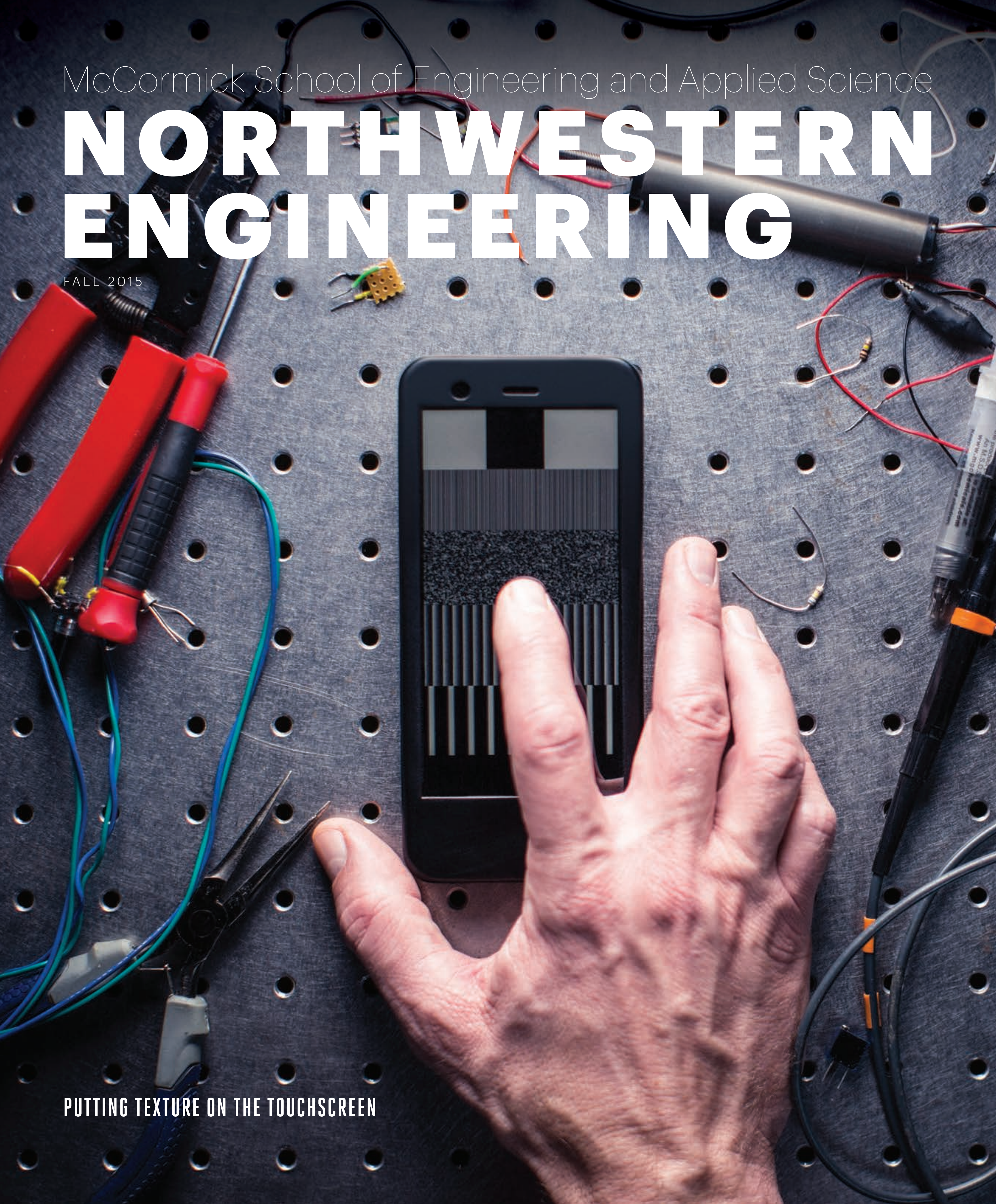
McCormick School of Engineering and Applied Science

NORTHWESTERN ENGINEERING

FALL 2015



PUTTING TEXTURE ON THE TOUCHSCREEN

INTELLIGENT WORKSPACE

Northwestern Professor Larry Birnbaum's Practicum in Intelligent Information Systems course is one of the first classes held in The Garage, Northwestern's new entrepreneurship and collaboration hub. Students work in the open and flexible space—which includes a prototyping area, 3-D printer, and collaboration tools—to plan and build working intelligent systems.

"IN THIS ISSUE WE HAVE ASSEMBLED A BROAD PICTURE OF STAYING POWER AND LONG BETS, OF WHAT'S HAPPENING NOW AND WHAT'S LOOMING ON THE HORIZON. WE SHOW THE VALUE OF LARGE INTERDISCIPLINARY TEAMS AND OF DESIGNING AN ENVIRONMENT FOR THE PERSONAL GROWTH OF OUR MOST VALUABLE ASSET: OUR STUDENTS."

GREETINGS FROM NORTHWESTERN ENGINEERING

How do we tell the story of Northwestern Engineering? Communicating our core values in this magazine is a balance between the big picture and the smallest details, between aesthetics and reader usability, and between stories that will inform and stories that will delight.

Putting it together is a complex design project. Twice a year, my team and I get together and discuss how to best tell our story. We have to balance a multitude of objectives and constituencies: our goals at the school level range from the lofty (conducting research that will help solve global problems and uncover new frontiers) to the personal (making sure each student is prepped for lifelong success). Our audiences spread from our alumni and friends to peer schools and the general public. After all the iterations are finished, the magazine should tell the story of the innovation that is core to the DNA of Northwestern Engineering.

In this issue we have assembled a broad picture of staying power and long bets, of what's happening now and what's looming on the horizon. We show the value of large interdisciplinary teams and of designing an environment for the personal growth of our most valuable asset: our students.

Our cover highlights the work of Ed Colgate and Michael Peshkin, two professors who have become world leaders in the field of haptics, a feedback technology that allows users to interact with the digital world through touch. They are among the most successful entrepreneurs in our school, having successfully launched a number of ventures. Their latest startup, Tanvas, aims to change the way that we use our smartphones and other electronic devices by heightening the sense of touch. They are also part of our broad robotics team that is pushing the boundaries between robotics and biology.

An example of tremendous staying power is the recent success of Naurex, a startup company based on the research of Joe Moskal. Naurex was recently acquired by Allergan, which will continue development of two novel antidepressants. Joe has been working on this research for a remarkable 29 years, and we are tremendously proud of this well-deserved success.

Highlighting the power of large interdisciplinary partnerships, including many departments and other institutions, we focus on one of the greatest practical problems of our time: the search for better batteries. Our faculty are making contributions to new battery technologies that could fundamentally change our transportation and electronics industries.

Lastly, a focus on innovation in education. We get four years (sometimes five, with co-op or internships) and a limited number of action points to design the education of our students and make sure that, when they graduate, they emerge with the best first draft of themselves. This issue features our Office of Personal Development, which is focused on personal growth. We welcome exceptionally high caliber students to Northwestern Engineering, and this is one of many efforts to ensure that we provide a supportive environment that prepares our students to leave here and set the world on fire with their ideas.

As always, I welcome your feedback.

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

On the Cover

Northwestern Engineering researchers are developing new technologies to bring texture to touchscreens on smartphones and other electronics. Read about their work on page 14.

Photograph by Chris Strong

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Northwestern | McCORMICK SCHOOL OF ENGINEERING

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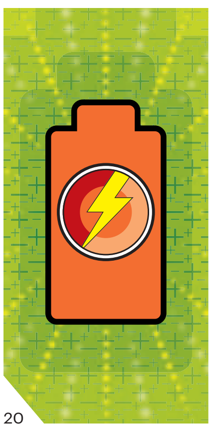
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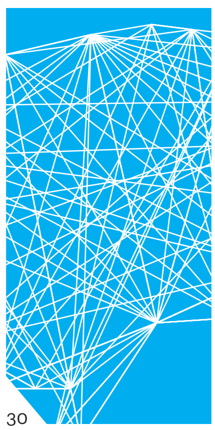
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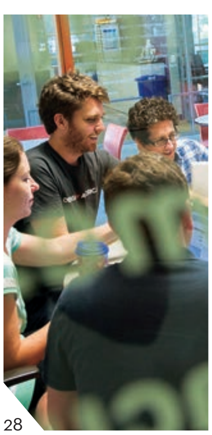
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NORTHWESTERN ENGINEERING
FALL 2015

NEWS

"JOHN'S RESEARCH IS SO INNOVATIVE THAT IT IS ESTABLISHING NEW FIELDS—ITS BREADTH CANNOT BE CAPTURED BY EXISTING NAMES. HIS WORK STRENGTHENS THE CRITICAL AND CREATIVE INTERFACE BETWEEN ENGINEERING AND MEDICINE."

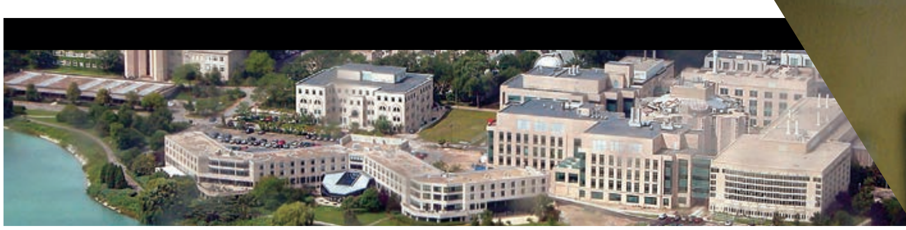
DEAN JULIO M. OTTINO

BIOELECTRONICS PIONEER TO JOIN NORTHWESTERN

John A. Rogers, a materials scientist and pioneer in the field of bio-integrated electronic devices, will join Northwestern in September 2016 as the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering, and Medicine.

Rogers, currently the Swanlund Chair at the University of Illinois Urbana-Champaign, is internationally renowned for designing and developing classes of electronic devices that can bend, stretch, and twist, be integrated with the human body, and have diverse diagnostic and therapeutic functions. His research spans disciplines and exploits novel approaches to problems with the potential to change the fields of industrial, consumer, and biocompatible electronics.

At Northwestern, Rogers will lead the new Center for Bio-Integrated Electronics, which will be housed in the Simpson Querrey Institute for BioNanotechnology in the new Louis A. Simpson and Kimberly K. Querrey Biomedical Research Center on Northwestern's Chicago campus.



NORTHWESTERN AMONG WORLD'S MOST INNOVATIVE UNIVERSITIES

What does it mean to be innovative? Who is the most innovative? *Reuters* recently took on the challenge of finding answers to those tricky questions.

Using a data-based methodology with 10 different metrics, *Reuters*' researchers developed a list of the world's top 100 most innovative universities. Northwestern University ranked sixth.

The rankings used proprietary analysis tools to measure factors such as patent volume and success, research article volume and patent citations, and research collaboration with industry. Northwestern's high ranking was due to its $600 million in annual research funding, recent start-up successes, and numerous patents.

Examples include Naurex, a biopharmaceutical startup spun off from research conducted by biomedical engineering professor Joseph Moskal, which was recently sold to pharmaceutical company Allergan for $560 million (see story on page 34). MAKO Surgical, originally founded by mechanical engineering professor Michael Peshkin, was purchased by Stryker Corp. in 2013 for more than $1.6 billion.

From 2008 to 2013, Northwestern filed 300 patents and was granted 47 percent of those applications. Its commercial impact score (as measured by academic papers cited in patent filings) was 65.5, compared to an average of 54.2. *Reuters* also cited Northwestern's new Garage, an ideas incubator where student entrepreneurs can prototype their ideas.

$8.5 MILLION GRANT FOR DEVELOPING NANO PRINTING TECHNOLOGY

Northwestern received a five-year, $8.5 million grant from the US Department of Defense's competitive Multidisciplinary University Research Initiative program to develop a "4-dimensional printer"—the next generation of printing technology that will print 3-D structures that transform over time. Once developed, the 4-D printer, which operates on the nanoscale, will be used to construct new devices for research in chemistry, materials science, and national defense-related areas that could lead to new chemical and biological sensors, catalysts, microchip designs, and materials designed to respond to specific materials or signals. Professors Chad Mirkin and Milan Mrksich (above) lead the multi-institutional effort.

"THE FUNDING OF THIS PROJECT REPRESENTS A NEW ERA IN HIV PREVENTION RESEARCH AT NORTHWESTERN AND PLACES OUR TEAM AT THE CUTTING EDGE IN BOTH BASIC SCIENCE AND CLINICAL DEVELOPMENT OF HIV PREVENTION AND TREATMENT TECHNOLOGIES."

PATRICK KISER
ASSOCIATE PROFESSOR OF BIOMEDICAL ENGINEERING

NORTHWESTERN RECEIVES $17.5 MILLION FOR HIV RESEARCH

Led by Professors Patrick Kiser and Thomas Hope, an interdisciplinary group of University scientists received a five-year, $17.5 million grant from the National Institutes of Health for a project that aims to invent, develop, and test an implantable drug delivery system to protect high-risk individuals from HIV infection for up to one year at a time.

The Sustained Long-Acting Protection Against HIV program will bring together 15 scientists from 15 departments across the McCormick School of Engineering, Feinberg School of Medicine, and Kellogg School of Management.

Current methods to prevent HIV transmission require behavior modifications that are often not followed. "Long-acting systems have the great advantage of not requiring repeated modification of behavior," Kiser said. "With implants or injectable systems that deliver antiretroviral drugs, a person no longer has to worry about contracting HIV for a relatively long period of time."

In the project's first year, Kiser and Hope will work to invent a new kind of implant that delivers antiretroviral drugs in a controlled way. Specifically, they are interested in a drug called cabotegravir that stops the HIV virus from putting its DNA into a host's genetic material.

JERRY THE BEAR VISITS THE WHITE HOUSE

Sproutel, a startup company founded by alumni Hannah Chung ('12) and Aaron Horowitz ('12), joined 32 other companies at the first-ever White House Demo Day. They introduced President Barack Obama to Jerry the Bear, an interactive teddy bear first developed in 2009 as a project with Design for America. Jerry encourages diabetic children to build healthy behaviors through play. When his fingers are pressed, Jerry makes comments, such as "I feel great!"

Part of an effort to boost racial and gender diversity in the startup scene, Demo Day welcomed companies founded by women and/or underrepresented minorities. Calling the product "fantastic" and "fun," the President, who was celebrating his 54th birthday, pressed Jerry's finger, prompting it to chirp "Happy birthday, Mr. President!" to delighted laughter.

230

Students who participated in Northwestern's Big Data Initiative: Programming Boot Camp to learn the programming skills needed to collect, process, and analyze data.

1,700

nScope backers on Kickstarter.

"LAB IN A BACKPACK" REVITALIZES ELECTRONICS CLASS

Lecturer Nicholas Marchuk and graduate student David Meyer developed the nScope, a small, portable USB-powered device that turns any laptop computer into an electronics workbench. nScope provides an oscilloscope, function generator, and power supply all on a small card—allowing users to build, measure, and test electronics and capture related data on their computers. The popular tool completed a successful run on the crowd-funding site Kickstarter, where it exceeded its $25,000 funding target within days, and ultimately reached $187,000.

HAPTICS RESEARCHERS CONVENE ON CAMPUS

Haptics researchers and students from around the globe converged on Northwestern's campus June 22 to 26, 2015, for the World Haptics Conference. The event offered workshops, presentations, and hands-on demonstrations related to haptics, a tactile feedback technology that allows users to interact with the digital world through touch. With 450 attendees, this year's conference was the best attended in the event's 10-year history. Half of the attendees came from outside the United States, traveling from countries such as Canada, Japan, Korea, Germany, Spain, and Italy.

"IT'S INSPIRING TO SEE SO MANY PEOPLE WHO ARE EXCITED ABOUT HAPTICS IN THE SAME BUILDING TOGETHER. THE INCREASE IN INTEREST FOR THIS YEAR'S CONFERENCE SHOWS THAT THE FIELD IS REALLY GROWING."

ED COLGATE
PROFESSOR OF MECHANICAL ENGINEERING

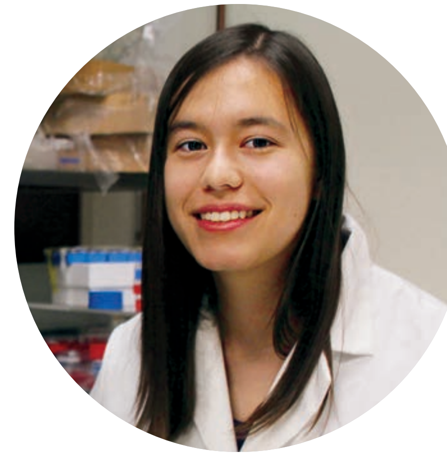
One of the most popular demonstrations focused on Tanvas, a company founded by mechanical engineering professors Ed Colgate, the conference's general chair, and Michael Peshkin. Tanvas is developing a surface technology that allows users to feel what they see on their touchscreens. Earlier this year, the company received a $5 million investment from Chicago venture fund R7 Partners, trading firm Peak6, and Northwestern.

1,000

The number of students now involved in Design for America nationwide.

14

The number of graduate students from Northwestern's Segal Design Institute who took part in a roundtable discussion about the launch of the Apple Watch. The story appeared in the *Chicago Tribune*.



UNDERGRADUATE LEANNE FRIEDRICH WINS GOTAAS AWARD

Materials science undergraduate Leanne Friedrich received Northwestern Engineering's 2015 Harold B. Gotaas Undergraduate Research Award. Her winning project explained the biological structure of the chiton's eyes. Chitons, primitive marine molluscs, have the only lenses in the animal kingdom composed of aragonite. Friedrich posited that insight into the eye's processing, structure, properties, and performance could open new doors for designing bio-inspired materials. She completed her research in professor Derk Joester's laboratory.

FIGHTING CANCER WITH NANOTECHNOLOGY

Northwestern received a five-year, $11.7 million grant from the National Cancer Institute to use nanotechnology to develop next-generation cancer treatments. With this support, the new Northwestern University Center for Cancer Nanotechnology Excellence will use nucleic-acid-based nanoconstructs called spherical nucleic acids (SNAs) to gain access to intracellular environments, discover new aspects of cancer biology, and create effective cancer treatment options. Led by professor Chad Mirkin, a diverse team will work toward developing SNA nanostructures to improve lives of patients suffering from glioblastoma multiforme and prostate cancer.

MUSEUM OF SCIENCE AND INDUSTRY EXHIBITS MATERIALS SCIENCE RESEARCH

Since March 19, the *Materials Science* exhibit, a collaboration with Northwestern's Materials Research Science and Engineering Center, has occupied a gateway space on the lower level of Chicago's Museum of Science and Industry. The exhibit features work from professors Mark Hersam, Lincoln Lauhon, Gregory Olson, and David Seidman.

While one portion of the exhibition reveals how materials shape everyday lives, an adjacent gallery focuses on the field's frontiers and highlights how emerging materials influence the future of electronic technologies. More than one million visitors will have an opportunity to view the exhibit before it closes on January 31, 2016.

BRINSON, BURGHARDT JOIN SENIOR LEADERSHIP TEAM

Effective September 1, 2015, L. Catherine Brinson became Northwestern Engineering's associate dean, and Wesley Burghardt succeeded Stephen Carr as associate dean of undergraduate engineering.

In her newly created position, Brinson, the Jerome B. Cohen Professor of Mechanical Engineering, manages an ever-growing array of new initiatives and focuses on the school's professional master's degree programs. Burghardt, professor of chemical and biological engineering, oversees the undergraduate program, including curriculum and professional and personal development.

4C

Professor Alok Choudhary's data science startup company, which recently bought a European television ad-tracking company to allow the syncing of advertisements across online, mobile, and television platforms.

1,700

Commercial forms of Chad Mirkin's NanoFlares sold in 230 countries.

STUDENTS HACK DATA FOR SOCIAL GOOD

During spring quarter 2015, students in Northwestern Engineering's new Analytics for Social Good course explored the challenges and opportunities of achieving social good in the age of big data. At the end of the course, they participated in a two-day hackathon, where they tackled data from the American Red Cross, seeking to improve a variety of operations for the nonprofit organization.

The winning team developed an algorithm to cull the Red Cross's multiple incoming incident platforms into a single message stream so dispatchers could more easily filter and respond to events. Taught by professor Karen Smilowitz, the course will be offered again this academic year.

Student Design Leaders Tackle Down Syndrome

The sixth annual Design for America Leadership Studio brought together nearly 100 students from 28 universities across the country to develop solutions for people touched by Down syndrome. After attending workshops and interviewing parents and caretakers, student teams used human-centered design to brainstorm solutions. One team introduced a series of care packages delivered to families coping with their baby's diagnosis to provide emotional support and practical resources. Another team pitched a collection of "Me Too!" dolls, modeled after notable individuals with Down syndrome.

"WE WANTED STUDENTS TO EMPHASIZE INCLUSIVITY AND REMOVE THE TABOOS ASSOCIATED WITH DOWN SYNDROME. WE INSTRUCTED THEM TO FOCUS ON PEOPLE'S ABILITIES RATHER THAN DISABILITIES BECAUSE EVERYONE HAS SOMETHING TO OFFER THE COMMUNITY."

SAMI NERENBERG ASSOCIATE DIRECTOR OF DFA

LAB NOTES

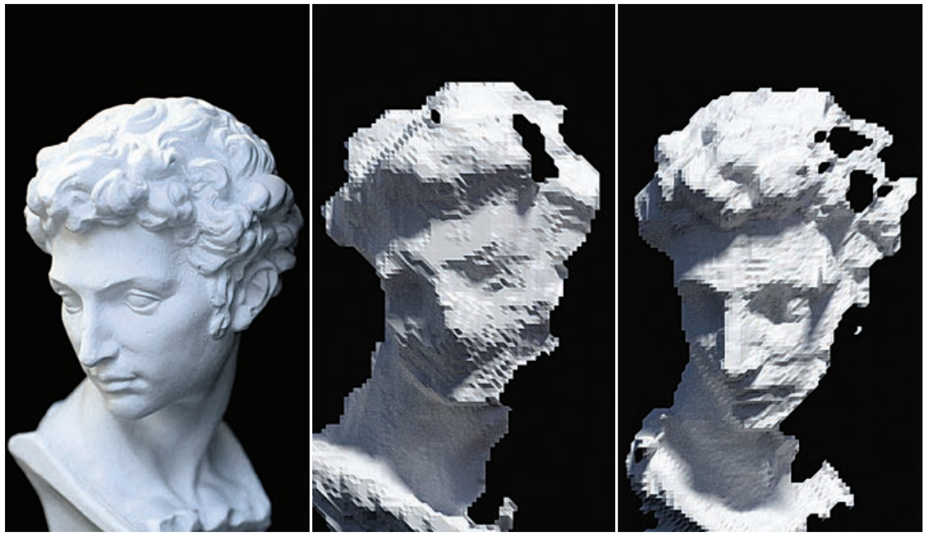


Photo Kinect Cossairt's camera

A Faster, Higher-Quality 3-D Camera

Inspired by the Microsoft Kinect, professor Oliver Cossairt and his team developed an inexpensive 3-D capture camera that produces high-quality images and works in all environments—including outdoors.

Both first- and second-generation Kinect devices project light patterns, which are then sensed and processed to estimate scene depth at each pixel on the sensor. Although these devices work quickly, they are less precise than expensive single-point scanners, which use a laser to scan points across an entire scene or object.

Cossairt's camera uses single-point scanning in a different way. Modeled after the human eye, it scans only the parts of the scenes that have changed, making it much faster and higher quality.

While the Kinect does not work well outdoors—sunlight overpowers its projected light patterns—the laser on Cossairt's camera is much brighter than ambient light. Therefore, it works in sunlight and other everyday, normal environments.

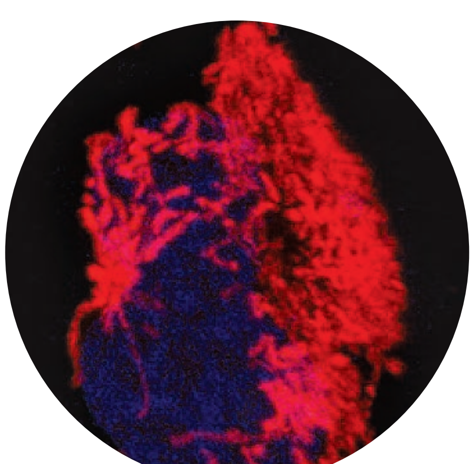
The new camera has many applications in science and industry for devices that rely on 3-D shapes of scenes "in the wild," such as, robotics bioinformatics, augmented reality, and manufacturing automation. It can also be installed on anything from a car to a motorized wheelchair for navigation.

5%

The percentage of youth baseball pitchers who suffer a serious elbow or shoulder injury within their first decade playing the sport. Professor Wendy Murray's motion analysis highlights the bigger role muscles play in injury risk and prevention than previously thought.

4 TO 7

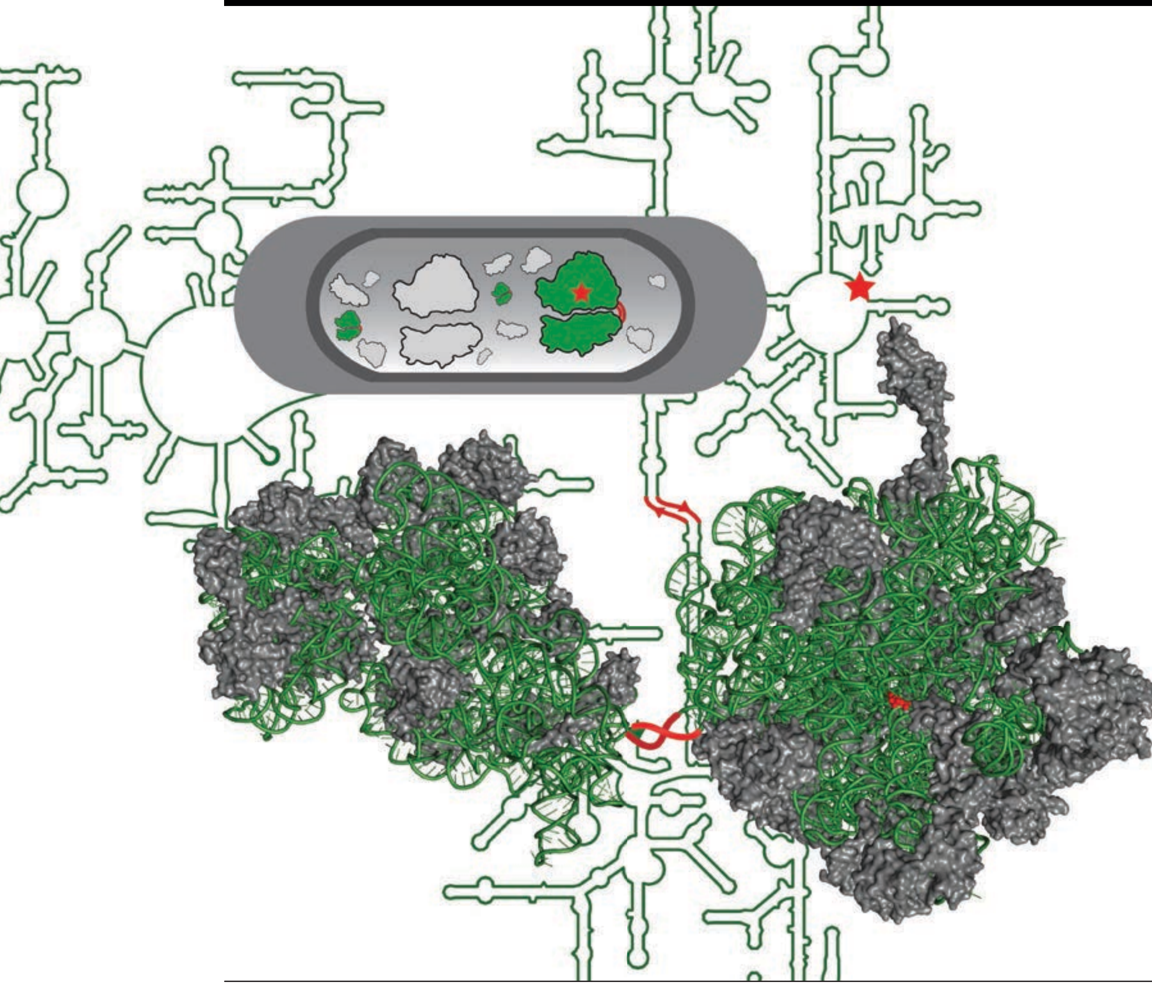
Percent of weight airplanes could lose through 3-D printing, according to professor Eric Masanet's analysis.



NEW TOOL FOR INVESTIGATING RNA GONE AWRY

A new technology developed by professor Chad Mirkin and his team offers the first real-time method to track and observe the dynamics of RNA inside living cells. Called "Sticky-flares," the technology has the potential to help scientists understand the complexities of RNA better than any analytical technique to date. It might also give them a new way to observe and study the biological and medical significance of RNA misregulation, which plays a critical role in the development of many disorders, including autism and cancer.

Sticky-flares enter living cells to target and transfer a fluorescent reporter, or "tracking device," to RNA transcripts. This fluorescent labeling can be tracked using fluorescence microscopy as it is transported throughout the cell.



RESEARCHERS DESIGN FIRST ARTIFICIAL RIBOSOME

Northwestern engineers have developed a tethered ribosome that works nearly as well as the authentic cellular component, or organelle, that produces all the proteins and enzymes within the cell. The engineered ribosome may enable the production of new drugs and next-generation biomaterials and lead to a better understanding of how ribosomes function. No one has ever before developed something of this nature.

The artificial ribosome, called Ribo-T, was created in the laboratories of Northwestern Engineering's Michael Jewett and Alexander Mankin of the University of Illinois at Chicago. Scientists may be able to manipulate the human-made ribosome in the laboratory to function in ways that natural ribosomes cannot. This could include producing unique and functional polymers for exploring ribosome functions, designer therapeutics, or even non-biological polymers.

"OUR NEW PROTEIN-MAKING FACTORY HOLDS PROMISE TO EXPAND THE GENETIC CODE IN A UNIQUE AND TRANSFORMATIVE WAY, PROVIDING EXCITING OPPORTUNITIES FOR SYNTHETIC BIOLOGY AND BIOMOLECULAR ENGINEERING."

MICHAEL JEWETT

ASSOCIATE PROFESSOR OF CHEMICAL AND BIOLOGICAL ENGINEERING

MAKING A CASE FOR CONVERGENT EVOLUTION

Using computer simulations, a robotic fish, and videos of real fish, professors Malcolm MacIver and Neelesh Patankar studied 22 fish species to understand how diverse creatures have evolved to swim with elongated fins using the same mechanical motion that optimizes their speed. The team is among the very few to quantify the mechanical basis for a case of convergent evolution, where similar features evolve in unrelated organisms as adaptations to similar lifestyles and environments. In their study, the researchers found that every species' ratio of undulation length to sideways movement was 20—without a single exception. These findings could help scientists better understand evolution and help pave the way for highly agile underwater vehicles.

SEARCHING FOR LIFE OUTSIDE OUR SOLAR SYSTEM

A Northwestern Engineering team received a $1 million grant from the W.M. Keck Foundation to develop a fast, ultrasensitive camera that could be the first to directly image light reflected by planets outside our solar system. The camera will help scientists in their search for life on Earth-like exoplanets. Professor Hooman Mohseni, who invented the enabling technology, is the principal investigator on the grant.

The researchers will design, create, and test a completely new camera that operates in the near infrared range of the light spectrum, with far better sensitivity and utility than existing light detector technologies. Used on a telescope, such a camera could directly image planets about 100-times fainter than those that can be imaged by current technology.

"The Keck award will push this technology to its limit and a whole new performance level," Mohseni said. "Our very challenging goal is to produce ultra-small structures—as small as a virus—on this bio-inspired detector to get the light sensitivity we need to image planets outside our solar system."

Scientists have discovered nearly 2,000 exoplanets, or extrasolar planets, so far, but because of limitations in imaging systems, most of these have only been detected indirectly. The innovative Northwestern imaging technology—inspired by the light detection mechanism of the rods in the human eye—would be used to image potentially habitable planets and provide new observations to help astronomers better understand how our solar system and other planetary systems developed.

The first imaging target outside our solar system will be Jupiter-sized planets located in the habitable zone. The prototype camera would be combined with other sophisticated technology on the Subaru Telescope in Hawaii, one of the premier imaging telescopes in the world, to directly image these extrasolar gas giants in reflected light.

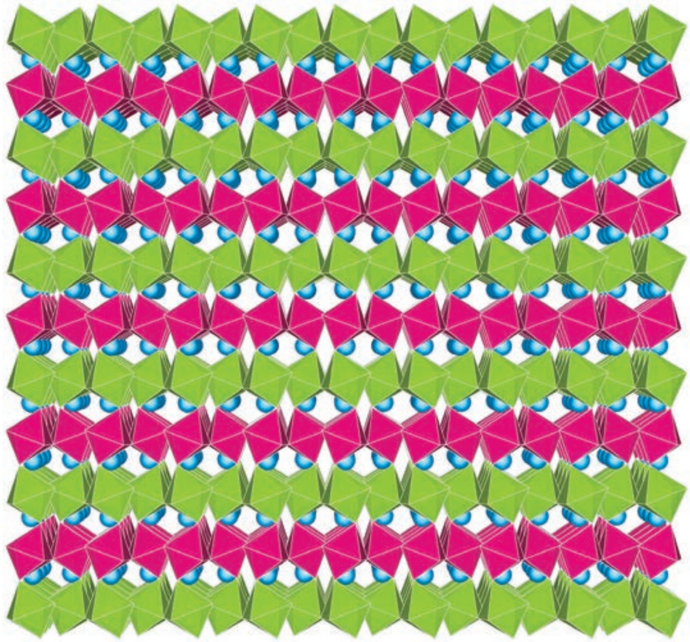
OPTIMIZING SHALE GAS PRODUCTION

Professor Fengqi You is exploring ways to make hydraulic fracturing, or fracking, easier on the environment and the wallet. He designed computational models to analyze the "well-to-wire" life cycle of electricity generated from shale gas. You believes that optimized design and operations for the shale gas supply chain will produce both environmental and economic benefits.

You's models suggest that using a network of pipelines, rather than trucks, to transport freshwater to drilling sites and to transport shale gas to processing and power plants will conserve gasoline and cut exhaust emissions. Another suggestion is to distribute drilling activities evenly over time instead of drilling all at once. This would avoid transporting gas to long-term storage facilities and reduce the amount of water needed at any one time.

2 MONTHS

Energy payback time for perovskite solar panels, according to professor Fengqi You. Current silicon-based panels need two years to return the investment.



SUPERLATTICE DESIGN REALIZES ELUSIVE MULTIFERROIC PROPERTIES

From the spinning disc of a computer's hard drive to the varying current in a transformer, many technological devices work by merging electricity and magnetism. But finding a single material that combines both electric polarizations and magnetizations remains a challenge.

Professor James Rondinelli is interested in combining ferromagnetism and ferroelectricity, which rarely coexist in one material at room temperature. His team used quantum mechanical calculations to study lithium osmate, a metallic oxide with a structural disposition to ferroelectricity, and sandwiched it between an insulating material, lithium niobate.

While lithium osmate is a non-magnetic and non-insulating metal, lithium niobate is insulating and ferroelectric but also non-magnetic. By alternating the two materials, Rondinelli created a superlattice, which at the quantum scale became insulating, ferromagnetic, and ferroelectric at room temperature.

"OUR WORK HAS TURNED THE PARADIGM UPSIDE DOWN."

JAMES RONDINELLI
ASSISTANT PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING

UNUSUAL PIGMENT IN ANCIENT PORTRAITS

Scientists and art conservators from Northwestern Engineering and the Phoebe A. Hearst Museum of Anthropology found that ancient Egyptian artists used the pigment known as Egyptian blue as material for underdrawings and for modulated color in mummy portraits and panel paintings—a finding never before documented. Because it has to be manufactured, blue typically is reserved for very prominent uses, not hidden beneath other colors. The discovery changes scholars' understanding of how this pigment was used in the second century A.D.

Keeping Surfaces Dry Underwater

Northwestern engineers have discovered why certain surfaces can stay dry underwater. A team led by professor Neelesh A. Patankar identified the ideal "roughness" needed in the texture of a surface to keep it dry when submerged in water for a long period. The researchers found that the valleys in the surface roughness typically need to be less than one micron—one millionth of a meter—in width. That's a nanoscopic valley with macroscopic impact.

"The trick is to use rough surfaces of the right chemistry and size to promote vapor formation, which we can use to our advantage," Patankar said. Understanding how surfaces deflect water so well could result in high-value applications to other materials on a mass scale. Possible applications with the potential to generate billions of dollars in savings across a variety of industries range from antifouling surfaces for shipping to pipe coatings with lower drag.

NEW APP SHEDS LIGHT ON PHONE USAGE

Professor Fabián Bustamante and his PhD student John Rula developed Application Time, or AppT, a new smart phone app that enables users to track, monitor, and analyze mobile device usage. The team hypothesized that most people never realize how much time they actually spend on different applications. With better knowledge of their behavior, users could become empowered to control their device dependency.

AppT runs every time the phone's screen is on. Every 1.5 seconds, it records which app is in the foreground. It then displays visualizations to show which apps have been used, how frequently, and for how long. AppT has very low demands and does not run when the screen is off, so it does not drain the phone's battery.

> "UNLOCKING YOUR PHONE TIME AND AGAIN THROUGHOUT THE DAY HAS BECOME A SUBCONSCIOUS HABIT. RECOGNITION IS THE FIRST STEP IN BEHAVIOR CHANGE."

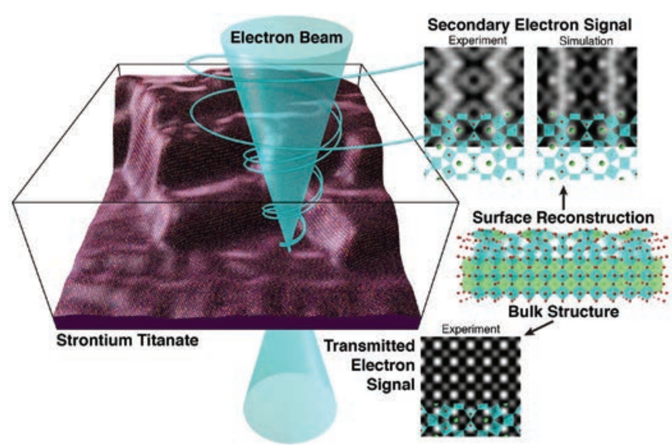
FABIÁN BUSTAMANTE PROFESSOR OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

3-D Printing Aircraft Parts

Professor Eric Masanet has found that using 3-D printing for some metal aircraft parts could reduce manufacturing waste and the weight of the airplane, which in turn would save fuel and money and decrease carbon emissions. Compared to traditional methods, 3-D manufacturing requires far fewer raw material inputs and can produce parts that minimize weight through better design. This could reduce the weight of the aircraft by 4 to 7 percent and fuel consumption by 6.4 percent.

PRINTING GRAPHENE IN 3-D

Northwestern engineers led by professor Ramille Shah developed a novel graphene-based ink that can be used to print large, robust 3-D structures. The fast and efficient method could open up new opportunities for using graphene-printed scaffolds in regenerative engineering and other electronic or medical applications. The ink contains graphene nanoflakes mixed with a biocompatible elastomer and quickly evaporating solvents. At 60 to 70 percent graphene, the ink preserves the material's unique properties, including its electrical conductivity, while remaining flexible enough to print strong macroscopic structures.



NEW WAY TO IMAGE SURFACES ON NANOSCALE

A multi-institutional team has developed a new imaging technique that uses atomic resolution secondary electron images in a quantitative way to determine the arrangement of atoms on the surface. This could give insight into the many important processes that take place at surfaces, including how bridges and airplanes rust.

LEARNING FROM BIOLOGY

Surveying everything from sea cucumbers and Venus flytraps to human muscles and trees, professor Sinan Keten published a review paper in *Nature* in which he broadly explores the strategies that biology employs to create different functions and the mechanics at play within those functions. Discovering how and why biological systems attain desirable static and dynamic mechanical functionalities often reveals principles that inform new synthetic designs.


Sinan Keten


Harold Kung


Michael Peshkin


Michael Jewett


Chad Mirkin


Evan Scott


Zdeněk P. Bažant


Wei Chen


Q. Jane Wang


Vadim Backman


J. Edward Colgate


Kristian Hammond

Faculty Awards

Sinan Keten Receives Navy Young Investigator Award
Keten, assistant professor of mechanical and civil engineering, received the 2015 Young Investigator Award from the Office of Naval Research.

Michael Jewett Receives Camille Dreyfus Teacher-Scholar Award
The national award honors faculty members in the chemical sciences who demonstrate leadership in research and education.

Zdeněk P. Bažant Elected to Royal Society
Bažant, McCormick Institute Professor and Walter P. Murphy Professor of Civil and Environmental Engineering, was one of 10 foreign members and 47 fellows elected to the Royal Society of London.

Vadim Backman Awarded Ver Steeg Research Fellowship
Backman, the Walter Dill Scott Professor of Biomedical Engineering, was named the 10th recipient of the Dorothy Ann and Clarence L. Ver Steeg Distinguished Research Fellowship Award, which supports research and scholarship by a Northwestern professor whose work enhances the school's reputation.

Harold Kung Receives Wilhelm Award
Kung, Walter P. Murphy Professor of Chemical and Biological Engineering, received the 2015 R.H. Wilhelm Award in Chemical Reaction Engineering from the American Institute of Chemical Engineers.

Chad Mirkin Receives Inaugural NAS Prize
Leading nanotechnology researcher Mirkin was awarded the inaugural $400,000 Raymond and Beverly Sackler Prize in Convergence Research from the National Academy of Sciences.

Wei Chen Receives Design Award
Chen, Wilson-Cook Professor in Engineering Design, received the American Society of Mechanical Engineers' 2015 Design Automation Award.

Professors Honored as Entrepreneurs
Mechanical engineering professors J. Edward Colgate and Michael Peshkin were elected to the Chicago Area Entrepreneurship Hall of Fame.

Evan Scott Receives NIH New Innovator Award
The award will support Scott, assistant professor of biomedical engineering, as he develops a combination of immunotherapies for heart disease.

Q. Jane Wang Receives International Award
Wang, professor of mechanical engineering, received the International Award from the Society of Tribologists and Lubrication Engineers, which recognized her contributions to the field.

Kristian Hammond Named Technologist of the Year
Hammond, professor of computer science, was honored by the Illinois Technology Association for championing technological innovation as co-founder of Narrative Science.

CONNOISSEURS O

Photograph by Chris Strong

NORTHWESTERN ENGINEERING RESEARCHERS BREAK THROUGH THE TOUCHSCREEN TECHNOLOGY, PUTTING TACTILE INFORMATION AT USERS' FINGERTIPS. LITERALLY.

F TOUCH

WITH THE RELEASE OF ITS REVOLUTIONARY iPHONE IN 2007, APPLE USHERED IN THE ERA OF MULTI-TOUCH TOUCHSCREENS, ENABLING USERS TO INTERACT WITH THEIR PHONES WITH PINCHES, SWIPES, AND TAPS. DESPITE THE GROWING POPULARITY OF THE UBIQUITOUS TOUCHSCREEN, THERE'S AN UNDENIABLE IRONY ABOUT THE NAME: TOUCHSCREENS DON'T OFFER MUCH OF ANYTHING TO TOUCH.

> **THE TECHNOLOGY SENSES WHERE YOUR FINGER IS, SO IT CAN MODULATE FRICTION IN RESPONSE TO YOUR FINGER'S LOCATION RELATIVE TO WHATEVER IS DISPLAYED VISUALLY.**

"We say 'touch' in 'touchscreen,' but that's only half of touch," says Northwestern Engineering's J. Edward Colgate. "You're telling it something, but it's not telling you much back."

Colgate and his longtime collaborator Michael Peshkin, both professors of mechanical engineering at Northwestern, consider themselves "connoisseurs of touch" and aim to bring tactile feedback to our digital interfaces. They think touchscreens should give you the same physical satisfaction as buttons that click and toggles that snap.

Peshkin points to his 35-year-old HP25 calculator with protruding rectangular buttons and a long, slender display. "You feel those keys and you realize that someone put considerable effort into making them feel efficient," he says. "You know when you've pushed them. People so quickly forget that's something of value."

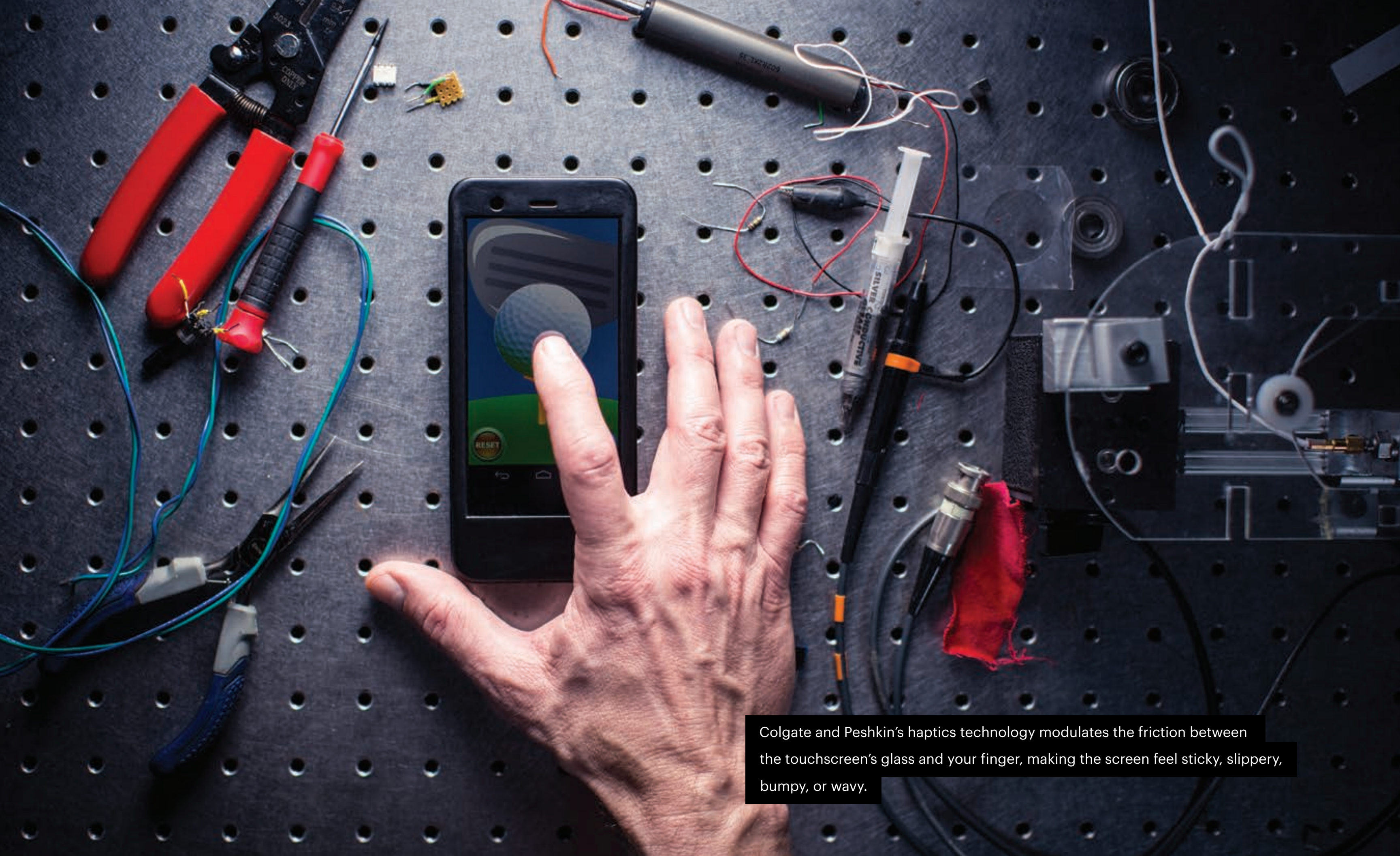
If this seems fairly esoteric, consider that touch is one of our five basic senses and provides critical information for managing almost every aspect of our lives. Touch helps us make our way through dark rooms and adjust the car radio without looking at the dial. It tells us whether something is too cold or too hot, clean or dirty, hard or soft, not to mention the role it plays in personal relationships, enabling us to comfort, nurture, and communicate with others.

TOUCHING EXPERIENCES

To make digital touch a reality, Colgate and Peshkin have spent years developing technology that makes flat, glossy touchscreens feel bumpy and textured, allowing users to "feel" the scalloped edges of a key or the smooth swipe of a turned page.

Now, they have incorporated this technology in what they call the TPad phone: a standard smartphone nestled in a case that enables physical textures to be communicated through the screen. The unassuming case, which looks like a typical protective cover, houses a lightweight circuit board. A thin glass plate covers the phone's screen. As your finger slides across the glass, ultrasonic waves in the glass modulate the friction between it and your finger. The technology senses where your finger is, so it can modulate friction in response to your finger's location relative to whatever is displayed visually. It can make the screen feel sticky, slippery, bumpy, or wavy—or it can create an "edge" effect as your finger moves onto a button or icon.

"The physical effect is really happening," Peshkin says. "But what your brain does with that is interesting. If you feel bumps on the screen while touching an image of a golf ball, your brain will interpret those bumps as dimples. It's a pretty powerful illusion."



Colgate and Peshkin's haptics technology modulates the friction between the touchscreen's glass and your finger, making the screen feel sticky, slippery, bumpy, or wavy.

THE 'OLD GUYS'

When Colgate and Peshkin began their careers, engineers didn't use the word "haptics." Originally from the Greek *haptikos*, which means "to touch," haptics was a term mainly used by the psychology community to describe the perceptual system. Both researchers worked in robotics, with a particular interest in touch, but they didn't define it as such until years later.

"I worked in telemanipulation," Colgate says. "A telemanipulator typically involves two robots: the 'master' that a human grasps and moves like a joystick, and the 'slave' that may be far away but mimics the motions of the master. My students and I built a master but ran out of money for the slave, so instead we used a computer program to simulate a 'virtual' slave interacting with a virtual world. Unbeknownst to me—or anyone at the time—that was a haptic display."

In a twist that neither expected, Colgate and Peshkin became pioneers in the haptics field. They have developed three companies together and each holds numerous patents. Colgate also cofounded the Haptics Symposium, which is the field's oldest conference, and served as the inaugural editor of *IEEE Transactions in Haptics*, the first scientific journal dedicated to the field.

"We're recognized as the 'old guys' in haptics," Colgate says.

"Come on now," Peshkin laughs. "That can be said in other ways."

After 27 years of close collaboration, the pair has developed a playful partnership, replete with teasing, shared triumphs, and productive arguments. Both say they owe their careers to one another, that they wouldn't have made the same progress on their own.

Peshkin joined Northwestern University in 1987, and Colgate, who is also the Allen K. and Johnnie Cordell Breed Senior Professor in Design, followed suit just one year later. Soon after meeting, they decided to combine forces, taking a literal sledgehammer to the wall between their individual labs to create a shared space. They still share a lab and practically everything else: student researchers, group meetings, grants, and businesses.

Tanvas, formerly called Tangible Haptics, is Colgate and Peshkin's most recent business venture and is poised to become the most ground breaking. The five-year-old company has already captured the attention of investors, who gave it a $5 million boost in June. The financing will fund the team's further work into electrostatic technology for haptic touchscreens. Commercial developers and academic researchers can purchase the TPad through Tanvas.

Photograph by Chris Strong

INSPIRING THE NEXT GENERATION

As the "old guys," Colgate and Peshkin, who is also the Bette and Neison Harris Professor in Teaching Excellence, have developed a vibrant student culture within their shared lab at Northwestern that allows the next generation of researchers to develop haptic technology. PhD candidate Joe Mullenbach says, "Before I came here, I took a tour of the lab and felt the TPad. It was incredible. I knew right then that I wanted to be a part of it." Mullenbach and fellow student Craig Shultz helped further develop the device into what it is today.

NEW APPLICATIONS

Mullenbach is working on more features, such as finding ways for the screen to push a finger along the glass, even when that finger is just resting passively on the glass. The group is also developing applications, including TextureShop, the subject of a grant funded by the National Science Foundation. As Photoshop is for pictures, TextureShop will offer users a toolkit of textures and sensations that they can apply to user interface icons, or even to images, on a touchscreen.

"Today, algorithms that we use to go from an image to a touch sensation are very simple," Mullenbach says. "In the future, these will only get more realistic."

This realism could potentially even extend to photos we take ourselves. Mullenbach and Shultz developed a "picture loader" application that allows the user to upload a photo or computer-generated image and feel it on the screen, or even snap a new photo and be able to feel it immediately.

NEW SOFTWARE

Another PhD candidate, David Meyer, is working on the software component for Mullenbach's forthcoming TextureShop application. Meyer measured the textures on an array of materials, including wood, carpet, burlap, foam, plastic, and cardboard, and uploaded them into a tool he developed called "Texture Composer." Users can edit the touch sensation of these textures to make them feel quite different on the screen.

"You can make something rough feel softer," Meyer explains. "It's kind of like how Auto-Tune works for music, which can take unpleasant sounds and make them more pleasant."

Meyer imagines that touch could one day become a regular part of online shopping. Shoppers might be able to touch a blanket or article of clothing on their screens and decide whether or not they like the fabric. And if Craig Shultz has anything to say about it, those shoppers will also be able to knock on a wooden table on their screen to see if it's solid or hollow.

NEW CAPABILITIES

Shultz is working on an audio-tactile display for acoustic touch. Made of aluminum and aluminum oxide, the special electrostatic surface turns a finger into a speaker, enabling it to play music. Here's how it works: The user holds an electrode that is hooked up to a computer. The user then touches an electrostatic surface that has a voltage across it, which alters the friction between the skin and the surface. As the user's finger slides across the surface, changes in friction cause the skin to vibrate. Those vibrations are the music, which emanates right from the finger. For anyone concerned about the current running through the body, Shultz says it's about the same amount as in the electrical signals between nerves.

"We recognize objects by their acoustics," Shultz says. "This project isn't just about playing music. It could lead to new interfaces that allow you to feel whether something is hollow, metallic, or ceramic."

"WE DON'T YET KNOW ALL THE APPLICATIONS THAT WILL BE POSSIBLE WITH THIS TECHNOLOGY."

DAVID MEYER PHD CANDIDATE

NEW RESEARCH

To better understand how haptics works, graduate student Becca Fenton Friesen has been studying the finger and how it interacts with surfaces. She is particularly interested in how the slight bit of air between the fingertip and a surface affects vibrations and other tactile sensations. She has been constructing artificial fingertips to use in experiments in which a human finger cannot be used, such as within a vacuum chamber.

"We originally thought that if it were squishy like a finger, it would work like a finger," she says. "It turns out that it's more complicated than that. We're trying to understand what materials in the artificial fingertip make it work or not on the TPad."

These projects venture out into the unknown world of digital touch. "It's like a silent movie," Meyer says. "Before audio was introduced, people didn't even know they wanted it. But then audio and video together transformed the world. We don't yet know all the applications that will be possible with this technology."

ROBOTIC TOUCH

"FLEXIBLE MANIPULATION IS THE NEXT GRAND CHALLENGE OF ROBOTICS."
KEVIN LYNCH PROFESSOR AND CHAIR OF MECHANICAL ENGINEERING

When we manipulate an object with our hands, we can do much more than just pick it up and carry it. We can throw it into the air and catch it, let it slip or rotate within our grasp, push or roll it along a surface, or tap or jiggle it to make small corrective motions. These manipulation modes are enabled by visual feedback and the many sensors we have in our hands and arms. Waves of haptic information help us dynamically manipulate objects without even thinking about it.

The current inability of robots to use these manipulation modes limits their usefulness in the human world. Kevin Lynch, professor and chair of mechanical engineering, and his students are bringing robots one step closer to human-level dexterity through the development of ERIN, a state-of-the-art robotic manipulation system.

ERIN consists of a high-speed seven-joint robotic arm with a four-fingered robot hand. Each fingertip is equipped with more than twenty tactile sensors measuring temperature and local contact pressure. ERIN's visual feedback comes from ten high-speed cameras strategically placed around the robot's workspace that capture images of objects manipulated by ERIN at 360 frames per second.

"The fingertip tactile sensors provide information on contact forces and fine motion of the object during manipulation, such as slip," Lynch says. "The vision system tracks the motion of the object. If I throw an object to the robot, the vision tracking system works with a robot arm feedback controller to move the arm into position to catch the object."

One goal of the research is to produce a robot with human-like dexterity that can operate in human environments. There is still a long way to go. Robots already exceed humans in strength, speed, and precision, but still missing are algorithms that turn sensor data into robot motor commands. Lynch's team is building a library of algorithms for human-like capabilities, including pushing, rolling, sliding, batting, and throwing and catching objects. "Flexible manipulation is the next grand challenge of robotics," Lynch says.

To learn more about Lynch's research and other touch-inspired robotics projects at Northwestern, check out the short video at

bit.ly/engineeringtouch.

"I LOOK FORWARD TO PEOPLE BECOMING CONNOISSEURS OF TOUCH, AND I THINK THEY WILL."
MICHAEL PESHKIN PROFESSOR OF MECHANICAL ENGINEERING

FUTURE OF THE FIELD

Colgate, Peshkin, and their students are excited by how far the haptics field has come just within just the past five years. This year's World Haptics Conference, hosted by Northwestern, attracted a record number of attendees. Another good sign for the field's future: Apple has started using the word for its products. The new Apple Watch has a "Taptic Engine" that produces haptic feedback in the form of a light tap on the wrist.

"You can go to Apple's homepage and read about their product and they actually use the word 'haptic,'" Colgate says. "That's a very new thing, and we're all excited about that."

The team hopes that haptics will become a part of everyday conversation and more people will become "connoisseurs of touch." Colgate and Peshkin compare it to developing a refined palate. If you're not trained to taste and talk about wine, chances are that you cannot taste and describe the range of flavors and aromas. They say most people can't differentiate among different touch sensations because they aren't used to it and lack the vocabulary to express what they feel.

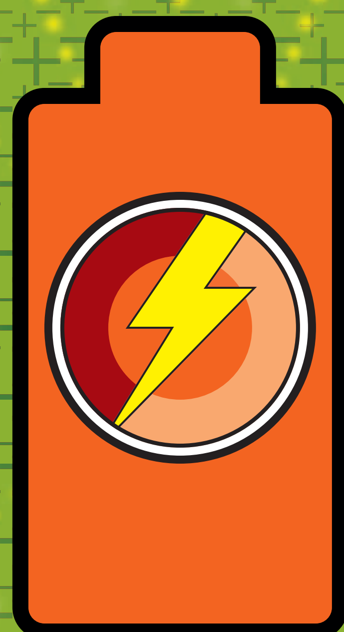
"Everyone expects their touchscreen to feel flat," Peshkin says. "It's possible that we have lost our sense of touch or at least our expectation of being able to feel something on a touchscreen. I look forward to people becoming connoisseurs of touch, and I think they will."

"Meanwhile, we just want to make this stuff work," Colgate says. "There are still a lot of problems to solve before this becomes a part of modern commercial electronics, which we desperately want to happen. We're big believers in haptics."

AMANDA MORRIS

SUPERCHARGED

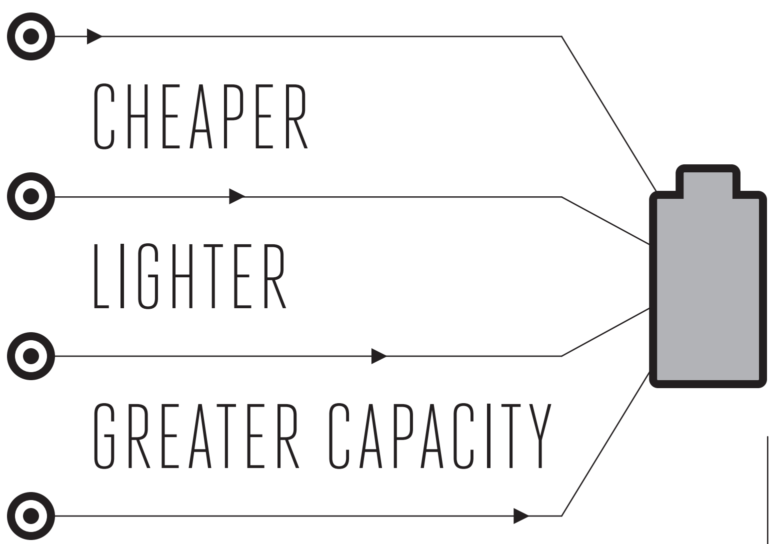
BETTER BATTERIES AHEAD



FROM ANODE TO CATHODE—AND EVERYTHING IN BETWEEN—NORTHWESTERN ENGINEERING RESEARCHERS ARE FINDING WAYS TO MAKE CHEAPER, LIGHTER BATTERIES THAT WORK BETTER AND LAST LONGER.

WHAT'S DRIVING—OR MORE ACCURATELY, NOT DRIVING—WIDESPREAD CONSUMER ADOPTION OF ALL-ELECTRIC AUTOMOBILES? IT'S NOT LACK OF CHOICE. FROM TESLA TO NISSAN, MANUFACTURERS TODAY OFFER MORE ALL-ELECTRIC, COMPLETELY BATTERY-POWERED MODELS THAN EVER.

SUCH CARS CERTAINLY MAKE GREAT SENSE ENVIRONMENTALLY. With zero tailpipe emissions, they could put a major dent into the amount of carbon dioxide in the atmosphere, reduce fossil fuel reliance, and help slow climate change. But that's only if people actually drive them. So far, they don't, thanks to **decades-old battery technology** that **limits their range and offers few options for charging**.



That could change fast. A team of Northwestern engineers is working to design better batteries—batteries that are cheaper, lighter, and with much greater capacity than today's models—that could make all-electric cars more feasible for average citizens, affecting the environment in an enormously positive way.

The implications of their work extend far beyond automobiles, of course, to include virtually all battery-dependent devices and gadgets. As Northwestern Engineering's **CHRISTOPHER WOLVERTON**, professor of materials science and engineering, notes,

"**We all want a  that will survive an entire transatlantic flight without dying. But improving automotive technology: that's the Holy Grail**."

"**TRANSPORTATION IS ONE OF THE BIGGEST ENERGY-CONSUMPTION SECTORS**. THE OBVIOUS SOLUTION IS TO REPLACE FOSSIL FUELS WITH RENEWABLE ENERGY. BUT RIGHT NOW, THE RENEWABLE GENERATION OF ELECTRICITY IS STILL MORE EXPENSIVE THAN CONVENTIONAL METHODS. **WE HAVE TO DEVELOP A SOURCE OF ELECTRICITY THAT POSES NO DRAWBACKS**."

HAROLD KUNG Walter P. Murphy Professor of Chemical and Biological Engineering

THE HIGH PRICE OF POWER

In an all-electric car, the battery comes in as the single most expensive component. In Tesla's flagship Model S, for example, the battery pack alone costs approximately $30,000, or 42 percent, of the total cost. Such a significant price tag catapults electric cars to a higher price point than most consumers can afford. And price isn't even the most troubling problem.

Many drivers suffer from "range anxiety": the fear of running out of power before they can get to the next recharging station. The fear is not unfounded, as such stations are still few and far between. A typical electric car can only travel a couple hundred miles before reaching the end of its charge, when it must be plugged in to recharge for several hours. That range is much shorter than the 300 to 400 miles that a conventionally powered car can cover on one tank of gas.

"**You can't use an electric car the same way you use a normal automobile, which you can drive across country**," says **MARK HERSAM**, Walter P. Murphy Professor of Materials Science and Engineering. "**Or, at least you have to manage it differently, and people aren't used to that. We need to build batteries that give drivers an experience similar to what they're used to—or better**."

HOW BATTERIES WORK

Ever since Sony released it in 1997, the **lithium-ion battery has set the gold standard for battery technology**. Compared to their ancestors, **lithium-ion batteries offer the lowest density battery with the greatest energy-to-weight ratio.**

THIS POPULAR ITERATION HAS **THREE COMPONENTS**:

1 ANODE

The *anode*, typically made of graphite, holds the negative charge.

2 ELECTROLYTE

The *electrolyte*, held within a solid polymer composite, serves simply as a transport medium for the lithium ions to move between the anode and cathode.

3 CATHODE

The *cathode*, a combination of lithium, a conductive metal, and an oxide, holds the positive charge.

WHEN A BATTERY IS IN USE, LITHIUM IONS TRAVEL FROM THE ANODE TO THE CATHODE.
WHEN THE BATTERY IS CHARGED, THE IONS MOVE BACK TO THE ANODE, WHERE THEY ARE STORED.

ANODE RESEARCH

Coming up with the best materials, tools, and designs for building better batteries requires exhaustive **research involving materials science and chemical engineering**.

ONE OF THE CONSISTENT QUESTS IS TO MAKE A BATTERY THAT CAN STORE MORE ENERGY IN THE ANODE.

Researchers discovered that **anodes made with silicon rather than the traditional graphite can hold more lithium**, but silicon expands and contracts during the charging and discharging process. These size fluctuations can cause the anode to crack and the battery to eventually fail.

Professor Kung solved this problem by sandwiching silicon between graphene sheets, capturing all the benefits of silicon, along with padding to accommodate volume changes during use.

THE RESULTING ANODE COULD BE **A GAME-CHANGER IN THE BATTERY WORLD:** IT CHARGES **10 TIMES** FASTER WITH **10 TIMES** GREATER CHARGE THAN TODAY'S BATTERIES.

This work, which could pave the way for better batteries for , , and  has spawned a Northwestern spin-off company, **SiNode Systems**, to commercialize the research. Kung predicts his battery could hit the market within three years.

Jiaxing Huang, associate professor of materials science and engineering, is also addressing the same problem with graphene—but with a twist. Huang developed a **crumpled graphene "pocket" that can also protect the silicon nanoparticles as they change in size.**

"IF THE COATING IS A TIGHT SHELL, WHICH IS USUALLY EASIER TO MAKE, IT WILL CRACK WHEN THE SILICON PARTICLES EXPAND. THE **CRUMPLED GRAPHENE** HAS A LOT OF WRINKLES THAT SIMPLY SMOOTH OUT WHEN THE SILICON EXPANDS AND THEN WRINKLE BACK UP WHEN IT CONTRACTS."

JIAXING HUANG
Associate Professor of Materials Science and Engineering

CATHODE RESEARCH

MOST BATTERY RESEARCH FOCUSES ON THE CATHODE SIDE:

TWICE AS MANY

SCHOLARLY ARTICLES EXAMINE THE CATHODE OVER THE ANODE,

AND RESEARCH BY NORTHWESTERN ENGINEERS FITS SOLIDLY WITHIN THIS TREND.

"**In some sense, the cathode is where the action is because it controls the voltage**," Wolverton says. "**It has the lithium in it when the battery is discharged. When you plug in your phone and charge it, lithium is being pulled out of the cathode**."

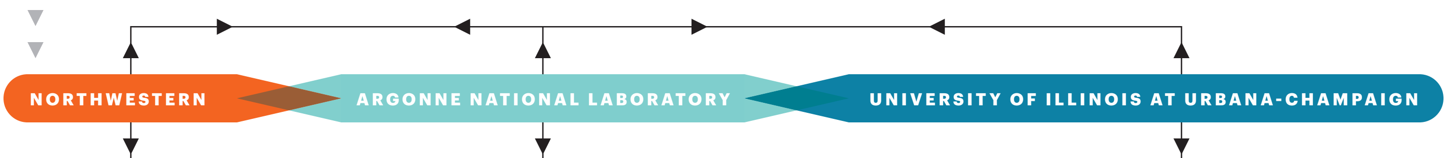
"**The cathode limits the overall performance of the battery more than the anode**," adds Hersam. "**You have to make a major improvement to the anode side to see any difference in performance. Even a small change to the cathode side can make a significant difference overall**."

Researchers are still searching for materials that will give the cathode significantly higher capacity. The most common battery—the kind found in smart phones—uses lithium and cobalt, but cobalt is toxic, expensive, has a limited capacity for lithium, and is capable of overheating.

> "**THE CATHODE** REALLY REQUIRES COMPLETELY NEW MATERIALS THAT, AT THIS POINT, ARE UNKNOWN.
>
> **MARK HERSAM** Walter P. Murphy Professor of Materials Science and Engineering

AN INTERDISCIPLINARY SEARCH

Six years ago, the US Department of Energy established an **Energy Frontier Research Center** (**EFRC**) dedicated to advancing lithium-ion batteries, with particular focus on the cathode. Called the **Center for Electrochemical Energy Science** (**CEES**), it's a collaborative effort among



"THE BATTERY PROBLEM IS SO BIG THAT WE NEED MANY **DIFFERENT PERSPECTIVES WITH A HIGHLY INTERDISCIPLINARY APPROACH**," says Hersam, Northwestern's principal investigator on the project.

Along with Hersam and Wolverton, Northwestern members include **SCOTT BARNETT**, **MICHAEL BEDZYK**, **VINAYAK DRAVID**, and **TOBIN MARKS**.

"I THINK THE NORTHWESTERN EFFORT WOULD BE SUCCESSFUL IF SELF-CONTAINED, BUT **IT'S AMPLIFIED BY OUR PARTNERS**."

The search for a new cathode material has been challenging, but one candidate stands out: **lithium-manganese-oxide**, or **LMO**, which has many desirable attributes.

LMO LITHIUM-MANGANESE-OXIDE

IT CAN BE **OPERATED AT A HIGH VOLTAGE**, IT'S **CHEAPER THAN COBALT**, AND IT'S **ENVIRONMENTALLY FRIENDLY**.

But as the battery charges and discharges, the manganese leeches into the electrolyte, significantly decreasing the battery's lifetime.

A CEES-based team, including Hersam, Dravid, and Wolverton, developed **a single-layer graphene coating** to prevent the manganese from dissolving. When applied to the cathode, **the coating acts as a filter**, allowing the lithium ions to travel to the anode and back while keeping the manganese in place. Highly conductive graphene also enables the battery to charge faster.

AFTER CAREFUL TESTING, THE TEAM FOUND THAT THE COATING IMPROVES THE LMO BATTERY'S LIFETIME BY A FACTOR OF 10.

"**Because graphene is so stable chemically, the electrolyte no longer makes direct contact with the LMO, minimizing the chance for chemistry to occur at that interface**," Hersam says. "**That may also contribute to improved performance**."

To further understand this promising material, the team plans to examine it with an **X-ray scattering technique** at Argonne's Advanced Photon Source (APS).

X-RAY SCATTERING TECHNIQUE THE HIGH-ENERGY, ULTRA-BRIGHT X-RAY BEAMS CAN REVEAL INFORMATION ABOUT LMO'S CRYSTAL STRUCTURE, CHEMICAL COMPOSITION, AND PHYSICAL PROPERTIES.

"**X-RAY SCATTERING CAN ESSENTIALLY ALLOW US TO SEE INSIDE OF THE BATTERY**. BUT FOR THE TECHNIQUE TO WORK, WE NEED A VERY THIN, COMPLETELY FLAT LAYER." **SCOTT BARNETT** Professor of Materials Science and Engineering

To produce this material for X-ray analysis, Barnett employs TWO DIFFERENT METHODS.

1. **ONE TECHNIQUE USES A LASER TO STRIKE THE MATERIAL**, which vaporizes it and then deposits it as a thin film onto a substrate.

2. **THE OTHER TECHNIQUE USES ENERGIZED IONS TO COLLIDE WITH THE MATERIAL**, which ejects particles onto a substrate, forming a thin film.

"SOME METAL OXIDES ARE KNOWN COATING MATERIALS AND OFFER **PROMISING REAL-WORLD IMPROVEMENTS**. BUT IS LMO THE BEST WE'VE FOUND IN OUR COMPUTATIONS? NO. **WE HAVE OTHER MATERIALS WE THINK ARE BETTER**, BUT WE HAVEN'T TESTED THEM YET."

CHRISTOPHER WOLVERTON

Professor of Materials Science and Engineering

While promising, **LMO is not the only material with potential as a cathode material**. Wolverton's group performs high-throughput computations to find new materials for various applications, including batteries. He has used this technique to search for coatings other than graphene for LMO as well as for completely different alternatives to LMO.

The Dow Chemical Company has tasked Wolverton with finding ways to fix problems in a lithium-rich material, for which it holds the intellectual property rights. The material stores much more lithium than existing batteries, but with one major drawback: **the battery's voltage fades every time it is charged or discharged, which means performance declines with use over time**. Wolverton's group is designing a material that coats the cathode to prevent this problem. Using computation, he can explore why certain coating materials work and others do not.

"**Once we've done a large number of these high-throughput computations and have a database of possibilities, we can quickly scan through our options**," Wolverton says. "**That gives us lots of new combinations to try**."

As the lithium-rich battery degrades, hydrofluoric acid forms as a byproduct. According to Wolverton's hypothesis, this acid attacks the cathode, dissolving the metal. His team is designing a coating that will sacrificially react with the acid. "**It will essentially scavenge all of the hydrofluoric acid that comes near the cathode and react with it, leaving the cathode to still do its work in the battery**," he says.

LOOKING BEYOND CATHODES AND ANODES

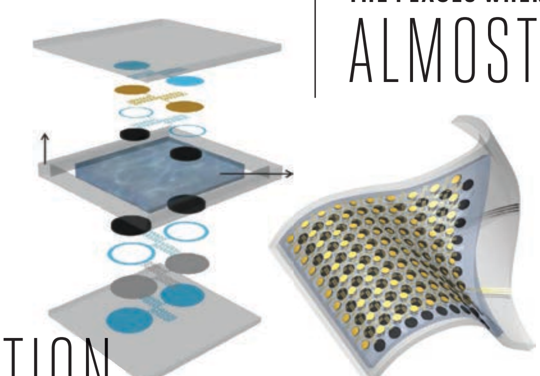
Sometimes battery research has nothing to do with the cathode or the anode, but instead addresses something else entirely.

HERE ARE A FEW EXAMPLES OF OUTSIDE-THE-BOX EFFORTS TO BUILD A BETTER BATTERY.

STRETCHABLE BATTERIES

YONGGANG HUANG, Walter P. Murphy Professor of Civil and Environmental Engineering and Mechanical Engineering, has designed a **rechargeable battery that can bend, stretch, and twist—and then snap back into its original shape**. The flexible battery, developed in collaboration with the University of Illinois' **JOHN ROGERS**, who will join Northwestern next year as the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering, and Medicine, can

STRETCH BIAXIALLY UP TO **400 PERCENT** OF ITS ORIGINAL SIZE—OR **16 TIMES** ITS ORIGINAL AREA—AND STILL FUNCTION.



The device embeds tiny, lithium-based batteries into a paper-thin silicon sheet. The batteries are connected by a framework of coiled conductive wires, which uncoil when the battery is stretched. The device can **work for eight to nine hours before it needs recharging**, which can be done wirelessly.

Because Huang's stretchable electronic device is completely **independent of a cord and electrical outlet**,

THE PLACES WHERE IT MIGHT BE USED ARE

ALMOST LIMITLESS.

This includes implanting it inside the human body, where it could **power the monitoring of anything from brain waves to heart activity**, succeeding where flat, rigid batteries would fail.

SWEAT EQUITY

Three Northwestern Engineering graduate students have developed a whole new way to **charge batteries using kinetic energy**. Called **AMPY**, the portable device captures energy as the wearer walks, runs, cycles, or fidgets, and turns it into an electric charge.

A **30-MINUTE RUN**, FOR EXAMPLE, **CAN GIVE A SMARTPHONE A THREE-HOUR CHARGE** OR **A SMARTWATCH A 24-HOUR CHARGE**.

The device works with a **patent-pending, proprietary inductor technology that generates electricity to charge an internal battery**. It can store a week's worth of energy, which can then be used to charge any device with a USB port.

ION HIGHWAY SYSTEMS

The research of Northwestern's **MONICA OLVERA DE LA CRUZ** could lead to a class of **batteries that use plastic instead of lithium**. In earlier work, Olvera de la Cruz, the Lawyer Taylor Professor of Materials Science and Engineering, examined plastics known as *block copolymers*.

BLOCK COPOLYMERS

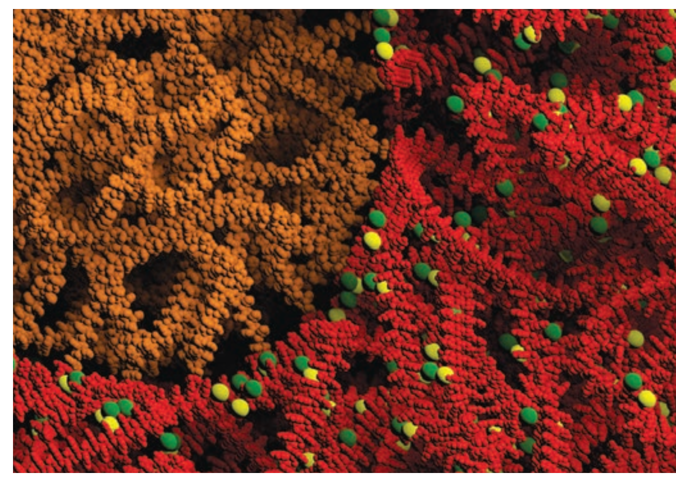
COMPOSED OF TWO TYPES OF POLYMERS STUCK TOGETHER, THEY SELF-ASSEMBLE INTO NANOSTRUCTURES THAT BOTH ENABLE ION CHARGE TRANSPORT WHILE MAINTAINING STRUCTURAL INTEGRITY, MAKING THEM A LEADING MATERIAL FOR USE AS ION CONDUCTORS.

Block copolymers innately have nanochannels through which ions can travel, but the charges themselves manipulate the shape of the channels. **To use the material in batteries**,

RESEARCHERS MUST FIND A WAY TO **CONTROL THE SHAPE OF THE NANOCHANNELS** TO ENABLE THE CHARGE TO MOVE EFFICIENTLY.

Olvera de la Cruz and her team discovered that **ions and counter-ions found in the nanochannels attract each other to form a salt**. These salts cluster into miniature crystals, which exert a force on the nanochannels, changing the channels' structures.

THIS UNDERSTANDING MAKES IT POSSIBLE TO PREDICT AND EVEN DESIGN A "**HIGHWAY SYSTEM**" THROUGH WHICH IONS ARE TRANSPORTED, **MAXIMIZING THE POWER** OF THE BATTERY.



SAVING SILICON

In manufacturing wafers for computer chips, a chainsaw slices through a bulk piece of silicon, generating silicon dusts that are swept up and thrown away. That means about half of that expensive material is wasted in the process.

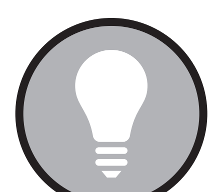
For two decades, researchers have tried **different ways to recycle the wasted silicon**. Some have suggested melting the powder down to make more computer chips; others have recommended adding it to concrete. Most ideas either require expensive refining processes to make the powder useful, or convert the silicon powder into less valuable materials.

"**BATTERY APPLICATIONS** ARE MUCH MORE TOLERANT OF IMPURITIES THAN MAKING CHIPS. NOW YOU CAN **TAKE WASTE FROM ONE INDUSTRY AND REPURPOSE IT** AS A MUCH VALUE-ADDED MATERIAL FOR ANOTHER INDUSTRY."

JIAXING HUANG
Associate Professor of Materials Science and Engineering

NORTHWESTERN'S **JIAXING HUANG** RECENTLY CAME UP WITH

A NEW IDEA:



USE THE POWDER FOR BATTERIES.

Collaborating with former visiting scholar **HEE DONG JANG** in Korea, Huang found that the silicon powder, once extracted, could be used as-is in the anode without further refining.

ADVANCING COLLECTIVE INNOVATION

NORTHWESTERN ENGINEERING'S LIZ GERBER USES HER EXPERIENCE IN PRODUCT DESIGN TO BUILD NEW TOOLS TO HELP PEOPLE INNOVATE BETTER TOGETHER

Working as a designer at a toy company in San Francisco 16 years ago, Liz Gerber was confronted with an intriguing challenge: implement an outreach program to foster children's interest in design.

Her team's response, the Kid Inventor Challenge, invited children from around the country to take their best shot at designing their ideal toy. Entrants submitted their drawings to Gerber and her team, who then posted them online for other kids to comment on and vote for the best ideas.

Most amazing to Gerber was not the design ideas. Rather, it was how the online platform empowered the kids to collaborate with peers who shared their passion for design as well as the rate at which new ideas were developed and expanded within the company.

For Gerber, the contest showcased how a large number of people in disparate locations could work together effectively in a coordinated, meaningful way. She reasoned that if hundreds of children could use technology to achieve a greater level of collaboration and innovation in the toy industry, what might result if such platforms were used in fields like healthcare, technology, and education?

COLLECTIVE INNOVATION AT WORK

Gerber, now associate professor of mechanical engineering, leverages her toy designer experience as she explores the social and technological principles behind how people innovate across industries. At Northwestern, she's developing the theory and end-user technology that promote what she calls collective innovation: innovation that harnesses the diverse and untapped human, social, and economic capital from distributed networks that together can discover and implement new ideas.

"People used to think of a designer or entrepreneur as someone who sat alone and came up with an idea," Gerber says. "With the Internet, that single person can now engage with hundreds or even thousands of other people to advance an idea or develop a product."

As a member and co-founder of Northwestern's Delta Lab, an interdisciplinary research lab whose members major in engineering, physics, psychology, anthropology, economics, and computer science, Gerber is building tools to support the burgeoning field of crowdfunding—a contemporary example of collective innovation—in which a large number of people contribute funds to help launch a startup enterprise.

Guiding the lab's work, Gerber applies certain principles to maximize the impact of this form of collective innovation. Specifically, crowdfunding must:

- Remain inclusive to novices and underrepresented individuals
- Provide transparent goals and intentions
- Support resource exchange of all kinds (information, money, time)
- Strive to connect communities instead of simply raising funds.

TOOLS OF INNOVATION

Critiki, one of the first collective innovation tools the lab developed, provides users a way to gather feedback on one of the most important and influential components of any crowdfunding effort: the pitch video. Created by PhD student Michael Greenberg, Critiki helps novice crowdfunders gain substantive feedback on both the pitch video's technical structure as well as its content.

"Pitch videos have evolved in just a few years from recording an amateur home video to hiring a production company to give the pitch a professional polish," Gerber says. "Even then, crowdfunders often don't receive constructive feedback on the effectiveness of their videos before their campaign goes live. Critiki offers the opportunity for feedback from experienced peers so campaign organizers can make improvements before launch."

Another project in development by PhD students Julie Hui and Yongsung Kim seeks to tap the collective intelligence of experienced crowdfunders to offer a comprehensive education resource for first-timers. Dubbed Cyber Incubator, Gerber believes the platform will help novices better understand the behind-the-scenes planning and networking required to launch a successful campaign.

"Users will be able to review their fundraising and manufacturing plans and goals by comparing data we've collected from experienced crowdfunders," she says. "If someone wants to raise $50,000 for a startup business, they will be able to learn how similar campaigns were planned, including elements like how big of a donor network organizers needed to target or how reward levels should be structured."

A FIELD IN PERPETUAL FLUX

Many scientists examine data only after its variables have become stable. Gerber's research, on the other hand, relies on continually evolving technology that yields little regularity. She estimates as many as 800 crowdfunding outlets can be found online today catering to dozens of niche efforts, from helping authors raise funds to publish a new book to assisting researchers involved in scientific study.

As the available means for practicing collective innovation continue to grow, so too do expectations for performance. Gerber points to the "professionalization" of crowdfunding, which has resulted in lower acceptance rates from platforms like Kickstarter. She also notes a greater desire for transparency from potential donors.

"People are less naïve toward crowdfunding as they've witnessed the field taking shape over the past few years," Gerber says. "Donors now expect greater transparency from organizers about what their goals are, how they plan to achieve them, and how they will deal with the inevitable hiccups along the way."

While Gerber acknowledges the importance of qualifying her research to reflect the technological and social changes she sees, she maintains that her guiding theory on collective innovation has remained consistent and applicable. She cites as evidence the outreach she receives from current crowdfunders.

"Crowdfunders and platform designers contact us every week asking for advice or to stay in the loop of what we are working on," Gerber says. "To study something so culturally relevant and pervasive is very powerful. To me, it's the most exciting place to be as a researcher."

ALEX GERAGE

Photographs by Lisa Beth Anderson

KEEPING EMOTIONS IN MIND

NORTHWESTERN ENGINEERING'S **EMOTIONAL INTELLIGENCE** COURSE TEACHES STUDENTS HOW TO SUCCEED IN A STRESSFUL WORLD

Have you ever driven across town, arrived at the destination, and wondered, “How did I get here?” You can’t remember driving there—were you thinking about the presentation you need to give tomorrow? Worrying about where your kids might be? Wondering who was calling/emailing/texting you?

Such experiences are not all that uncommon. Too often we live our lives lost in thoughts and worries, unaware of the present moment.

“If people understood that mastering their attention is one of the most powerful things they can do to manage their stress, impact their level of happiness, and enable their success, the sky would be the limit to realizing their full potential,” asserts Joe Holtgreive, assistant dean for personal development at Northwestern Engineering.

Holtgreive believes so strongly in this concept that he has brought it into the classroom. His Emotional Intelligence (E.I.) 101 course, co-created and co-taught with David Shor, director of clinical services for Northwestern’s Counseling and Psychological Services (CAPS) program, gives Northwestern students the tools they need to master their attention. By doing so, they manage stress and improve focus, self-awareness, and empathy for others.

The class is one of many offered by the Office of Personal Development, which provides resources and opportunities for personal growth to Northwestern Engineering students. The office strives to cultivate a community of students who are more self-aware, empowered, and resilient, and who develop the required skills to become lifelong adaptive learners.

FIRST “FAILURES”

“When Northwestern students were in high school, they were all at the top of their classes,” Holtgreive says. “The norm for our entering freshmen is 98th percentile. But once they come here, the new norm is the 50th percentile. Intellectually and emotionally, many students can’t grasp that.”

While some students develop new strategies and adjust their expectations, others struggle. Some work twice as hard, forgoing food, sleep, and friends to maintain demanding study schedules. They often isolate themselves and eventually burn out, or they panic and drop classes at the first sign of trouble.

“In that first year—even in the first quarter—most students share the same experience,” Holtgreive says. “Many will encounter a perceived failure for the first time. For some that could be earning an ‘F’ or for others an ‘A-.’ Either way, they panic because they’re afraid of what this grade says about them.”

Many students are so overwhelmed by stress that they “unplug” from their emotions. Instead of working through problems, they direct their attention away from their discomfort and toward distractions. Holtgreive says this is a common survival strategy for students, especially freshmen, and can cause them to lose important information held in the present moment.

TEACHING EMOTIONAL INTELLIGENCE

To help prepare students to deal with stress, Holtgreive, Shor, and Rob Durr, also from CAPS, created Emotional Intelligence 101 three years ago. Holtgreive and Shor had met 13 years prior in a Lamaze class with their wives, and after striking up a friendship, bonded over their shared interest in emotional intelligence training and mindfulness. “I taught mindfulness to student athletes, actors, and musicians,” Shor says. “Then we came to realize that all students are performers in one way or another, and everyone can benefit from mindfulness skills.”

Based on the Bar-On Model of Emotional Intelligence, the course is divided into five topics: stress management, self-perception, self-expression, interpersonal relationships, and decision-making. The model, developed by psychologist Reuven Bar-On, trains students to conceptualize and apply emotional intelligence and social competence. At the beginning of the quarter, students undergo an E.I. self-assessment—and most score below the mean, which isn’t necessarily surprising. “Students are so focused on academics that they aren’t paying attention to emotional intelligence,” Shor says.

The students spend the quarter working to improve their E.I. by listening to guest speakers, writing papers, and completing exercises. Most students experience a significant increase in their E.I. assessment scores by the end of the quarter.

BUILDING A CALM FOCUS

Often, the students’ stress can be abated with a simple exercise: meditation. At the beginning of each class period, Shor and Holtgreive invite students to close their eyes and focus on their breathing, which brings their attention back to the present. As students’ minds naturally drift, they are instructed to non-judgmentally recognize when their attention has wandered and to steer it back to their intended focus. Staying in the moment keeps the mind away from worries about the future or regrets of the past and leads to an accurate awareness of one’s self and surroundings. “This cultivates intentional attention,” Shor says. “There are so few things in life that we can actually control. But where we offer our attention is one of them.”

Julian Munizzo (’13) took Emotional Intelligence 101 three years ago and still applies the lessons he learned to life, work, and his relationships. A materials science and engineering graduate, Munizzo is now a battery engineer at Tesla Motors, where competition is as stiff as ever. “Everyone I met in college was at the top of their class in high school,” he says. “Now, everyone I work with was at the top of their class in college. I used to always try to play it off as healthy competition, but it’s incredibly stressful.”

Munizzo still practices meditation exercises to stay grounded instead of getting caught up in stress and his heavy workload. “It’s the only class I still think about on a regular basis,” he says. “It introduced me to topics that I didn’t expect to learn in engineering.”

That, Holtgreive says, is the goal: to teach students skills they can use throughout their lives. “The best thing we can do to help our students succeed is to teach them that they possess the capacity to respond productively in the face of uncertainty. It is this capacity that empowers them to meet challenges,” Holtgreive says.

AMANDA MORRIS

D●RTY W●RDS

ENG●NEER●NG *A* L●TERARY CLEANUP

In an interdisciplinary effort, Northwestern computer scientists use machine learning to correct glitches in digitized historic texts.

For years, Martin Mueller has been plagued by ugly black dots. A professor emeritus of English and classics at Northwestern's Weinberg College of Arts and Sciences, Mueller studies and enjoys early English texts. Over the past decade, unsightly black dots have crept into the words of the digitized versions of some of his favorite books, giving them what Mueller calls a serious "yuck factor."

"I don't like dirty things," he says. "These texts are cultural heritage objects, and they should be clean. We don't have much of the past left. We want to keep it right."

WHENCE COMETH THE BLACK DOT?

In 1999, several universities and libraries established the Text Creation Partnership (TCP) to digitize English books published before 1700. By transcribing texts and putting them online, the TCP developed a searchable, navigable, free database for students, scholars, and readers everywhere. Transcribed by non-English speakers, these digital versions were not copied from the original books but from digital scans of microfilms—some of which were more than 60 years old.

"You can imagine that with a process like that, a lot of things can go wrong," Mueller says. "And a lot of things did."

The resulting 50,000 transcribed texts have roughly five million incomplete words. Many of the aged books were browned and splotchy from the start, and their legibility was further compromised by poor quality scans. If transcribers could not read or understand a portion of the text—for example, if it was cut off at the margins, obscured by previous owners' handwritten notes, or included arcane abbreviations and spellings—they replaced the unknown character with a black dot. Thus the word "love," for example, became "lo●e."

To solve the problem, modern readers could arguably comb through the texts and fix all the errors, but Mueller estimated it could take several minutes for a human to fix just one error. To tackle all of the errors, it would take one person years of non-stop work—an impractical, if not humanly impossible, task.

HENCE LIT MEETS COMPSCI

Northwestern Engineering's Doug Downey embraced Mueller's dilemma as a challenge. Four years ago, then associate dean Stephen Carr connected Downey, an associate professor of computer science, with Mueller. An expert in statistical language modeling, Downey proposed using machine learning to help correct the texts.

Language modeling is most popularly known for its role in auto-correct and voice recognition programs. It assigns probabilities to sequences of words to estimate the likelihood of what word is missing or coming next. For example, the word "lo●e" might be "love," but it also might be "lone," "lore," or "lose." A language model evaluates the context of the word in question—comparing it to known contexts where the candidate words have been used—to choose the correct option. If the context is "she was in lo●e with him," then the program assumes the missing word is, indeed, "love."

Downey's group first trained the language model on 363 relatively clean texts from the same era. Once the computer program understood common semantics, it was ready to work through a sample of 359 flawed texts, which included plays, textbooks, court transcripts, treatises, biblical commentary, romance novels, and more.

The program finds "blackdot words" and spelling errors, and evaluates 35 characters to the left and right of each character in question. It then submits zero to three replacement possibilities, assigning a probability to each option based on the context. This past summer, Weinberg undergraduates combed through the options to select the correct one.

"The project is a lot more involved than it originally appears," says Katie Poland, a junior studying English and philosophy. "We're just working with single words, but there can be so much hidden in there."

In many cases, the undergraduate students did not just deal with blackdot words but also non-standardized spellings—"France" and "color" were spelled "Fraunce" and "coulloure." Other times, the transcribers might have mistaken old letters for modern letters. The Old English letter "s," for example, looks very similar to a modern-day "f."

SPREADING THE RESULTS

While the Weinberg students work to solve the language riddles, Northwestern Engineering students are working on an interactive website for the project. They have built a site where humanities scholars can search for words in different texts and fix errors right on the spot. Super users then either accept or reject the corrections. Accepted fixes are automatically updated into the system.

"Machine learners can also learn from that feedback," Downey says. "A little bit of crowdsourcing like that could go a long way. Eventually we could have super high-quality transcriptions."

Yue "Hayley" Hu, a sophomore studying computer science, has been working on the site's database. Although she previously had little exposure to early English texts, she has enjoyed discussing them with the English students. "It's neat that we can offer a computer science-based solution."

The collaboration's initial results indicate that approximately three-quarters of the incompletely or incorrectly transcribed works can be definitively corrected with a combination of machine learning and machine-assisted editing—without the need to consult the original printed text. This could drastically reduce the human-time cost from minutes to a mere seconds per word.

Corrections are automatically reintroduced and reintegrated into the texts, which form a larger and more accurate set of training data used for fixing blackdot and misspelled words in other texts. Eventually, Downey posits, the machines will be confident enough to require hand verification for just small text samples.

"It's energizing that we can apply research in a way that will impact a real community of users," Downey says. "It's rare to have a customer of your basic research where you can deliver something today that makes a difference."

AMANDA MORRIS

BRIGHTER FUTURES FOR PATIENTS, RESEARCHERS, AND INVESTORS

COLLABORATION BETWEEN RESEARCHERS AND INDUSTRY WILL BRING NEW THERAPEUTICS TO MARKET AND STIMULATE FUTURE EXPLORATION OF BRAIN AND NERVOUS SYSTEM DISORDERS.

left to right Bill Gantz, Norbert Riedel, Joe Moskal

JOE MOSKAL REMEMBERS WHEN IT ALL BEGAN.

He was wearing jeans and sneakers working as a senior staff fellow at the National Institute of Mental Health's Intramural Research Program, developing molecules and monoclonal antibodies to use as probes to understand neural pathways of learning and memory.

After injecting the antibodies into an animal model, Moskal experienced a major breakthrough in his research. The animal models acted exactly as he predicted they would.

"I wanted to see if the antibody would stimulate learning and memory," Moskal said, "and it did. The injected animal learned twice as fast as the controls. This was a real, functioning mammal that was truly learning."

That was 1983. Over the next 30-plus years, that original spark of an idea became the focus of a research group headed by Moskal at Northwestern Engineering. It developed into a novel antidepressant with promising results, spawned a startup called Naurex Inc., and serves as a platform for even more promising pharmaceuticals. Now, at last, it stands at the brink of bringing relief to those who need it most.

THE WAY FORWARD

This past summer, Allergan, a large pharmaceutical company, acquired Naurex for a $560 million upfront payment, paving the way for the promising antidepressant programs to proceed into late-stage clinical trials and eventually enter the market. Under the terms of the all-cash transaction, there is potential for additional success-based research and development and commercial milestone payments.

The transaction caps decades of neuropharmaceutical development in the laboratory and seven years of business development by a team with many Northwestern Engineering connections. The transaction structure also results in a new spin-off company that will allow Moskal, distinguished research professor of biomedical engineering, and his colleagues to continue discovering and developing novel modulators of the NMDA receptor and innovating with that technology to discover new therapies for brain and nervous system disorders.

"We finished proving these molecules have dramatic potential through much of the early clinical work," Moskal says of the Naurex drug candidates acquired by Allergan, rapastinel and NRX-1074. "Now it's time to hand these important therapies to a capable party with the necessary large resources—and to focus on repeating this innovation with our proven team and technology."

A NEW PATH FOR TREATMENT

According to the National Institute of Mental Health, major depression is the second leading cause of disability in US adults, affecting as much as 10 percent of the population.

Rapastinel (previously called GLYX-13), Naurex's fast-acting drug candidate for major depression disorder, has shown unrivaled success in Phase I and II clinical trials: It takes effect within hours of a single dose, and one dose can last for one to two weeks without any serious side effects. Last year, the intravenous injectable drug received the highly coveted fast-track designation from the Food and Drug Administration, a classification given only to drugs that demonstrate superior effectiveness and safety.

With rapastinel now approaching Phase III clinical trials, the company's second antidepressant drug, NRX-1074, has shown similar success. It is now in Phase II clinical trials and will be available in an orally deliverable pill. Because they work differently from other antidepressants, rapastinel and NRX-1074 could provide much-needed therapeutic alternatives for the 30 to 40 percent of patients who are unresponsive to currently available medications.

Photograph by Chris Strong

"IT CAN BE A CHALLENGE TO TURN RESEARCH INTO A FULLY FUNCTIONING COMPANY. BUT WHAT'S WONDERFUL ABOUT JOE IS HIS CURIOSITY, WHICH EXTENDS NOT ONLY INTO SCIENCE BUT INTO BUSINESS AND HOW THINGS WORK COMMERCIALLY." **BILL GANTZ**

"Patients often go from one therapy to another to another," said Naurex president and CEO Norbert Riedel. "One treatment might work for a short time, but then they have to start all over. Meanwhile, they are burdened with all sorts of side effects that interfere with their quality of life."

Both rapastinel and NRX-1074 work by targeting the brain's NMDA receptors, which are involved in learning and memory mechanisms. This is a markedly different approach from current, widely used antidepressants that instead increase serotonin levels.

While rapastinel and NRX-1074 are not the only drugs to target NMDA receptors, they are potentially the safest. None of the clinical trial subjects thus far have experienced serious adverse side effects related to the drugs. By contrast, other drugs on the market and in development that target these same NMDA receptors with a different mechanism of action can cause hallucinations, nausea, insomnia, and even psychotic episodes.

Moskal posits that, unlike most other NMDA receptor-targeted drugs, rapastinel and NRX-1074 do not block the receptor's ion channel, which may be the reason they don't have the same side effects. "Fundamentally, we have found the key to unlocking the way to modulate this receptor to restore normal brain function," he said.

MODEST BEGINNINGS

After those jeans-and-sneakers days at NIMH, Moskal joined Northwestern University in 1990 and founded the Falk Center for Molecular Therapeutics with the goal to translate discoveries into clinically useful compounds. There, he advanced his research with the successors to his early work with large monoclonal antibodies—smaller molecule derivatives that he suspected might get into the brain and have therapeutic potential. GLYX-13, now called rapastinel, was one of them.

With the goal of bringing his therapeutics to market, Moskal founded Naurex in late 2006 and started raising meaningful seed funding in 2008. It was the fourth company to grow out of his research, but the first to deliver on its hoped-for promise. He credits some of the success to Northwestern's supportive culture of innovation, which enabled him to work alongside students and world-class researchers while developing a business. Those who worked with him readily acknowledge that much of the success has come from Moskal's unflappable determination and resilience.

"If you're going to be in this business for 30 or 40 years, you're going to experience failure," he said. "For me, failure never felt like failure. It was just a different kind of data."

BUILDING THE RIGHT TEAM

In 2011, Naurex raised $18 million in financing, jumpstarting momentum for the company. That attracted the attention of Bill Gantz and Norbert Riedel, both veterans of the pharmaceutical industry and members of Northwestern Engineering's McCormick Advisory Council. At the time, Gantz was on the board of Adams Street Partners, a private equity firm that invested in Naurex. Riedel was the corporate vice president and chief science and innovation officer at Baxter International, where he developed Baxter Ventures in 2011 with a goal to invest in startups. One of the fund's first grants went to Naurex.

Convinced that Moskal and his team had discovered a breakthrough treatment for depression, Gantz and Riedel joined Naurex motivated also by their confidence in Moskal himself. Described by Riedel as "a bundle of energy," at age 65, Moskal, who talks fast and laughs easily, shows no signs of stopping.

"It can be a challenge to turn research into a fully functioning company," Gantz said. "But what's wonderful about Joe is his curiosity, which extends not only into science but into business and how things work commercially."

With the right team in place, Naurex became virtually unstoppable. Prior to the acquisition by Allergan, the company raised $163 million of venture funding and investments, with $80 million of the total coming from just one round of financing in November 2014.

AN EVEN BRIGHTER FUTURE

Moskal and his team are now poised to continue innovating in new disease areas with their spin-off company, Aptinyx Inc., which will move forward with the discovery engine and early-stage programs started at Naurex. For example, they have found that the NMDA receptor is involved not only in depression but in many other central nervous system disorders as well. Aptinyx will work to discover and develop other small molecules that modulate the same receptor to treat a wide array of debilitating diseases and disorders of the brain and nervous system, which Moskal says have few effective treatments and are "ripe" for his compounds.

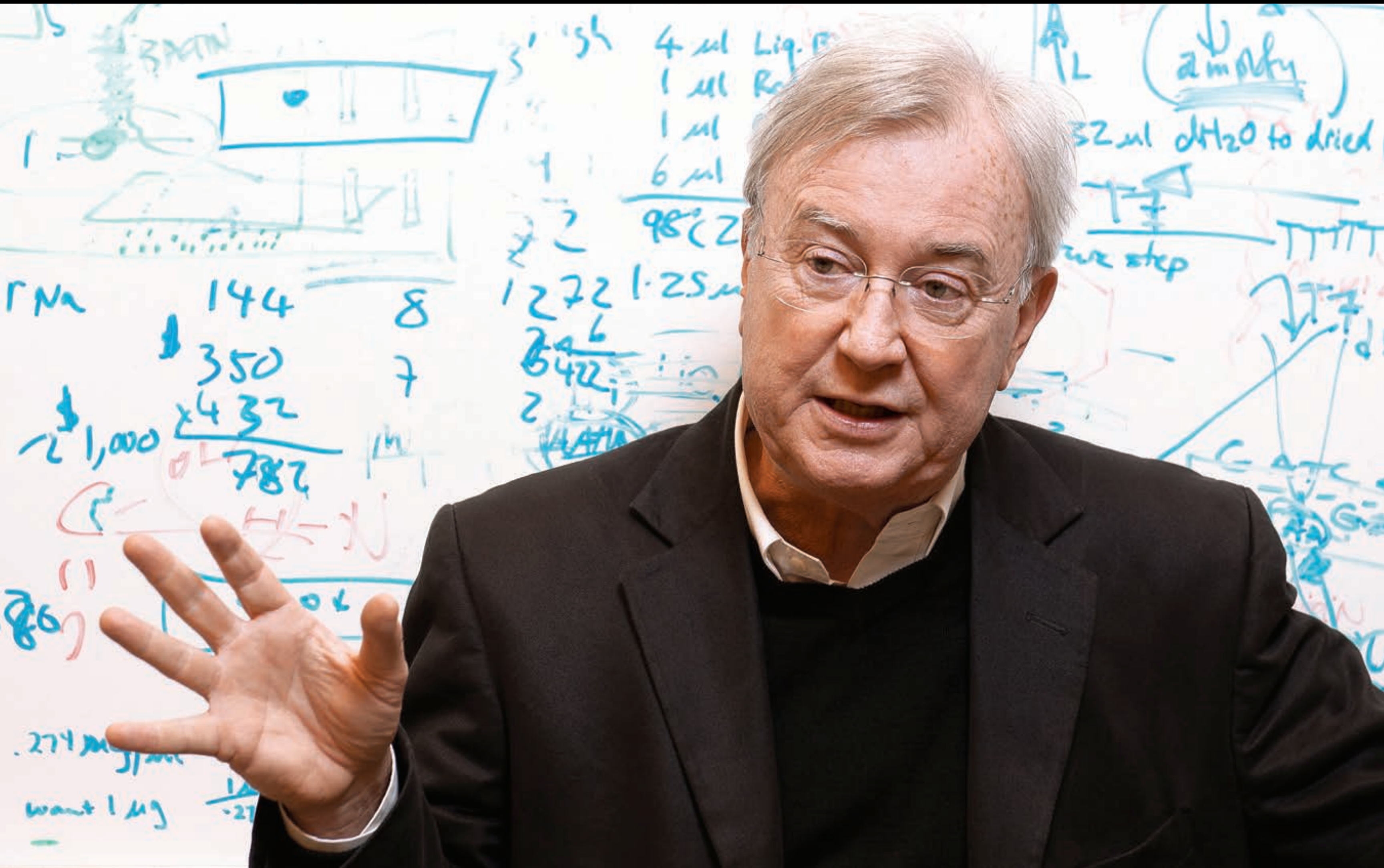
"Joe's research has opened a whole universe of understanding brain conditions where the same master switch is either involved in the normal physiology of the brain or involved in helping trigger the disease," Riedel said. "If we now take a small molecule and administer it to models of many brain and nervous system conditions, we see striking therapeutic benefits in all instances."

AMANDA MORRIS

"FOR ME, FAILURE NEVER FELT LIKE FAILURE. IT WAS JUST A DIFFERENT KIND OF DATA."

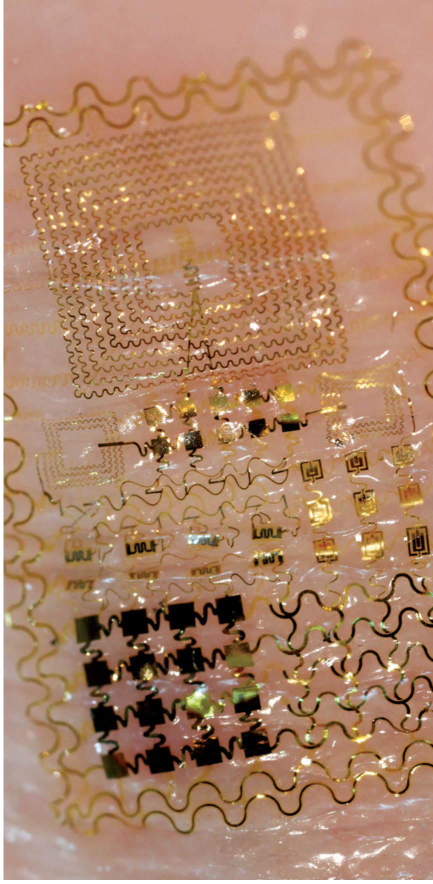
JOSEPH MOSKAL

Distinguished Research Professor of Biomedical Engineering
Director of the Falk Center for Molecular Therapeutics



Karen and Dennis Chookaszian

John Rogers



WE WILL.
THE CAMPAIGN FOR NORTHWESTERN

NORTHWESTERN UNIVERSITY'S MULTI-YEAR CAMPAIGN WAS ANNOUNCED IN MARCH 2014.

THESE ARE SOME RECENT NOTABLE GIFTS TO MCCORMICK'S CAMPAIGN.

$6.5 MILLION FOR COMPUTER SCIENCE

Trustee **Dennis H.** ('65) and **Karen M. Chookaszian** ('02 P) have made a campaign commitment of $6.5 million to establish the Chookaszian Family Program in Computer Science at McCormick. This gift will support faculty, novel technologies and methods for teaching computer science, women in computing, and research at the intersection of computer science and learning. The Chookaszians are co-chairs of the McCormick Campaign Committee.

RENOWNED PROFESSOR TO LEAD NEW CENTER FOR BIO-INTEGRATED ELECTRONICS

John Rogers, a materials scientist and pioneer in the field of bio-integrated electronic devices, will join Northwestern as the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering, and Medicine. Trustees Louis Simpson (WCAS '57) and Kimberly Querrey have made multiple campaign gifts supporting nanotechnology and biomedical research at Northwestern. When they learned that Rogers was considering joining Northwestern, they offered an additional gift through their foundation and increased their total contribution to **We Will. The Campaign for Northwestern** to $125.8 million.

New auto bays provide more space for the Solar Car, Formula SAE, and Mini Baja competition teams to design, build, and test their cars.

Thanks to these and thousands of other donors, McCormick has raised $131 million of its $200 million campaign goal to date.

NEW MAJOR GIFTS

Yie-Hsin Hung ('84) and **Stephen Farinelli** (WCAS '84) gave $250,000 to create the Yuan-Chung Hung Collaboration Space in the new McCormick Education Center. The gift was in honor of Hung's late father, a PhD graduate in civil engineering from the class of '65.

Friends and family of emeritus faculty member **Masahiro "Mike" Meshii** (PhD '59) have pledged more than $250,000 to endow the Masahiro and Eiko Meshii Fund for Distinguished Teaching. Professor Meshii helped develop and teach the freshman design curriculum and advised 45 PhD candidates and approximately 100 post-docs over his long tenure as a materials science and engineering faculty member.

Taher and **Cherine Helmy** ('06 P, '15 P) made a major commitment to the Office of Personal Development to support students and provide opportunities for their personal growth, as well as to empower them to develop into whole-brain engineers. Both of their children attended McCormick.

Ford Motor Company and **Altec, Inc.** each made $100,000 contributions to the new auto bays for the Solar Car, Formula SAE, and Mini Baja teams. This will more than triple the space available to the student competition teams. 3M also previously gave $100,000. The new space was dedicated on November 6.

Thanks to these and thousands of other donors, McCormick has raised $131 million of its $200 million campaign goal to date.

If you would like to join in making a special gift to McCormick's campaign, please contact Ben Porter, senior development director, at 847.467.5212 or b-porter@northwestern.edu.

CHELSEA STONER ('96)
HAS BUILT A BRILLIANT CAREER IN PRIVATE EQUITY ON HER STRONG ENGINEERING FOUNDATION.

The Right Direction

"It's all about problem solving at the end of the day, taking apart a really big problem, breaking it into a lot of little pieces, and tackling it. I definitely learned that at Northwestern. It's been a really good foundation for building my career."

Most people go to college expecting to find the right career path. Spending hours alone in a dark campus lab, Chelsea Stoner discovered the road she *didn't* want to take. And that has made all the difference.

Growing up with a passion for math and chemistry, Stoner loved her chemical engineering courses at Northwestern. She always assumed an engineering degree would lead to a job in research. Her expectations shifted, however, during her junior year, when she worked as an intern for up to 40 hours a week in a lab.

"The lab didn't have windows," she remembers. "It was your prototypical, basement lab environment. After doing it for about 18 months, I thought, 'This is not for me.' I just couldn't see myself working in a lab with no other people for the rest of my life."

The realization that she wanted a job that involved interacting with a team took her down an entirely different path, one that has led to a successful career in private equity. Today, Stoner serves as general partner at Battery Ventures, a global technology-focused investment firm, where she concentrates on the software and healthcare IT sectors.

FINDING HER PATH

Resolved to direct her career along a different course, Stoner approached her adviser, who reassured her that a foundation in chemical engineering could open many doors. "She told me I could do anything I wanted, that the world was my oyster," Stoner remembers. "I often say now that it's not what you know you want to do—who the heck knows what they want to do?—it's what you know you *don't* want to do."

After graduation, Stoner joined Accenture as a consultant leading technology and strategy projects. The experience propelled her into positions with Merrill Lynch and Classified Ventures. As she delved deeper into finance implementation and accounting, she began to notice a gap in her economics skill set. Once again, she trusted her instincts about what felt right for her.

"It was another enlightening moment when I said, 'This is a skill that I would like to have,'" she shares. "I also knew I wanted a family, and consulting is a tough job because you're on the road all the time. I wanted to make a career change, plus I really needed finance skills, so I thought, 'Let's go back to school.'"

After earning an MBA from the University of Chicago, Stoner became an associate at Key Principal Partners, a private equity firm. There, her interactions with entrepreneurs fueled even greater interest in the private equity field. "What really got me excited was meeting people who are very passionate about their businesses," she says. "They're entrepreneurs who have decided to put everything aside and start a company."

In this niche, Stoner found the people-filled environment she had longed for in the lab. She also relished learning about new business models and the challenges of solving new and different problems.

In 2006, Stoner joined Battery Ventures as a senior associate, drawn by their focus on technology. "They were starting to build out more of their private equity team," she remembers. "I wasn't doing technology at the time, and I really wanted to get back into it. I thought this is a great opportunity for me to marry everything that I loved in technology with what I'm doing on the deal side."

That decision has paid off for Stoner, who rose to become the first female partner in the global firm's 30-year history. Focusing primarily on software as a service (SaaS) and healthcare IT, she was involved with Battery's investments in Glassdoor, Data Innovations, and Marketo, and currently serves on the boards of Avalara, Brightree, Intacct, and WebPT. In 2013, she made *Forbes'* Midas "Hot Prospects" list of up-and-coming venture capitalists.

"I love it—it's everything I could ever ask for in a job," Stoner says. "I like doing something different every day. No day is the same."

Charged with finding interesting businesses to invest in, Stoner and her team come up with new investment ideas and then look for companies that fit them. "It's a lot of finding needles in haystacks and hunting for the right opportunity."

Seeing the companies they work with succeed and deliver a good return for investors is incredibly rewarding. "When you've put so much time and energy into something, and you see it through to completion, that's the ultimate goal," she shares. "It's this happy place where you've made your investors and the management team happy."

Thinking back to her time in the lab, Stoner says she's grateful for the engineering skills that helped propel her up the ranks of the private equity/venture capital field. "It's all about problem solving at the end of the day, taking apart a really big problem, breaking it into a lot of little pieces, and tackling it. I definitely learned that at Northwestern. It's been a really good foundation for building my career."

SARA LANGEN

CLASS NOTES

1980s

Joseph J. Rencis (MS '82), dean of engineering and the Clay N. Hixson Chair for Engineering Leadership at Tennessee Tech University, is the 2015–16 American Society for Engineering Education president.

Michael L. Sheldon ('82), co-president at Vincere Resource Group LLC, was appointed to the board of directors at Oracle Mining Corp.

Yie-Hsin Hung ('84) co-president of New York Life Investment Management LLC (NYLIM), a subsidiary of New York Life, was promoted to chief executive officer.

Gregory P. Lemense ('85), pulmonologist at Pulmonary Specialists of Knoxville, joined Blount Memorial Hospital's medical staff.

John J. D'Annunzio ('86) was appointed senior vice president of global channel sales at GENBAND.

Robert L. Armacost, Jr. ('87) was appointed engagement director at Iknow LLC.

Rita D. Brogley ('87) is CEO of MyBuys, a multi-channel marketing company that is merging with Magnetic, a digital advertising technology company. Brogley will join Magnetic's board of directors.

Demitris A. Kouris (PhD '87), member of the faculty of the departments of engineering and physics at Texas Christian University, and former dean of the university's College of Science & Engineering, was appointed provost and vice president for academic affairs at South Dakota School of Mines and Technology.

Kristina M. Ropella (PhD '89), former interim Opus dean of the Opus College of Engineering at Marquette University and professor of biomedical engineering, was named permanent Opus dean.

1990s

Rhonda Smith Ferguson ('91), vice president, corporate secretary, and chief ethics officer at FirstEnergy Corp., was appointed to the board of directors at Leadership Akron, a non-profit leadership development program.

Joseph Michael Schimmels (PhD '91), professor at Marquette University, was inducted into the National Academy of Inventors for his impact in areas including patents and licensing, innovative discovery and technology, significant impact on society, and support and enhancement of innovation.

Heather H. Vacek ('91) published a new book with Baylor University Press titled *Madness: American Protestant Responses to Mental Illness*.

William C. Kircher ('92), former vice president of Singapore overhaul and repair at Pratt & Whitney and president of UTC Aerospace Singapore, was appointed chief executive officer at VAS Aero Services.

Kathleen A. Neumann (PhD '92), interim dean of the College of Business & Technology and associate provost for budget, planning, personnel, and technology at Western Illinois University, was appointed dean of the college.

Ram Devanathan (PhD '93), materials scientist at the Department of Energy's Pacific Northwest National Laboratory, was elected to the rank of fellow in the American Ceramic Society.

Matthew J. Cole (MEM '98, KSM '98) was appointed senior vice president and general manager of the industrial business unit at Littelfuse, Inc.

Patrick R. McCarter ('98), managing director at the Carlyle Group LP, will lead the firm's new office in Menlo Park, California.

2000s

Brian Matthew Desharnais (PhD ’00), vice president at Commonwealth Engineers, received a 2015 Career Achievement Award from Rose-Hulman Institute of Technology.

Jeri Ward (MEM ’01, KSM ’01) was promoted to vice president and chief communications officer at Audi of America.

Erik James Seidel (MEM ’02, KSM ’02) was promoted to vice president of sales of Bridgestone Americas Tire Operations (BATO).

Michael M. Blake (MS ’03), former CIO at Commune Hotels & Resorts, was appointed executive vice president and chief executive officer at HTNG.

Kanya Rajangam (PhD ’07), former executive director of the oncology and immune-oncology program at Nektar Therapeutics, was appointed vice president, clinical development at Cleave Biosciences.

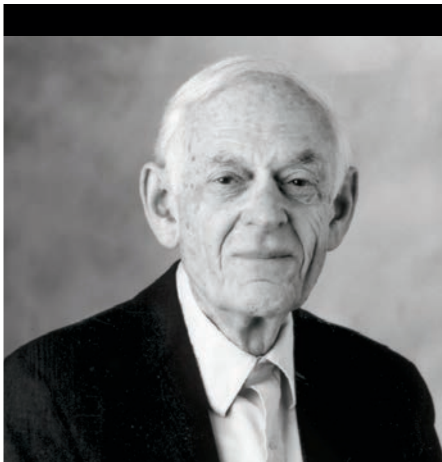
Bryan Gerard Smith (PhD ’09), former research group manager, information and communications technologies at Callaghan Innovation, was appointed chief data scientist at Movio.

Dennis Gray (MS ’10) was promoted to manager at Premier International, a niche consulting firm specializing in data migration.

Han Man (PhD ’13) was promoted to consultant at Mars & Co, a management consulting firm specializing in business strategy and operational improvement.

IN MEMORIAM

Mr. Kenneth F. Landis ’40
Mr. Bernard S. Hattis ’43
Dr. Carl R. Blanche ’44
Mr. Robert W. Kling ’44
Mr. Robert J. Lowe, Sr. ’44, ’51
Mr. Graham Davis ’46
Mr. Clovis W. Harrison ’46
Mr. Rollin H. Kimball, Jr. ’46
Mr. Jack A. Koefoot ’46
Mr. Robert V. Kremer ’46
Mr. William W. Montgomery ’46
Mr. Warren E. Pettee ’46
Mr. Wayne C. Wendelsdorf ’46
Mr. Adolph J. Gawin ’47
Mr. Charles J. Krippes ’47
Mr. Jack R. Schoenfeld ’47
Mr. Walter C. Waltrip ’47
Mr. Herbert E. Carlton ’48
Mr. James W. Pervier ’48, ’50
Mr. Girard J. Zimmerman ’48
Mr. George H. Bodeen ’49, ’70
Mr. John R. Duncan ’49
Mr. John T. Graves ’49
Mr. John M. Hellgeth ’49, ’60
Mr. Alston P. Manning ’50
Mr. Arnold Simon ’50
Mr. Wendell G. Bark ’51, ’52
Mr. Richard N. Congreve ’51
Mr. Granger Cook, Jr. ’51
Mr. John T. Craig ’51
Mr. Richard T. Voelz ’51
Mr. Robert A. Cannon ’52, ’63
Mr. Robert E. Stoffels ’52
Mr. William G. Whitney ’52
Mr. William F. Klinger ’53
Mr. Fred R. Pflederer ’53
Mr. Norman E. Bartelt ’55, ’73
Mr. Robert L. Billingsley ’56
Mr. Robert D. Kitchen ’56
Dr. Frank P. Mertes ’58
Mr. Jack W. Newhard ’59
Mr. Bobby G. Calhoon ’60
Mr. Raymond J. Thill ’60
Mr. Robert S. Weiner ’62
Mr. Thomas W. Lohmann ’63
Mr. John W. Rotter ’63
Mr. Paul H. Wittman ’63, ’65
Capt. Roy N. Poust ’64
Mr. Carl O. Clausen ’65
Mr. Robert F. Hart ’66
Mr. Karl J. Reimann, PhD ’70
Dr. William S. Stewart ’72
Mr. Larry Harold Burck, PhD ’75
Mr. Douglas V. Oride ’75
Ms. Dale C. Troppito ’76
Mr. Heinz P. Zicher ’79
Mr. Illes Santa ’80
Mr. Robert L. Burch, PhD ’81, ’82
Mr. Richard M. Damisch ’81, ’85
Mr. Alfred A. Juras ’83
Mr. Clay S. Maloney ’83
Dr. Benita Beamon ’88
Mr. Gary Richard Chamberlin ’88
Dr. Wai-Lam Kwok ’90



Morris E. Fine

Morris E. Fine, the Walter P. Murphy Professor Emeritus and Technological Institute Professor Emeritus of Materials Science and Engineering, passed away September 30. Fine, who joined Northwestern’s faculty in 1954, cofounded the world’s first Department of Materials Science. The many honors in recognition of his work included election into the National Academy of Engineering and the American Physical Society. His research to improve steel led to NUCu, a copper-hardened steel that was used in two Illinois bridges. Fine retired in 1988, but continued as an active member of the University community until his final days. He inspired his colleagues by coming to work nearly every day and continuing to write proposals and publish research.

IN MEMORIAM

Stanton R. Cook

Lee Dayton

Ira Uslander

Hamlin Jennings

LIFE TRUSTEE, RETIRED TRIBUNE CEO **STANTON R. COOK**

Retired Tribune Company Chairman Stanton R. Cook, a life trustee, devoted alumnus, and longtime benefactor of Northwestern University, died September 3 of natural causes. He was 90.

Cook received a BS in mechanical engineering in 1949 from McCormick. After graduating, he began his career as a salesman with Shell Oil Company. He later moved to the *Chicago Tribune* and rose through the ranks, eventually becoming the newspaper's general manager, president, CEO, chairman, and publisher.

Cook received an Honorary Doctor of Humane Letters degree from Northwestern in 1985 and received the 1987 Alumni Medal. He was elected to the Northwestern University Board of Trustees in 1987 and became a life trustee in 1996. Cook was a member of the Northwestern Leadership Circle and the McCormick Advisory Council.

In 1989, Cook played a key role in obtaining a $30 million pledge to the Campaign for Engineering and Physical Sciences from the Robert R. McCormick Charitable Trust. The gift was one of the largest ever made to Northwestern at the time and resulted in the school of engineering being renamed the Robert R. McCormick School of Engineering and Applied Science.

FORMER DIRECTOR OF CORPORATE RELATIONS **IRA USLANDER**

Ira Uslander, who served as director of corporate relations at McCormick from 1995 until his retirement in 2008, died July 23 at the age of 81. Prior to joining Northwestern, he had a long career in technology development, culminating in his role as CEO of Global Technology, Inc., a holding company for a network of joint-venture companies with offshore technology and component sources. During his time at Northwestern, Uslander's background in technology assessment and his understanding of industrial strategic requirements and culture served his goal of increasing collaborative relations between the University and industry.

FORMER MCCORMICK ADVISORY COUNCIL MEMBER **LEE DAYTON**

Lee Dayton, retired corporate vice president for IBM, passed away in his home in Utah on August 25 following a battle with cancer. He was 72. Dayton graduated in 1965 with a BS in industrial engineering and then joined IBM as a systems engineer. His 36-year career included positions in sales and marketing, product management, general management, and international assignments. In 1993, Dayton was named head of corporate development to manage mergers, acquisitions, and divestitures; throughout his tenure he managed the implementation of 85 acquisitions totaling $9.6 billion. He served on the McCormick Advisory Council from 2000 until spring 2015.

FORMER CIVIL AND ENVIRONMENTAL ENGINEERING PROFESSOR AND CHAIR **HAMLIN JENNINGS**

Former Northwestern University professor Hamlin M. Jennings passed away on July 8 at age 68 after a long battle with cancer. Jennings was a member of the Northwestern University faculty from 1987 to 2010. During that time, he spent four years as chair of the Department of Civil and Environmental Engineering.

A prominent scientist and engineer, Jennings was widely recognized as a preeminent researcher in the field of cement chemistry. He was a leading innovator in the electron microscopy of cement and developed the fundamentals of cement sciences, which transformed the concrete engineering field. His work greatly advanced the scientific community's understanding of hydrated cement's microstructure and its response to the environment.

BUILDING THE SHARING ECONOMY

SHELBY CLARK ('04) LEVERAGES HIS NORTHWESTERN ENGINEERING TOOLKIT AND ENTREPRENEURIAL SPIRIT TO BUILD PRACTICAL, SOLUTION-FOCUSED START-UPS

"ENGINEERING IS A BROAD SKILL SET TO SOLVE PROBLEMS AND A TOOLKIT I'M STILL USING DAILY."

Shelby Clark's light bulb moment occurred in 2008 as he biked past hundreds of other people's cars parked along Boston's streets on his way to rent a Zipcar.

"Why can't I just grab one of these?" he wondered, looking at rows of idle automobiles. Why not, indeed, he later discovered. The United States has more automobiles than drivers, many of whom it turns out are ready to make productive and profitable use their automotive assets.

Today, Clark is recognized as a pioneer in the swelling sharing economy as the architect of RelayRides, a peer-to-peer car sharing platform that now boasts nearly 100 employees, a dedicated user community across the country, and clones around the globe.

"I'm proud to have created something much greater than myself," says Clark, who stepped away from RelayRides' daily operations in 2013 but remains on its board.

An unlikely journey

Arriving at Northwestern from his native Colorado on a swimming scholarship in 2000, Clark switched his engineering major multiple times, from industrial to manufacturing to mechanical before latching onto biomedical, a decision motivated by the passing of his father during Clark's sophomore year.

"I was interested in the intersection of business and biotech, particularly if it meant other people wouldn't have to lose a loved one like I did," Clark says.

After graduation, he spent two unfulfilling years as a management consultant, eventually taking a nonprofit sabbatical and landing at a then-upstart agency called Kiva.org. As one of Kiva's earliest employees, Clark helped build the internal systems that allowed the peer-to-peer microfinancing organization to scale.

Entrepreneurship, he realized, could spur social change. "I was fascinated by the idea of connecting people online to drive change in the offline world," Clark says, calling "commercialization and scale just as important as discovery."

After six years with Kiva, including time in Uganda, Clark joined a biotech hedge fund. While listening to dreamy-eyed entrepreneurs passionately pitch ideas to cure cancer or grow kidneys, Clark realized he was on the wrong side of the table.

He quit the hedge fund, entered Harvard's MBA program with the explicit goal of starting a company, and launched RelayRides in 2010, testing a series of hypotheses to understand how people would interact with and use the novel platform.

"I always considered myself a rational, logical thinker who enjoyed finding solutions to large problems," Clark says. "RelayRides was just that—and a leap of faith."

Clark has brought that same mindset to his new position as the CEO of Peers, a San Francisco-based startup that supports workers in the emerging sharing economy workforce. "Engineering is a broad skill set to solve problems and a toolkit I'm still using daily," he says.

DANIEL P. SMITH

A Lifetime of Problem Solving

LARRY LARKIN ('60) HELPED MAKE HISTORY IN AMERICA'S SPACE PROGRAM AND LEVERAGED THE EXPERIENCE FOR CREATIVE PROBLEM SOLVING THROUGHOUT HIS CAREER.

Larry Larkin's interest in engineering emerged out of necessity. Growing up in the aftermath of World War II, he found that material goods were scarce. If you wanted something, you would likely have to build it yourself.

"You couldn't purchase new cars or appliances, so people had to think creatively about how to get what they wanted," Larkin says. "I couldn't buy a radio, but I could build one."

Larkin's affinity for problem solving eventually brought him to Northwestern, where he studied electrical engineering against the backdrop of the Cold War and the early days of the United States' space program.

After graduating in 1960, Larkin found himself at the forefront of one of the era's most important and historic science and engineering endeavors, Project Mercury, America's first human space flight program. There, he helped develop the electrical systems that would assist astronauts, including such notable pioneers as John Glenn and Alan Shepard, on their return to Earth following time in orbit.

"To walk out of school and into that environment was the most exciting time of my life," Larkin says. "You couldn't have experienced a more stimulating career in research and applied engineering."

Larkin assisted in the design of the Mercury capsule's nose cone recovery system, responsible for deploying parachutes, issuing a radio beacon to ground control and recovery vessels, and releasing a flotation collar all at pivotal moments during the capsule's descent and water landing. Looking back, he credits his McCormick experience for the right approach to tackle the problem.

"The practical skills I learned, like designing vacuum tube circuits, became obsolete soon after I graduated," Larkin says. "But Northwestern also taught me how to look at data and reach a creative solution, which was far more helpful while working on Project Mercury."

Now retired, Larkin has directed his problem-solving skills toward a lifelong passion: restoring historic boats. A resident of Lake Geneva, Wisconsin, Larkin is an established historian of the town's boating culture, having published two books on the subject. His most recent, *Grand and Glorious* (Sealark Publications, 2002), memorializes Lake Geneva lifestyle and the community's relationship to boats at the start of the new millennium.

While Larkin has always recognized a classic boat's aesthetic elegance, he notes his engineering career has built a newfound appreciation of what's underneath the frame. "There are lots of little problems within the complex electrical and mechanical systems that need to be fixed during any restoration," Larkin says. "I've learned to appreciate how all of those parts interact together to help a boat run its best."

ALEX GERAGE

UNLOCKING THE SECRETS OF THE IMMUNE SYSTEM

AS CHIEF MEDICAL OFFICER AT A BIOTECHNOLOGY COMPANY, **SHEILA GUJRATHI** LED INNOVATION AT THE INTERSECTION OF MEDICINE, ENGINEERING, AND BUSINESS

Throughout her career, Sheila Gujrathi ('92, MD '96) has focused on blending engineering, medicine, and business, though her passion lies in immunology.

"I'm fascinated with the body's immune system," she says. "It's a beautiful, elegant, intrinsic system. The practical applications of it were intriguing to me because it seems to be the center point of preventing or treating a number of different diseases."

Gujrathi stood at the center of immunology research as chief medical officer at Receptos, a biopharmaceutical company developing therapeutic candidates for the treatment of immune and metabolic diseases. The opportunity to help grow the business drew her to Receptos in 2011 after serving as vice president of the Immunology therapeutic area at Bristol-Myers Squibb.

"I was looking for an entrepreneurial environment, and I wanted to be part of building a company—that was really exciting," she shares. "The science drew me to Receptos in particular. It has an excellent scientific platform and a great group of scientists."

A clear focus on improving lives

Early in her career, as a management consultant at McKinsey & Company, she provided strategic advice on projects in the healthcare and pharmaceutical industry. She then held roles of increasing responsibility at Genentech in the immunology and tissue growth and repair clinical development group.

Then, as chief medical officer at Receptos, she continued down that path focused on expanding the body of knowledge about the nature of human response to disease. "It's definitely cutting-edge science," she says. "We learn more about the immune system every day. I'm able to contribute to that evolution of our understanding."

Because scientists can only rely so much on animal models and in vitro experiments, human clinical trials are vital to understanding how the immune system works in patients, says Gujrathi. She also acknowledges the incredible challenges associated with designing the best possible clinical trials: ensuring safety and efficacy while keeping in mind global regulatory requirements and health insurance factors. Applying the lessons she learned at McCormick has been key to confronting those challenges every day.

"It requires a lot of strategic and analytical thinking," she says. "The engineering background paid off tenfold in my understanding of how to look at a problem, break it down analytically, and address each part of it to ultimately solve the entire equation. I still use those basic problem-solving and analytical skills on a daily basis."

For Gujrathi, using her engineering training to help others has proven incredibly satisfying. "When you develop the therapy and have a positive clinical trial; when you actually see that a compound is working, and patients can benefit from it; when you're fulfilling unmet needs for those patients and helping make their lives better, those are the top three reasons I find working in biotechnology so rewarding."

With the recent purchase of Receptos by biotechnology company Celgene Corp., Gujrathi is consulting for Celgene during the transition while she considers where her love for immunology will take her next.

SARA LANGEN

"THE ENGINEERING BACKGROUND PAID OFF TENFOLD IN MY UNDERSTANDING OF HOW TO LOOK AT A PROBLEM, BREAK IT DOWN ANALYTICALLY, AND ADDRESS EACH PART OF IT TO ULTIMATELY SOLVE THE ENTIRE EQUATION. I STILL USE THOSE BASIC PROBLEM-SOLVING AND ANALYTICAL SKILLS ON A DAILY BASIS."

FOLLOWING HIS PASSION

AFTER LEADERSHIP ROLES WITH CHICAGO PUBLIC SCHOOLS AND YEAR UP, **ALAN ANDERSON** (MS '99) RETURNS TO NORTHWESTERN TO BUILD STRONG COMMUNITY PARTNERSHIPS.

"I'VE NEVER FELT ANY OBSTACLE WAS TOO GREAT BECAUSE THE ENGINEERING DISCIPLINE TELLS ME THERE'S A SOLUTION SOMEWHERE."

In Alan Anderson's final quarter as a master's student in electrical engineering at Northwestern, he took a technical entrepreneurship course with professor Michael Marasco. The goal of the course was direct, yet daring: build a product and pitch it to investors.

Over 10 weeks, Anderson and his teammates conceptualized a cart-mounted payment device allowing grocery store patrons to bypass checkout lines. They ran a business model and constructed their pitch.

It proved to be a life-altering experience for Anderson.

"Being a problem solver was in me and I wanted to do it more," Anderson says. "I saw how important creativity, ingenuity, and the entrepreneurial mindset were to advancing the world."

So even after Anderson had earned his master's and returned to his previous employer, Motorola, his heart was elsewhere.

"I was fascinated by opportunities, solutions, and selling an idea, particularly in the areas of youth development and education, which had become passion projects for me," he says.

A meaningful pathway back

After nine years at Motorola, Anderson departed in 2006 to pursue his passion. He joined the Chicago Public Schools as an Eli Broad Fellow, a program that leverages the skills of professionals from nontraditional backgrounds to improve urban school district operations. Over the next four years, Anderson spearheaded school turnarounds, guided staff development initiatives, and led accountability programs, learning plenty about the public sector, messaging, and navigating bureaucracy.

"At the end of the day, I'm a fact-driven, pragmatic person who tries to address problems in a thoughtful way, and that's what I did," Anderson says.

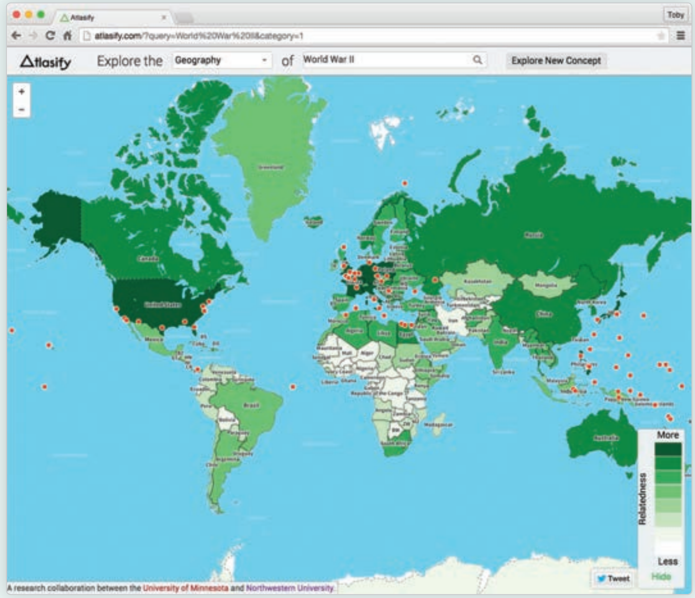
In 2010, Anderson moved to Year Up, an upstart nonprofit that provides adults with a high school-level education access to professional skills development and internship opportunities. Charged with building the organization's Chicago presence from scratch, he relentlessly honored its mission; lives were transformed as graduates' incomes and attitudes jumped.

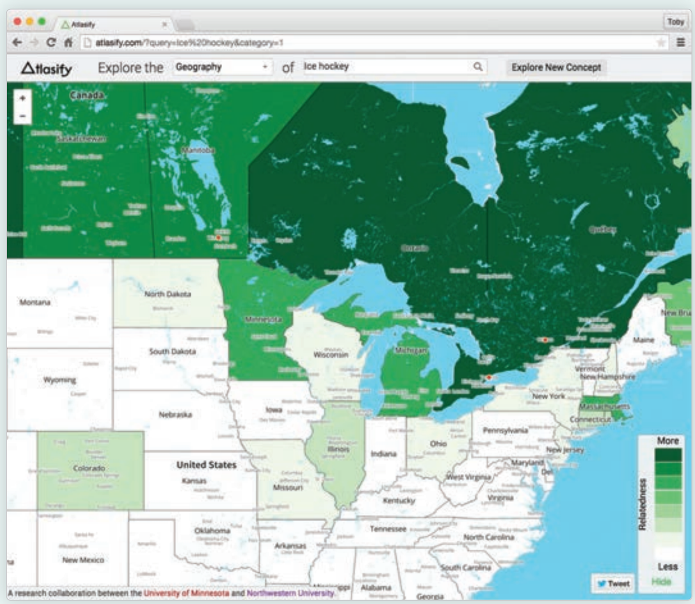
"I've never felt any obstacle was too great because the engineering discipline tells me there's a solution somewhere," says Anderson, who also holds an MBA from Northwestern's Kellogg School of Management.

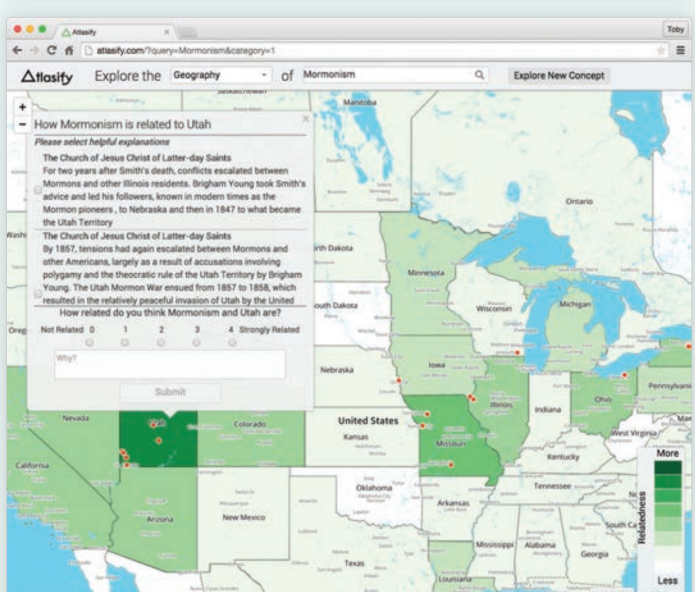
This past summer, Anderson came onboard with Northwestern as executive director of neighborhood and community relations, tasked to foster beneficial relationships between the University and the greater Evanston community through initiatives such as the existing STEM program at Evanston Township High School.

"The exciting part is that I get to come back to a place I love and use all of the skills I've developed over the years to write this new chapter, which even includes a way to influence the next generation of engineers," Anderson says.

DANIEL P. SMITH







VISUALIZING RELATEDNESS, GEOGRAPHICALLY AND BEYOND

This past summer, Northwestern engineers launched a new search engine that could change the way people think about finding information on the Web. Called "Atlasify," the tool does more than respond to queries; it invites users to explore new concepts by generating cartographic "atlases" about subjects of interest.

If a user searches for "ice hockey," for example, Atlasify superimposes the results over a color-coded world map to generate a "thematic atlas." Regions that appear darker in color relate more closely to ice hockey, and lighter colored regions relate less.

When a user clicks on a country, state, province, or place of interest in the interactive visualization, an explanation of the relatedness appears, detailing in natural language how the clicked place is related to ice hockey. In this scenario, Canada and Sweden—two countries where hockey is popular—appear the darkest, while Saudi Arabia and Brazil are white and have no recorded relationship to the sport.

"The heat maps allow you to see how related your query is to different places, and then you can dig into reasons why it's related," says Douglas Downey, associate professor of computer science and co-inventor of Atlasify.

The site uses an "explanatory semantic relatedness algorithm" developed by Downey and former Northwestern Engineering PhD student Brent Hecht, who is now at the University of Minnesota. The algorithm mines Wikipedia to determine the amount of relatedness between concepts and uses text from the popular online encyclopedia to explain the relatedness.

Although Downey and Hecht refer to Atlasify as "the geography of everything," the search engine enables users to go beyond maps. Other visualization options include the periodic table of elements, US Senate seating chart, and a historic timeline, so users can also explore how topics are related to chemistry, politics, and history.

To try out Atlasify, visit www.atlasify.com.

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BEYOND LITHIUM

Professor Monica Olvera de la Cruz and her team are researching plastic batteries as a safer alternative to current lithium-ion battery technologies. Her research explored how two types of polymers (the orange and red chains in the image) could be connected to form block copolymer (BCP) nanomaterials. She found that the shape of the nanochannels through which ions (shown as green and yellow dots) travel can be controlled in BCP plastics. And by controlling the movement of ions in these nanochannels, BCPs can optimize the electricity a battery generates. See story on page 20.