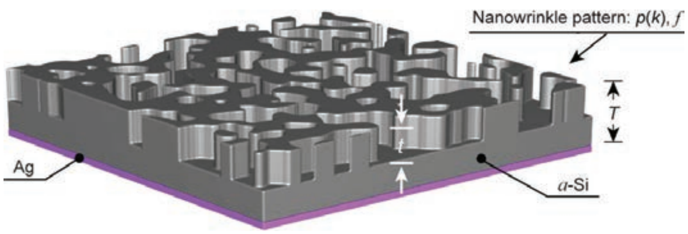
Professor Samuel I. Stupp has developed a promising bioactive nanomaterial for stimulating bone regeneration, a method that could be used to treat pain due to disc degeneration, trauma, and other back problems. The material's regenerative power comes from sugar molecules on its surface.

When researchers studied the effect of the "sugar-coated" nanomaterial on the activity of a clinically used growth factor, they discovered that the amount of protein needed for a successful spinal fusion was reduced by 100 times.

This is good news because the growth factor in question is known to cause dangerous side effects when used in the amounts required to regenerate high-quality bone.

Stupp's nanomaterial works by functioning as an artificial extracellular matrix, which mimics what cells in the body usually interact with in their surroundings. Consisting of tiny nanoscale filaments, the material binds the protein by molecular design in the same way that natural sugars bind it in the human body and then slowly release it when needed.

SIMULTANEOUS DESIGN AND NANOMANUFACTURING SPEED UP FABRICATION

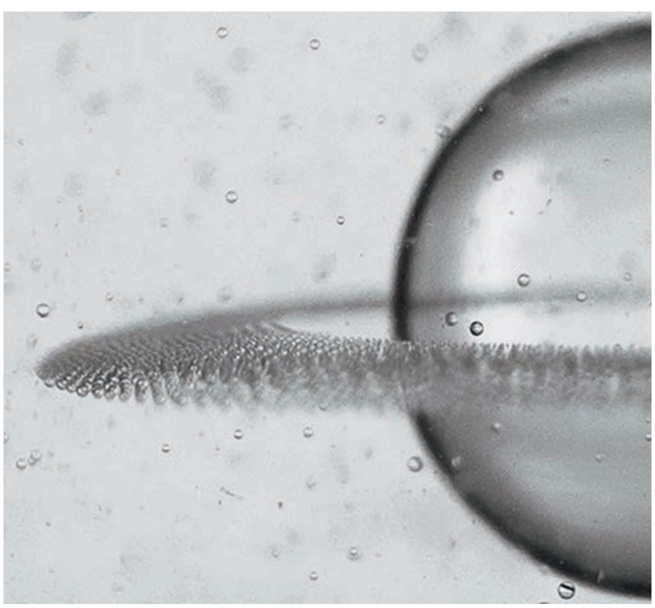


"Instead of designing a structure element by element, we are now designing and optimizing it with a simple mathematic function and fabricating it at the same time."

WEI CHEN
WILSON-COOK PROFESSOR IN ENGINEERING DESIGN AND PROFESSOR OF MECHANICAL ENGINEERING

Professors Wei Chen and Teri Odom have used mathematics and machine learning to design an optimal material for light management in solar cells, then fabricated the nanostructured surfaces simultaneously with a new nanomanufacturing technique. The fast, highly scalable, streamlined method could replace cumbersome trial-and-error nanomanufacturing and design methods, which often require vast resources to complete.

The team demonstrated the concurrent design and manufacturing method to fabricate 3D photonic nanostructures on a silicon wafer for potential use as a solar cell. The resulting material absorbed 160 percent more light in the 800 to 1,200 nanometer wavelength—a range in which current solar cells are less efficient—than other designs. Next, Chen and Odom plan to apply their method to other materials, such as polymers, metals, and oxides, for other photonics applications.



PUTTING A NEW TWIST ON ELECTROSPRAYS

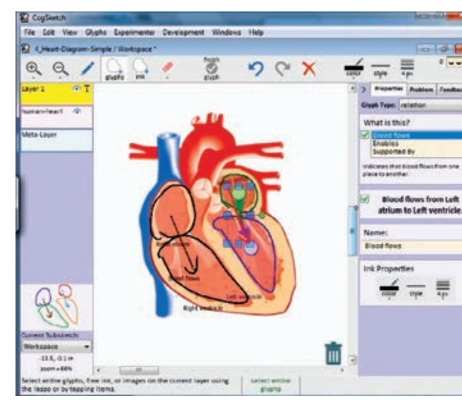
Created when an electric field is applied to a conductive liquid drop, electrosprays emit a stream of tiny, uniform droplets. Professor Petia Vlahovska wondered if her team could make an electrospray with multiple jets to generate millions of drops at once. She submerged drops of silicone oil in castor oil, which is more electrically conductive, then applied an electric field. The silicone drops surprisingly flattened into a lens-like shape encircled by concentric rings, which broke up to form an array of micro-droplets around the equator. The Saturn-shaped drops eventually transformed into millions of microscopic, uniformly sized beads. The outcome could enable precisely dosed pharmaceuticals, new materials for photonics, innovative printing methods, and more.

3

Weight, in pounds, of a CubeSat satellite that will contain a Northwestern freeze-casting experiment in 2018

111

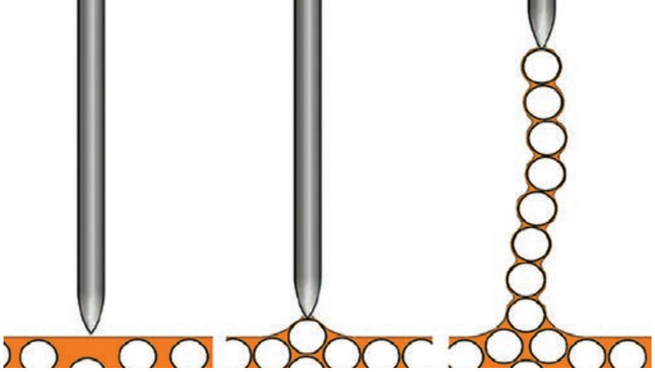
Number of garments and accessories showcased in the MoMA's new fashion exhibition, which includes John Rogers's innovative "sweat patch"



AI MAKES GRADING SKETCHES FASTER AND EASIER

Although sketching exercises can help students learn many subjects, they are woefully underused in the classroom. "Sketches are difficult and time-consuming to grade," says Professor Ken Forbus. "And intelligent tutoring systems rarely are capable of understanding sketches."

Forbus and his team have developed a solution called "Sketch Worksheets," software that can provide on-the-spot feedback by analyzing student sketches and then comparing them to the instructor's sketches. The software is based on CogSketch, an artificial intelligence platform previously developed in Forbus's laboratory, which uses visual processing algorithms to automatically reproduce and understand human-drawn sketches.



INTERNATIONAL TEAM SOLVES MYSTERY OF COLLOIDAL CHAINS

Professor Erik Luijten and a team of Polish researchers have discovered that when an electrode is dipped into a mixture of micron-sized, spherical metal particles, its charged tip polarizes each sphere. These induced dipolar interactions cause the spheres to stick together. A resulting chain could contain hundreds of thousands of spheres, reaching up to 30 centimeters in length. The team found that the chains maintain their structures because of liquid "bridges" between adjacent particles. This finding could lead to a new generation of electronic devices and a fast, simple method to write two-dimensional electronic circuits.

WORKSHOP EXPLORES THE FUTURE OF ARTIFICIAL INTELLIGENCE

Northwestern's Center for Optimization and Statistical Learning hosted the ACNTW Workshop, a biennial gathering of 150 computer scientists, statisticians, and optimization researchers from Argonne National Laboratory, the University of Chicago, Northwestern, the Toyota Technological Institute at Chicago, and the University of Wisconsin. At the May event, Professor Jorge Nocedal outlined the primary challenges facing optimization methods for large-scale machine learning problems and praised algorithm design featuring both strong generalization properties and the ability to parallelize.

NEW FRAMEWORK FOR NON-EQUILIBRIUM SYSTEMS

Professor Erik Luijten and Steve Granick from Korea's Institute for Basic Science have discovered a non-equilibrium system that quantitatively behaves like an equilibrium system. The finding could lead to a set of rules that makes possible predicting the properties of non-equilibrium systems, which experience constant changes in energy.

The discovery occurred when Luijten and Granick noticed a swarm of self-propelling colloids undergo phase separation, a characteristic of substances in equilibrium. Luijten's team repeated the experiment in computational simulations and found that only when the particles rotated with small radii did they phase separate, meaning that the length of the radii could function as a control parameter.

20

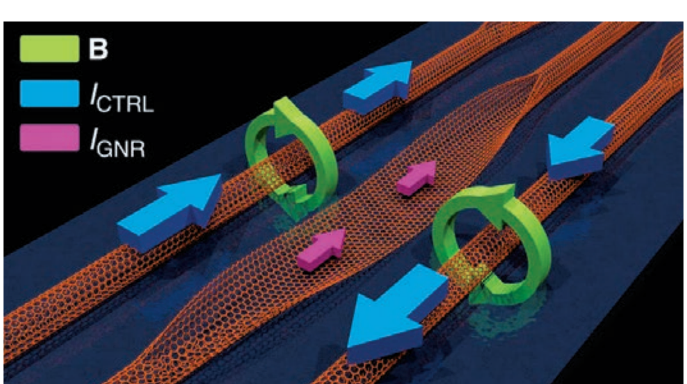
Number of medical tents throughout the Bank of America Chicago Marathon's course optimized by Karen Smilowitz and her students to ensure that medical supply met race-day demand

INTERNATIONAL SYNTHETIC BIOLOGY TEAM TO CREATE AN ANCIENT CELL

With funding from the highly competitive Human Frontier Science Program, an interdisciplinary team including Professor Michael Jewett plans to unravel millennia of evolution to create an ancient version of a cell. Using synthetic biology, the team will create a cell that uses RNA enzymes, called ribozymes, to recapitulate a key step in evolution: the invention of translation and the establishment of the genetic code. Their project could illuminate why cells needed to evolve to make proteins. It will also help scientists understand how to use evolutionary optimization to build multi-scale systems.

"THIS CONCEPT COULD REVOLUTIONIZE THE FABRICATION OF THE CIRCUITS USED TO MAKE COMPUTERS AND MOVE US PAST THE LIMITATIONS OF CURRENT SEMICONDUCTOR TECHNOLOGY TO MAKE MUCH SMALLER AND FASTER SYSTEMS."

ALAN V. SAHAKIAN THE JOHN A. DEVER PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE



RESEARCHERS SPIN ALL-CARBON COMPUTER DESIGN

Northwestern and University of Texas at Dallas engineers have designed a novel computing system made solely from carbon. The system could replace the silicon transistors that power today's electronic devices. The design exploits electrons' spin, which relates to their magnetic properties rather than electric fields. "This concept could revolutionize the fabrication of the circuits used to make computers and move us past the limitations of current semiconductor technology to make much smaller, faster systems," says Professor Alan Sahakian, co-author of the study.


Linda Broadbelt


Laurence Marks


Michael Peshkin


Jian Cao


Bernard J. Matkowsky


James Rondinelli


Prem Kumar


Chad Mirkin


David Seidman


Julius Lucks


Monica Olvera de la Cruz


Aravindan Vijayaraghavan

Faculty Awards

Linda Broadbelt Presented with Two Research Awards Broadbelt received the E.V. Murphree Award in Industrial and Engineering Chemistry from the American Chemical Society and Northwestern's Dorothy Ann and Clarence L. Ver Steeg Distinguished Research Fellowship Award.

Jian Cao Honored with Charles Russ Richards Memorial Award The first woman to receive the award from the American Society of Mechanical Engineers and Pi Tau Sigma, Cao was honored for her outstanding achievements in mechanical engineering.

Prem Kumar Awarded Secretary of Defense Medal for Outstanding Public Service The award is one of the highest distinctions from the US Secretary of Defense to non-career employees, private citizens, and foreign nationals for their contributions and support.

Julius Lucks Receives Camille Dreyfus Teacher-Scholar Award Lucks is among 13 selected to receive the research grant, which honors young faculty in the chemical sciences who have created an independent body of outstanding scholarship and demonstrate a commitment to education.

2017 Surface Structure Prize Goes to Laurence Marks Given at the International Conference on the Structure of Surfaces, the award recognizes a researcher each year for outstanding achievement in the field of surface and interface structure.

Bernard J. Matkowsky Receives Neumann Lecture Prize The John von Neumann Lecture Prize is the Society for Industrial and Applied Mathematics' highest honor.

Chad Mirkin and Monica Olvera de la Cruz Recognized by the Sherman Fairchild Foundation Each received a five-year grant to support innovative materials science research.

Michael Peshkin Presented with 2017 Ralph Coats Roe Award The annual, national award from the American Society for Engineering Education recognizes Peshkin for his sustained efforts to provide students with hands-on experiences.

James Rondinelli Honored by the Materials Research Society Rondinelli received the society's Outstanding Young Investigator Award, which recognizes young researchers who demonstrate exceptional promise to become leaders in the field.

David Seidman Receives 2019 ASM Gold Medal One of the society's most prestigious awards, the medal honors Seidman's exceptional ability to diagnose and solve diversified materials problems.

Aravindan Vijayaraghavan Receives NSF CAREER Award The National Science Foundation award honors young faculty members who exemplify the role of teacher-scholar through outstanding research, excellent education, and the integration of education and research.

By Water, By Land, By Air

Northwestern Engineers tackle energy efficiency issues from multiple fronts.

PROFESSOR YIP-WAH CHUNG knows energy efficiency—or perhaps more accurately inefficiency—by the numbers. If asked, he can rattle them off the top of his head.

35%[1]

The average energy efficiency of a US fossil fuel-burning power plant.

27%[2]

The world average energy efficiency of a coal-burning power plant.

15–20%[3]

The energy efficiency of the average automobile.

3,000 GALLONS[4]

The fuel a Boeing 747 burns every hour—much of which is wasted.

1 US Energy Information Administration Monthly Energy Review

2 World Coal Association

3 Holmberg, K.; Andersson, P.; Nylund, N.-O.; Mäkelä, K.; Erdemir, A. "Global energy consumption due to friction in trucks and buses." *Tribology International* 78 (October 2014): 94–114.

4 The Boeing Company; number represents the fuel burn rate at cruise speeds (550 mph)

"IF WE CAN SOLVE THE PROBLEM OF ENERGY INEFFICIENCY, WE CAN CHANGE THE WORLD. I HONESTLY BELIEVE THAT."

YIP-WAH CHUNG Professor of Materials Science and Engineering

The numbers go on and on. "It's mind numbing," says Chung, a professor of materials science and engineering in Northwestern's McCormick School of Engineering, referring to the dismal energy efficiency numbers. "It's impossible to get to 100 percent efficiency, but there's a lot of room for improvement to use less energy to accomplish the same amount of work. Every fraction of a percent counts."

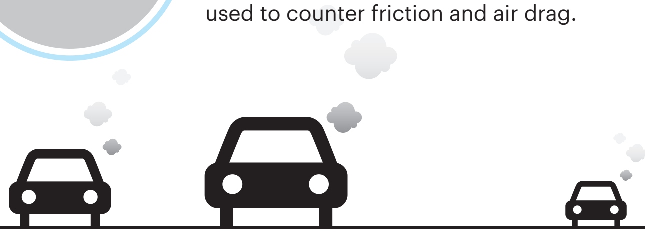
Chung is one member of an extended and growing team of Northwestern engineers avidly working to make industries, transportation, and individual households more energy efficient. They are tackling the issue from all sides: land, water, and air.

WHAT IS ENERGY EFFICIENCY?

Energy efficiency is the percentage of energy put into a machine and consumed in useful work, rather than wasted as heat or other byproducts.

Of the fuel put into a car, for example, only about **20 percent** actually propels the vehicle down the road.

The rest is wasted as heat exhaust or used to counter friction and air drag.



"If we can solve the problem of energy inefficiency, we can change the world," Chung says. "I honestly believe that." There are some PRACTICAL BENEFITS for increased energy efficiency in how people use equipment and lead their lives. For starters, it would:

- LOWER ENERGY COSTS
- REDUCE POLLUTION AND GREENHOUSE GAS EMISSIONS
- MITIGATE OVERALL ENERGY NEEDS
- INCREASE NATIONAL SECURITY BY DECREASING RELIANCE ON IMPORTS

Although renewable energies such as wind, solar, and battery power can address cost and pollution issues, Northwestern Engineering experts also believe in the importance of getting the most out of fossil fuels.

"There's already a huge legacy and huge infrastructure in place for fossil fuels," says David Dunand, professor of materials science and engineering.

"We need to look for more efficient ways to burn fossil fuels and to improve solar and wind technologies. It's not one or the other. It's both."

MATERIALIZING SOLUTIONS FOR POWER PLANTS

ELECTRICAL POWER PLANTS ACCOUNT FOR **40 PERCENT** OF ENERGY CONSUMPTION IN THE UNITED STATES.

They produce electricity by setting off a long chain of events that starts by burning fuel to produce steam. That steam then drives a turbine, which powers a generator to ultimately make electricity. **Increasing the energy efficiency of power plants could dramatically decrease the cost of power production and reduce the volume of carbon emissions**.

David Dunand and David Seidman, Walter P. Murphy Professor of Materials Science and Engineering, are working toward those goals from a materials perspective. The backbone of their work is **Carnot's theorem**, based on the second law of thermodynamics. **A simple formula, the theorem outlines the maximum amount of electricity (useful work) that can be extracted from a unit of fuel.** The efficiency depends solely on the difference in temperature between the hot and cold components involved in the process. For power plants, it all comes down to the steam. The hotter the steam, the more electricity is produced.

"Essentially, the hotter you can get the temperature to burn the fuel, the more electricity you can extract," Dunand explains. "The cold part is just the surrounding air, so you can't do much about that. What you can do, though, is get the hot part hotter."

Though Carnot's formula is a straightforward statement, the simplicity ends there. **The challenge that researchers face lies in finding materials for the turbines that can function in extreme heat.** For the past 100 years, researchers have toiled to create alloys that can withstand higher and higher temperatures. Nickel-based and iron-based superalloys, which initially emerged quickly as the two leading materials, have nearly reached their potential.

"These alloys have been tweaked and tweaked," Dunand says. "The current nickel-based superalloys have 15 elements in them. Researchers keep adding more elements—a pinch of this, a whisper of that. There's not much more we can do; we're starting to plateau."

Researchers, including Dunand and Seidman, have pinpointed cobalt as nickel's successor. Next to nickel on the periodic table of elements, cobalt shares several of its sister element's best assets. Both, for example, resist corrosion. And though both exhibit great strength at high temperatures, cobalt does one better.

It melts at a temperature 50°C higher than nickel, which could increase the energy efficiency of power plants dramatically.

"**THAT'S A BIG DEAL**," Dunand says. "If you get an improvement of one degree per year, you're happy. So 50 degrees would be tremendous. You'd save billions of dollars in fuel and reduce megatons of carbon emissions."

Supported by the Center for Hierarchical Materials Design and the National Institute of Standards and Technology, Dunand and Seidman are manipulating the microstructure of a cobalt-based superalloy to make it less likely to deform at high temperatures yet remain resistant to oxidation. Their existing superalloy contains 10 elements, which Dunand likened to a human taking 10 different medications.

"Each element has its own side effects," he says. But he believes this new material could increase power plants' energy efficiency by 1 or 2 percent to save billions of dollars and gigatons of emitted carbon. What's better, the turbines can be simply dropped into existing power plants to work with current infrastructure.

"Scientifically, we know where we're going, and what's possible," Dunand says. "We're moving much faster than researchers moved when developing nickel-based alloys. The payoffs will be huge."

"Scientifically, we know where we're going, and what's possible. We're moving much faster than researchers moved when developing nickel-based alloys. The payoffs will be huge."

DAVID DUNAND Professor of Materials Science and Engineering

Living an Efficient Life

Yip-Wah Chung walks the talk about energy efficiency. When he moved into his new house, he immediately put his knowledge into action. By making a few simple changes, he slashed both his energy waste and his power bill.

"There are so many things we—not as scientists and engineers, but as private citizens—can do to make an impact," he says. "To me, that's empowerment."

Here are Chung's top tips for leading more efficient lives:

IN THE HOUSE

Turn off lights when leaving the room

Set the thermostat so HVAC systems run less frequently while sleeping or away from home

Switch from regular light bulbs to LED bulbs

"LEDs seem expensive, but they are a one-time investment," Chung says. "They last for years, so over time, they cover their own costs. If you don't expect to live in the same place for the life of the bulb, take it with you when you move."

Improve home insulation to prevent heat and cool air from escaping

Replace appliances with ENERGY STAR certified models

IN THE CAR

Remove junk from inside the car; excess weight reduces fuel economy

Change oil every six months to minimize friction and wear

Anticipate traffic changes to avoid sudden braking or accelerating

On highways, drive the speed limit

"At highway speeds, aerodynamic drag is the main source of energy loss," Chung says. "Drag increases as the square of the vehicle speed, which means that by driving 10 percent faster—60 miles per hour instead of 55—the drag and gas consumption increase by about 20 percent."

Choose a hybrid or electric model

SUPERALLOYS ALOFT

Dunand and Seidman's superalloys don't just apply to turbines in power plants. Jet engine turbines could also be constructed from the Northwestern duo's materials. Like power plants, jet engine turbines are commonly made of nickel-based superalloys. But existing commercial airplanes have already maxed out the temperature that these materials can withstand.

Nickel melts at 1,450°C, but an airplane's combustion chamber reaches 1,400°C. A ceramic coating on the turbine blades creates a thermal barrier that drops the melting temperature by 150°C. Engineers hollow out the blades and fill them with coolants, which further reduces the blade's melting temperature. **Replacing current turbines with Dunand and Seidman's cobalt-based superalloys might enable engineers to forgo the hollow cooling chambers altogether, increasing the energy efficiency across the turbine's lifecycle**.

"Then you could have a much cheaper blade because you wouldn't have to create all those intricate channels," Dunand says. "You could make the blade lighter, thinner. Lighter infrastructure would allow you to have more passengers. There's more than one way to cash in on that increased performance."

Allies and Alloys

Engineers first put superalloys into jet engine turbines at the end of World War II. Since then, superalloy materials have become a multi-billion-dollar industry and a lynchpin for society. "Superalloys helped win the air war between Germany and England because the British were the first to put them into jet engines," Dunand says.

Printing Plane Parts

When it comes to increasing airplanes' energy efficiency, Eric Masanet's solution comes in three dimensions.

Masanet, an associate professor of mechanical engineering and chemical and biological engineering, discovered that by manufacturing metal aircraft parts with 3D printing, airlines could save a significant amount of fuel, materials, and other resources.

Masanet and his team used aircraft industry data to complete a case study of the lifecycle environmental effects of using 3D printing for select aircraft parts, a technique already being explored by the industry. The team concluded that 3D printing the lighter and higher performance parts could significantly reduce manufacturing waste and the weight of the airplane, saving fuel and money and reducing carbon emissions.

The currently used conventional manufacturing methods tend to be inefficient and wasteful. The manufacturing process for a one-kilogram bracket for an airplane, for example, might require 10 kilograms of raw material. From an engineering design perspective, that final bracket might still contain much more metal than required for the job. 3D printing, on the other hand, not only requires far fewer raw material inputs, but can also produce parts that minimize weight through better design.

"We have suboptimal designs because we're limited by conventional manufacturing," Masanet says. "When you can make something in layer-by-layer fashion, those constraints diminish."

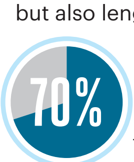
GROUND CONTROL

While the production of electricity accounts for 40 percent of US energy consumption, **transportation comes in a close second at 30 percent**, a number that continues to grow. Because energy consumption increases as the population grows and living standards rise, the level of fuel waste is likely to surge as well.

"Energy consumption per person becomes higher and higher as lifestyle improves. Everybody used to walk. Now everybody drives. We can't tell people to go back to walking or not to drive. We have to develop technology solutions."

Q. JANE WANG Professor of Mechanical Engineering

Although many solutions can gouge the wallet, such as replacing fuel-burning cars with electric cars, Professors Wang, Yip-Wah Chung, and Tobin Marks have developed a simpler alternative to improve the efficiency of everyday vehicles. **The team has created new lubricant additives that can significantly reduce friction and wear on modern automotive engine components without poisoning the catalytic converter**. For the average car, about 15 percent of fuel consumption is spent overcoming friction. Reducing friction not only enhances fuel efficiency but also lengthens the engine's life.



The team recently developed a new lubricant additive group called **CYCLENS, which can reduce friction by up to 70 percent and wear by up to 90 percent** compared to conventional lubricant counterparts.

Cyclens additives are made of organic molecules with nitrogen centers. The multiple nitrogen centers enable the lubricant to bind to a surface, an important factor that keeps the lubricant in place between surfaces.

"It's a drop-in replacement, so you don't need to do anything except add this chemical to the oil," Chung says. "And then bang! The friction drops."

Wang and Chung have also partnered with Jiaxing Huang, professor of materials science and engineering, to explore a more unusual lubricant additive: crumpled graphene balls. About six years ago, Huang discovered crumpled graphene balls—a novel type of ultrafine particles that resemble crumpled paper. He made the particles by drying tiny water droplets with graphene-based sheets inside.

"Capillary force generated by the evaporation of water crumples the sheets into miniaturized paper balls," Huang said. "Just like how we crumple a piece of paper with our hands."

In a series of tests, a base oil modified only with crumpled graphene balls outperformed fully formulated commercial oil, both in terms of reducing friction and the degree of wear on steel surfaces. Because of their unique shape, crumpled graphene balls self-disperse without needing surfactants that are attracted to oil. With their pointy surfaces, they simply can't make close contact with other graphene balls. Even when squeezed together, they easily separate again when disturbed.

WATER FROM THIN AIR

Gathering, treating, and transporting water is one of the most energy-expensive tasks that humans undertake. Delivering water to remote, dry regions usually means constructing miles of pipelines, travelling long distances by truck or ocean tanker, or desalinating seawater.

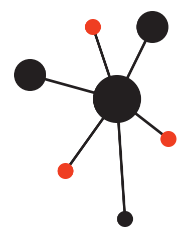
All of those methods can be very costly and energy intensive and come with varying environmental and social impacts. Using locally available water is, of course, more cost effective and energy efficient, but some regions have no readily apparent local sources of water. Even though it's not visible to those regions' residents, the solution could be literally in front of their noses.

"Where is water?" asks Neelesh Patankar, professor of mechanical engineering. "It's underground in wells and on land in oceans, rivers, and lakes. But there is also water vapor in the air. The question is: Are we leaving money on the table there?" And that's exactly what Patankar is trying to answer.

He and Kyoo Chul Park, assistant professor of mechanical engineering, use surface engineering to harvest water from the atmosphere. **Their decentralized solution could allow people in all regions to collect their own water without the need for long-distance transportation. And because water vapor is high quality, this water source requires less filtering—another energy efficiency.**

The harvesting method manipulates water's phase behavior—the temperatures at which it boils, condenses, and freezes. Most people believe that water must be boiled to vaporize. "Actually, forming vapor without boiling water is not unheard of," Patankar explains. "If I put a drop of water on the table, it's going to evaporate eventually. Our idea was to reverse this trick by making surfaces on which vapor would like to condense as dew and easily roll-off."

Inspired by the hydrophobic surfaces of lotus leaves—micro- and nanoscopic bumps on the leaves cause water to bead up and roll off—Patankar and Park developed surfaces on which water drops can easily slide off. Park found a combination of surface chemistry and roughness that causes water vapor to condense easily as dew and roll-off quickly for collection. People can then harvest the dew for drinking water.



"Chemistry-wise, we're thinking about low surface energy coatings," Park says. "If we consider the interactions between molecules, we can have lower and lower energy surfaces to repel more and more water."

Patankar and Park imagine that people in water-scarce regions could someday have coolers inside their homes to harvest atmospheric water for drinking. The process would also solve other problems by dehumidifying houses to prevent mold formation, protect electronics in humid regions, and improve the quality of life.

"Our work is about investing in a sustainable future," Park says. "We want to help alleviate suffering in the developing world by contributing to the next generation of technologies that address water scarcity."

"Our work is about investing in a sustainable future. We want to help alleviate suffering in the developing world by contributing to the next generation of technologies that address water scarcity."

KYOO CHUL PARK Assistant Professor of Mechanical Engineering

Coming Next: Self-cleaning Energy?

Not only does the lotus leaf repel water, it's also self-cleaning. When water beads up and rolls off the leaves, it takes dirt with it. Professor Kyoo Chul Park wants to use his energy efficient surface coatings on solar cells to create the same effect.

"Within a couple months of installation, solar cells get dirty, and their energy efficiency decreases by 40 percent," Park says. "It's important to maintain a high quality of transparency." Park believes that a functional coating to make solar cells self-cleaning could increase energy efficiency.

Written by Amanda Morris

Solving Big Problems with Big Data

WITH SOLUTIONS-FOCUSED PRAGMATISM AND AN ENGINEERING MINDSET, LUÍS AMARAL IDENTIFIES INTERSECTIONS AND PATTERNS TO UNDERSTAND COMPLEX, SEEMINGLY UNRELATED ISSUES.

How does an engineer think?

By seeing the simplicity in the complex, and the complexity in the simple. That's how Luís A. Nunes Amaral can look at airport systems and human cells and find similar networks.

Amaral, Erastus Otis Haven Professor of Chemical and Biological Engineering, uses big data and the skills of engineering—measuring rigorously, uncovering patterns, and identifying system symmetries—to build frameworks for approaching vastly different complex problems.

"He looks at big data to solve the intractable problems of our day," says co-collaborator Teresa Woodruff, director of the Women's Health Research Institute at Northwestern University Feinberg School of Medicine. "He's fearless in his desire to match big problems with big data."

Amaral's discoveries in one area of study often inform later work on a seemingly dissimilar topic. In a study about airport systems, for example, Amaral and his team learned that larger airports, like Chicago's O'Hare International, are more connected to other highly connected major hubs, like San Francisco International, than one would expect.

"That's because the number of people flying into airports must balance the number of people flying out. People are not collecting in one place. They are leaving and returning," the native of Portugal says. "There's a balance, a type of conservation required."

Sometime later, while studying the body's metabolic network, Amaral recognized echoes of the airport network system. "The metabolic network carries molecules. They come in, are transformed, and about the same number leave," he says. "You don't want things accumulating. Again, there is a balance. The need for conservation determines the structure of the network."

Research at the intersections

All of Amaral's studies examine complex systems that involve the intersections of physical, chemical, biological, and social interactions. "When many components interact, you have emergence—things that couldn't exist without all these components coming together," says Amaral, who also serves as co-director of the Northwestern Institute on Complex Systems. "It makes predicting what will happen very hard."

In studying intersections, he has examined a disparate array of social issues, from the connection between school shootings and unemployment, to the relationship between participation in online communities and weight loss, to the persistence of gender discrimination in genomics.

Collaborating at the frontiers

Amaral credits Northwestern's culture of collaboration among departments and disciplines for enabling him to work so deeply on such diverse topics. "My collaborators are some of the best in the world in their fields," he says. "You can get to the frontier of knowledge very fast. It's incredibly rewarding intellectually, and to me, it's the most fun in the world to learn from such knowledgeable colleagues."

"As engineers, we see a problem, and we want to solve it. Sometimes, in the challenging 'real world,' there are roadblocks to progress. Engineers can't wait for everything to be perfect to solve a problem. We must work toward an answer."

LUÍS AMARAL

Currently, Amaral is working on two projects with Northwestern's Feinberg School of Medicine. One study, funded by the US Army, looks at creating best practices to help physicians, nurses, and other medical providers avoid potentially deadly errors.

"All the pressure to treat so many patients puts physicians in a difficult position," he says. "Medical mistakes cause 440,000 deaths each year. That's a huge, scary number. We're looking to help clinicians avoid mistakes in ways that fit into their workflow without adding to the pressures they already feel."

In the other project, funded by the National Institutes of Health, Amaral is collaborating with critical care and pulmonary medicine researchers at Feinberg to study aging and what happens at the molecular level. The research is based on big data collected from mouse studies.

"There will be an enormous amount of information," he says. "One of the challenges in a study with this much data is seeing things that look like explanation but turn out not to be. The trick will be to find patterns that are reliable and real."

"Luís is always anxious to find the next problem and examine it to discover solutions," says Woodruff, who is also dean of The Graduate School. "He's able to find the signal through the noise."

Mixing open-mindedness, teamwork, and pragmatism

The key to Amaral's work, he says, is keeping an open mind. "Don't go in thinking that you know what you'll find at the end," he advises. "Understand that your initial hypothesis could be wrong. You might find something even more interesting. Don't be afraid to change course."

The importance of teamwork is a lesson he tries to pass on to students. "It's important to be an effective worker within a team," he says. "I tell students: Step back and assess your strengths. Be confident in your abilities, but evaluate the competence and knowledge of others. They might have strengths where you don't. This is how to build a team that works effectively."

No matter the topic, Amaral always brings an engineer's pragmatism. "As engineers, we see a problem, and we want to solve it," he says. "Sometimes, in the challenging 'real world,' there are roadblocks to progress. Engineers can't wait for everything to be perfect to solve a problem. We must work toward an answer."

JULIANNE HILL

Photograph by Chris Strong

TRAINING ECOSYSTEM TAPS THE POWER OF COMMUNITY

HAOQI ZHANG'S AGILE RESEARCH STUDIOS IS CHURNING OUT THE NEXT GENERATION OF RESEARCH SUPERSTARS.

In just the past three years, Professor Haoqi Zhang's students snagged top prizes in three major computer science student research competitions. They claimed 29 undergraduate research grants and earned more than $30,000 in outside funding for their projects. And nine student teams published full papers and extended abstracts at premier peer-reviewed conferences.

"This kind of success is almost unheard of," says Zhang, the Allen K. and Johnnie Cordell Breed Junior Professor of Design and assistant professor of computer science. "But this outcome is not our goal in and of itself. It's a natural result of the process."

That process is Agile Research Studios, a community-based research training system that Zhang developed over several years and, in 2015, implemented into the Design, Technology, and Research program that he co-leads with Professor Eleanor O'Rourke. Agile Research Studios is a computational ecosystem in which the research process, social structures, and tools work together to support community members learning how to conduct self-directed research.

The inspiration behind Agile Research Studios is simple: faculty members are overtaxed. To develop into dynamic thinkers and problem solvers, students need the quality mentoring and sustained training that faculty members are often unable to provide one-on-one. Zhang removed the one-on-one aspect of mentoring and replaced it with a robust network of faculty, student peers, and graduate students.

"Students help faculty with research, but they're often not being trained in the process," he says. "They typically just follow a plan that's handed to them. We want to create independent researchers who drive research and approach complex problems."

HOW IT WORKS

Agile Research Studios makes research goals more attainable by breaking down long-term projects into manageable two-week-long design sprints. During these sprints, students plan and complete specific, smaller goals that deliver value to the project. The process encourages students to dive into their research by building simple prototypes, running tests, making measurements, and reflecting. At first, their experiments might be low fidelity, but prototypes and tests increase in sophistication as the students learn and develop their skills.

"The point is that students are getting involved with authentic research sooner," Zhang says. "They learn by doing many iterations—even if those experiments are imperfect."

"It makes use of expertise in the most effective way possible. Pairs are matched to help each other, so reciprocity is built into the system. Over time, this reciprocity builds a more supportive community."

HAOQI ZHANG ALLEN K. AND JOHNNIE CORDELL BREED JUNIOR PROFESSOR OF DESIGN

In all projects, researchers will eventually hit an impasse. This is where the community comes into play. Agile Research Studios' social structure facilitates help-seeking and collaboration to promote learning and progress. In virtual and in-person meetings, mentors and peers help students think through problems and strategize ways to overcome them.

FINDING HELP ALONG THE WAY

One way students find help is through Pair Research, an online platform that simplifies the process of asking for and receiving help. Students can visit the online platform, describe the task they need help with, and estimate how much time is needed to accomplish the task. For example, the student might need someone to proofread a paper, test computer code, or provide motivation to stop procrastination.

Other users then respond to the request, rating their ability to help with the task on a scale of one to five. A matching algorithm then recommends the most optimal pairings for collaboration, informal learning, and productivity.

"It makes use of expertise in the most effective way possible," says Zhang, who developed Pair Research with Professor Elizabeth Gerber. "Pairs are matched to help each other, so reciprocity is built into the system. Over time, this reciprocity builds a more supportive community."

Agile Research Studios' results speak for themselves. Most recently, junior Sarah Lim took first place at the Association for Computing Machinery Computer-Human Interaction Student Research Competition in spring 2017 for her system that inspects web pages to find specific snippets of source code. This allows users to search for relevant code for their own pages without sifting through volumes of complex HTML hierarchies.

While Agile Research Studios enables students to blossom into independent thinkers and researchers, it also helps grow their confidence. Throughout the course of the program, students become more autonomous and self-directed. Zhang is continually amazed by the personal growth he witnesses in students from the start to the end of the program.

"I'm proud of my students' accomplishments but most proud of their continued growth and depth of understanding," Zhang says. "By leveraging the whole community, they learn how to make arguments, think critically, solve problems, and write papers. That's what the program is designed to do."

AMANDA MORRIS

SECRETS OBSCURED FOR CENTURIES COME TO LIGHT

By fusing visible hyperspectral and x-ray fluorescence imaging, Northwestern researchers reveal sixth-century Roman law text hidden in a bookbinding.

They may never make it to the big screen in an *Indiana Jones*-inspired adventure or top the best-seller list with a *Da Vinci Code*-like mystery, but an interdisciplinary team of Northwestern University researchers has generated a good measure of excitement among historians and scientists alike with a new, nondestructive technology that promises to reveal text hidden for hundreds of years inside ancient bookbindings.

Between the 15th and 18th centuries, bookbinders recycled the bindings from medieval parchments into new binding materials for printed books. While scholars have long known that books from this time period often contain hidden fragments of earlier manuscripts, they never had the means to read them.

"For generations, scholars have thought this information was inaccessible, so they said, 'Why bother?'" notes Marc Walton, senior scientist at the Northwestern University-Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS). "But now computational imaging and signal processing advances open up a whole new way to read these texts."

Judging a book by its cover

The book responsible for sparking the study is a copy of Greek poet Hesiod's *Works and Days* from 1537. Purchased by Northwestern in 1870, the copy is the only remaining imprint retaining its original slotted parchment binding. Although this binding originally caught the attention of Northwestern librarians, the suggestion of writing beneath the parchment on the book board excited new interest.

When NU-ACCESS researchers studied the book's cover, they noticed that the bookbinder tried to remove the writing on the book board, likely through washing or scraping. But it retained two ghostly columns of writing surrounded by marginal comments.

"The ink beneath degraded the parchment, so you could start to see the writing," says Emeline Pouyet, a postdoctoral fellow in NU-ACCESS. "That's where the analytical study began."

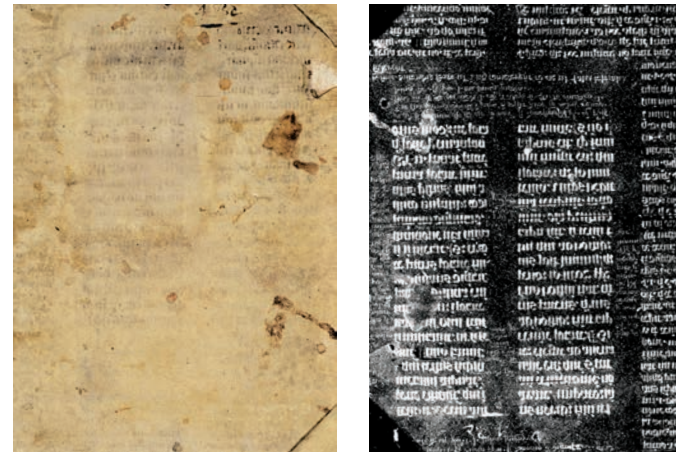
Early attempts prove promising

Walton and Pouyet used a visible light hyperspectral imaging technique to view the writing, but it yielded poor results because of the parchment's irregular degradation. While the technique made the writing a bit clearer, it was not legible enough for Northwestern historian Richard Kieckhefer to read.

Next, the pair tried x-ray fluorescence imaging using a portable instrument. The technique provided the first information about the ink composition, but the text remained unreadable.

In search of a more powerful imaging source, Walton and Pouyet sent the book to the Cornell High Energy Synchrotron Source (CHESS) in Ithaca, New York, where the bright x-ray source and fast detection system allowed for a full imaging of the main text and marginalia. When the researchers sent the more clearly imaged writing to Kieckhefer, he immediately recognized it as sixth-century Roman law code with interpretive notes referring to the canon law.

Walton and Pouyet hypothesize that the parchment originally might have been used in a university setting where the study of



Book binding (left), and as viewed with nondestructive fused imaging (right)

Roman law formed a basis for understanding canon law, a common practice in the Middle Ages. Eventually, the legal writing was covered and recycled, most likely because society had already struck down the Roman laws to implement church code.

Collaboration solves the mystery

Although pleased with the initial outcomes, Walton and Pouyet faced a challenge in extending their work beyond this single example. "The problem is that you can't always bring priceless books to an often out-of-reach synchrotron beamline," Walton says. "We wanted to be able to use our lab-based instruments."

The pair contacted Northwestern electrical engineering and computer science professors Aggelos Katsaggelos and Oliver Cossairt to help explore new ways to image the book. "There is a vast number of wavelengths in the electromagnetic spectrum, and each wavelength has its advantages and disadvantages," says Katsaggelos, the Joseph Cummings Professor of Electrical Engineering and Computer Science. "Some of them can penetrate deeper into the specimen, some of them have better resolution, and so on."

Using a machine-learning algorithm developed by his team, Katsaggelos discovered that rather than using one imaging technique, a fusion of two would yield the best results. His team combined visible hyperspectral imaging, which includes wavelengths within the visible light spectrum to provide high spatial resolution, with x-ray fluorescence imaging, which provides high intensity resolution. The algorithm informed the researchers of the relative contribution of each to produce the best image.

Katsaggelos's data fusion image was so clear that it rivaled an image of the main text that had been produced by the powerful x-ray beams at CHESS.

Although the mystery of the hidden text in Hesiod's *Works and Days* has now been solved, Walton and Pouyet believe their work has just begun. "We've developed the techniques now where we can go into a museum collection and look at many more of these recycled manuscripts and reveal the writing hidden inside," Walton says. "This is really the start of a much larger initiative."

AMANDA MORRIS

SUMMER RESEARCH WORTH THE REWARDS

ENGINEERING UNDERGRADUATE RESEARCHERS SPEND SUMMER BREAK MAKING NEW DISCOVERIES IN SCIENCE AND ABOUT THEMSELVES

For many Northwestern Engineering undergraduate students, giving up summer break to engage in research is no sacrifice. The experience and knowledge they gain top even the best vacation.

Each year, about half of engineering students pursue undergraduate research projects, with many choosing to stay on campus over the summer, when they can focus exclusively on research. By doing this, students find they accomplish more in a few months than they typically could during a full academic school year.

Thanks to the generosity of alumni, Northwestern Engineering provides undergraduate research fellowships to students during the summer. Students have also received funding from the Office of Undergraduate Research to the tune of more than $600,000 over the past five years across the academic year and summer.

Being able to conduct research without the distractions of course work and other activities is one reason students pursue summer projects. More opportunity for one-on-one interaction with faculty is another. *Northwestern Engineering* spoke with three undergraduates about how their summer experiences advanced their development, which in turn can advance Northwestern's strong research reputation.

AS TOLD TO SARA LANGEN

CLEAN ENERGY. CONVERTING DAILY ACTIVITY INTO ELECTRICAL POWER.

AKASH BORDE

COMPUTER ENGINEERING (ALSO PURSUING MS IN CHEMICAL ENGINEERING)

I've always been interested in science and math, so engineering seemed like a cool way to pursue both while applying my knowledge right away. With traditional science, it can take longer to see the application of research, but engineering is generally more direct in solving problems.

I wanted to spend my summer diving into research and getting a good understanding of what it's like. I decided to give it a full commitment to see if it's something I want to do in the future.

Some of the biggest challenges scientists and engineers face today are in the clean energy field. Fossil fuels are cheap and readily available, but they're neither sustainable nor good for the environment. I'm interested in helping develop something that's good for the planet.

I was drawn to Professor Harold Kung's research on generating and storing electricity in a clean way. He and his graduate students Thomas Yu and Aditya Mandalam are investigating using graphene materials for energy capture and storage. The work I did is part of the lab's larger research goal to develop a foam that will reliably produce significant amounts of current when compressed.

The idea is to capture the energy generated from day-to-day activities, such as walking and driving, that is otherwise lost as heat. My summer project was to help develop a material that captures the mechanical energy that goes into compressing the ground and converts it into electricity. I examined how different methods of preparing a chemically reduced graphene oxide hydrogel in a polyurethane matrix can improve how efficiently the foam converts compressive energy into electricity.

Graphene is conductive and flexible, and by compressing these graphene foams when submerged in an electrolyte, we can change how much charge the foams hold. Compression of the foam displaces the electrolyte that previously would have filled the foam's uncompressed pores, which creates a charge imbalance that drives a current or voltage. What we would like to achieve is to use this charge imbalance to do electrical work. There are a lot of potential applications down the line.

I enjoy mixing the chemicals—just the raw chemistry of it is fun. It reminds me of when I first studied chemistry in high school, which eventually led me to chemical engineering. We're essentially making something from scratch by taking raw, pencil-lead graphite and turning it into something new. We can't power anything meaningful yet, but if this works, it will be really striking.

"I WANTED TO SPEND MY SUMMER DIVING INTO RESEARCH AND GETTING A GOOD UNDERSTANDING OF WHAT IT'S LIKE. I DECIDED TO GIVE IT A FULL COMMITMENT TO SEE IF IT'S SOMETHING I WANT TO DO IN THE FUTURE."

Photograph by Chris Strong

“I decided I wanted to be an engineer when I was in fourth grade. I like the human impact of engineering. Science is very truth oriented, but engineering is more people oriented.”

URBAN FLOODING.
SEEKING SOLUTIONS IN GREEN SPACES.

LOREN AYALA

BS CIVIL ENGINEERING '17, MS ENVIRONMENTAL ENGINEERING

I wouldn't say I gave up my summer to work on the Multifunctional Urban Green Spaces research project. I really wanted to stay in Chicago last summer and thought this project was a great idea with a lot of potential. I also knew Liliana Hernandez Gonzalez, a PhD student already involved in the research.

It's a multidimensional environmental project focused on using instrumentation for long-term data collection on stormwater retention and climate adaptation from green spaces. The data will be used to inform the implementation of new techniques in other green spaces and how humans interact with their built green environment, which largely affects human health.

The long-term objective is to document how urban green spaces can help in reducing urban flooding. We're monitoring many different factors, such as groundwater, water flow, road salt deposition, ambient air temperature, and sunlight.

We've had a couple setbacks, but it's progressed really well, and the initial installations are revealing a lot of interesting patterns. For example, from the groundwater wells, we can definitively see the different soil types acting on the land's rainwater drainage patterns. The changes that happen when it rains are sometimes dramatic.

Professor Aaron Packman, who oversees the project, is my academic adviser. He has a big imagination and always has a bigger plan than we do. This project started smaller, but over time he added components here and there that enhanced it in unexpected ways.

I enjoy how the project brings many different pieces together. I started out doing fieldwork and installations. I went on to chemical analysis, and right now I'm doing microbial analysis, which is really cool. The microbial analysis is my baby; I'm spearheading that part of the project. I like that you can look at all the information from many perspectives—chemical, microbial, physical, and so on.

I decided I wanted to be an engineer when I was in fourth grade. I like the human impact of engineering. Science is very truth oriented, but engineering is more people oriented. After Northwestern, I plan to work at a consulting firm so I can broaden my skill set, and then I hope to join an environmental firm that focuses on water resources.

Photograph by Chris Strong

ALZHEIMER'S DISEASE. MIMICKING NATURE TO COMBAT THE EFFECTS.

JOSEPH DRAUT

CHEMICAL ENGINEERING

I wanted do research from the day I stepped onto campus. Professor Josh Leonard's Laboratory for Cellular Devices and Biomolecular Engineering was my number one choice. Last fall, he said that MD/PhD candidate Patrick Donahue had a synthetic biology project that would be a great fit for me.

We're attempting to design a synthetic gene circuit that can drive cells to a particular neuronal cell type. Current methods are pretty much like throwing proteins at the cell and hoping they do what you want. If we can fine-tune the gene circuit in the lab to mimic the differentiation pathways found in nature, we'll get a higher purity yield of the target cells.

The decline in the population of this type of neuron has been closely associated with the onset of Alzheimer's disease, and restoration of this neuron population in mice was sufficient to relieve the effects of the disease. The data thus far indicates that if we're able to restore this population of neurons with high purity and efficiency, we'll be able to combat the effects of Alzheimer's.

I enjoy the sense of being on the front line of these new discoveries and applications. I often find myself thinking that if this works, or even if it doesn't, the discoveries we make here will push forward the frontier of research and our ability to help people. Biology has always interested me, and the idea of taking what we see in nature and recreating it for our own therapeutic purposes really appeals to me. To do that in a way that can help people is incredible.

During the summer, you have so much more time to actually work on research projects because you don't have classes or other obligations. The progress I made during those three months is probably equivalent to, if not greater than, everything I did during the school year.

One of the main things I've taken away from this experience is a sense of independence in solving problems and testing the solutions on my own. Working with Professor Leonard has helped me to see where I want to go after Northwestern. I hope to do graduate work in synthetic biology, and laying the groundwork now will be very useful.

"ONE OF THE MAIN THINGS I'VE TAKEN AWAY FROM THIS EXPERIENCE IS A SENSE OF INDEPENDENCE IN SOLVING PROBLEMS AND TESTING THE SOLUTIONS ON MY OWN."

Photograph by Chris Strong


DESIGN
WRITE A REVIEW
DESIGN for

MAKING CITIES MORE ACCESSIBLE WITH HUMAN-CENTERED DESIGN

NORTHWESTERN'S 2017 DESIGN FOR AMERICA LEADERSHIP STUDIO CHALLENGES 105 STUDENTS TO CREATE SOLUTIONS INSPIRED BY THE DIFFICULTIES COMMUNITY MEMBERS FACE.

A grassroots, student-led network, DFA began at Northwestern in 2009 and has spread across the nation to 37 universities, including Stanford, Massachusetts Institute of Technology, Carnegie Mellon, and Yale. More than 1,300 students are now involved with the organization, where they assess social challenges using a human-centered design process and work collaboratively to implement solutions.

For Octra Edwards, the simple act of grocery shopping can present frustrating challenges.

"Often, the items I need aren't at a level where I can reach them," says Edwards, who navigates the aisles in a wheelchair. "And then, people sometimes overlook me when I need help because I'm down lower. I can sit there for a long time just trying to get help."

Although wheelchair ramps and accessible restrooms have become more prevalent than ever, America's cities still have a long way to go to becoming welcoming and safer to people with diverse accessibility needs. By sharing her story with students at the eighth annual Design for America (DFA) Leadership Studio, Edwards hopes her struggles will highlight some of the more overlooked needs and spark new solutions.

Held the first weekend of August on Northwestern's Evanston campus, the 2017 Leadership Studio welcomed 105 students from 33 universities to learn about design, social innovation, and creative leadership. Sponsored by 3M, The James Dyson Foundation, Shure, and Sodexo, the event challenged students to use design innovation for social good by developing solutions that could improve accessibility in urban areas.

After meeting and talking with several community members, including Edwards, Leadership Studio participants brainstormed and prototyped accessibility solutions in a two-day design sprint challenge. The sprint culminated in a Project Expo, where teams presented their solutions to an audience of community members, business professionals, design experts, Northwestern faculty members, and DFA staff and alumni.

Inspired by Edwards's story, one team presented Vertishelf, an organization method that brings items on stores' top shelves within reach. "If you're in a chair, reaching items on the top shelf is really impossible," says Lydia Krauss, a junior at Rensselaer Polytechnic Institute. "We developed a simple solution that makes items more accessible to all types of users."

Instead of organizing items horizontally on shelves, Vertishelf displays items vertically. In a typical store, for example, one shelf might hold only milk, another yogurt, and a third cream. Using the Vertishelf method, the students proposed placing a number of cartons of milk, yogurt, and cream on all three shelves.

"It's just rearranging what they already have, so stores don't need to invest in new hardware," Krauss says. "Whether you're seven feet tall, five feet tall, or sitting in a chair, you can reach one of everything easily."

Another team presented a new art immersion experience designed for people who are seeing or hearing impaired. Their proposed gallery, called Enhance, included multi-sensory experiences, featuring more audio and tactile pieces.

"One community member with seeing impairment told us she can't experience art galleries as well as fully-sighted people," says Lilie Bahrami, a sophomore at the University of Colorado Boulder. "She said even if she uses an audio-guided tour, it doesn't add to her experience. She could listen to that from her couch and have the same experience."

Other DFA projects to improve urban accessibility included:

RUMPLE
A bumpy barrier between the crosswalk and street for people with visual impairments

LEANING LIGHT
A light that people in wheelchairs can illuminate to let an approaching bus driver know they will need the boarding ramp

XS
A crowd-sourced, online platform that holds accessibility information about public places to help people with disabilities know what to expect

KNIGHTWATCH
A wearable device that alerts people with hearing impairments to potential threats, such as oncoming traffic, in their immediate surroundings

MOBILE MARKETS
A traveling store that brings fresh, local foods to users and that has trained staff to carry groceries for shoppers

AMANDA MORRIS


Northwestern | DESIGN INNOVATION
SEGAL DESIGN INSTITUTE at the McCORMICK SCHOOL OF ENGINEERING
DF
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DESIGN for AMERICA
DESIGN for AMERICA
DESIGN for AMERICA

SOLVING GLOBAL PROBLEMS WITH ENGINEERING

MEMBERS OF NORTHWESTERN'S CHAPTER OF ENGINEERS WITHOUT BORDERS USA TAKE ITS COMMITMENT TO SOLVE THE WORLD'S MOST PRESSING PROBLEMS PERSONALLY.

Although landlocked, Los Llanos, Guatemala has become like an island. Located just 19 miles south of the country's capital, the village has become virtually inaccessible thanks to deteriorating roads and a mammoth, 50-foot-deep ravine.

"The ravine has isolated Los Llanos from commerce, travel, and trade," says Northwestern Engineering senior Jacob Morgan, president of the University's chapter of Engineers Without Borders (EWB-NU). True to the organization's mission, EWB-NU students are working with village community members to build a vehicular bridge that will reconnect Los Llanos with the rest of the world.

COLLABORATING TO EMPOWER COMMUNITIES

Founded in 2001, Engineers Without Borders USA is a national organization that pairs groups of students and professional engineers with communities, many in the developing world, to pinpoint their needs and implement engineering solutions that improve lives. Northwestern's chapter, which began with a small group of students in 2013, has since grown to 30 members, 25 of whom are engineers.

"We do a lot of research to identify underlying needs," Morgan says. "We meet with community members in churches and in their homes and work with them on solutions. We want to make community members feel happy and empowered when we leave."

Morgan notes that mistakes made by others in the past have reinforced the wisdom of adopting this collaborative strategy. As an example, he recalls that another organization, having observed the women of an African town walk two miles to fetch water, built a water pump in the town's center. When the organization's well-intentioned members returned a year later, they discovered that the pump had gone unused.

"What they didn't know was that women used their long walks as a way to talk and build community," Morgan says. "That time was important for the women, and its value had gone completely unnoticed by the organization."

Learning from the experiences of others, EWB-NU has accepted the challenge of applying its signature community-minded approach to the bridge project in Guatemala with guidance from David Corr, clinical professor of civil and environmental engineering. A team of students will make its first visit in December to assess the ravine and determine the optimal location for the bridge to best meet the community's needs.

PERSISTENCE PAYS OFF

EWB-NU launched its first—and ongoing—project in Kenya. The group has made five trips to Kimuka, a small Maasai village just outside Nairobi, to work on a clean water project. Prior to the group's involvement, villagers drank and used water from small ponds in which animals also bathed.

> "WHAT WE DO MATTERS, AND THE COMMUNITIES HOLD US TO OUR PROMISES. IT'S A LOT OF PRESSURE TO HAVE THAT KIND OF RESPONSIBILITY, BUT IT'S SATISFYING TO DESIGN LASTING SOLUTIONS."
>
> **JACOB MORGAN**
> PRESIDENT OF ENGINEERS WITHOUT BORDERS

During their first assessment trip, students tested the water and discovered E. coli and other types of coliform contamination. Up to 60 percent of the village children require monthly doctor visits as a result of ingesting these potentially deadly bacteria.

Not only is the water dangerously contaminated, it's in a remote location. Families often travel up to three kilometers each day just to reach these small ponds formed by surface run-off and rainwater.

Three years ago, to help alleviate the problem, the Northwestern team implemented a water pump, which they quickly realized only introduced new complications. The pump lacked the power required to extract water from a three-kilometer-deep well. When the team installed a booster pump to solve that problem, the cost of water quintupled, making it unaffordable for community use on a regular basis.

"The pump used too much energy," Morgan says. "That not only could cause the pipe to burst, but it's also very wasteful. As engineers, we want to create a solution that will be cost-effective and sustainable for many years to come."

Subsequently, the team met with the community water committee, electricity company Kenya Power, and other individuals to gain a more comprehensive understanding of the problem. Then they put their engineering skills to work.

They ran new calculations to find the exact pressure the pipe could handle, the amount of electricity it could draw, how quickly it could fill the tank, and how best to reduce costs. When the team returns over spring break in March, it will continue to work on an optimal solution.

"I'm proud of what our team has done," Morgan says. "We will expand the system as we go—one step at a time."

CLOSER TO HOME

Although it might take several more years to complete the bridge in Guatemala and to fully perfect the water pump in Kenya, EWB-NU is actively working to fulfill other goals closer to home. Group members participate in a mentorship program with Chicago Public Schools, making weekly visits to Frank W. Reilly Elementary School to discuss science and international aid.

This year, EWB-NU helped the school's students design cities for the Chicago Future City Competition. Two of the teams won special awards for best education enhancement, excellence in mobility technology, and water resources.

Morgan believes all the hard work—on campus and beyond—is worth it. "It's amazing to see the connection between our work and improving lives," he says. "What we do matters, and the communities hold us to our promises. It's a lot of pressure to have that kind of responsibility, but it's satisfying to design lasting solutions."

AMANDA MORRIS

STARTUPS ENJOYING SUSTAINABLE GROWTH

Northwestern Engineering alumni entrepreneurs are changing the way the world builds batteries, transports gases, ships produce, and manages natural resources by bringing to market innovative green technologies that took root in the University's research labs and classrooms. *Northwestern Engineering* reached out to the leaders of four sustainability-focused, alumni-founded startups to learn about their latest successes and future plans.

Image courtesy of NuMat Technologies

Hazel Technologies Founded: 2015

THE ALUMNI

Patrick Flynn (computer engineering '15), chief marketing officer

Amy Garber (MS Law '15, Kellogg Executive Certificate '15), chief intellectual property officer

Aidan Mouat (PhD chemistry '16), co-founder and chief executive officer

Adam Preslar (PhD chemistry '15, Kellogg Management Certificate for Scientists and Engineers '15), co-founder and chief operating officer

THE BUSINESS Hazel Technologies' biodegradable produce carton inserts, FruitBrite™ and BerryBrite™, use smart biotechnology to maintain freshness and extend the shelf life of fruits and vegetables.

THE START Hazel Technologies grew out of NUvention: Energy, a course offered by the Farley Center for Entrepreneurship and Innovation in which interdisciplinary student teams work to launch startups in the sustainable energy and clean technology space. During the course, the team spoke with food distributors and retailers to learn what happens when produce spoils. Motivated to develop an environmentally friendly solution, the team created a prototype for FruitBrite—a small pod placed in shipping containers that releases natural biomaterials into the air to inhibit ethylene, a hormone in fruits and vegetables that spurs ripening. The team found that its solution helped keep produce fresh up to three weeks longer than other current technologies.

PREVIOUSLY After initial product testing in early 2016, the team earned a $100,000 Phase 1 Small Business Innovation Research (SBIR) grant from the United States Department of Agriculture and the $500,000 top prize from the Clean Energy Trust at its 2016 Clean Energy Challenge.

THE LATEST In June 2017, Hazel Technologies announced a partnership with Dresick Farms, the ninth largest fruit grower by acreage in California, to include FruitBrite in all of its honeydew, cantaloupe, and mixed melon containers exported to Asia. With an expanding customer base that includes produce growers in Florida, Washington, and California and anticipating an even more robust 2018, the team plans to add new staff, launch new test trials, and scale production in the coming months.

SiNode Systems Founded: 2012

THE ALUMNI

Cary Hayner (PhD chemical and biological engineering '17), co-founder and chief technology officer

Joshua Lau (materials science and engineering '12), co-founder and vice president for product development

Samir Mayekar (BA '06, KSM MBA '13), co-founder and chief executive officer

Nishit Mehta (KSM MBA '13), co-founder and former vice president of business development

Thomas Yu (materials science and engineering '11, graduate student in materials science and engineering), co-founder

Guy Peterson (MBA, MEM '13), co-founder and former vice president of business development

THE BUSINESS Using its proprietary silicon-graphene composites, SiNode Systems is building a longer-lasting, faster-charging alternative to traditional lithium-ion batteries, which have plateaued in effectiveness while consumer demand for on-the-go electronics continues to grow.

THE START SiNode Systems spun out of the Farley Center's NUvention: Energy course in 2011 after the team acquired the licensing rights to advancements in next-generation lithium-ion batteries made in the labs of Harold Kung, Walter P. Murphy Professor of Chemical and Biological Engineering, and Jiaxing Haung, professor of materials science and engineering. The professors had developed battery anodes made of silicon nanoparticles and graphene that produced higher cell-level density to house more power than standard silicon-based anodes. Their unique design also allowed lithium ions to enter more quickly through tiny holes in the anode, shortening a battery's charging time.

PREVIOUSLY In 2013, the team was chosen to ring the NASDAQ closing bell in recognition of winning the Rice Business Plan Competition. In 2016, Hayner was named to *Forbes* "30 Under 30: Energy" for helping lead the startup's efforts to build better batteries.

THE LATEST A recipient of the 2017 Sustainable Practice Impact Award from VentureWell, the SiNode Systems team is developing advanced battery materials for target markets, including the company's first product for the consumer device space. In addition, the company won a $4 million contract from the United States Advanced Battery Consortium to develop advanced anode materials for automotive lithium-ion battery applications, which could help accelerate growth in the electric vehicle industry.

THE TEAM

Omar Farha (research professor of chemistry), co-founder and chief science officer

Ben Hernandez (industrial engineering '06, JD-MBA '13), co-founder and chief executive officer

Chris Wilmer (PhD chemical and biological engineering '13), co-founder and advisory board member

NuMat Technologies Founded: 2013

THE BUSINESS Innovating at the intersection of big data, predictive analytics, and chemistry, NuMat Technologies designs and builds atomically engineered systems that harvest, store, and deliver high-value resources. The startup is the first to commercialize a new class of nanomaterials called metal-organic frameworks (MOFs), which are programmed at the atomic level to interact with gases, chemicals, and liquids. NuMat's fully engineered products that integrate MOFs are disrupting the $500 billion gas industry by removing the need to highly compress gases.

THE START As a PhD candidate in the lab of Professor Randall Q. Snurr, Wilmer developed proprietary software algorithms that could design and predict the performance of MOFs. After collaborating with Farha to synthesize and validate the ultra-high performing nanomaterials in the lab, the two met Hernandez, then a JD-MBA graduate student interested in starting a business based on Northwestern innovations. The trio forged a bond and soon began what would become NuMat.

PREVIOUSLY NuMat received $300,000 and the Emerging Growth Award at the Clean Energy Trust's 2015 Clean Energy Challenge.

THE LATEST NuMat has strengthened its core computational and synthetic capabilities while forward integrating to fully design and build engineered hardware systems enabled by MOFs. In addition to being named one of "10 Startups to Watch" in 2016 by *Chemical & Engineering News*, the company announced a global partnership with The Linde Group, the world's largest industrial gas company, to develop next-generation separation and storage technologies using NuMat's foundational technology. In July 2017, the company established a commercial alliance with Versum Materials to distribute and sell ION-X, a compressionless gas storage system that safely stores and delivers electronic gases for semiconductor manufacturers.

THE ALUMNI

Alex Grant (MS chemical engineering '17), co-founder and director of engineering

David Snydacker (PhD materials science and engineering '16), co-founder and chief executive officer

Lilac Solutions Founded: 2016

THE BUSINESS Lithium is in high demand as an essential material for high-energy batteries used in portable electronics and electric vehicles. Conventional lithium mining processes require large evaporation ponds and long processing times to extract the material from salt brines. Even then, only approximately 40 percent of the available lithium is recoverable. Lilac Solutions' ion exchange technology uses unique materials to selectively absorb lithium from a brine and then release it at high concentrations, increasing the accessible supply of lithium and mitigating the environmental impact of its production.

THE START As a PhD student, Snydacker partnered with colleagues in Professor Christopher Wolverton's research group to search for new materials that could improve current lithium extraction processes. Using Wolverton's existing Open Quantum Materials Database, Snydacker identified 13 potential new materials for ion exchange that could extract lithium faster at a higher concentration and with a smaller carbon footprint.

PREVIOUSLY Lilac Solutions won $15,000 in the Green Energy + Sustainability track at the 2016 Northwestern Venture Challenge. The team also earned a Phase 1 Small Business Innovation Research (SBIR) grant from the US Department of Energy to expand the company's portfolio of ion exchange materials for lithium extraction.

THE LATEST Lilac Solutions is working with developers of North American brine projects to access a vast new source of lithium. In June 2017, the startup completed a demo-scale manufacturing process with its unique ion exchange beads, which generated new angel investments. The team believes that the company's recent success will stimulate increased interest from investors in the battery and natural resource industries, as well as the acquisition of new customers and pilot projects.

Written by Alex Gerage

ASPIRING ENGINEERS EXPLORE SUSTAINABILITY IN GERMANY

Northwestern University students and company leaders in the Junker-Filter factory, near Heidelberg, Germany. The textile filtration company makes renewable energy and water conservation a priority in its manufacturing processes.

Would your career trajectory have changed if, at age 19, you could have discussed cutting-edge technology, innovative efforts in sustainability, and career opportunities with the head of a multinational corporation in a country widely recognized for its global leadership in sustainability?

That's exactly the experience that 15 Northwestern Engineering rising sophomores had in September 2017 in Heidelberg, Germany as part of the inaugural Global Engineering Trek in Sustainability. The trek focused on giving young engineers first-hand exposure to international companies, non-governmental organizations, entrepreneurs, and universities that have taken the lead in developing sustainable solutions to everything from energy production and urban infrastructure to manufacturing and carbon science.

"In Germany, we saw how government incentives and the general culture of the population help incentivize and make it economically viable to make big investments and changes in favor of sustainability," says Andre Schweizer, an industrial engineering major.

Created jointly by McCormick Global Initiatives and the Institute for Sustainability and Energy at Northwestern (ISEN), the trek is tailored to rising sophomores. Because these students still have several years of study remaining, the program could affect the direction of their studies.

"It was clear that we needed a new program of this sort," says Matthew Grayson, director of McCormick Global Initiatives, associate professor of electrical engineering and computer science, and one of the trip's leaders. "One that could inspire our youngest engineers with international opportunities that would enrich their remaining three years at Northwestern, and launch their career as future global leaders in engineering."

During the inaugural trek, site visits to renewable energy facilities, like wind and solar farms, and tours of green chemistry factories showed students potential future applications of their engineering degrees. "I realized what an issue energy storage is for renewables," says Tess Russell, an environmental engineering major. "It made me more confident in choosing my major because I know this is a problem I want to work on in the future."

The trip was made possible in large part by funding from the Murphy Society. Based on the first year's success, the program will continue in 2018 with past student participants taking on leadership roles.

MORGAN LEVEY

Graduate student at Northwestern's Medill School of Journalism and embedded reporter on the Global Engineering Trek in Sustainability.

CLASS NOTES

"McCormick was always consistent in educating technically competent engineers. The school also taught us how to write, present, and collaborate, all skills I'm applying regularly today."

BRIGHT, YOUNG, AND MAKING AN IMPACT.

Alum **Beth Carter** ('08) earns a spot on the American Institute of Chemical Engineers' inaugural 35 Under 35 list.

Not even a decade removed from her studies at Northwestern University, Beth Carter has firmly established her presence in the chemical engineering field. In August 2017, the American Institute of Chemical Engineers (AIChE) announced it had named Carter among the recipients of its first 35 Under 35 Award, which salutes the industry's brightest young minds.

As a lead development specialist in the Refining Development Group at Honeywell UOP, Carter heads R&D teams cultivating novel process, equipment, and catalyst technology solutions in oil refining. According to Carter, it's an opportunity to address real customer needs with innovative technologies, such as a new process that will replace sulfuric acid and hydrofluoric acid with an ionic liquid catalyst to bring heightened efficiency and environmental value to the current petroleum refining process.

Northwestern Engineering interviewed Carter to get more insight into her career since graduation and what the award means to her.

How did you react when you learned about the AIChE award?

I was excited. People often receive awards at the end of their careers when they have a long laundry list of accomplishments. I didn't think that was me, but receiving the award helped me realize that I've had a real impact on energy technology development.

What do you most enjoy about your work at UOP?

I enjoy working with a diverse team of really smart people. Plus, UOP has the resources for tech development—pilot plant, analytical capabilities, process design, commercialization resources, and more—that allow us to bring impactful technologies to market.

Did you always have engineering on your career radar?

I decided to become an engineer largely to avoid having to do a lot of writing. I learned in my first-year Design Thinking and Communication course that wouldn't be the case. McCormick was always consistent in educating technically competent engineers. The school also taught us how to write, present, and collaborate, all skills I'm applying regularly today.

What experiences and people at Northwestern propelled you to where you are today?

I got my job at UOP through Northwestern adjunct professor Gavin Towler. I met him my freshman year, and he helped me land an internship with UOP that summer. He showed me the possibilities of a career in chemical engineering and how it could lead to having an impact on the world.

Northwestern also gave me an opportunity to get involved in novel projects like the autonomous robot competition. Sometimes it's hard to be a young engineer. People tend to think that the good engineers all have gray hair. That competition taught me that it's not the gray hair, but rather the approach to problem-solving and bringing ideas to life that makes an engineer successful.

DANIEL P. SMITH

Intellectual Curiosity and the Well-Trained Mind

PROBLEM-SOLVING AND CRITICAL THINKING SKILLS LEARNED AT NORTHWESTERN HAVE POWERED UNION PACIFIC'S **RHONDA S. FERGUSON** ('91) TO CAREER HEIGHTS PREVIOUSLY UNIMAGINED.

For Rhonda S. Ferguson, her position as executive vice president and chief legal officer at Union Pacific Railroad provides a rare opportunity to serve in a historic company that remains an integral part of the American economy today.

Connecting 23 western states by rail, Union Pacific provides a critical link in the global supply chain. "Everything goes through our logistics channel, whether it's housing, automobiles, chemicals, industrial products, or food," Ferguson says. "The work done by the men and women of Union Pacific directly impacts every industry in the United States."

Ferguson joined the $20 billion enterprise in 2016 after an executive recruiter approached her about a position at the company's Omaha, Nebraska, headquarters. She initially dismissed the idea of leaving her hometown of Cleveland, where she had built a 20-year career in litigation and corporate law. Nonetheless, she discussed it with her husband, and they decided it couldn't hurt to hear more about the company.

Ferguson met the Union Pacific team in Omaha and immediately fell in love with the company's family-like culture. "Never say never," she laughs. "It's the best job I've ever had, and I've had a lot of wonderful opportunities. It's the culmination of everything I've done that has prepared me for this role, at this company, at this time in my life."

Prior to joining Union Pacific, Ferguson served nearly a decade as vice president, corporate secretary, and chief ethics officer at FirstEnergy, where she learned important leadership skills. "I was responsible for several large teams, which was challenging but very rewarding," she says. "It was a sweet spot for me."

Earlier in her career, she served as assistant general counsel and assistant corporate secretary at Ferro Corporation, and before entering corporate law, she was a partner at BakerHostetler LLP and a litigation associate at Thompson Hine LLP. She earned her juris doctor degree from Case Western Reserve University.

Throughout her career, Ferguson has used the industrial engineering approach to problem-solving that she honed at Northwestern. A committed lifelong learner, Ferguson says, "Engineering pushes you to think critically. That intellectual curiosity drives you to find creative and innovative ways to do things that you never imagined you would do."

She remembers her time at Northwestern fondly and stays in touch. In 2016, she participated in a panel discussion hosted on campus by the National Society of Black Engineers, an organization that has served as a vital support network for her. The first in her family to graduate from college, Ferguson's experience and success helped persuade her sister Rita Beckford ('94) and daughter Kristen Ferguson ('20) to pursue Northwestern Engineering degrees.

"I attribute the vast majority of my career success to the education and strong foundation I acquired at Northwestern," she says. "The University opened doors and allowed me to have a career beyond my wildest imagination."

SARA LANGEN

Head in the

When Narinder Singh co-founded cloud consultancy company Appirio in 2006, the startup was just "four guys in a room building something." A decade and 1,200 employees later, Appirio is a global leader in helping brands such as eBay, Facebook, Coca-Cola, and L'Oréal maximize the business potential of innovation through mobile and cloud technology.

But international success wasn't Singh's main focus during the 10 years leading up to Appirio's $500 million acquisition by Wipro in 2016. The entrepreneur and engineer was devoted to building the company one goal at a time.

"We didn't have a long-term master plan—we had goals for next week, next month, next year. We deconstructed each phase as a problem and worked on it," he remembers. "We had a big vision, but day to day we didn't focus on creating a really big company."

Staying focused on "building" is what helped the company succeed, Singh says. It's an approach he learned at Northwestern. "In engineering, you're basically trying to take things apart, figure out the concepts, and then construct a solution," he explains. "That core framing came in handy again and again in my career."

An obsession with technology

An engineer with a desire to be more than "just a techie," Singh started his career in 1995 in the San Francisco Bay Area writing code at Accenture's Center for Strategic Technology. He planned to apply to law school, but the possibilities opening up at the epicenter of Internet development were too enticing to leave. "By then, I was obsessed with technology," he recalls.

Instead of going to law school, Singh joined the startup webMethods (now Software AG), where he led new product creation as vice president and general manager. He developed the niche product webMethods Trading Networks in 2000. It became the most successful new product introduction in the company's history and became the foundation of all of the webMethods business-to-business products.

"It was unexpectedly successful, accounting for about a third of the company's revenue. It was a fantastic rise," Singh says. "We went public, and I thought, 'I'm never going to have to work again,' but then the crash happened."

Having watched the company's stock plummet during the dot-com crash, Singh became determined to understand what had happened. That's when he decided to pursue an MBA at the Wharton School of the University of Pennsylvania.

An engineering mindset

In 2004, his newly minted MBA in hand, Singh moved into management consulting at computer software company SAP in the Office of the CEO's Corporate Strategy Group. There he tackled corporate and competitive strategy, operational efficiency, and organizational effectiveness. The requisite attention to detail suited his engineering sensibilities.

While at SAP, he continued to aid in the growth of the Sikh Coalition, a non-profit he co-founded after the 9/11 tragedy to educate people about and fight discrimination against

“Healthcare is a space that is entrepreneurially interesting, the technology is highly relevant, and if you do it well, you have the opportunity to do some good in the world.”

Clouds

Cloud technology pioneer and Appirio co-founder NARINDER SINGH (’95) has set his sights on revolutionizing how healthcare decisions are made.

the American Sikh community. Singh searched for software solutions to handle fundraising and legal data. When he couldn’t find what he needed, he decided to build it himself using Salesforce, a new software-as-a-service company.

“I basically built a donor management solution tailored to our needs in a day and a half,” he confides. “The ease of creating and deploying it through the Internet instead of installing software was incredible.”

His engineering mindset started kicking in, and Singh became convinced that this model of deploying software over the web was going to become huge. He left SAP in 2006 and co-founded Appirio with friends from webMethods.

“We were focused on what was happening with consumers who were shifting from AOL CDs to using the web for software,” he says. “We knew this was going to happen for businesses, and that it would be transformative.”

Partnering with companies like Salesforce, Google, and Workday, Appirio became a leader in applying cloud and emerging technologies to improve organizations’ processes and create disruptive market solutions. “We pushed forward this concept that enterprises needed to think about cloud technology if they wanted to remain competitive and nimble,” Singh notes.

A never-ending curiosity

While he remained on the Appirio board of directors, Singh left daily operations in 2015 to pursue the next chapter in his ongoing quest to understand how things work from the bottom up, this time focusing on the healthcare industry. To understand the industry better, he earned a master’s degree in translational medicine from a combined program at University of California, Berkeley and University of California, San Francisco. “Healthcare is a space that is entrepreneurially interesting, the technology is highly relevant, and if you do it well, you have the opportunity to do some good in the world,” he says.

Singh is seeking startup and early-stage opportunities to apply techniques like artificial intelligence to medical data to help medical professionals and patients make better decisions. It reminds him of the first time he used his tech skills for a non-engineering subject at Northwestern, when he helped his constitutional law professor, Jerry Goldman, build a legal application for PCs. “Professor Goldman gave me the opportunity to apply my technology skills to something that had ‘nothing’ to do with technology,” he recalls, “and that was a formative experience.”

Goldman, now retired professor emeritus, is proud that he helped the budding entrepreneur find his path. “Narinder went on to accomplish great things, and I’m delighted that I may have contributed in some small way to his development at Northwestern,” Goldman says. “It’s touching for me to know that I had such influence. That is the great gift of my Northwestern experience, and it continues to pay dividends.”

SARA LANGEN

LEARNING TO SUCCEED

ALUM **JOHN STROUP** ('88) APPLIED LESSONS LEARNED FROM HIS UNDERGRADUATE EXPERIENCES TO LEAD HIS COMPANY TO RECORD PERFORMANCE.

"BECAUSE I LEARNED THE FOUNDATIONS OF ENGINEERING AT NORTHWESTERN AND WAS CHALLENGED TO ALWAYS BE AT THE TOP OF MY GAME, I CAN CONVERSE MEANINGFULLY AT ALL LEVELS AND DRIVE THE BUSINESS FORWARD. THAT'S PROVEN TO BE AN UNDENIABLE ADVANTAGE AND A GIFT I'M GLAD I RECEIVED."

As a mechanical engineering undergraduate at Northwestern, John Stroup endured a dynamics course—and in the process, experienced a personal awakening.

Until that point in Stroup's academic life, the Minnesota native admits that classwork had come rather easy. The dynamics course's formidable content coupled with an unapologetically tough professor, however, left Stroup feeling intimidated and unsettled.

"I had to push myself to an entirely new level," he says. "I had no other option." Having survived the dynamics course, Stroup emerged empowered and confident and took with him memories that strengthened his resolve and energized his future.

"That truly was the first time I realized I was capable of achieving more than I thought I could," he says. "There have been times over the past 30 years when I've been similarly challenged to meet a high bar. That dynamics class showed me I could overcome obstacles and exceed my own perceived limits."

A case in point is Stroup's last dozen years as CEO of Belden, a 103-year-old, St. Louis-based company specializing in end-to-end signal transmission solutions. When he arrived at Belden in 2005, about 90 percent of its revenue derived from simple, passive products, like industrial cable. In addition, its service area was confined primarily to the United States and to Western Europe, a region where financial performance had chronically languished in the red.

Stroup quarterbacked Belden's 21st century transformation, expanding its global footprint and its product portfolio into connectivity, networking, and cybersecurity in response to the world's insatiable and ever-growing appetite for data. As a result, Belden's earnings have increased seven-fold since 2005. With more than 8,400 employees worldwide, Belden now serves any entity—from television networks and manufacturing facilities to healthcare institutions, universities, and more—that needs hardware and software solutions to tie its technology together.

To create a more robust, responsive company, Stroup has embraced the realities of an increasingly interconnected, tech-dependent world. "Most people don't know Belden," Stroup says, "but our products are a part of people's everyday lives."

Stroup says that he has leaned on his Northwestern education as he's met the wide-ranging challenges facing him as CEO, from communicating about product development with Belden engineers in Germany to wooing a large broadcast customer in China to strategizing with his company's cybersecurity team in Oregon.

"Because I learned the foundations of engineering at Northwestern and was challenged to always be at the top of my game, I can converse meaningfully at all levels and drive the business forward," Stroup says. "That's proven to be an undeniable advantage and a gift I'm glad I received."

DANIEL P. SMITH

IN MEMORIAM

PROFESSOR EMERITUS ROBERT GEMMELL

Robert Gemmell, professor emeritus of civil and environmental engineering, passed away at age 84 on September 17, 2017. He will be remembered as a devoted teacher and mentor, dedicated researcher, and valued colleague and friend.

Gemmell was an early pioneer for environmentalism. A member of Northwestern's faculty since 1964, he was an expert on water resources and sanitary engineering. He joined Northwestern from Harvard University, where he served as a lecturer and research fellow. He earned his bachelor's and master's degrees in civil engineering from The Ohio State University and his PhD from Harvard University.

During his time at Northwestern, Gemmell led important research in urban wastewater collection and treatment plants. He also directed a wastewater management study for Lake Michigan and drew up guidelines for public utilities planning. Committed to understanding how humans affect the environment, he developed two classes for Northwestern that were first offered in 1973: Simulation Models in Environmental Health Engineering and Environmental Impact Analysis.

A member of the American Society of Civil Engineers, Gemmell became a leading authority in the area of water research. He represented Northwestern on a state-wide committee for the Water Resources Center, served on committees for the American Water Works Association and International Water Resources Association, and participated in the First World Congress on Water Resources. He also served as a consultant for government, industry, and non-profit organizations, including the US Army Corps of Engineers, Argonne National Laboratory's Center for Environmental Quality, and the US Department of Housing and Urban Development.

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Mr. Earl W. Mallick '46
Mr. Gerald W. Simmons '47
Mr. Robert H. Galstan '48
Mr. Raymond G. Kroker '48
Mr. G. Jerome Tabern '48
Mr. John A. Tempka '50
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Mr. Tsung Wei Sze '54
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Mr. Richard C. Fetzer '55
Mr. Stephen W. Coakley, Jr. '56
Mr. Ernest W. Stalder '57, '58
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Mr. Darryl E. Gustafson '59
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Mr. Ralph F. Medcalf, Jr. '62
Mr. Charles Pokorny, III '62
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Mr. Howard Frank '64, '65
Mr. Lawrence W. Hicks '64
Mr. Elliott M. Philofsky '66, '68
Mr. Steven J. Wilson '66
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Mr. Brian E. Monaghan '79
Mr. Paul W. Lentz '01
Mr. Eric Peter Judge '15

WE WILL.

THE CAMPAIGN FOR NORTHWESTERN

Northwestern University launched the multi-year We Will campaign in March 2014. Here are some recent notable gifts to Northwestern Engineering's campaign.

Jennifer Cahill and **Charles Cahill** pledged $100,000 to create the Cahill Family Scholarship Fund to support Northwestern Engineering undergraduate students.

Richard Divine ('74) and **Margaret Divine** made a $250,000 bequest provision to Northwestern Engineering for undergraduate scholarships.

John Ruan Foundation Trust pledged $1 million to establish the Ruan Family Transportation Fund, an endowed fund to support the Transportation Center.

John E. Kranjc ('77) and **Martha C. Kranjc** pledged $100,000 to support Northwestern Engineering.

Erica M. Myers (WCAS '70) and **Scott D. Myers** pledged $100,000 to the Masahiro and Eiko Meshii Fund for Distinguished Teaching.

The **National Academy of Engineering** made a $250,000 contribution in honor of Dean Julio M. Ottino's 2017 Bernard M. Gordon Prize.

The **Shaw Family Supporting Organization** pledged $500,000 to support CS+X at McCormick in partnership with the Weinberg College of Arts and Sciences. CS+X is a cross-disciplinary initiative that creates transformational partnerships between computer science and other fields.

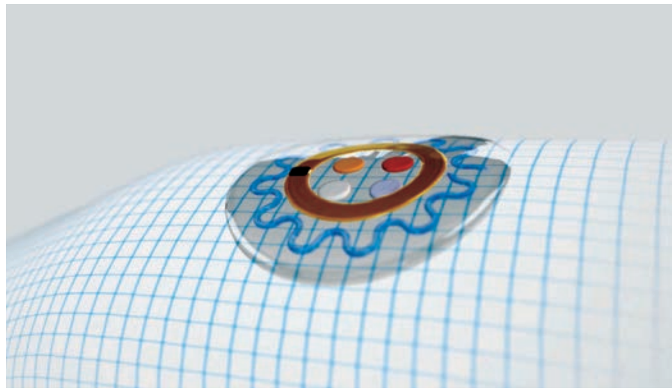
The **Sherman Fairchild Foundation, Inc.** pledged $4.5 million to Professor Monica Olvera de la Cruz's project *Controlled Assembly and Function of Protein-Based Membranes*.

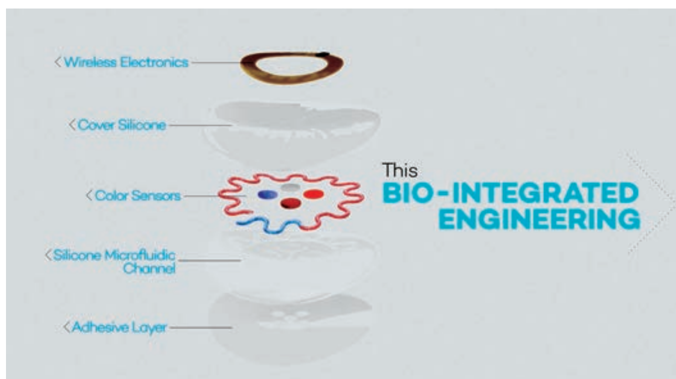
Mary Ellen Van Ness pledged $450,000 to establish three new endowed funds that will support graduate and undergraduate students at Northwestern Engineering in their research and study. The gift honors the memory of James E. Van Ness (MS '51, PhD '54), emeritus professor of electrical engineering and computer science.

Todd M. Warren (WCAS '87) and **Ruth Warren** pledged $500,000 to establish the Todd and Ruth Warren Computer Science Fund to provide postdoctoral fellowship support in computer science and to support the Women in Computing student group.

If you would like to join in making a special gift to the campaign, please contact Patrick Hankey, development director, at 847–467–2950 or patrick.hankey@northwestern.edu.

BIG IDEA





Tech as Art

One of Professor John Rogers's wearable technologies is among the 111 garments and accessories showcased in the Museum of Modern Art's *Items: Is Fashion Modern?* exhibition. The device is a soft, flexible microfluidic system that easily adheres to the skin and measures the wearer's sweat to show how his or her body responds to exercise. Other items in the exhibit, which examines fashion that has made a strong impact on the 20th and 21st centuries, include Levi's 501 jeans, the sari, flip flops, and the little black dress.

Accompanying Rogers's displayed device is a short video (shown in the screenshots on the left) that explains his current research and its future potential to monitor internal body chemistry and even help organs function.

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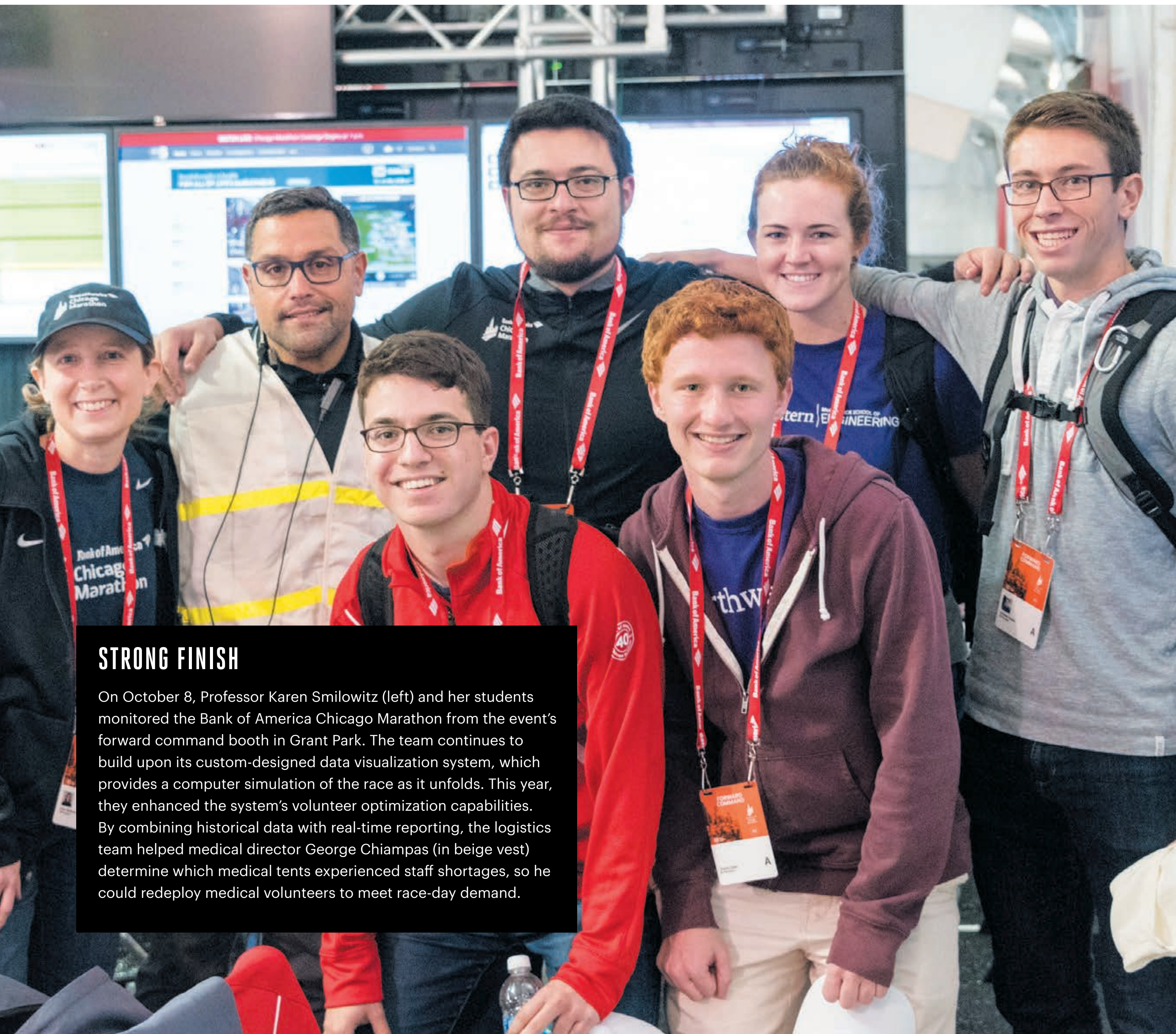

STRONG FINISH

On October 8, Professor Karen Smilowitz (left) and her students monitored the Bank of America Chicago Marathon from the event's forward command booth in Grant Park. The team continues to build upon its custom-designed data visualization system, which provides a computer simulation of the race as it unfolds. This year, they enhanced the system's volunteer optimization capabilities. By combining historical data with real-time reporting, the logistics team helped medical director George Chiampas (in beige vest) determine which medical tents experienced staff shortages, so he could redeploy medical volunteers to meet race-day demand.