

McCormick

NORTHWESTERN UNIVERSITY ENGINEERING / *fall 2013*



DATA AS ART

WHAT HAPPENS WHEN INFORMATION MEETS AESTHETICS?



On the cover: “Chicagos” is one of three projects to come out of the inaugural Data as Art course, a collaboration between McCormick and the School of the Art Institute of Chicago. Using public school data, census numbers, and public transit information, the team explored the issue of school choice with a series of temporal maps that show how easy or difficult it is for transit users to reach other parts of the city. This map shows transit times experienced by a person living in Chicago’s downtown Loop area. See story on page 20.

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Greetings from McCormick.

A few weeks ago, I was in Copenhagen to speak at a large event to commemorate the seminal 1913 papers of Niels Bohr. Many of Denmark’s leaders, including the queen, congregated during parallel events to celebrate work that, though written when Bohr was just 28, gave birth to atomic theory and quantum mechanics. Bohr went on to win a Nobel Prize in physics, but what followed was even more amazing: 38 people mentored by Bohr also won Nobel Prizes. What was the secret of Bohr’s success? What led to such an explosion of talent? Is it possible to recreate that magic?

Bohr’s success is one of many clusters of amazing intellectual output throughout history. Some of these were planned and structured: Florence in the Renaissance had L’Accademia delle Arti del Disegno, the Bauhaus was organized in Germany in the early 20th century, and Bell Labs, birthplace of an explosion of a wide range of revolutionary technologies, existed within a company. (This famously led to seven Nobel Prizes and two Turing Awards.)

However, other hotbeds of innovation occurred without a structure: Vienna in the 19th century emerged without a master plan; the Lunar Society of Birmingham—among the first places to connect engineers, scientists, and industrialists, which emerged in the context of the Industrial Revolution—had a very loose structure. In modern times, Silicon Valley has developed an entirely new high-tech sector that affects every part of our lives, but it relies on an overall network, not a planned structure, to drive innovation.

Despite their differences, one pattern is evident in all of these examples: mentorship, intellectual power, and collaboration across disciplines can lead to explosions in innovation.

At McCormick, we combine those same elements to spur innovation by building an environment that brings together the best of Northwestern and Chicago. Take, for example, our recent partnership with the School of the Art Institute of Chicago (page 20). This summer we offered a joint course, Data as Art. Faculty from both institutions (nine in all) taught, and students were grouped in interdisciplinary teams to analyze

large data sets to create visual representations that would both educate and provoke. The results were incredible.

In this issue you will find other outputs from our network, including stories from our interdisciplinary NUvention courses and updates from Design for America. These areas are already exploding with results—student teams and recent graduates have swept many high-level competitions, including the Rice Business Plan Competition, the *Wall Street Journal* Startup of the Year (page 4), and the pitch competition at the *Fortune* Most Powerful Women Summit (page 7).

While we find new ways to teach creative, right-brain skills to McCormick students, we also find that other Northwestern students are increasingly seeing the value in learning the solid and time-tested technical left-brain skills of an engineer. Enrollment in our undergraduate computer science courses has tripled over the last five years. While the number of computer science majors has nearly doubled, many students enrolled in the courses are nonmajors looking to enhance their skill sets.

You will also read about the basic research that will drive future innovation, such as our pioneering work with graphene (page 34). Basic research is what sets a university apart—the most daring research may not have a clear application in mind. I am certain that the young Niels Bohr did not anticipate that his research would lead to the transistor, the iPhone, and the atomic age.

This is the beauty of a place like McCormick. We are surrounded by amazing people and ideas, providing a sort of glimpse into the future. Some of our work is in response to needs that we clearly see around us, while other work anticipates or creates future needs and provides the toolset to deal with future challenges that we cannot predict.

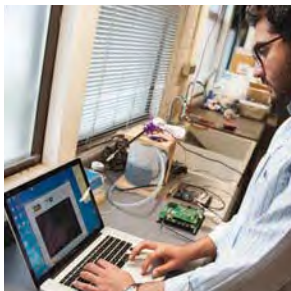
McCormick is an inspiring place to be, and we are happy to have you as a part of our community.

Julio M. Ottino, Dean | November 2013

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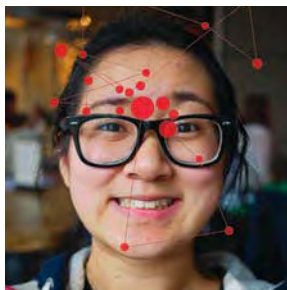
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McCormick news

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NEW METHOD PROPOSED FOR NONLINEAR OPTICAL EFFECTS



In most media—including air, water, and vacuums—particles of quantized light beams, called photons, do not interact; when two light beams intersect in space, for example, they simply continue on their paths. But in certain crystalline materials and with a powerful enough laser, it is possible to make photons interact with one another and take on special characteristics. Known as nonlinear optical effects, these characteristics could be manipulated for applications in both the classical and the quantum domains.

Researchers at Northwestern, led by **Prem Kumar**, AT&T Professor of Information Technology, have proposed a new, more practical method for realizing nonlinear optical effects. The method is based on the quantum Zeno effect, a counter-intuitive phenomenon originating from the famous “arrow paradox” raised more than 2,000 years ago by the philosopher Zeno of Elea, who argued that since an arrow in flight was not seen to move during any single instant, it couldn’t be moving at all. Applying this effect to realistic nonlinear optical resonator systems, the researchers found that single photons can interact strongly with each other without ever overlapping in real space on any significant level.

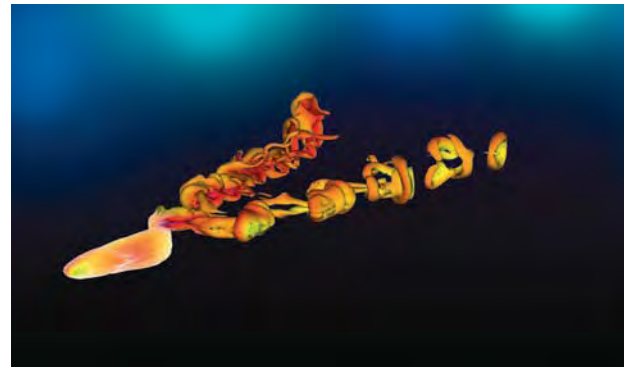
The results represent a step toward quantum computing and could have interdisciplinary applications in areas such as gravity wave detection and biological microscopy.

COMPUTATIONAL METHODS REVEAL HOW FISH SWIM

How do fish swim? This seemingly simple question has no simple answer.

Using computational methods to test assumptions about preferred evolutionary characteristics, researchers at McCormick have revealed some of the mechanical properties that allow fish to perform their complex movements. They found the optimal values for muscle activation and body stiffness properties of the most successful swimmers.

“Our results suggest that precursors of a backbone would have given rise to animals with the appropriate body stiffness,” said professor of mechanical engineering **Neelesh Patankar**, who led the research.



The researchers also confirmed that the ability to swim, while dependent on mechanical parameters, is not sensitive to minor generational changes; as long as body stiffness is above a certain value, the ability to swim quickly is insensitive to the value of the stiffness.

Finally, making a connection to the neural control of movement, the researchers analyzed the curvature of a fish’s undulations and determined that a single bending torque, not precise bending torques at every point along the body, gave rise to complicated-looking undulations.

The findings could provide insights into evolutionary biology and lead to better understanding of the neural control of movement and to development of bioinspired underwater vehicles.

OVARIAN CANCER DETECTION TECHNOLOGY HOLDS PROMISE



New biophotonics technology developed at Northwestern is the first method to detect the early presence of human ovarian cancer by examining cells easily brushed from the cervix or uterus

and not the ovaries themselves.

Using partial wave spectroscopic microscopy, **Vadim Backman**, Walter Dill Scott Professor of Biomedical Engineering, and Hemant K. Roy, a former NorthShore University HealthSystem physician, conducted a clinical study of ovarian cancer patients. The researchers saw diagnostic changes in cells taken from the cervix or uterus of patients with ovarian cancer even though the cells looked normal under a standard microscope.

No reliable early-detection method for ovarian cancer currently exists. PWS uses light scattering to examine the architecture of cells at the nanoscale and can detect the earliest known signs of carcinogenesis. Changes can be seen in cells far from the tumor site or even before a tumor forms. The results have the potential to translate into a minimally invasive early-detection method using cells collected with a swab, exactly like a Pap smear.

In previous Northwestern-NorthShore studies the PWS technique has shown promising results in the early detection of colon, pancreatic, and lung cancers using cells from neighboring organs. If commercialized, PWS could be in clinical use for one or more cancers in about five years.

NEW METHOD TARGETS DELIVERY OF MOLECULES INTO CELLS



McCormick researchers have developed a new method for delivering molecules into single targeted cells through temporary holes in the cell surface, a technique that could find applications in drug delivery, cell therapy, and related fields.

Bulk electroporation—which exposes cells to electric pulses, creating reversible nanopores in the cell membranes—is an increasingly popular method of introducing molecules such as nucleic acids or proteins into a cell to change its properties, a process called cell transfection. But electroporation of a bulk cell solution results in heterogeneous cell populations and often low cell viability. **Horacio Espinosa**, James and Nancy Farley Professor of Manufacturing and Entrepreneurship, and his group have developed a novel tool for single-cell transfection.

Their nanofountain probe electroporation (NFP-E) method allows researchers to deliver molecules into targeted cells through temporary nanopores created by applying a localized electric field to a small portion of the cell. With the ability to control dosage by varying the duration of the electric pulses, researchers have unprecedented control of cell transfection.

MCCORMICK OFFERS ITS FIRST MOOC



This fall for the first time McCormick offered a MOOC—a massive open online course in which large numbers of participants can explore a new field or feed a curiosity for free. The endeavor will benefit from a new, professor-created recording studio specifically designed for filming online lectures.

More than 17,000 people signed up for “Everything Is the Same: Modeling Engineered Systems,” available on Coursera.org. Covering modeling and analysis techniques for electrical, mechanical, and chemical systems, the introduction to engineering course includes 24 lectures that average less than seven minutes each.

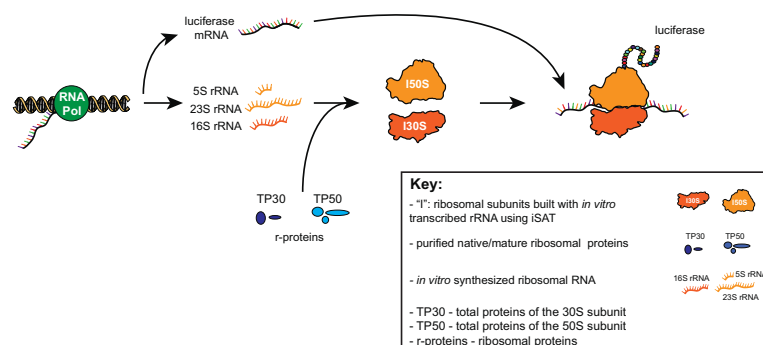
“We are trying to embrace groups that elite universities have not traditionally accessed: those without a college education, those with a curiosity about engineering, and high school students trying to decide on a career path,” said course instructor **Todd Murphey**, associate professor of mechanical engineering.

Designed for people with a background in introductory calculus, the eight-week MOOC gives students a foundation in physical modeling with topics like Newton’s, Kirchoff’s, and Fick’s laws. Online demonstrations featuring students from Murphey’s lab explain how ideas can be applied to real examples.

The course was partly filmed in a McCormick recording studio designed for video instruction by **Michael Peshkin**, professor of mechanical engineering. A mirrored video camera reverses the diagrams professors draw on a special glass panel so they appear correctly to viewers.



Integrated rRNA synthesis, ribosome assembly, and translation (iSAT)



RESEARCHERS SYNTHESIZE RIBOSOMES THE NATURAL WAY

Working with partners at Harvard Medical School, synthetic biology researchers at Northwestern have for the first time synthesized ribosomes—cell structures responsible for generating all proteins and enzymes in the human body—from scratch in a test tube.

Past efforts to synthesize ribosomes from their constituent parts under conditions that did not replicate the environment of a living cell yielded poorly functional ribosomes. In addition, attempts to combine ribosome synthesis and assembly in a single process have failed for decades.

Michael C. Jewett, assistant professor of chemical and biological engineering, and researchers from Harvard mimicked the natural synthesis of a ribosome, allowing the natural enzymes of a cell to facilitate the manmade construction. Working with *E. coli* cells, the researchers combined natural ribosomal proteins with synthetically

made ribosomal RNA, which self-assembled *in vitro* to create semisynthetic, functional ribosomes. The synthesis process developed—termed “integrated synthesis, assembly, and translation” technology—mimics nature by enabling ribosome synthesis, assembly, and function in a single reaction and in the same compartment.

Cells require ribosomes to live. Ribosomes translate messenger RNA into proteins, a core process of the cell. The thousands of proteins per cell in turn carry out a vast array of functions, from digestion to the creation of antibodies.

The new technology could lead to the discovery of antibiotics targeting ribosome assembly; an advanced understanding of how ribosomes form and function; and the creation of tailor-made ribosomes to produce new proteins with exotic functions that would be difficult, if not impossible, to make in living organisms.



STUDENT STARTUP FEATURED IN WSJ DOCUMENTARY

SwipeSense, a medical startup founded by two recent Northwestern graduates through the University student group Design for America, was included in the *Wall Street Journal's* documentary *WSJ Startup of the Year*.

The episodic video series, which premiered June 24 on the online video platform *WSJ Live*, matches 24 startups with global business leaders and influencers and tracks their progress over five months.

Created by Design for America cofounders **Murt Iseri** (right, combined studies '11) and **Yuri Malina** (left, integrated science '11), SwipeSense offers a way to help solve the problem of hospital-acquired infections, which kill an estimated 90,000 people a year in the United States. About the size of a pager, the portable hand-sanitizing system affixes to healthcare professionals' belts and dispenses sanitizer at the swipe of a hand. A wireless tracking system monitors the frequency of hand sanitizing.

Design for America is a national student group founded at Northwestern that creates local and social impact through interdisciplinary design.

McCormick

IN THE MEDIA

STRETCHABLE BATTERY WIDELY FEATURED IN NEWS



A revolutionary stretchable battery developed by **Yonggang Huang**, Joseph Cummings Professor of Civil and Environmental Engineering and Mechanical Engineering, has been featured by several news outlets.

Huang worked with John A. Rogers, the Swanlund Chair at the University of Illinois at Urbana-Champaign, to create

the flexible battery. The two connected a series of wavy, tightly packed wires to the components of a small battery, which allowed the battery to change shape and stretch up to three times its normal size.

"When we stretch the battery, the wavy interconnects unravel, much like yarn unspooling, while the storage components almost keep undeformed, because of their much larger rigidity than the interconnects," Huang explained.

The battery's charge lasts up to nine hours and can be boosted wirelessly. It is the final piece of the researchers' line of stretchable electronics and could be used to power future medical devices.

The findings were published in the online journal *Nature Communications* and have been covered by NBC News, the BBC, *Smithsonian Magazine*, and *Live Science.com*.

STUDENT SLEEP PROJECT PROFILED IN NEW YORK TIMES

As Northwestern's football team takes to the field this fall, McCormick students are trying to arm them with a secret weapon: plenty of sleep.

In a new study spearheaded by three McCormick undergraduates, the Wildcats are wearing motion-sensor armbands that track the quality and quantity of their sleep. The data, collected voluntarily and shared with Northwestern's football coaches, can be used by players to better understand the connection between sleep and performance.

"Study after study says that sleep has a huge effect on memory, mood, strength, and endurance, yet there's this sleep machismo at a lot of universities, like sleep is for lazy people," said project cocreator **Jeffrey Kahn**, a BS/MS student studying health systems engineering. "We wanted to explore how much sleep students are getting and how it is affecting them."

Working with Segal Design Institute clinical associate professor **Dan Brown**, Kahn and complex-systems major **Jacob Kelter** spent



STEPHEN J. CARRERA

months reading scientific literature about sleep, interviewing students and sleep experts, and tracking their own sleep cycles. They tested a variety of sleep-monitoring technologies before selecting a suite of four sensors that track subjects' position and body temperature during sleep. Working with computer engineering student **Leon Sasson**, they also created a web app on which Wildcat coaches can access the data.

The study was featured in the *New York Times* and *Chicago Tribune*.

EMERITUS PROFESSOR PUBLISHES OP-ED ON TRANSPORTATION SAFETY



While the cause of each transportation disaster varies, they all involve the interaction between automation, training, and human psychology, **Elmer Lewis**, professor emeritus of mechanical engineering, wrote in

an op-ed piece published in the *Los Angeles Times* in August and subsequently picked up by several news outlets. Lewis called on the transportation industry to reflect on the relationship between operators and automation.

"The designers of planes, trains, and even automobiles increasingly automate some functions once performed by those who

operate these conveyances, and from a safety standpoint, there is much to be gained by it," he wrote. But automation has drawbacks: operators can become either too reliant on it or override it with reckless behavior.

"When many people's lives are at stake, we have all the more reason to demand safety systems that cannot be overridden by errant operators," Lewis said.

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STUDENT ROCKET BREAKS RECORD



Northwestern students go the extra mile. If they're NUSTARS, they go a mile and six feet.

The Northwestern University Space Technology and Rocketry Society broke a record in April when members launched a homemade rocket in NASA's University Student Launch Initiative outside Huntsville, Alabama. NUSTARS, a student engineering organization founded last year to construct high-powered rockets for NASA's university-level competitions, had spent eight months perfecting its rocket.

Forty teams from around the country competed in the event, in which students were challenged with designing a rocket to reach 5,280 feet (one mile) in altitude and no farther. Northwestern's nine-foot rocket reached 5,286 feet, so the team was docked several points for passing the one-mile mark and missed out on the first-place Altitude Award. But Northwestern took second place and achieved a competition record for coming closest to the one-mile altitude target.

AMERICAN CERAMIC SOCIETY TOP HONOR TO KATHERINE FABER



Katherine Faber, Walter P. Murphy Professor of Materials Science and Engineering, has been named a 2013 Distinguished Life Member of the American Ceramic Society. The society's highest honor, the award recognizes eminent contributions to the ceramic and glass profession.

A member of Northwestern's faculty since 1988, Faber researches porous ceramics for energy applications; graphite- and silicon carbide-based cellular ceramics synthesized from natural scaffolds, such as pyrolyzed wood; and thermal and environmental barrier coatings for engines and gas turbines. Faber recently extended her research to include cultural heritage science. She codirects the Northwestern University–Art Institute of Chicago Center for Scientific Studies in the Arts, which offers interdisciplinary scientific research collaborations to museums across the country.

Faber joined the American Ceramic Society in 1975, was made fellow in 1992, and served as president from 2006 to 2007.

STUDENTS RECEIVE GRANTS FOR GLOBAL WORK

The Global McCormick office awarded grants to six students to help promote and enhance international undergraduate experiences this summer. The following recipients benefited from grants to support their research and internships abroad:

- **Kelsey Ann Berning** conducted research at Shanghai Jiao Tong University, China.
- **John Patrick Boueri** interned as a trainee engineer at ACWA Emirates in Dubai, United Arab Emirates.
- **Alex Clark Freedman** conducted research at the Technische Universitaet Muenchen in Germany.

• **Yoon Hyung Lee** conducted research in the Translational Neural Engineering lab of École Polytechnique Fédérale de Lausanne in Switzerland.

• **Ambar Pankaj** interned at PriceWaterhouseCoopers in Abu Dhabi, United Arab Emirates.

• **Heun Mo Yoo** conducted research at Eidgenössische Technische Hochschule Zürich in Switzerland.

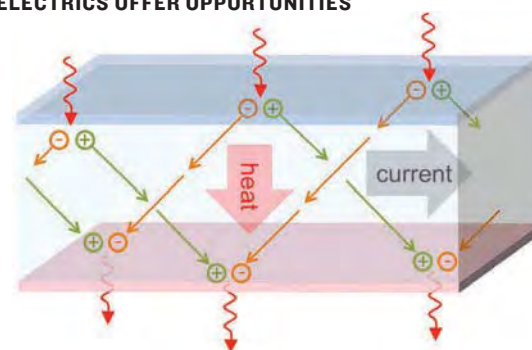
Global McCormick enables students, faculty, and alumni to explore, experience, and engage with global scholarly activities anchored by McCormick programs and initiatives.

TRANSVERSE THERMOELECTRICS OFFER OPPORTUNITIES

Thermoelectrics—materials that convert heat to electrical energy, and vice-versa—find everyday use in portable refrigerators and waste heat electrical generators. However, they have limitations. Devices made of standard materials with positive (“p-type”) or negative (“n-type”) charges moving parallel to the heat flow stop operating at cryogenic temperatures below 150°K and cannot be scaled down much smaller than a millimeter.

Northwestern researchers recently developed a strategy to fabricate semiconductors in which positive and negative charges move perpendicular to each other (called “p n-type” or “p-by-n-type”), inducing heat to flow transverse to the electrical current. This opens the door for novel thermoelectric applications, particularly at small scales and at cryogenic temperatures where current technologies fail.

Led by **Matthew Grayson**, associate professor of electrical engineering and computer science, the researchers determined that a type II superlattice with alternating layers



of indium arsenide and gallium antimonide possesses orthogonal p-type and n-type characteristics and described how such materials could be fabricated.

While standard materials are extensively used in today's thermoelectric devices, tremendous opportunities for new applications arise with these transverse thermoelectrics. Because they can operate at very low temperatures or be scaled down to very small sizes, it could become possible to reduce solid-state refrigerators to micron-size cooling devices that could be built into integrated circuits. The materials also have potential for refrigerating to cryogenic temperatures and converting a few degrees of temperature difference around room temperature into hundreds of volts of electrical potential.

STUDENTS HONORED AT CONVOCATION



Several students were honored at McCormick's convocation in June.

Julian Minuzzo (BS/MS '13 materials science and engineering) won the 2013 Harold B. Gotaas Undergraduate Research Award. Named in honor of McCormick's third dean, the annual award is given to the senior with the best research paper. In "A Self-Assembled Organic/Inorganic Lamellar Hybrid Nanostructure for Photovoltaic Applications," Minuzzo described his process for making solar cells with an ordered nanostructure ideal for charge separation and conduction. During solar cell fabrication, perpendicularly aligned layers of electron-donating and electron-accepting materials self-assemble into solar cell structure. The work was conducted under the advising of **Samuel I. Stupp**, Board of Trustees Professor of Materials Science, Chemistry, and Medicine and director of Northwestern's Institute for BioNanotechnology in Medicine and the Simpson and Querrey Center for Regenerative Nanomedicine. Minuzzo (center) is pictured above with Stupp (left) and **Stephen Carr**, associate dean of undergraduate engineering.

Three teams of seniors were awarded the Mickelson Prize for insightful, innovative, and/or creative projects:

First prize: **Avanti Badrinathan**, **Grace Bushnell**, **Hongyu Chen**, and **Jonathan Lamano** for "Intracranial Aneurysm Endovascular Coil Embolization Force Measurement: Research and Training System"

Second prize: **Frank Cummins**, **Matt Doerfler**, and **Ewa Glowik** for "Infant Warming Device for Pediatric Surgeries at the University College Hospital Ibadan in Nigeria"

Third prize: **Timi Chu**, **Nam Ryul Kim**, **Wesley Sutton**, and **Stanley Weng** for "Heel Stick Medical Simulator"

Three additional undergraduate prizes were awarded: the Ovid W. Eshbach Award to **Mark Ellison Fischer**; the McCormick Alumni Award to **Brittany Lauren Croone**; and the Co-op of the Year Award to **Darien Rae Hanington**.

MOVE TO CLOUD WOULD SAVE ENERGY

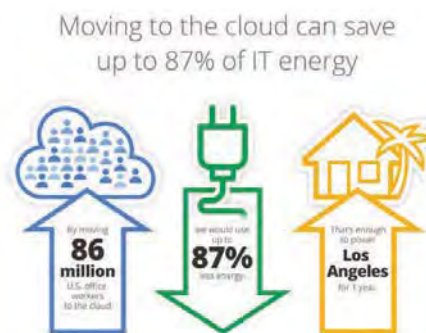
A six-month study has found that if common software applications used by 86 million US workers were moved to the cloud, enough electricity could be saved annually to power Los Angeles for a year. The Lawrence Berkeley National Laboratory study was led by **Eric Masanet**, associate professor of mechanical engineering and chemical and biological engineering, with funding from Google.

The report looked at three common business applications—email, customer relationship management software, and bundled productivity software (spreadsheets, file sharing, word processing, etc.). It showed that moving these software applications from local computer systems to centralized cloud services could cut information technology energy consumption by up to 87 percent—about 23 billion kilowatt-hours.

A primary goal was to develop a state-of-the-art model that both researchers and the public could use to analyze the energy and carbon impacts of cloud computing. The

model takes into account all of the factors—such as data centers, transmission systems, client devices, and transportation systems—necessary to assess the environmental benefits or costs of shifting from local or physical resources to the cloud.

"Well-thought-out analysis is especially important with new technology, which can have unforeseen effects," Masanet said. "Our public model allows us to look forward and make informed decisions. What we found overall is that when services are hosted on the cloud as opposed to locally, the savings are pretty robust."



HIV SCREENING GUIDELINES TOO CONSERVATIVE, STUDY SAYS



Current Centers for Disease Control and Prevention HIV screening guidelines are too conservative, and more frequent testing would be societally cost effective for both high- and low-risk groups, a Northwestern study concludes.

The Northwestern researchers, led by assistant professor of industrial engineering and management sciences **Benjamin Armbruster**, performed a mathematical modeling study of HIV screening in different risk groups to assess the best tradeoff between the societal costs of testing versus the benefits of earlier HIV diagnosis over a patient's lifetime. They

concluded that screening should be done up to every three months for those at high risk and every three years for those at low risk. The CDC currently recommends annual testing for high-risk groups and once-in-a-lifetime testing for low-risk groups, whose annual risk of acquiring HIV is only .01 percent.

Frequent testing has been shown to be an effective method for identifying new HIV infections. In the past, people with new HIV infections weren't treated until they had significant declines in immune functioning, as measured by the CD4 cell count. But there is a growing consensus that antiretroviral treatment is beneficial for all HIV-infected patients, regardless of CD4 count. Starting treatment immediately after diagnosis also reduces the risk of transmitting HIV.

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RECENT GRAD WINS STARTUP COMPETITION, PRAISE FROM WARREN BUFFETT

Hannah Chung, a recent McCormick graduate and cocreator of an educational toy for children who have diabetes, won a pitch competition October 17 at *Fortune's* Most Powerful Women Summit.

Billionaire investor Warren Buffett, one of the contest's judges, complimented Chung on her "extremely good" presentation during the Perfect Pitch challenge, in which four tech and science companies gave five-minute pitches to a panel of judges.

Chung (mechanical engineering '12) and **Aaron Horowitz** (combined studies, mechatronics and user interaction design '12) are the cofounders of Sproutel, a startup that makes interactive games for children who have chronic illnesses. Their first product is Jerry the Bear, an interactive robotic toy for children with type 1 diabetes.

Chung was nominated to attend the Most Powerful Women Summit, an invitation-only event that convenes preeminent women in business, government, and other areas. This year, attendees included Cathy Coughlin (WCAS '79), a Northwestern trustee and senior executive vice president and global marketing officer for AT&T, who also judged the Perfect Pitch session; Ginni Rometty (McCormick '79), chairman, president, and CEO of IBM; *Lean In* author Sheryl Sandberg; Yahoo! CEO Marissa Mayer; Deborah DeHaas, a Northwestern trustee and chief inclusion officer of Deloitte; and Sally Blount, dean of the Kellogg School of Management.

"It meant a lot to pitch in front of these amazing women," Chung said, "especially with all the Northwestern support in the audience."

IEEE ELECTROMAGNETICS AWARD TO TAFLOVE



Allen Taflove (BS '71, MS '72, PhD '75), professor of electrical engineering and computer science, has been awarded the 2014 IEEE Electromagnetics Award by the Institute of Electrical and Electronics Engineers.

The award—sponsored by IEEE's Antennas and

Propagation, Electromagnetic Compatibility, Microwave Theory and Techniques, and Geoscience and Remote Sensing Societies—is given for outstanding contributions to the field of electromagnetics through theory, application, or education.

A member of McCormick's faculty since 1984, Taflove pioneered finite-difference time-domain computational solutions, a method for solving fundamental rules of nature that govern nonquantum interactions of electric charges, currents, and electromagnetic waves. He was cited for contributions to the development and application of FDTD solutions of Maxwell's equations across the electromagnetic spectrum.



EVENT EXPLORES TECHNOLOGY'S HUMAN CONSEQUENCES

The Agony and the Ecstasy of Steve Jobs, a play about how the former Apple CEO's obsessions changed the world, marked the sixth season of ETOPIA: Engineering Transdisciplinary Outreach Project in the Arts. The McCormick outreach initiative seeks to inspire cross-disciplinary dialogue about the role of science and technology in society.

A harrowing tale of pride, beauty, lust, and industrial design, *The Agony and the Ecstasy of Steve Jobs*

takes the audience all the way to China to investigate the factories where millions toil to make iPhones and iPods, shining a light on our love affair with devices and on the human cost of creating them. The one-man show, written by Mike Daisey, starred Chicago actor Lance Baker and ran at the Technological Institute from September 27 to October 20.

"This play is a riveting exposé of the sometimes quirky, sometimes shocking secrets behind Steve Jobs's genius and the legacy of industrial innovation that he left behind," said **Matthew Grayson**, producer of the annual ETOPIA event and associate professor of electrical engineering and computer science.

NORTHWESTERN RECOGNIZED FOR DIVERSITY EFFORTS

Northwestern was one of three universities to receive a 2013 Impact Award from the National Society of Black Engineers and ExxonMobil. The \$10,000 award recognizes efforts to retain underrepresented minority students in engineering programs.

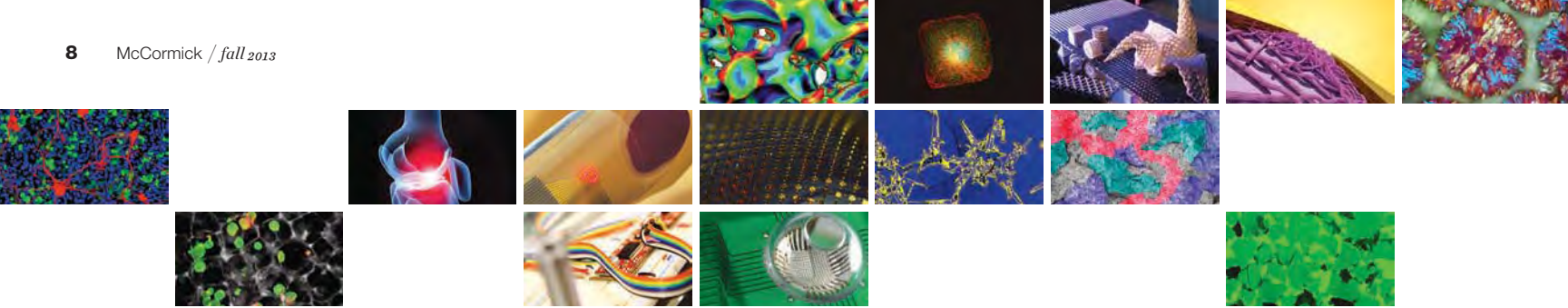
Northwestern was cited for its EXCEL program, an intensive five-week initiative that prepares students for their freshman year by fostering a supportive community and reinforcing excellence

in academics. The program includes study-skills development, mentoring, peer-to-peer engagement, and exposure to a variety of engineering disciplines.

Andy Nwaelele, vice president of Northwestern's NSBE chapter, said the award money will help pay for tutors to attend NSBE's Sunday night study sessions ("Study Jamz") and for student scholarships to NSBE conventions.

"We want to seek ways to improve our retention even more by living

our mission, which is to 'increase the number of culturally responsible black engineers who excel academically, succeed professionally, and positively impact the community,'" said Nwaelele, a biomedical engineering major. "With more money, we hope to continue those efforts and continue to get young people interested in the opportunities STEM [science, technology, engineering, and mathematics] fields present."



stories from the intersection

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Health and wellness

Biofilms research may help in battle against stubborn infections

Bacteria on a surface wander around and often organize into highly resilient communities known as biofilms. Within biofilms, bacteria change their gene expression patterns and are far more resistant to antibiotics and the body's immune defenses.

Erik Luijten, associate professor of engineering sciences and applied mathematics and of materials science and engineering, worked with a multidisciplinary team of researchers from UCLA and the University of Washington to

elucidate the early formation of biofilms. The study is the first to identify the strategy by which bacteria form the microcolonies that become biofilms. The research, published in May in the journal *Nature*, may have significant implications for battling stubborn bacterial infections that do not respond to antibiotics.

The researchers developed algorithms that describe the movements of the different strains of the bacterium *Pseudomonas aeruginosa* and conducted computer simulations to map the bacteria's movements. *P. aeruginosa* can cause difficult-to-treat and even lethal infections, including those found in cystic fibrosis and AIDS patients.

The researchers found that as bacteria move across a surface, they leave trails. This network of trails creates a process of positive feedback and enables bacteria to organize into microcolonies that mature into biofilms.

Interestingly, the researchers found that these biofilms develop in accordance with Zipf's Law, which has been used to describe the rich-get-richer phenomenon in the US economy.

Energy and environment

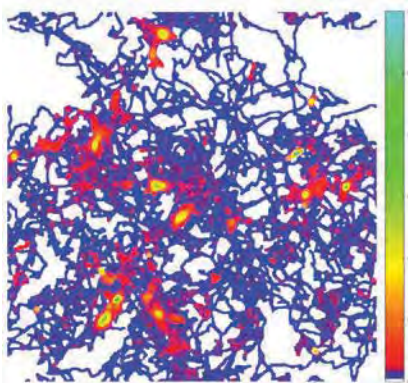
Insights could help preserve coral reefs

Corals themselves contribute to their susceptibility to deadly coral bleaching due to the light-scattering properties of their skeletons, an interdisciplinary research team from Northwestern and the Field Museum of Natural History has found.

Using optical technology designed for early cancer detection, the researchers discovered that corals that are less efficient at light scattering retain algae better under stressful conditions such as temperature changes and are more likely to survive. Corals whose skeletons scatter light most efficiently have an advantage under normal conditions but suffer the most damage when stressed.

The study of nearly 100 different species of reef-building corals, including many from the 1893 World's Fair in Chicago, was conducted by Luisa A. Marcelino, research assistant professor of civil and environmental engineering, and Vadim Backman, Walter Dill Scott Professor of Biomedical Engineering, with researchers at the Field Museum.

The team used Backman's low-coherence enhanced back-scattering technique to measure light transport and light amplification inside the skeletons of 96 coral species. Until LEBS became available, it was impossible to measure how fast light amplification increases with the loss of algae.



Bacteria lay sugar trails (shown here in computer simulations) to help find each other. The green/yellow areas have the highest sugar concentration and act as formation points for bacterial colonies that grow into biofilms.

Creating leaders

Students build home for Nicaraguan family

As volunteers with Architecture Brigades, a group of McCormick students traveled to Nicaragua during spring break to build a home for a family in need. The program, part of the student-led global health and sustainable development organization Global Brigades, enables students to design and construct socially responsible and sustainable architecture solutions in underdeveloped countries.

Working with members of the community, the students mixed concrete, dug trenches, and built a new house from the ground up. While their engineering skills came in handy, the most important thing they brought to the experience was compassion.

"I learned that going down to Central America to help build a home for somebody doesn't require any complex equations or any high-level thinking," said junior Ryan Yang. "It just really requires the desire and the will to help somebody out."



Materials

Researchers create desktop nanofabrication tool

A new low-cost, high-resolution tool is primed to revolutionize how nanotechnology is produced from

the desktop, according to Northwestern researchers.

Most nanofabrication is currently done in multibillion-dollar centralized foundries. This breakthrough allows the construction of very high-quality materials and devices, such as processing semiconductors over large areas, with an instrument slightly larger than a printer.

The research was led by Chad Mirkin, the George B. Rathmann Professor of Chemistry in the Judd A. and Marjorie Weinberg College of Arts and Sciences and professor of medicine, chemical and biological engineering, biomedical engineering, and materials science and engineering.

Mirkin's team created a tool that produces working devices and structures at the nanoscale level in a matter of hours, right at the point of use—the nanofabrication equivalent of a desktop printer. The tool is poised to prototype a diverse range of functional structures, from gene chips to protein arrays to building patterns that control how stem cells differentiate.

Because the materials used to make the desktop nanofabrication tool are easily accessible, commercialization may be as little as two years away.



Systems

Android antiviral products easily evaded, study says

Working with partners from North Carolina State University, McCormick researchers tested 10 of the most popular antiviral products for Android and found each could be easily outsmarted.

Yan Chen, associate professor of electrical engineering and computer science, and his group began by testing six known viruses on

the fully functional versions of 10 of the most popular Android antiviral products, most of which have been downloaded by millions of users.

Using a tool they developed called DroidChameleon, the researchers

applied common techniques—such as simple switches in a virus's binary code or file name—to transform the viruses into slightly altered but equally damaging versions. Dozens of transformed viruses were then tested on the antiviral products, often slipping through the software unnoticed.

The researchers found that all of the antiviral products could be evaded but weren't equally susceptible to the transformed attacks.

The products' shortcomings are due to overly simple content-based signatures, special patterns used to screen for viruses, the researchers said, suggesting that the products should use a more sophisticated static analysis to accurately seek out transformed attacks.

*Entrepreneurship courses launch startups
into the marketplace—and they're making it*

VENTURING OUT

In fall 2011 a group of business, law, and engineering students crowded into an observation room at Northwestern Memorial Hospital. As part of Northwestern's NUvention: Medical Innovation course, the students had come on assignment to watch a minimally invasive—or laparoscopic—surgery, an operation performed with instruments and video cameras through a small incision in the patient's body.

Laparoscopic surgery has benefits—reduced bleeding, less pain, and speedier recovery—but internal bleeding is a significant risk because surgeons must rely on tools to see what they are cutting. As the students watched the procedure on an operating room monitor, law student Jonathan Gunn leaned over to his classmates. “Why hasn’t anyone integrated blood vessel detection into surgical tools?” he asked.

It was the kind of “aha” moment that marks the start of a great venture—for those with the skills to bring it to life. At Northwestern, students gain that know-how in NUvention, a suite of experiential learning courses offered by the Farley Center for Entrepreneurship and Innovation. NUvention takes students from schools across the University, assigns them to multidisciplinary teams, and exposes them to the entire life cycle of a startup, from innovation to funding to execution. Faculty members, alumni, and entrepreneurs help students identify a problem, understand customer needs, and find a solution using “lean startup” methodology, which focuses on short business plans and minimal capital.

NUvention courses include Medical Innovation, Energy, Web, Innovate for Impact (in which students tackle unmet

needs in resource-limited settings), and three recent additions: Digital Media, Nanotechnology, and Analytics. Some teams commercialize existing technology created in Northwestern labs; others develop their own products from scratch.

Since NUvention's 2007 launch, 12 startups have gone on to become full-fledged money-making ventures, but not all outlive the one- or two-quarter courses. That's okay, says McCormick Dean Julio M. Ottino, because starting companies isn't the point. “Entrepreneurial skills are important for all McCormick students, not just those who envision a future in business,” says Ottino. “Today's engineers cannot thrive without creativity, communication, and problem solving, all skills that are key to NUvention. And if the students happen to find a project that extends beyond the classroom, all the better.”



“It took us a few iterations to realize that what investors really cared about was not how the technology works but how it performs and at what cost.”

JOSHUA LAU

Formed in Northwestern’s NUvention: Energy course, SiNode Systems commercializes rechargeable battery technology developed by McCormick’s Harold Kung. The SiNode team (left to right): Joshua Lau, Samir Mayekar, Cary Hayner, Nishit Mehta, Thomas Yu. Not pictured: Guy Peterson.

- **PROBLEM:** Mediocre lithium-ion battery performance
- **SOLUTION:** SiNode Systems

When SiNode Systems took the stage in April at the 2013 Rice Business Plan Competition, the world’s richest and largest graduate-level business plan contest, team members showed the judges two photos. In the first, a sea of mourners gathered outside St. Peter’s Basilica in Rome following the 2005 death of Pope John Paul II. The second, shot during a papal speech in 2013, was almost identical—except nearly every person in the crowd was holding up a glowing smartphone.

SiNode’s message was clear. “We’re in the middle of a mobile revolution, and battery life is holding us back,” explained Cary Hayner, a PhD candidate in chemical and biological engineering and SiNode’s chief technology officer. “It is a problem that resonates with everybody.”

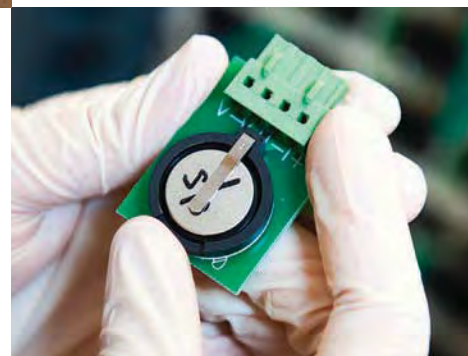
The pitch worked. SiNode won first place and more than \$900,000, then went on to take top honors in the next stage of the contest, the second annual US Department of Energy National Clean Energy Business Plan Competition. (SiNode is the second student-led Northwestern startup in two years to win

the DOE competition. NuMat Technologies, which designs high-

performance materials for the safe and efficient storage of gases, won last year’s inaugural contest.)

Founded in 2011 in NUvention: Energy, SiNode commercializes battery technology developed in the lab of McCormick’s Harold Kung, Walter P. Murphy Professor of Chemical and Biological Engineering. For the past seven years, Kung has worked to create an electrode for lithium-ion batteries—rechargeable batteries such as those found in cellphones—that allows batteries to last for days and charge in minutes. The anodes are made of layers of silicon nanoparticles and graphene—an improvement over standard silicon-based anodes, which degrade quickly, causing the battery to weaken—that are pitted with tiny holes to allow lithium ions to enter the anodes more quickly, shortening the battery’s charging time.

When published in 2011, Kung’s research attracted the attention of media such as *Forbes* and *Popular Science* as well as battery companies and venture capitalists. But working with Northwestern’s Innovation and New Ventures Office—which manages invention



disclosure, assessment, patenting, and marketing for Northwestern’s research discoveries—a NUvention: Energy team acquired the licensing rights.

The team assessed its finances, talked to customers about their needs, discussed the technology’s potential with energy experts, and developed a go-to-market strategy before entering its first competition in 2012, the Clean Energy Challenge, while its original nine members were still enrolled in the course. The technology got rave reviews, but the students’ delivery fell short. “Our pitch was too technical for our audience,” says Joshua Lau (MS materials science ’13), a SiNode research engineer and cofounder. “It took us a few iterations to realize that what investors really cared about was not how the technology works but how it performs and at what cost.”

Still, the judges' positive feedback propelled them. When the course ended, a core group of five members—Lau and Thomas Yu from McCormick and Guy Peterson, Samir Mayekar, and Nishit Mehta from the Kellogg School of Management—brought on Hayner, who worked in Kung's lab and had coined the technology. A startup wasn't in Hayner's plans, but he jumped at the chance. "I came to McCormick to work on renewable energy and sustainable science, so I was happy just working on the battery project," he says. "Now to see my first research baby go beyond the lab is really exciting."

SiNode still faces challenges. While \$900,000 may sound like enough to catapult the company to commercial success, building a lab is extremely costly. The team plans to complete a seed funding round this fall—a feat that could be difficult in a particularly challenging clean-energy market. "Investors want to see something that can translate to the marketplace quickly," says Hayner. "But this isn't a web app, where you can make a billion dollars in a short few years. Clean tech is a long-term investment with much greater global impact and reward."

Of course, Internet entrepreneurs have their own set of challenges. Just ask the creators of Chisel.

With the end of their first quarter of NUvention: Web approaching, one team's members were in a bind. They had started with what seemed like a strong concept—improved productivity for word processing on mobile devices—but they had already pivoted twice, ditching first an idea for an app to make PDF and Microsoft Word documents more reader friendly on mobile devices, and later a plan for an improved touchscreen keyboard. The apparent problem was that the mobile app space was crowded—so crowded that every idea was already being done, and done well, by others. Finally the team landed on a concept for a note-taking app, but advisers and friends warned team members of the steep competition.

Disheartened, the students gathered late one night in the Master of Engineering Management lounge in the Ford Motor Company Engineering Design Center. On a dry-erase board they wrote

- **PROBLEM:** Lackluster note-taking apps
- **SOLUTION:** Chisel

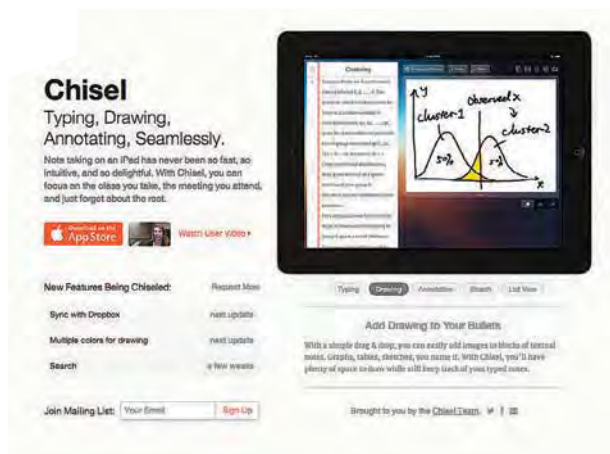
every web-related startup idea they could think of, then crossed off those that were unmanageable because of technical, financial, or time constraints. Next they crossed off those that weren't lucrative, and finally—with three options remaining—asked themselves if another company had already taken the idea to market. All three had direct competitors.

"It was in that moment I resolved to stop caring about the competition," says Westin Hatch, a student in Northwestern's MMM program, which combines McCormick's MEM degree with a Kellogg MBA. "I said to the team, 'Forget about what the competitors are doing. Let's just do what we love and what we do well.'"

The team returned to its note-taking app concept. Hatch tackled the business end with Amrit Kanasa-Thasan, an undergraduate from the Weinberg College of Arts and Sciences; Alex Wilson (BS/MS electrical engineering and

"We saw a real opportunity to capture what students need in an app that allows you to type, draw, and annotate documents seamlessly."

ALEX WILSON



As the creators of a note-taking application for mobile devices, Chisel team members (left to right) Amrit Kanasa-Thasan, Alex Wilson, and Samatha Zhang knew they faced steep competition. Even the team was surprised when 1,000 people downloaded their app in its first three days in the Apple Store. Not pictured: Westin Hatch.



computer science '13) worked on programming; and Medill graduate student Samantha Zhang spearheaded design and marketing.

They knew the shortcomings of the apps already on the market. Students they had interviewed had complained of disjointed apps with limited functionality; to write, draw, and import PDFs required several apps. “We saw a real opportunity to capture what students need in an all-in-one note-taking app that allows you to type, draw, and annotate documents seamlessly,” says Wilson.

After two months of development, the team launched Chisel in Apple’s App Store. Three days later the app ticked past 1,000 downloads, surpassing Chisel’s goal for the entire quarter. “We immediately started getting feedback from real users who were emailing us and asking for new features, many of which were already in the pipeline,” says Wilson. The tech blog App Advice praised the app, saying, “Chisel could be the only note-taking app you’ll ever need.”

While team members are still working out how to monetize Chisel—a premium version is available from the App Store for \$9.99, but only a few users have sprung for it—they have received validation that they can compete in a crowded field. “Everyone shot down our idea at first, thinking it’d be too difficult. One classmate told me we were crazy,” says Hatch. “Then he finally saw the app, and he wanted to use it.”

► **PROBLEM:** Energy-consuming, quick-draining smartphones

► **SOLUTION:** MyPower

On most NUvention teams, dividing tasks is easy. Students take on the work that best suits them: law students handle intellectual property issues, business students raise funds, engineering students design. But when students in the winter 2013 NUvention: Energy course were given the opportunity to choose their teammates, Mike Geier, Tejas Shastry, and Alexander Smith—all PhD students in materials science and engineering—decided to team up.

What do three engineers do when asked to start a company? They learn how to start a company. “A lot of teams were more diverse than we were, but we were really interested in learning all the parts of entrepreneurship,” says Geier. “For us, NUvention was really a crash course in marketing and business strategies.”

They chose a concept: a wallet-sized device that attaches to a runner’s clothing and collects kinetic energy to power a smartphone. While similar devices had been developed for other uses—mainly for hikers or campers traveling to remote locations—the runners’ market was untapped.

Smith knew design software, so he became product designer. Shastry, perhaps the most business inclined, served as front man. And Geier had worked at a battery startup, so he spearheaded the device’s internal

All three members of MyPower are engineers, so they had to learn quickly how to run a company. Their creation, a wallet-sized device that attaches to a runner’s clothing and collects kinetic energy to power a smartphone, won \$2,500 in the Dow Sustainability Student Challenge. Pictured, left to right, are Tejas Shastry, Alexander Smith, and Mike Geier.

“One of SafeSnips’s major advantages is the ability not just to recognize blood vessels but to see where you can’t see.”

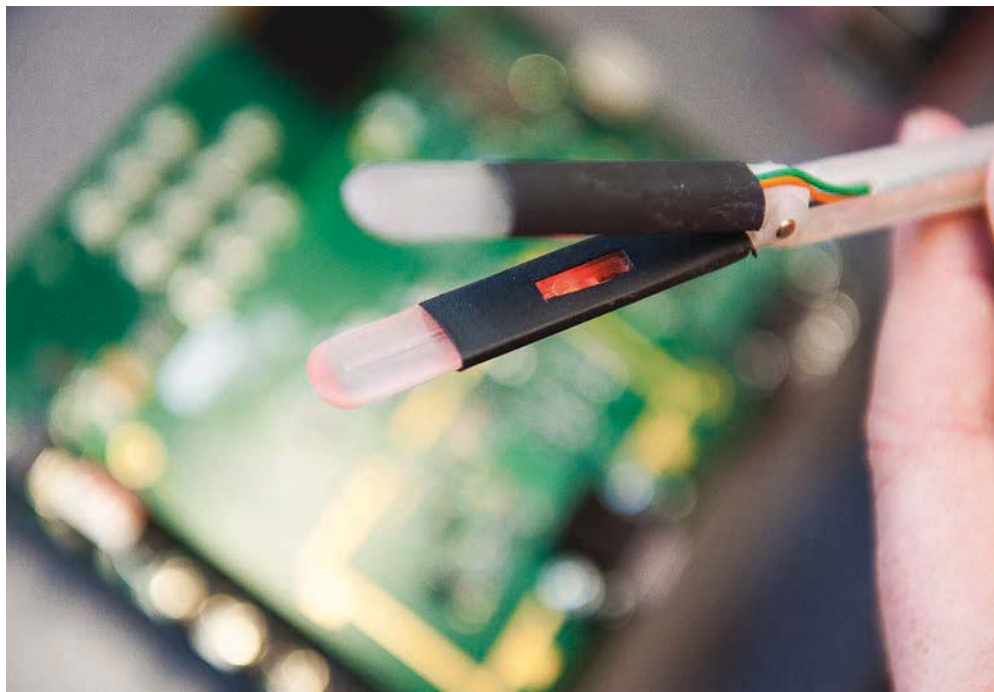
DAVID MAHVI

technology. They started with the idea of harnessing piezoelectricity, an electric charge that accumulates in crystals and ceramics when stress is applied, but the materials didn’t generate enough energy. So they turned to inductive charging, in which a magnet generates energy by oscillating inside a coil. The energy would charge a small lithium-ion battery inside the device, which in turn would charge a smartphone via a USB port. They called the device MyPower.

But would runners use it, and would it fulfill their needs? To answer that question, the students talked to as many runners as possible: friends, colleagues, and even strangers at sporting goods stores. They asked runners to jog with the device and provide feedback on comfort, usability, and size. A bigger device could create more power but could be awkward to carry, so they worked to find a middle ground. They learned that placing the device on the runner’s hip generated the most energy.

The team’s final iteration provided up to eight hours of battery life after a 45-minute run. “And it’s truly a green-energy solution,” says Shastry. “If you run with this device for a year, it will offset not only the carbon footprint of operating your smartphone but also the phone’s production cost.”

In June, MyPower won a \$2,500 runner-up prize in the Dow Sustainability Student Challenge, which recognizes environmentally friendly student innovations. The team plans to sell a small batch of devices to friends and family, file a patent application, and decide on a price point, ideally under \$50. “Once MyPower is optimized, we can begin to tailor it to other activities, like biking,” says Shastry. “There is definitely room for growth in this market.”



BriteSeed tackles the problem of internal bleeding in laparoscopic surgery with SafeSnips, blood vessel detection technology that can be integrated into existing surgical tools. The product has caught the interest of a Chicago incubator program, leading the team to pursue the company full-time.

- **PROBLEM:** Internal bleeding in minimally invasive surgery
- **SOLUTION:** SafeSnips

When they left the hospital’s observation room, the NUvention: Medical Innovation students had a great idea—but the hard work was just beginning. The first step: understanding the problem. By talking with surgeons from the Feinberg School of Medicine, the students learned that avoiding blood vessels is one of the biggest challenges in laparoscopic surgery. In open operations surgeons use their hands, allowing them to feel blood vessels pulsing, but with tools all tactile sensation is lost. Instead, surgeons must rely on their knowledge of anatomy, avoiding spots where arteries are known to be located in most patients. But bodies vary, and in surgery slight differences can be deadly: more than 3 percent of laparoscopic surgery patients experience unintended internal bleeding.

“That’s a significant number,” says Mayank Vijayvergia, a McCormick graduate student in biomedical engineering, “especially when you consider that in the United States, 18 percent of unintended bleeding incidents are fatal.

And patients who survive face hospital stays an average of nine days longer, as well as long-term complications.” Preventing unintended bleeding is also of interest to US hospitals, which spend billions of dollars to heal the injuries—an estimated \$210,000 per patient, at the hospitals’ expense.

After much research and iterating, the students developed a promising solution: SafeSnips, blood vessel detection technology that can be integrated into existing laparoscopic cutting tools. As surgeons cut and cauterize, near-infrared spectroscopy sensors embedded in the tool’s tip identify the presence and diameter of nearby blood vessels. Alerts are sent to video monitors already in the operating room.

At the end of the two-quarter course, the team—now named BriteSeed—presented its business plan, complete with financials and a go-to-market strategy, to a panel of venture capitalists. The feedback was promising. “SafeSnips is a leap in technology,” says BriteSeed advisory board member David Mahvi, president of Northwestern



(Left to right) Mayank Vijayvergia, Jonathan Gunn, and Paul Fehrenbacher cofounded BriteSeed in NUvention: Medical Innovation. Not pictured: Muneeb Bokhari.

NUvention takes students from schools across the University, assigns them to multidisciplinary teams, and exposes them to the entire life cycle of a startup.

Medical Group and chief of gastrointestinal and oncologic surgery at Feinberg. “One of its major advantages is the ability not just to recognize blood vessels but to see where you can’t see. My hope is that BriteSeed’s technology, which is initially used to detect bleeding, could eventually be used to see other things.”

After the course ended, the nine-member BriteSeed team slimmed down to a core of four cofounders representing three Northwestern schools: Vijayvergia from McCormick, medical student Paul Fehrenbacher, and from the Law School, Gunn and 2012 graduate Muneeb Bokhari. Mahvi and Hariharan Subramanian,

an alumnus of McCormick’s biomedical engineering program and a research professor in the lab of biomedical engineering professor Vadim Backman, joined as consultants.

In June 2012 BriteSeed scored its first major success: first place—and more than \$100,000 in cash and prizes—in the 2012 TechWeek Launch competition. Four months later the startup was one of nine companies named “Up-and-Comers” at the 2012 Chicago Innovation Awards, and in April at the 2013 Rice Business Plan Competition it was named Best Life Science Team, taking home more than \$273,000 in winnings.

Today BriteSeed’s home is Insight, a product development firm on Chicago’s North Side that has designed products for such Fortune 500 companies as Baxter and St. Jude Medical. Among Insight’s specialties are medical devices, including the cutting tools used in minimally invasive surgeries, so BriteSeed is a natural fit as the first startup in the Insight Accelerator Lab’s 18-month program. Vijayvergia, Gunn, and Fehrenbacher have put their graduate studies on hold to pursue the business full-time. “Several of us are a little older and have families, so there is a lot at stake,” says Fehrenbacher. “We think it is worth the risk.” **M** Sarah Ostman

women at the wheel

IN THE WORLD OF AUTO RACING, MEN USUALLY TAKE THE FRONT SEAT.
NOT AT NORTHWESTERN.



PICTURE A RACETRACK: REVVING ENGINES, FLAGS WAVING, MECHANICS SCRAMBLING UNDER CAR HOODS. NOW PICTURE THE PERSON IN THE DRIVER'S SEAT.

Chances are, you pictured a man. Even in 2013—after the success of female racecar drivers like Danica Patrick and Melanie Troxel—auto racing remains a male-dominated sport. It's true not just in professional races but also in collegiate teams across the United States. For example, of the Big Ten's more than two dozen racing teams, in 2012–13 only six were led by women.

The good news: half of those female-led teams were at Northwestern. Women ran all three of the University's car teams last year: the fast-racing Formula SAE, off-roading Baja SAE, and green-energy NU Solar. Under these women's leadership, the teams have not only succeeded but thrived—and the women have gained experience that has shaped their outlooks and, in some cases, their careers.

The new normal

Five years ago Shonali Ditz (manufacturing and design engineering '13) never would have dreamed that after graduation she would spend the summer in Europe, driving between auto races and cruising around on a motorcycle. Nor would she have imagined she would return home to start a career in the automotive industry. But she has learned how much can change in a few years—especially when working on Formula SAE.

Ditz always knew she excelled at building things—she found her niche constructing toothpick bridges and Rube Goldberg machines in high school physics—but at Northwestern she wasn't sure how to use those talents. "I had this desire to do something large and tangible outside the classroom," says Ditz, "to work with my hands and have something to show for it."

On a whim, she joined Formula, a student design competition organized by SAE International (formerly the Society of Automotive Engineers) in which university students design and build Formula-style racecars for annual competitions. The competitions are modeled after real-world production scenarios, with teams pitching their designs to a fictional manufacturing company that evaluates their work for production potential. In addition to entering various races, the cars must pass numerous safety tests and undergo extensive design judging, and students present hundreds of pages of carefully documented expense reports to panels of judges.

"Every Formula SAE car is made by great student engineers—that's a given,"

says Ditz. "These events force us to get up and talk about our car outside the terms we use in the shop. Northwestern is really good at that. We show that we're better than just the car."

When Ditz joined Formula SAE in 2009, Northwestern's three-year-old team had only a handful of members. Five of its founders had graduated, taking their knowledge with them. The team was building its second car but because of high turnover would need two years to put the pieces together.

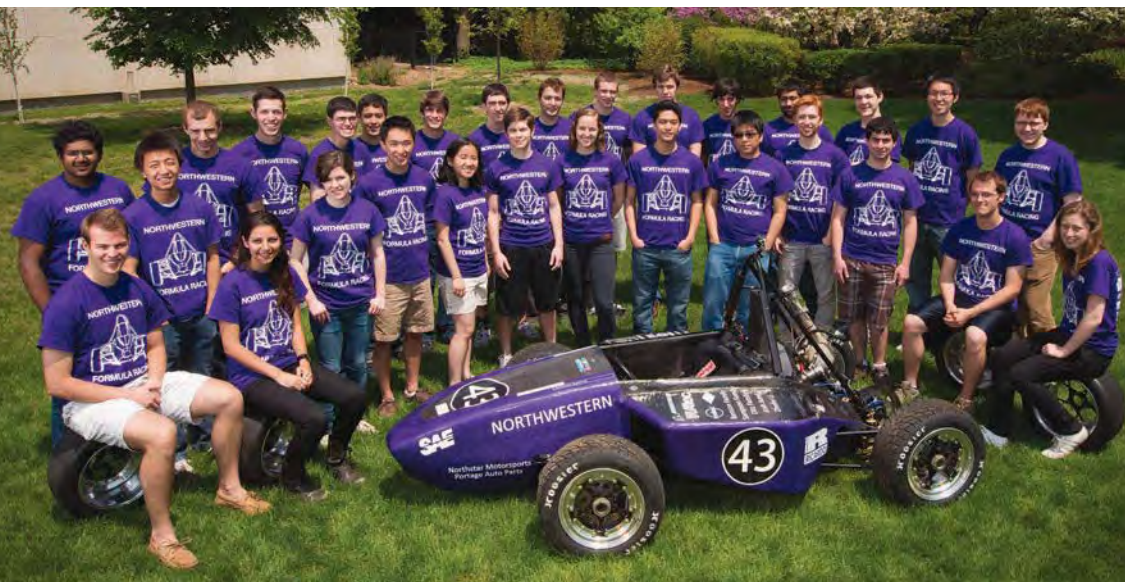
Ditz admittedly had little to offer at first, but manufacturing appealed to her. She started working on the car's frame—"something I could understand," she says—and learned to weld and design in the computer program SolidWorks. She also observed the team's dynamics, and there she spotted opportunity. "People were hungry," she recalls. "They had so much talent, but they didn't know how to bring it all together."

Working with the team's senior members, Ditz set out to fill the void. She took on the role of assistant project manager, and she and her partners reorganized the group, breaking members into teams based on their skills: frame, suspension, engine, and composites. They created a freshman training program to keep new members from feeling overwhelmed. "It's important that when new people show up, they feel like they have something to contribute," says Ditz. "That's what keeps people coming back."

With these improvements, the team has since made three new cars, speeding the design cycle from two years to one. They shaved 40 pounds off their

Of more than two dozen Big Ten auto racing teams in 2012-13, just six were led by women. Three of those were at Northwestern, thanks to Shonali Ditz (left), Camille Bilodeau (center), and Carolyn Jane Jones (right).





In Formula SAE, university students design, build, and race Formula-style racecars. Shonali Ditz (front, second from left) joined Formula SAE because she wanted to “work with her hands and have something to show for it.”

2012 car’s 450-pound design, giving them an advantage in competition. “We’re on a really steady path,” says Ditz, “consistently getting better every year.”

The skills Ditz gained working on cars gave her a leg up at Illinois Tool Works, where she did co-op; when the company rotated her from research and development into the automotive group before her senior year, she felt right at home. This fall she joined ITW full-time, working in its Deltar Fuel Systems business unit on the Global Capless Refueling System for passenger cars. She is one of a handful of women on her team. “I think because of Formula, I’m comfortable working in a predominantly male environment,” she says. “That’s become the norm for me.”

Bringing back Baja

For Carolyn Jane Jones (mechanical engineering ’14), being the only woman on her car team was completely normal—until she and Ditz went to a race.

“Shonali and I would walk around, and the guys on the other teams would ask us, ‘Oh, whose girlfriends are you?’ And we would say, ‘We are the project managers of two car teams, thank you very much,’” Jones says.

In high school Jones trained as a runway model, and she almost postponed college to pursue a career in Paris. At Northwestern she initially enrolled in the Weinberg College of Arts and Sciences

because of her fascination with literature, arts, and language. But she soon became enamored with engineering after talking to a family friend whose son had founded a Baja SAE branch at his college.

Formula’s grittier cousin, Baja SAE challenges students to design and build off-road vehicles that can tackle the roughest terrain: snow, mud, rocks, and sometimes water. Jones thought off-road racing sounded fun, but she didn’t know whether Northwestern even had a Baja team. In truth, the team was hanging on by a thread. Founded in 1988 by a group of undergraduate engineers, Baja was the University’s first car team, but by 2012 membership had declined to just a couple of students, and their two-year-old car was in disrepair.

Jones had all but forgotten about Baja when she overheard a classmate, the team’s chief engineer, talking about it. She jumped at the chance to join the team. “I told them that I knew nothing about cars but that I wanted to be a part of the team and be super involved,” says Jones. “And they said, ‘Cool. Go write this grant proposal.’”

Jones was the only woman on the team, but that didn’t faze her. The more pressing problem was that she knew nothing about running a car team, so she turned to her friend at Formula SAE. “I sat down with Shonali and made a list of what

“We all do so much and we inspire one another, just as much as the car does. It’s a great community.”

CAROLYN JANE JONES

the team had to do to be functional,” says Jones. “And then I was project manager, two hours in.” Jones led a recruitment push that secured several more dedicated members, unveiled a new logo and website, and solicited financial support from the Chicago SAE group, Northwestern’s Department of Mechanical Engineering, and Boeing.

Jones also established a work schedule, and she and the other six Baja members got started fixing the car. Rough terrain creates a unique set of challenges, especially for the car’s suspension and safety. Each collegiate team uses the same engine—a Briggs and Stratton 10-horsepower Intek model—but the rest of the design is entirely in the students’ hands. “If we want multiple gears, reverse, a long car, a short car, more speed, more power, it’s all up to us,” says Jones.

In April, Northwestern Baja raced in the Baja SAE Tennessee race. The four-day event started with a technical inspection and design presentation, followed by racing events that included acceleration, land maneuverability, and a sled pull. On the final day, the team competed in a four-hour endurance race through creeks, fields, and forests. “It was amazing,” says Jones. “I got to drive the car first, and I did as well as any of the guys.”

Northwestern scored 311 of 1,000 possible points, placing 62nd out of 87 teams—not great numbers, but the team was proud. “We had no idea what to expect in competition, and still we beat dozens of teams,” says Jones. “We’re all set now to go into next year’s race and bump our scores much higher.” And this summer, team members began work on a new car that they hope to complete by the spring 2014 competition.

But, says Jones, winning isn’t the point. The point is working together, like a family, toward a goal—something that



can't be achieved in a lecture room. "We have all these really bright kids in Baja, but the focus isn't grades. No one is judging you for your GPA; they're judging you for how hard you work," she says. "We all do so much and we inspire one another, just as much as the car does. It's a great community."

Crossing the finish line

Another kind of camaraderie forms during races. After months of preparation, students from all over the country descend on a racetrack, tools in hand, hoping to be the first of hundreds of teams to cross the finish line—or just to make it onto the track. As students struggle and parts break, competition often falls by the wayside and opposing schools help each other out.

So for members of NU Solar, Northwestern's solar car racing team, it wasn't at all strange that after their car failed in last June's Formula Sun Grand Prix, their motor powered another team to first place.

The mechanical systems that power Formula and Baja cars are complex, but solar cars require other challenging elements: an electrical system and an array of solar cells. "All of Northwestern's car teams are really hands-on, but NU Solar combines being hands-on with being on the cusp of new technology," says project manager

To succeed in solar car racing, students must harness the sun's rays and use them wisely. Lower photo: NUSolar chief engineer Ayoka Hatcher-Stewart (center) and other students work on their car.

Camille Bilodeau (chemical engineering '14). "Solar cars don't exist yet. It's unexplored terrain."

Solar car racing is more about staying power than speed; the Grand Prix involves three eight-hour days of solid driving. To succeed, teams must not only harness the sun's rays but use them wisely. "There's a balance between how much energy you get from the sun and how much you expend by driving," says Bilodeau. "You have to estimate how much power you're going to take in, which isn't easy, especially when the weather shifts unexpectedly."

While NU Solar's current car, SC6, can travel up to 60 miles per hour, it races at a conservative 25. The speeds might be slow, but mechanical failures create drama. Flat tires and battery malfunctions are common; so are problems with computer software, which universities bring to run projection models while the race is under way. If something does go wrong with Northwestern's car, another female student leads the charge to fix it: Ayoka Hatcher-Stewart (mechanical engineering '14), the team's chief engineer.

That's exactly what happened at last June's Grand Prix in Austin, Texas. Before racing even began, NU Solar ran into trouble with the system that monitors the battery's temperature and voltage. Students worked through the night to fix the problem, and in the morning the car started its dynamic tests, exercises to demonstrate driving, turning, and braking. Helping Northwestern get up to speed were competitors from Oregon State. (The two teams had met at the 2012 race and assisted one another when problems arose.)

All appeared to be going well for NU Solar until the slalom test. In the driver's seat, Bilodeau maneuvered the car between a series of cones, then slammed on the brakes. "I just watched as the car fell a couple inches, and I

realized there was no chance we were going to race," she says. The force of braking the car with its wheels turned had dealt a fatal blow to its suspension.

The team members were disheartened, especially those who had toiled on the last-minute battery repair. But there was a silver lining. Later that day, the Northwestern students watched as Oregon State's motor gave out on the track. Without being asked, the NU Solar members pulled the motor out of their broken-down car and ran it to the "hot pit," where Oregon State had pulled off to assess the damage. Members of both teams worked quickly to jack up the car and replace the motor.

Oregon State went on to win the competition; Northwestern didn't even get to race. But while they're disappointed, Bilodeau and Hatcher-Stewart are more concerned about seeing the team succeed in the long run, even if it is after they've graduated. Their goal is to see the team make the American Solar Challenge—a cross-country road race held every other year for winners of the Formula Sun Grand Prix—or even beyond.

"After last year's race, we were talking about how NU Solar could go to the World Solar Challenge (a global version of the American Solar Challenge) in a few years if we played our cards right," says Hatcher-Stewart.

Making recruitment a priority

Formula, Baja, and NU Solar have all benefited from their female leaders' direction and diversity, says Ellen Worsdall, McCormick's assistant dean for student affairs. "It's as true on the racetrack as in a classroom. Bringing together people with different viewpoints helps us challenge our assumptions and broaden our understanding of the world."

Achieving diversity often comes down to recruitment, one-on-one interactions that convince students to think outside their preconceived notions. Looking forward, it's a priority these women hope their teammates will pursue.

"Last year we had five women on Formula SAE—a much higher number than at most schools," says Ditz. "It's a number that I'm proud of and something I hope future project managers continue to work on." **M** Sarah Ostman

DATA AS ART

Northwestern and the School of the Art Institute of Chicago collaborate to get students out of their comfort zones

It started with data—five centuries’ worth of names, dates, and places—chronicling the journeys of Korean brides as they traveled to join their new husbands.

Originally handwritten in thick genealogy books called *Jokbo* and passed down from generation to generation, the now-digital records provided a scant but fascinating picture of the arranged marriages: each bride’s origin, her destination, and the date.

With a giant Excel spreadsheet and two weeks’ time, Daniel Ha and his teammates were given a challenge: come up with a way to visualize the data that is not only informative but also aesthetically pleasing enough to be featured in a gallery exhibition.

“My initial reaction was, this is crazy. There were 100,000 data points for just one family,” says Ha, a junior studying manufacturing and design engineering. “And that was just dealing with the numbers. We hadn’t even tackled the question about how to create something artistic and thought provoking.”

Ha was one of 21 participants in Data as Art, a new collaborative course in which students from Northwestern and the School of the Art Institute of Chicago are tasked with translating complicated information into visual art or images that an average viewer can understand. Cotaught over Summer Session by nine faculty from both institutions, the course is based on the notion that communicating data is essential to the investigative process and can change the way

colleagues and the public respond to work.

Data as Art is not Northwestern’s first collaboration with the Art Institute of Chicago; for nearly a decade the two institutions have partnered to scientifically analyze museum masterpieces and to develop new methods and technologies to investigate art. But the course marks the first time that students from both schools—majoring in everything from materials science to print media, applied math to architecture—have collaborated in a structured way on a shared, interdisciplinary project: a public art exhibition.

Art meets science

For the first half of the inaugural course, students learned about computer programming and the history of graphic visualization and undertook a small-scale data collection project using pennies. Then they separated into three teams. Two were provided existing data sets collected by McCormick professors: 15 years of Chicago Public Schools enrollment data from Luis Amaral, professor of chemical and biological engineering, and the Korean genealogy records from Daniel Abrams, assistant professor of engineering sciences and applied mathematics.

In lieu of a data set, the third team—working with Steven Franconeri, associate professor of psychology in the Judd A. and Marjorie Weinberg College of Arts and Sciences—was introduced to eye-tracking technology, often used by social scientists and marketers to gain

insight into social interactions and ads’ effectiveness. The team was charged with collecting its own data with a computer screen-mounted device.

Each team was asked to develop three ideas for communicating its data and present them to fellow students and instructors. None of the teams ended up pursuing their first idea, but the process of incorporating feedback was new and beneficial for some of the science students. “In science, you work up to your deadline, and then you present your work,” Amaral says. “Artists do it differently and, some would say, better. They present and get feedback as part of the process, and it can result in a better end product.”

Arranging the data on arranged marriages

When the Korean genealogy team started brainstorming, members wanted a presentation idea that would resonate with people today. Their early concepts strayed from the hard data toward more artistic interpretations. They considered creating a kinetic structure with balls and chutes to represent the brides’ journeys, but the massive amount of work required wasn’t feasible in the two weeks remaining. Their second idea was interactive: viewers would chew gum while looking at a wall of pictures of fictitious Korean brides or photos of people from modern Korean dating websites, then use their chewed-up gum to connect couples they believed would be a good match. “It was a beautiful concept,” says



Visitors examine "Chicagos," one of three exhibits to result from the inaugural Data as Art course. The course tasked art and engineering students with transforming information into visual art, which was displayed at the School of the Art Institute of Chicago.

Tiffany Holmes, SAIC's interim dean of undergraduate studies, "one that touched on the fragility of the experience of being matched with someone you don't know."

But after a feedback session ("It might stink and could be disrespectful," was one comment), the team decided to go in another, more data-centered direction. The students narrowed their focus to one Korean clan of the ten for which it possessed *Jokbo* data. Using the Processing programming language, members created an animation that showed, year by year, the origin and ending point for each bride marrying into the clan. Accompanying the animation was a display of thousands of pink paper airplanes to illustrate the volume of arranged marriages. Each represented 100 unions.

A social question visualized

For the school enrollment team, creating visual representations of data resulted in not only art but also a new way of viewing an important social issue: school choice.

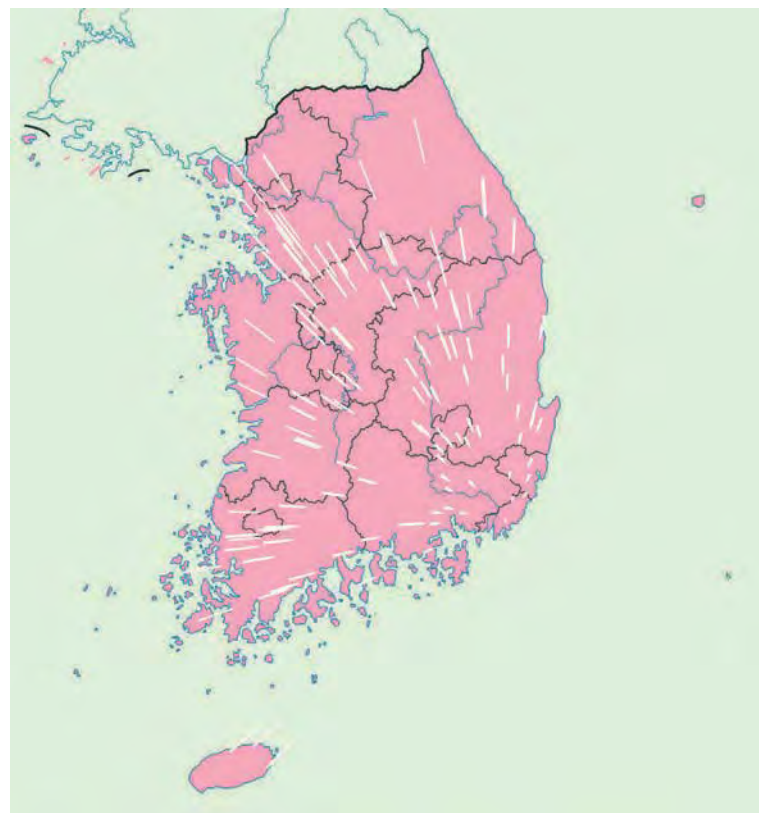
Allowing families to choose schools, even those outside regular neighborhood boundaries, is sometimes championed as one solution to Chicago's public-school problems. But, the team asked, is traveling to another school a good choice for all students?

The team decided to supplement the high school transfer data it had been given with census data, school test scores, and Chicago Transit Authority data—all information readily available to the public. With these multiple data sets, team members wrote code to create a series of temporal maps, one for each public high school. The maps demonstrated the ease or difficulty with which students could travel to schools outside their neighborhoods: the bigger the area, the longer the travel time. Other data integrated into the map suggested whether transferring schools would provide an advantage or disadvantage. Circles on the maps represented other high schools, and arrows inside a circle indicated whether that school's standardized test scores were higher or lower than the original school's.

In the exhibition, the maps covered the walls of an SAIC gallery space. In the center of



"Paper Trails" began with 500 years' worth of data describing brides' journeys across Korea to be with their arranged husbands. The resulting animation showed the origins of brides marrying into one clan in southeast Korea; each bride is represented by a line. The project was accompanied by thousands of pink paper airplanes.



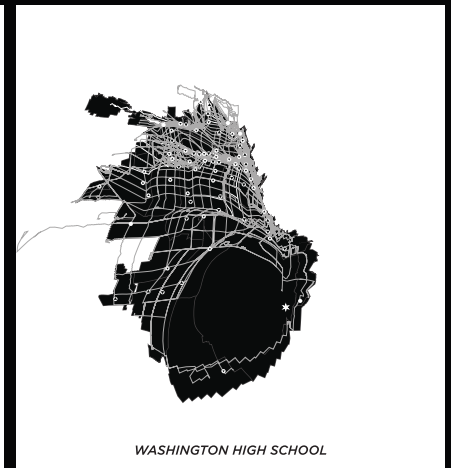
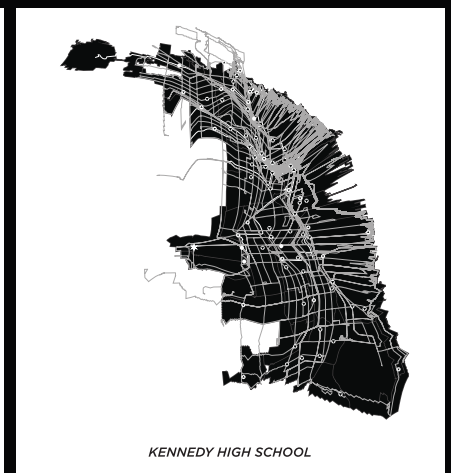
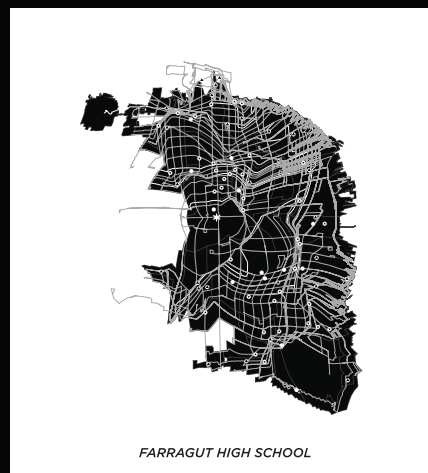
the room, a 3D contour map indicated neighborhoods' connectedness, and slides projected from above overlaid the structure with demographic information like crime rates and race. Higher elevations indicated neighborhoods that had better public transit connections to the rest of the city. "It's the idea of being in a valley versus being on a mountain," says SAIC master's student Richard Blackwell. "The higher you are up the mountain, the easier it is to ski down. The farther down you are in a valley, the harder it is to climb out."

It was clear from the maps that school choice wouldn't be a blanket solution. "Chicago is not a singular experience," says Nicholas Timkovich, a graduate student in Northwestern's Interdepartmental Biological Sciences Graduate Program. "We wanted to show that."

Examining gaze

The eye-tracking team members were in agreement that they wanted their art to be interactive, but as soon as they started brainstorming, the disagreements began. "For the first two weeks, all the Northwestern students wanted to do was read papers and research," says SAIC senior Shuting Zheng. "The SAIC students wanted to start with our inspirations and branch out from there." Forging ahead, members considered an examination of gaze in public versus private space and a study of males versus females, but eventually decided to investigate how people view themselves through "selfies," informal self-portraits typically taken with a cellphone and shared via social media.

For their project, "Me, My#selfie, and Eye," they snapped as many as 100 self-portraits each to get them right; then they opened the portraits on a computer screen and tracked their eye movements as they looked at them. The revised portraits showed their eye movements through lines and circles superimposed over their faces. The students also developed an interactive kiosk in which exhibition-goers could take their own selfies on a computer screen while the eye-tracker "watched," marking the digital photos with a web of criss-crossing lines. The resulting photos were tweeted at @MeMyselfieEye.



Using public school data, census numbers, and public transit information, the "Chicagos" team wrote code to create a series of temporal maps that showed how easy or difficult it is for transit users to reach other parts of the city. The project, which also incorporated school test scores and featured a 3D contour map, sought to explore the issue of school choice.



Using eye-tracking technology, “Me, My#selfie, & Eye” explored how people look at photos of themselves. A photo booth tracked visitors’ eye movements, and the resulting images were tweeted @MeMyselfieEye. Below: Steven Franconeri.

Finding common ground

Data as Art asked students to branch into fields outside their comfort zone, collaborating with partners who think and work differently. The students’ differences were apparent from the beginning, says Bruce Ankenman, one of the course creators. He points to the concept of variation. “Engineering students tend to think of variation as a bad thing—consider manufacturing processes or lab experiments, for example. We strive for consistency,” says Ankenman, associate professor of industrial engineering and management sciences. “On the other hand, art students want to understand the individual instead of the group. They *want* variation.”

But that conflict is precisely the point, says McCormick Dean Julio M. Ottino. “When I proposed that Northwestern and the Art Institute create this course, I hoped to produce a clash of

cultures and thinking styles. I am pleased to say we succeeded,” he says. “Creativity is essential in science and technology just as it is essential in the arts. To succeed, engineers must be able to communicate not only with people from different backgrounds, but with our own ‘right brains.’”

On August 16, students and faculty gathered in an SAIC gallery for a final critique of one another’s work, followed by an opening reception for the exhibition *Data Viz Collaborative*. Leaders from both schools applauded the finished products and the process. The students’ projects were displayed in the exhibition in two SAIC galleries in August and September. The art then moved to Northwestern, where select pieces remain on display at the Segal Design Institute in McCormick’s Ford Motor Company Engineering Design Center. **M** Sarah Ostman



WHY WE NEED THE HUMANITIES AND ARTS

View from the Intersection

Many academics fear a decline of the humanities in education. As an engineering dean, I am of course a fervent supporter of science and technology education. Yet the discussion has thus far presented a false dichotomy: science and technology or arts and humanities.

The two are not mutually exclusive. Not only are the arts and humanities essential, science and technology have much to learn from the way that those fields structure their education.

There is no doubt that science and technology education is key to the future. The world is increasingly incomprehensible without basic scientific knowledge. This knowledge gap will continue to widen as science and technology advance.

Without a basic understanding of how critical technologies work, we will become more and more disconnected from the systems that govern our lives. We will not be able to make rational decisions about them and their impact. Enriching science and engineering education is integral to our students' and our society's success—yet it cannot prosper alone.

Arts and humanities are vital to this new world. The primary reason: without a grounding in these fields, an entire range of human experiences and emotions will forever be invisible to us. Without them, we are doomed to an empty existence and a miserable old life.

The second reason is more pragmatic and has to do with solving the many problems we face. "Solving" may be a misleading descriptor; more and more, our problems come to us as dilemmas, tough irreconcilable choices: security or personal freedom, environmental protection or economic growth. There are rarely clear winners or ideal solutions.

Solving problems requires more than just developing tools to address a need. The thinking that happens before action, the crucial framing of the issues, is essential. Arts and humanities augment the analytical thinking that is the essence of science and technology.

In arts and humanities, students learn to contemplate and frame questions differently; creative and metaphorical thinking come into play. Questions are placed on a broader canvas, with context and an understanding of implications from the perspectives of individuals and groups. Not all thinking is problem driven. It is in the augmentation of possibilities—the things we never knew existed—where remarkable opportunities lie.

The boundaries between science, technology, and art will become more blurred, and each domain can be enriched by the others, particularly by appreciating their distinct thinking skills. Scientists think like scientists, probably the most organized of all. There is also humanistic thinking, with an emphasis on critical thinking, originality, and understanding relationships. While much less regulated, there is also artistic thinking, with its structure, aesthetics, and balance.

In the United States, students benefit by exposure to all three of these types of thinking for much longer than in other countries, where students make decisions early and are funneled into professions like law, engineering, or medicine. This is true in most of Europe and in South America; in the United Kingdom, specialization begins around the age of 16.

Our system promotes a solid, broad base in humanities, science, and arts. This is one of the major reasons we excel at creative thinking, innovation, and invention—skills that are the envy of other nations—but we are failing to exploit it to its fullest effect.

In science and engineering, students start by learning perfection. They re-create famous experiments with clear and predictable outcomes. When science education is at its worst, students are told to be creative only at the end. This change is abrupt; up until this point they have not been asked what they

think of calculus or linear algebra, nor have they been given open-ended questions to apply the tools they've mastered.

Too often this can be described as absorption and production, with little critical thinking in between. For many students (those who continue the furthest), it is not until the long apprenticeship of a PhD program that they are asked to exercise creative thinking and develop novel ideas. And even this is typically within very narrow confines.

The gap between learning and doing is too long. This structure of "delayed gratification" causes the loss of talented students. Students often do not have the patience to wait for the rewards, so our pipeline has developed leaks (if students enter the pipeline at all). Science and engineering, as learned in most universities, is mostly about absorbing knowledge, but in practice people who have creative skills and the ability to ignore the traditional boundaries are the ones who rise to the top.

We can learn from the humanities, which develop original thinking skills much earlier. Creative domains from writing to the arts emphasize the "doing" and "creating" components, rather than just absorbing knowledge. Artists are asked to dissect and criticize, to express and defend opinions.

Particularly in the arts, the focus is on doing from the word *go*; an individual goal of perfection is a goal at the end. At its best, art does not solve problems; it creates questions. It brings the ability to think with a clean slate, to begin with broad, unstructured initial thinking, followed by painstaking attention to detail. It shows us the world under new, sometimes unrecognizable, light. Seeing things in a completely new fashion is ultimately what innovation is about.

In some places, including at Northwestern, design thinking is used to fill the learning-doing gap; half the question in design is finding the problem behind the perceived problem. Universities compete based on offerings and perceived value, and these practices are getting rave reviews.

The consumption-production balance must be altered in science and engineering. We would be wise to embrace humanities in our students' education, but also to embrace the balance between learning and doing that arts and humanities provide. Our students must develop even stronger critical thinking skills to identify the real problems that we face and to understand the implications of their solutions. We will all benefit from it.



Julio M. Ottino

Dean, Robert R. McCormick School of Engineering and Applied Science, Northwestern University

STICKY WHEN WET

*Why biomedical engineer **Phillip Messersmith** thinks some of our favorite foods hold the key to safer surgery*

Mussels, red wine, chocolate, tea: the sources of Phillip Messersmith's inspiration sound more like a dinner menu than the spark for medical breakthroughs. But for nearly a decade, these foods' properties have aided Messersmith in his development of adhesive surface coatings that could improve surgery and save lives.

"Nature has created materials that can easily do what manmade materials cannot: adhere to wet surfaces," says Messersmith, Erastus Otis Haven Professor of Biomedical Engineering and of Materials Science and Engineering. "Our goal is to understand biological adhesives so we can mimic what nature does so well."

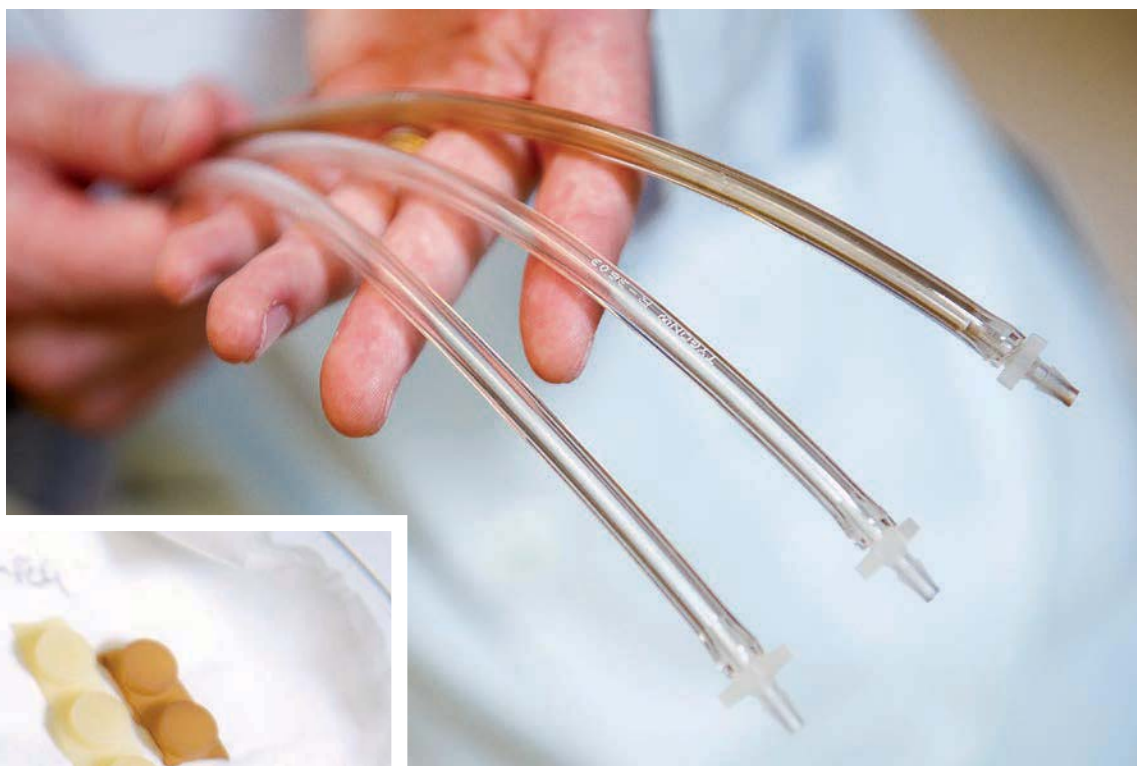
Top on Messersmith's list is developing a nontoxic antibacterial coating to help prevent device-related infections. Bacteria tend to attack medical devices when they are placed in the human body, sometimes causing life-threatening reactions; while fluid-based bacteria are relatively easy for immune systems to fight, surfaces provide a place for the microorganisms to assemble themselves into colonies called biofilms, which can resist the body's defenses and antibacterial drugs. Antibacterial coatings on medical devices like catheters and pacemakers could stave off infection, but they would have to be able to adhere to those devices inside the body's wet environment—a challenge for most synthetic adhesives, which deteriorate or fail in the presence of moisture. New synthetic adhesives could also be used to attach or repair tissues in surgery.

As Messersmith found, mussels can offer at least part of the solution. The bivalves can adhere to virtually all inorganic and organic surfaces underwater and even in turbulent tides, thanks to a special glue secreted from their tongue-like "foot." The glue is secreted as a liquid but hardens rapidly into a solid, water-resistant adhesive that can stick to minerals, metals, wood, and other surfaces. Key to the glue's stickiness are mussel adhesive proteins, a family of unique proteins containing a high concentration of the catecholic amino acid DOPA (dihydroxyphenylalanine).

Messersmith noticed that dopamine—commonly known as a neurotransmitter—shared the mussel proteins' essential elements. (Both have chemical structures with two hydroxyl groups, the segment of the molecule believed to provide adhesive qualities.) In his lab he re-created the mussel proteins' adhesive function in a few simple steps, dissolving a small amount of dopamine in a beaker of water and adjusting the water's acidity to match that of seawater. He then placed a solid object in the solution; several hours later, the object was coated with a thin polydopamine film less than 100 nanometers thick.

The polydopamine coating was not antibiotic, but it provided a surface with high chemical reactivity, a feature that could be useful not only for medical devices but also for manufacturing and industrial uses. "We can take advantage of that reactivity to apply the second layer," says Messersmith. "For example, I could place an iPod casing in





Phillip Messersmith and graduate student Tadas Sileika create plant-derived coatings from compounds found in common food and beverages. Coating medical polymers in these compounds could provide an intermediary layer to help other antibacterial coatings stick to them. Above and at left, two types of medical polymers are shown with various combinations of Messersmith's plant-derived coating and other antibacterial substances.

the dopamine solution, and a thin polydopamine coating would form. Then I could take it out and put it in a metal salt solution and form a coating of copper or silver." The same technique could be used to coat medical polymers in silver, which has excellent antimicrobial properties. Messersmith's group went on to develop a number of coatings that anchor onto surfaces using the same chemical interactions found in mussel adhesive proteins.

Recently Messersmith made another connection: he noticed that the chemical compositions of polyphenols—a large and diverse family of chemicals, common in plant tissues, that are often touted for their antioxidant properties—were very similar to those of mussel adhesive proteins. In plants, polyphenols have a wide range of purposes, such as camouflaging leaves and making them taste bitter, but one characteristic is especially appealing. "Plant-derived polyphenols are often intrinsically antibacterial," says Messersmith. "If we could perfect a polyphenol adhesive, it could be extremely valuable for surgical applications."

A simple experiment demonstrated how a plant-derived coating could work. Messersmith poured wine into a clean glass and let it sit for several hours in his kitchen sink, then poured out the wine and rinsed the glass so it appeared clean. When he added a colorant, however, a thin coating of polyphenols was revealed on the glass. Bacteria died when introduced to the coating.

"What's interesting is that the raw materials we regularly encounter in our diets can benefit us in a way we had never envisioned," says

Tadas S. Sileika, a graduate student in Messersmith's lab who worked on the polyphenol coating. "The coatings have innate properties that can help save lives and keep people healthy. Without any further modification, they can help prolong the life of a medical device, reduce inflammation in a patient's body, and prevent bacterial infections."

Based on this knowledge, Messersmith developed a method that could produce the coating more effectively. He found that immersing objects in a saline solution of tannic acid results in the same coating in less time. His team tested all kinds of materials—medically relevant polymers, engineering polymers, metals, inorganic substrates, and ceramics—and the coating stuck to each one. The coating could also be modified to take on additional characteristics, such as stronger antibacterial properties.

The plant-based adhesive has other benefits. Unlike the brown coloring of the mussel-inspired coating, the polyphenol coating is colorless, which is preferred for many manufacturing applications. The compounds used in producing the plant-based coating are also 100 times less expensive.

In 2004 Messersmith founded Nerites, a company to commercialize his polydopamine coating; he has since sold the company, but it continues to work toward getting the surgical adhesives into operating rooms. In addition to his mussel-based adhesive research, Messersmith is developing plant-based adhesives to make surfaces attract or repel water, technology that could be used to manufacture nonwetting or self-cleaning surfaces. **M** Sarah Ostman

Computer Science Everywhere

More nonmajors are delving deep into the computer science curriculum to prepare for work and life in the 21st century



Daniel Learner, a theater and psychology major, wrote a program that compared headlines from Northwestern's two student publications. He sent it to a friend, who wrote that Learner was "a magical human being."

Computer science is having a moment, and Northwestern students know it. Even during their short collegiate careers they have felt the field shift from unapproachable to accessible, from nerdy to cool, from fluorescent-lit basement labs to glamorous, trendy workplaces.

"When you can program, people look at you like you're a wizard," says Daniel Learner, a theater and psychology major who didn't take the computer programming class offered at his high school because only the "really, really, really nerdy kids took it." Now Learner, a senior, typifies many of the students found in McCormick's computer science courses: nonmajors who understand that computer science is a gateway to tomorrow's careers.

Over the past five years enrollment in undergraduate computer science courses has tripled at Northwestern. While the number of computer science majors has nearly doubled, many students enrolled in the courses are nonmajors looking to enhance their skill sets. McCormick has responded to demand by allowing more students into classes and offering more options. Classes like Data Structures that were previously offered once a year are now offered three or four times.

"If you go back several years it might be that students were taking Introduction to Programming to gain some computer literacy," says Professor Alan Sahakian, chair of the electrical engineering and computer science department. "More recently what I'm seeing is nonmajors taking courses deep into the computer science curriculum—courses that, in the past, only majors would have taken."

KATIE ZHU

That intersection entices Katie Zhu as well. Zhu arrived at the Medill School of Journalism, Media, Integrated Marketing Communications aiming to be the next Bob Woodward. But then she found that it wasn't the articles in student magazine *North by Northwestern* that intrigued her—it was the publication's online housing guide, a Flash graphic that let users decide on housing options based on room sizes and amenities. Zhu joined the magazine's interactive desk

her freshman year and began learning how to program basic interactive graphics.

"I remember the first time I made an alert in Javascript," she says. "I made a dialog box pop up. I remember thinking that was so cool, that you could tell computers what to do."

She worked with Jeremy Gilbert, associate professor of journalism, on a program that rewarded users for reading news articles. It was then that she realized her technical skills were lacking. "I didn't have any web development experience," she says. "I didn't really know how the Internet worked. I didn't know what a server was."

But it was the movie *The Social Network*—

especially the rhythmic scene in which, after getting jilted by his girlfriend, Mark Zuckerberg builds a website that ultimately crashes Harvard University's servers—that inspired Zhu to pursue a second major in computer science.

"College is about finding your true nature," she says. "And though seeing my byline in a newspaper was rewarding, after I'd spent two hours debugging some code only to find out that I'd misspelled some variable—a very small, dumb mistake—and then working to finally get that code to run, that level of satisfaction was more fulfilling for me."

Zhu admits to taking the hard road—she has

never been a math and science person, she says, and she didn't have a predisposition to programming—but she has found the resources and put in the time to develop a deep technical knowledge base.

Her efforts were rewarded last year, when she was one of six students nationwide to win the AP-Google Journalism and Technology Scholarship. In her application Zhu submitted a proposal for LedeHub, an open-source tool that would allow journalists and developers in the newsroom to share work and collaborate on projects. ("Lede" is a journalism term for the first paragraph of an article.) She's refining the idea after an internship at NPR last summer showed her the need for early-stage collaboration among reporters, editors, producers, and programmers.

After graduating in June, Zhu spent the summer interning on the *New York Times's* interactive desk before joining Medium, a content-creation platform started by Twitter cofounders Evan Williams and Biz Stone. The job provides her

with a way to help solve problems at the intersection of technology and media.

"Computer science teaches you a brand-new way of thinking, a new way to approach problems," she says. "It's scientific—there are rules and syntax—but within that framework, there is so much room for creativity."

Programming by day, making music by night

Creativity mixed with rules and syntax is the recipe for another field of study: music. No one knows this better than Lee Fan, a viola player who double-majored in music performance and computer engineering.

"Actually, I really wanted to go into just music, but my mom told me that if I wanted to do music, I had to have another degree," he says.

Programming came naturally to Fan after he taught himself to program basic games on his Texas Instruments calculator in middle school. At the same time his music teacher convinced him to leave the overcrowded field of violinists to play the deeper-voiced, and less commonly studied, viola.

"I like making music," he says. "I appreciate it as art and entertainment." His high school years were spent playing the viola in several orchestras and reading books on C++ that were lying around his house.

By the time he applied to Northwestern, his top school choice for its combination of music and engineering programs, Fan was more interested in how the computer itself interacted with programs. "I just could not wrap my head around how zeroes and ones would be interpreted by a computer," he says, so he chose computer engineering for his second major.

It turned out that writing code came more naturally than working with hardware. Fan found himself taking more and more computer science courses during the day and practicing his viola at night. To him, they were two separate worlds. In computer science, once he learned a piece of knowledge, he retained it without effort; it was digital, nondegradable. But his viola was analog; he had to constantly practice or the information would degrade—quickly. "If I don't touch my instrument for a day, I'm out of tune," he says.

The only crossover is technique. Before he plays, Fan imagines what the music should sound like. He uses a similar strategy when he



Lee Fan hopes to work for a software company and to teach viola.

codes. “Many people just like to jump in and start coding, but I like to play it out in my head. I’ll run simulations and debug mentally before I write anything.” He’s also channeled his creative side into developing a crowd-sourcing storytelling program that allows users to collaborate on choose-your-own-adventure narratives.

Fan decided to stay on at Northwestern for an extra year to earn his master’s in computer science through McCormick’s BS/MS program. After completing his degree he hopes to find the right balance of working for a large software company and teaching viola.

“I always thought I would end up playing music and writing code,” he says.

“A lot of fun and more interesting”

Sometimes nonmajors who take computer science courses don’t come all the way from across campus: they inch over from within the same department. That is the case for Gabriel Peal, a 2013 electrical engineering alumnus who took most of the computer science major courses.

“I almost molded it into a computer science degree,” he says. “That it wasn’t is more of a technicality.” Initially drawn to electrical engineering’s curriculum that teaches students the theory behind circuits and hardware but leaves plenty of quarters open for classes in other disciplines, Peal quickly learned that computer science “was a lot of fun and more interesting to me. I looked at what companies I might work for—Google, Apple—and they were just incredible.”

Peal was no stranger to coding. He had developed a program on his TI-83 calculator, one that could solve all the problems in his high school geometry class. But he thought computer science was for nerds. “I had this conception of it being bland guys in button-down shirts sitting in cubicles and typing code all day. I was really glad to discover through my internships that it wasn’t the case.”

What sealed Peal’s fate was the NUvention: Web course, where cross-disciplinary student teams are tasked with developing a web or software business. Peal’s team developed and launched Stagecoach, a project management solution for the film industry. Though the team didn’t continue developing the business after the class ended, the experience remains one of the most important of Peal’s undergraduate career.

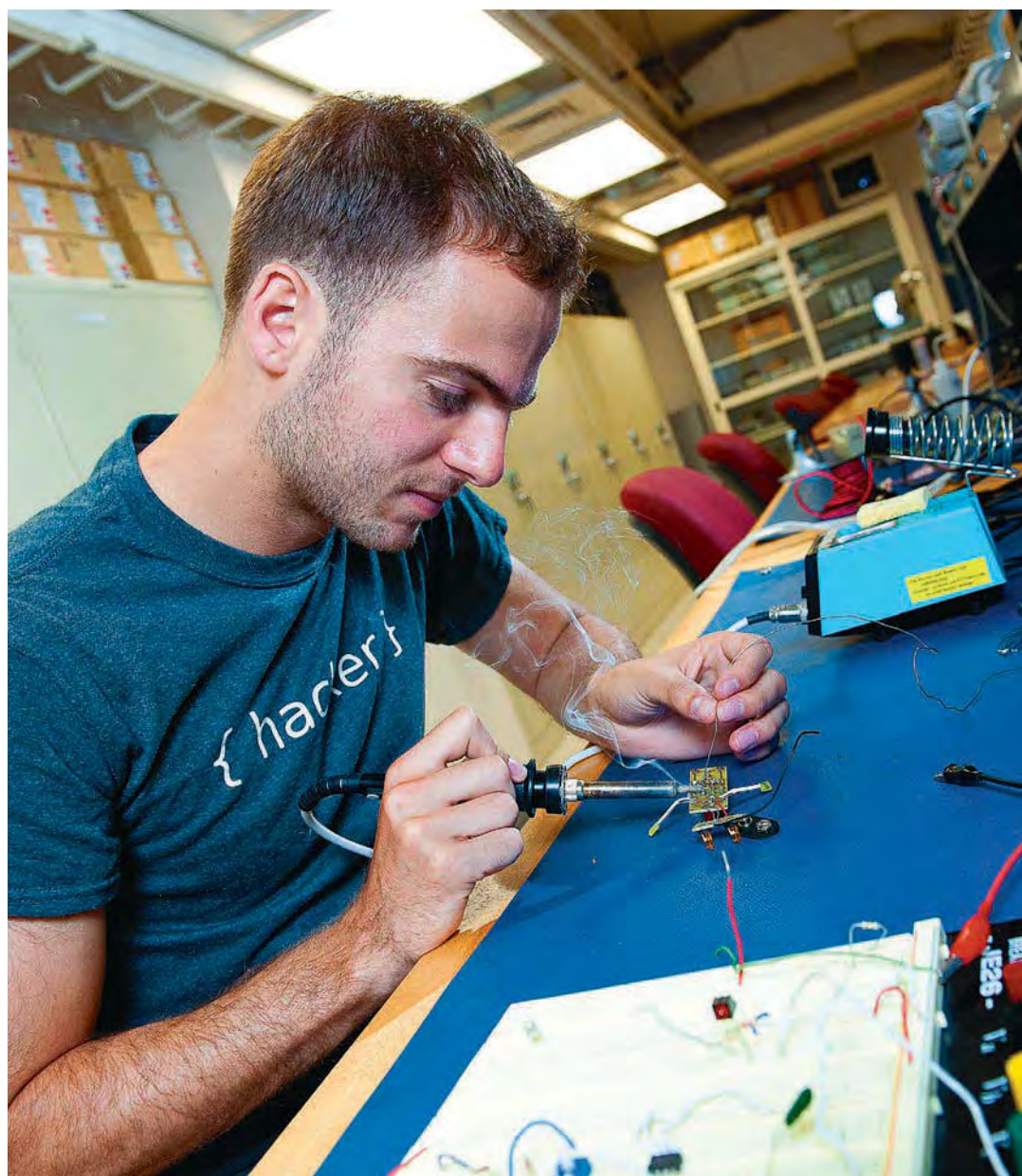
“It forced me to learn new web and app development tools—and to launch an actual business,” he says. “It really made me grow as a software engineer. We had to work in a team, set

Nonmajors understand that computer science is a gateway to tomorrow’s careers.

goals, and achieve them in a timely manner. It opened my world to so many possibilities. It was hands-down the best course I took.”

Peal had an internship at Google and ultimately accepted a position as a software engineer on the company’s Android team. “It’s a collaborative work environment, an open atmosphere,” he says. “Everyone there is at such a high level.” That’s a far cry from what a high-school-aged Peal had imagined life as a software engineer would be.

“The opportunities to change the world through computer science are available to anybody,” he says. “We get to change people’s lives and do really fun things.” **M** Emily Ayshford



Gabriel Peal thought computer programmers were bland guys in button-down shirts. Then he got an internship at Google. “I was really glad to discover that it wasn’t the case,” he says.



"ENGINEERS ARE IN DEMAND"

A conversation with McCormick's director of career development

It's a great time to be an engineer. Engineering is now a foundational discipline; engineers are defined not by what they do but by how they think. They are taught to approach problems both analytically and creatively and to find the actual problem behind the perceived problem. It's a skill that opens up myriad career opportunities across tech, business, media, and green sectors, giving students a chance to forge nearly any career path they choose. Starting salaries are high, and graduates are in demand; more than 90 percent of McCormick graduates have opportunities lined up before they graduate.

Of course, students need a little help along the way. The McCormick Office of Career Development, in an expanded role, now guides students to the right opportunities from the moment they step onto campus. It currently helps students find internships, research positions, and volunteer opportunities and offers career preparation courses, one-on-one advising, and mock interviews. Perhaps most important, it teaches students how to connect with Northwestern's alumni network.

We sat down with Helen Oloroso, assistant dean and director of career development, to discuss trends in employment.

Engineers are in demand. Even at its worst, in September 2009, the unemployment rate for engineers was 6.4 percent, compared with nearly 10 percent for all occupations. How does this influence how engineering students look at careers?

It's a great time to be an engineer. Because of the widespread information about the role of the tech sector in our economy, our students know they have more opportunities than many of their nonengineering peers. Some industries experience volatility during economic downturns, but engineering in general is poised to suffer less and recover more quickly.

That must make job hunting a little less stressful.

Perhaps, but the job search is still daunting—partly because of the overwhelming amount of information available to students and partly because they are often unsure of their own true interests. Many students who come to us are wrestling with uncertainty over whether engineering or business is a more suitable choice. I would say 20 percent of the sophomores we work with are only tentatively committed to their current major. At least half of these students will change majors before graduation.

How does your office help students become more certain of their true interests?

We help students through our Introduction to Career Development course, which is required of every student who participates in an internship or cooperative education program. Since the course began in 2007, more than 300

students have taken it each year. In one assignment, students must make a presentation on their dream job and find companies that operate in that space. Our advisers also work one on one with students to develop an individualized plan and hone their interviewing skills. One of the most helpful requirements is that students contact an alum to request an informational interview. That gets them thinking about what they seek in employers and vice versa. We train students to ask questions and tell the company what they can offer.

Beyond the course, every student is assigned a career adviser, and advising appointments continue throughout the students' time at McCormick. This is vital to helping students make informed choices throughout their undergraduate career.

In general, the more self-aware students are, the easier it will be to decide on a career and begin a

job search. Do they want to work in a large or a small company? We often ask them to think about their high school experience and whether they liked being part of big organizations or small ones. We often encourage students to look at midsize companies, which are likely to be overlooked because they are not household names.

Engineering students now have a wide range of career opportunities. What types of jobs are engineering students recruited for? How has that changed over the last 10 to 20 years?

Many employers desperately want to hire students who can handle and understand data. Computer science majors are the most in demand, especially at large companies that need to fill out their IT departments. In the traditional engineering disciplines, electrical, mechanical, and chemical engineering are most in demand.

Ten years ago the most popular destinations for McCormick graduates were traditional engineering industries—chemicals and materials, electronics hardware, manufacturing, biomedical, and the like. Now our students are often more business focused. Economics is the most popular second major among McCormick students, and many students go directly into business-related careers. Today, four out of every 10 graduates go into either consulting or finance—nearly double the number who did so a decade ago—though that number is trending back down from its peak a few years ago.

More recently, employers are realizing the need to come to campus earlier and seek out younger students. They offer more opportunities to



less-experienced students in order to recruit them into the field. In light of the leadership gap in many corporations, McCormick students are highly valued for their vision, talent, and ability to communicate well with others.

What do students want out of their careers?

More and more students want careers that involve the environment and sustainable development. They want design-based work and leadership roles that will enable them to make an impact on society. Because of McCormick's focus on entrepreneurship education, we also have several students who are forgoing traditional careers to start companies or join startups. It's an exciting time for them: they have the knowledge and abilities to create their own businesses without having many of the adult responsibilities that normally discourage engineers from taking risks. We are also trying to match up these students with established companies so the students can use their entrepreneurship skills within large corporations to help innovate and effect change.

How do engineers' salaries compare?

The National Association of Colleges and Employers reports that the top starting salaries nationally as of April 2013 were paid to computer engineering graduates, with a median salary of \$71,700. Other top salaries include chemical engineers at \$67,600 and mechanical engineers at \$64,000. Overall, it's clear that engineering careers are at the top end of the salary range and at the low end of the unemployment spectrum.

What's the best way for engineering students to prepare for the job search?

The ideal way continues to be through an experiential opportunity such as co-op or internships. According to the Collegiate Employment Research Institute at Michigan State University, 62 percent of employers plan to do


direct hiring from their pool of co-ops and interns in 2013-14 rather than a seniors-only recruiting strategy. Two-thirds of McCormick students have completed at least one quarter of related work experience, either as co-ops or as interns, before senior year. More students are looking to partake in a variety of internships across industries to get a better sense of what they want to do. This is a significant contributing factor to the success of our students.

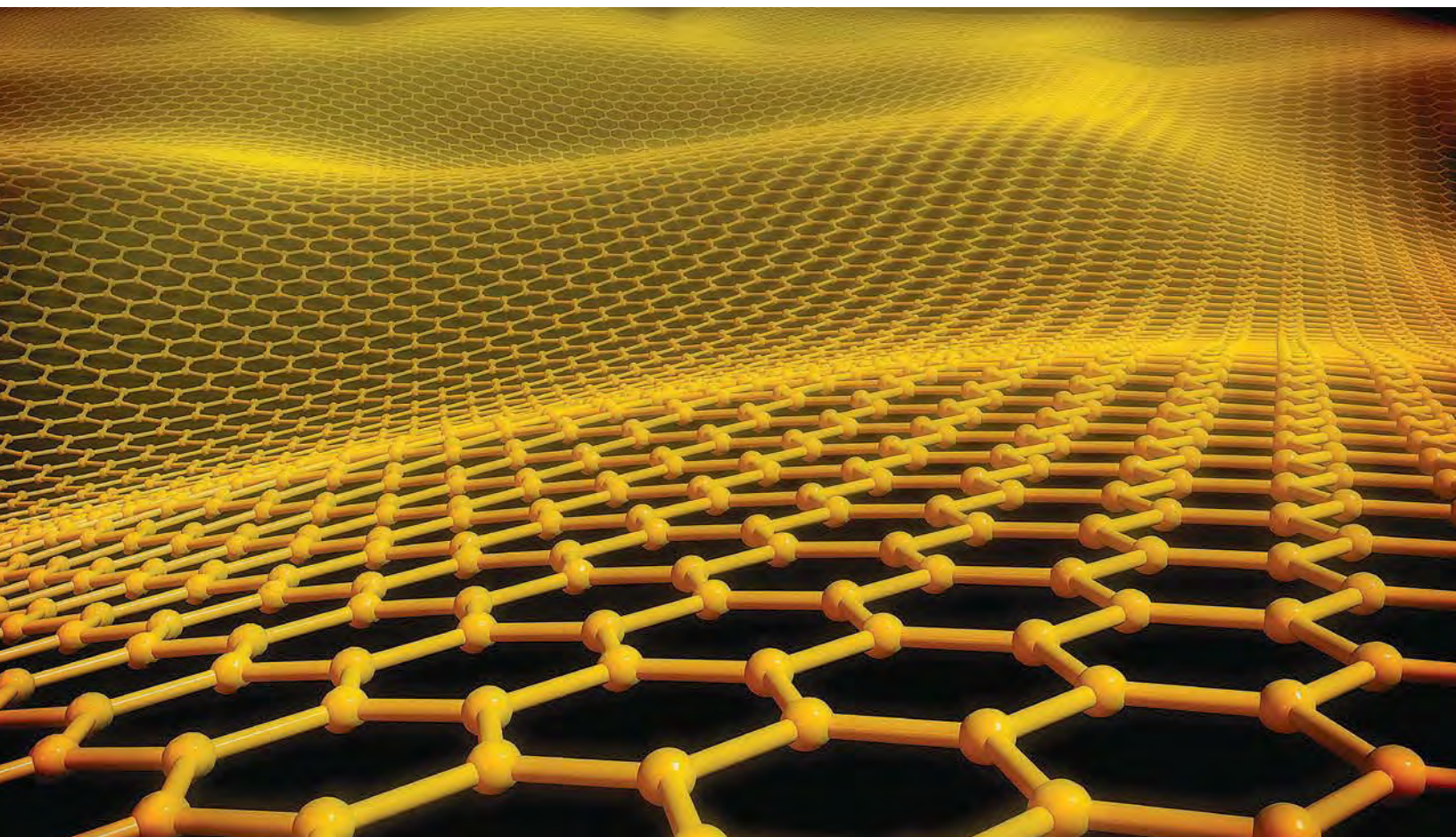
How can they stay at the top of their field as they move up in their career?

It is most important to understand that knowledge has a limited shelf life. More than most others, engineers have to stay on top of changes in their industry. Lifelong learning through an advanced degree is probably essential to remain competitive as a practicing engineer.

Another option for students who want to move up in their career is to join a leadership development program, available in most large corporations. These two- to three-year rotational programs are designed to augment an employee's technical background and develop the next generation of corporate leaders.

Two fields that seek engineering students for their analytical and problem-solving abilities are finance and consulting. We advise students to think carefully about where this route will take them, because these fields have very high rates of attrition after the first two to three years. Students who go directly into those fields may burn out within a few years, and by then they may not have the skills to go into a traditional engineering job. They often need to get a master's degree because the fundamentals have changed.

I often tell students that engineers need to add value to themselves throughout their careers. Students used to identify as "I am what I do"; now it's "I do what I am." Research shows that employers are increasingly looking for initiative. That wasn't even on the list 10 years ago. Now they are looking for people to bring ideas and mold their jobs themselves.  Emily Ayshford

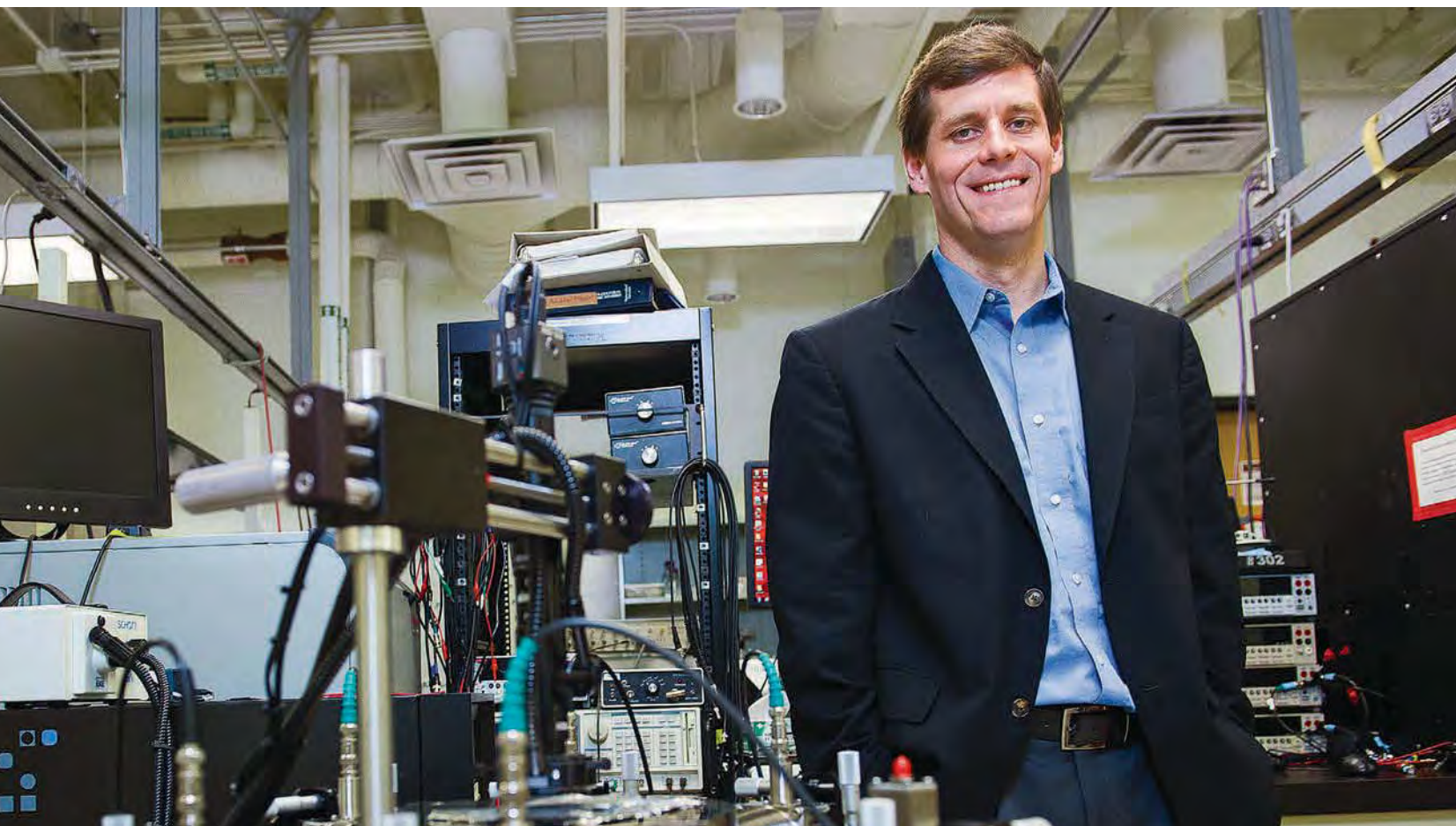


Miracle material

A DECADE AFTER ITS DISCOVERY, GRAPHENE IS **HOT**

It's the thinnest material on Earth but 200 times stronger than steel. It is exceptionally conductive—10 times better than copper—and can stretch, bend, twist, and bounce right back. And it's everywhere; if you've used a pencil, you've likely made some yourself.

If ever there was a “miracle material,” graphene is it. The substance is enabling faculty and students from across McCormick to pursue research areas that once seemed unimaginable.



C. JASON BROWN

Mark Hersam is working on high-performance applications for graphene, such as flexible electronics. These ambitions require graphene to be pristine, so Hersam's team must analyze each atom with high-performance scanning tunneling microscopes.

Discovering the miracle material

Molecularly speaking, it doesn't get much simpler than graphene. It is the thinnest possible slice of graphite, a virtually two-dimensional, one-atom-thick layer of carbon densely packed in a honeycomb-shaped lattice. But the potential this simple material holds is tremendous. Bendable electronics, superfast computers, lightweight cars and airplanes, nanoscale water purifiers—if it lives up to its promise, graphene could enable all of these and more.

Researchers were speculating about the amazing properties of single-layer carbon sheets as far back as the 1940s, but for years attempts to make the material failed. Fabricating it wasn't the problem; by the 1970s researchers knew how to grow graphene on top of crystal surfaces. But the material interacted with the surfaces on which it grew, making it impossible to study its properties. Some researchers attempted to make graphene by inserting molecular spacers between layers of graphite in an attempt to wedge them apart, but that tended to degrade the graphite into particles too small to be of use. Others scraped graphite against another surface to slowly wear the graphite down, a technique that proved moderately successful; some scientists whittled the thickness down to fewer than 100 atoms.

Most scientists concluded that isolating graphene in any usable form was impossible, however; a single sheet, they thought, would be thermodynamically unstable and, if isolated, would immediately

roll into a cylinder. (The cylindrical form of graphene, the carbon nanotube, had been discovered in 1991.) Graphene, it seemed, was doomed before it had been discovered.

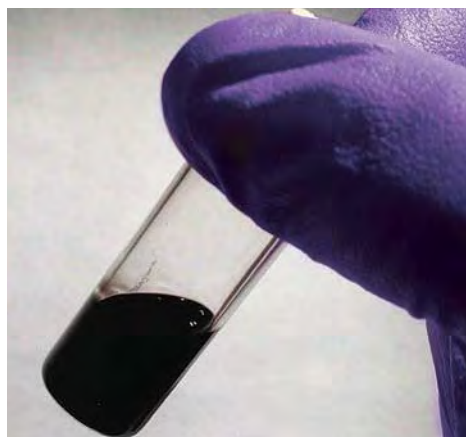
But, as scientists are wont to do when something is declared impossible, some researchers persisted, including Andrei Geim, a physics professor at the University of Manchester in the UK, and a former PhD student of his, Kostya Novoselov. In 2004 Geim and Novoselov realized they could place a small flake of graphite onto a piece of clear tape, fold the tape over, and pull it apart to split the graphite in two. They split layer after layer this way, and when they had a thin enough sample—in some places, only one atom thick—they transferred it to a silicon substrate where it could be characterized.

The discovery of graphene won Geim and Novoselov the Nobel Prize in physics in 2010. The race to develop applications was just beginning.

A global race

Thousands of research groups are developing and patenting graphene products worldwide, but three countries—China, the United States, and Korea, in that order—have filed more than two-thirds of patented discoveries. Recognizing graphene's potential, other countries are pooling resources to become more competitive.

Despite thousands of patent filings, graphene technologies have been slow to come to market. Mark Hersam, Bette and Neison



Graphene has the largest surface-to-weight ratio of any known material; one gram of it could cover nearly half of a football field.

At left: the first method for isolating graphene involved stripping extremely thin layers of graphite with clear tape. Though that technique is still effective, more efficient practices have become common. At right: Mark Hersam has developed a highly conductive, bendable graphene ink that could be used to print electrodes.

Harris Professor in Teaching Excellence and professor of materials science and engineering at McCormick, says it's largely an issue of integrating graphene with other materials. "No doubt, graphene is the new, hot material, but there is a big difference between winning the Nobel Prize and making a functional technology," Hersam says. "The solid-state transistor was invented in 1947, and it took 14 years to make the first integrated circuit. Integrating materials takes time."

While some graphene products are almost ready for the marketplace—such as graphene coatings that could make rechargeable batteries safer and longer lasting—others remain at the exploratory phase. That's partially because until the past few years, scientists lacked a large-scale graphene production method; unsurprisingly, Scotch tape turned out not to be an effective or cost-efficient method. (In 2008 graphene produced by mechanical exfoliation, or the Scotch tape method, was one of the most expensive materials on Earth, costing \$1,000 for a piece smaller than the thickness of a human hair.)

Today's graphene-making methods have become more efficient. Some labs can create graphene sheets that measure several feet across: stiff, semitransparent pieces that can be seen with the naked eye. There are various ways to make graphene, each with strengths and weaknesses; some lend themselves to certain end products. One of the most popular involves oxidizing graphite via acidic chemical treatments, then applying heat to reduce the resulting graphene oxide to pure graphene. While quick and inexpensive, that process introduces imperfections into the material, so it cannot be used for applications that require optimal conductivity, like computer chips.

For researchers like Hersam, who focus on high-performance applications—such as graphene electronics, now under development—it is vital that the graphene be pristine, even if the growing process is more energy intensive. Hersam's labs are full of high-performance scanning tunneling microscopes that enable him to carefully analyze each piece he creates. "Our laboratory works on the surface functionalization of graphene to better control the interface between it and other materials," Hersam says. "When you have a one-atom-thick material, individual atoms matter."

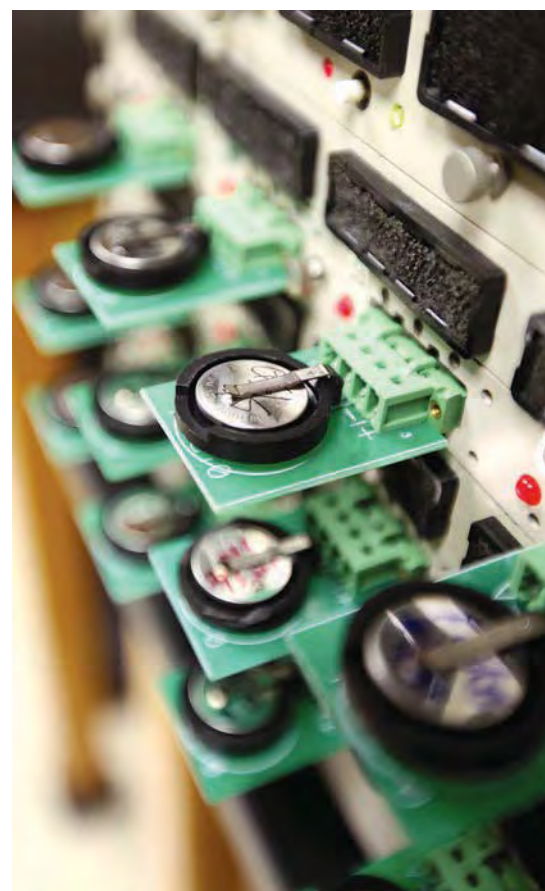
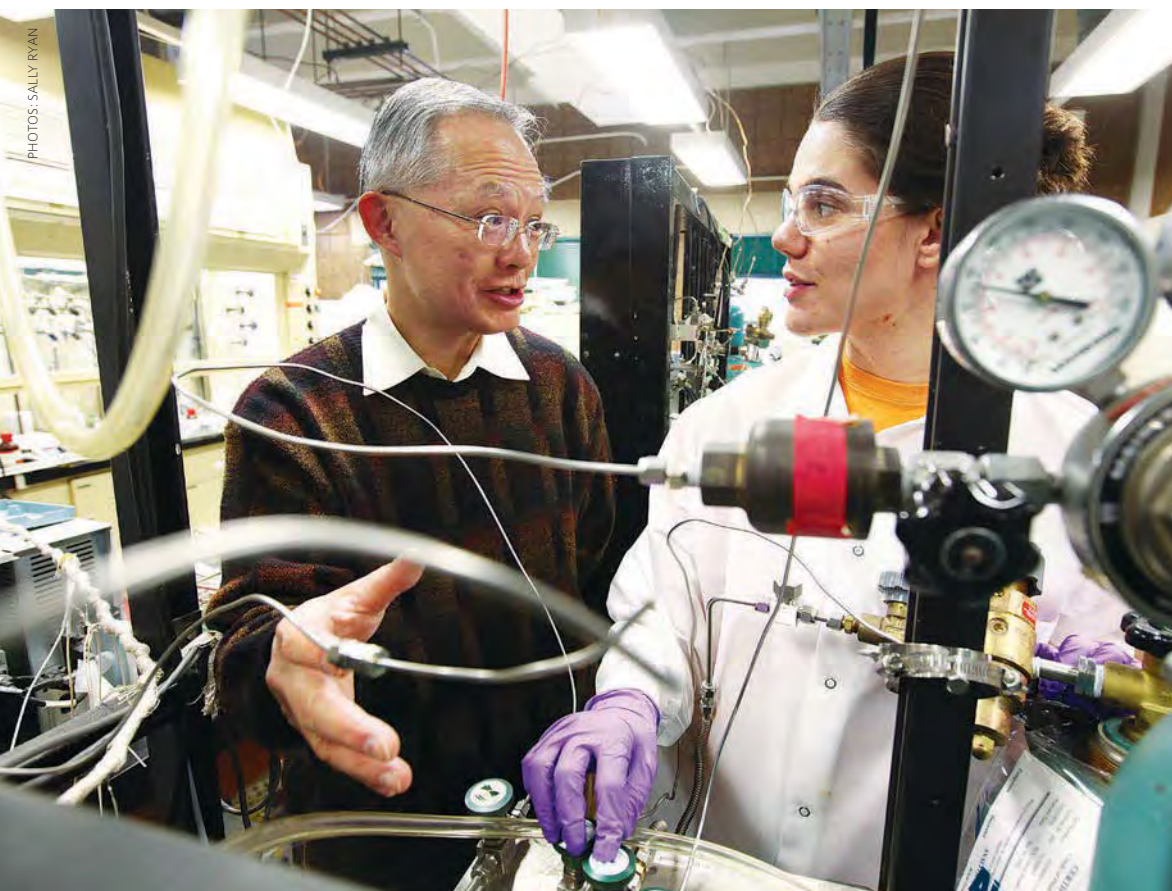
Electronics of the future

Many experts believe graphene could rival silicon, transforming integrated circuits and leading to ultrafast computers, cellphones, and related portable electronic devices. Among these high-tech visions are flexible electronics, such as a tablet computer that folds to become a smartphone, or electronics that can be integrated into clothing or the human body. Recently Hersam developed a highly conductive, bendable graphene-based ink that could enable such devices, and his lab has used it to inkjet-print patterns that could be used for extremely detailed, conductive electrodes.

Graphene ink is a smart choice for next-generation electronics: the graphene is extremely conductive and tolerant of bending, and printing provides an inexpensive and scalable method for exploiting these properties. Researchers previously explored the method, but it has remained a challenge because it is difficult to harvest a sufficient amount of graphene without compromising its electrical properties. But a new method that Hersam developed for mass-producing graphene—which uses ethanol and ethyl cellulose to exfoliate the material, resulting in a powder with a high concentration of nanometer-sized graphene flakes—alleviates that problem.

Hersam's printing technology has caught the attention of the US Office of Naval Research, which is funding Hersam to advance the technology in hopes of someday creating a brain-machine interface for Navy pilots, a skull-conforming cap with millions of printed sensors that could detect the brainwaves of pilots and wirelessly communicate their intentions to the vehicle's control center. The device would speed response times in combat, and it could also have medical applications, such as understanding brain damage and disorders in veterans. "It sounds a bit like science fiction," Hersam says, "but it's possible. Flexible electronics are key."

To realize this technology, Hersam's ink must mesh with materials from other labs, most likely semiconducting inks, to build full circuits—millions of electrodes acting in unison. Hersam is collaborating with Tobin Marks, Vladimir N. Ipatieff Professor of Catalytic Chemistry and (by courtesy) Materials Science and Engineering, who is creating metal oxide inks that could prove compatible.



Graphene can increase the charge capacity and rate of lithium-ion batteries, like those found in cell phones and electric cars. Harold Kung's graphene and silicon battery anode could increase a battery's charge speed tenfold.

Clean energy with graphene

Because of its unique combination of properties, graphene could also move solar cell technology forward. Solar cells require materials that are conductive and optically transparent—a rare combination. “If you think of optically transparent materials, you think of glass, which is not conductive. And if you think of conductive materials, you think of materials like copper that are optically opaque,” Hersam says. Today’s commercial solar cells rely on silicon and indium tin oxide, brittle and heavy materials that make the cells stiff and bulky, severely limiting their applications. Organic solar cells—which are made of polymers with carbon-based electronics—are lightweight and flexible, but with existing technology, their lifetime is shorter than silicon’s because their polymer layer degrades in wet or humid conditions.

By replacing the faulty polymer layer with graphene treated with ultraviolet light and ozone, Hersam has developed an organic solar cell with much higher environmental stability. The technology could increase organic cell lifetimes 20-fold. “This is one of the places where graphene really shines, because it is an inert material. You can heat it to 100 degrees and expose it to humidity, and it doesn’t degrade,” Hersam says. “This longevity is important, because solar power is more financially viable as a long-term investment.”

Researchers are also eyeing graphene for improvements to lithium-ion batteries, rechargeable batteries that power cellphones

“You can heat graphene to 100 degrees and expose it to humidity, and it doesn’t degrade.” MARK HERSAM

and electric vehicles. Most of today’s battery makers use graphite for the anode, the electrode in which lithium ions are stored when the battery holds a charge. Silicon has a benefit: it can hold more lithium ions, which flow from the cathode to the anode during charging. But silicon also rapidly deteriorates after just a few charge cycles, making it impractical in the long term.

Harold Kung, Walter P. Murphy Professor of Chemical and Biological Engineering at McCormick, proposes a solution: sandwiching clusters of nano-size silicon particles between graphene sheets. The combination allows more lithium ions into the electrode while using the flexibility of graphene to deter deterioration. The result is “the best of both worlds,” Kung says. “We have much higher energy density because of the silicon, and the sandwiching reduces the capacity loss caused by the silicon’s expanding and contracting. Even if the silicon clusters fracture and break up, the silicon is held within the graphene and won’t be lost.”

Kung makes his graphene through the oxidation technique—in which graphite is oxidized, then reduced to graphene, leaving behind imperfections in the form of tiny holes—and has found a way to use the material’s imperfection to his advantage. In his battery design

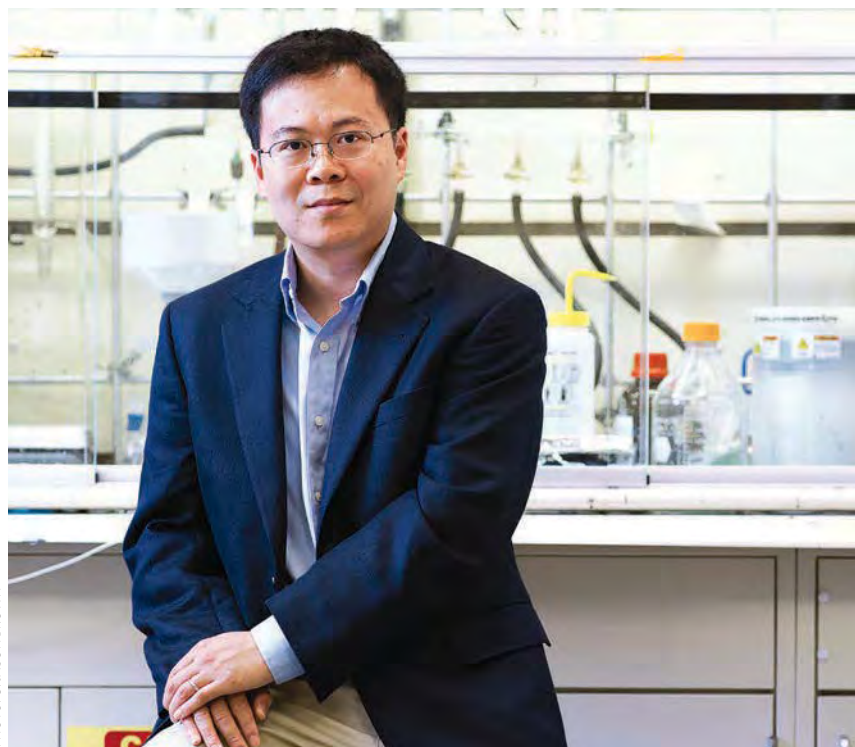
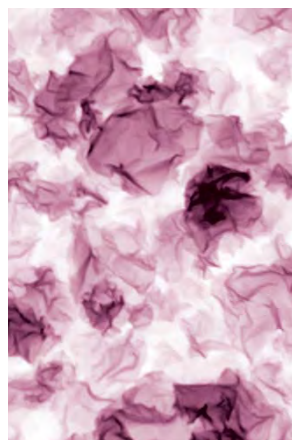
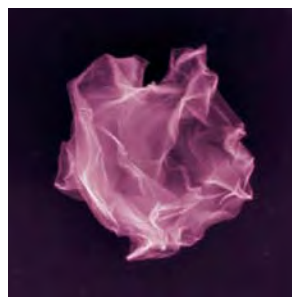


PHOTO: C. JASON BROWN



Graphene's paper-like qualities can make processing a challenge, so Jiaxing Huang (left) crumples the sheets into tiny balls. The resulting particles have the same electrical properties as flat sheets but are far more useful for industrial applications.

As a mechanical engineer, Catherine Brinson (opposite page) works to understand and tune graphene's properties to create functional materials. Her lab has sandwiched Jiaxing Huang's highly conductive, but mechanically weak, graphene crumples between a stiffer, stronger, but less conductive outer layer. The pairing achieves the best of both worlds.

“When you have a one-atom-thick material, individual atoms matter.”

MARK HERSAM

ity, charge time, and longevity. “Even after 150 charges, which would be one year or more of operation, the anode is still five times more effective than those in the lithium-ion batteries on the market today,” Kung says. The anode is currently being commercialized by SiNode, a Northwestern student startup founded in the NUvention: Energy course. (Read about SiNode on page 11.)

Where graphene falls short

Graphene is not perfect; some of its intrinsic properties pose a significant challenge. Unlike semiconductors like silicon, pure graphene is a zero-band-gap material, making it difficult to electrically turn off the flow of current through it. (Silicon has a band-gap closer to one.) As it is now, graphene cannot replace silicon in electronics. Researchers are pursuing ways to chemically alter graphene to make it more functional.

Making graphene processable for industry can also be difficult. Graphene has one of the largest surface-to-weight ratios of any known material; one gram of it could cover nearly half of a football field. All that surface area is useful for applications like water purification, ultracapacitors, and batteries, but often the surface area is lost during processing. “Graphene is basically an ultrathin sheet of paper,” says Jiaxing Huang, associate professor of materials science and engineering at McCormick. “When you try to process a number of these papers in a solvent, they stack together like a deck of cards.” This leaves the graphene rigid and far less effective.

Researchers have tried to alleviate the problem, with varying

the holes provide a shortcut for lithium ions to percolate into the anode, speeding the battery's charging time by up to 10 times. The result is improved charge capac-

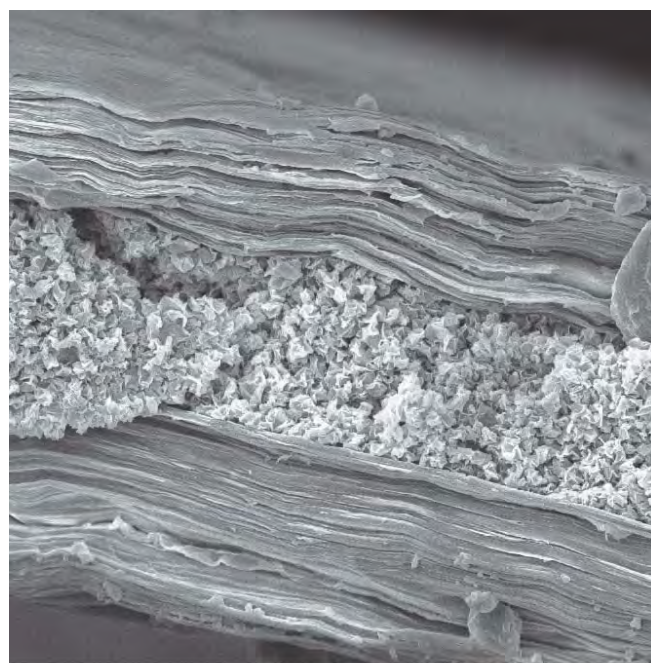
levels of success. Some have tried to insert “spacers” between the graphene sheets to physically separate them, but that changes graphene's chemical composition. Huang has developed another solution: crumpling the sheets into balls. “If you imagine a trash can filled with paper crumples, you really get the idea,” Huang says. “The balls can stack up into a tight structure. You can crumple them as hard as you want, but their surface area won't be eliminated, unlike face-to-face stacking.”

To make the balls, Huang and his team created freely suspended water droplets containing graphene-based sheets, then used a carrier gas to blow the aerosol droplets through a furnace. As the water evaporated, the thin sheets were compressed into near-spherical particles by capillary force. The resulting particles have the same electrical properties as the flat sheets but are more useful for applications that require large amounts of the material.

For other applications, graphene's tendency to aggregate can be used to researchers' advantage. Huang found that stacking inexpensive graphene-based sheets creates a flexible paper with tens of thousands of useful channels between the layers. The channels interconnect and water and electrolytes can flow through, creating nanoscale rivulets (or streams) that can be readily scaled up. Researchers in Huang's lab used a surprisingly low-tech “manufacturing” method—a pair of ordinary scissors—to cut the paper into a desired device shape. “Using such space as a flow channel was a wild idea,” Huang says. “In a way, we were surprised that these nanochannels can be made so easily and actually work. This can help to create new materials for use in water purification and as fast ionic conductors for fuel cells.”

Fine-tuning the mechanics

Much of the work of L. Catherine Brinson, Jerome B. Cohen Professor of Mechanical Engineering at McCormick, has involved directing the assembly of graphene-based materials, creating interesting



Mag = 16.81 K X 1 μm^* EHT = 4.00 kV
WD = 12 mm



PHOTO: SALLY RYAN

“You need graphene composites that are not just conductive but durable.” L. CATHERINE BRINSON

opportunities for engineers to tune its properties to create functional materials. Working with research assistant professor Karl Putz, Brinson has made strides in understanding the layered structures that result when individual graphene oxide nanosheets assemble into thicker papers that can be used as macroscopic materials.

Graphene oxide papers—stiff, strong, and lightweight papers with electrical properties distinct from those of individual graphene sheets—are made through a process called vacuum-assisted self-assembly. Researchers filter sheets of graphene oxide in a batch process that results in a self-assembly process of the individual sheets into a layered paper. Upon closer inspection, Brinson and Putz observed that the papers form a hierarchical structure made of multiple different length-scales—that is, patterns emerge both on the level of individual graphene sheets and of multiple sheets aggregated together into thin, plate-like structures called lamellae. Bones and other biological structures are similarly ordered; this multiscale patterning makes structures more robust.

Understanding the process enables Brinson and Putz to manipulate it for their needs. “We’re developing functional ways to make new materials, and at the same time we’re learning fundamental aspects of what controls graphene oxide paper’s properties,” Putz says. By adding polymers into the vacuum filtration mix, Brinson and Putz created nanoscale composites that incorporate the most useful characteristics of both materials, and they have experimented with replacing water in the solution with other chemical compounds to make the papers stiffer and stronger.

Brinson and Putz recently worked on a project with Boeing regarding the conductivity of composite materials used in the bodies of aircraft. To effectively withstand lightning strikes, engineers often place metal foils within the composites to effectively channel the

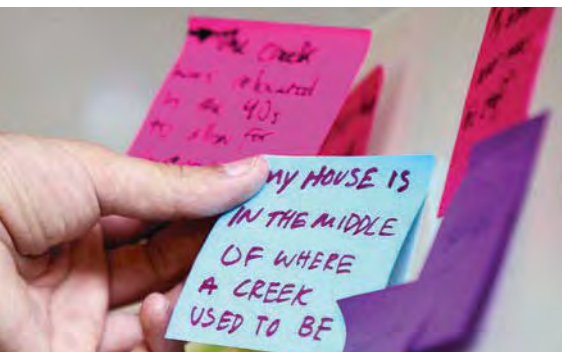
current. But the foils add weight and cost, so Boeing sought alternatives. “Using nanomaterials like graphene in addition to carbon fibers would create a conducting network inside the polymer matrix and could save both weight and cost,” Brinson says. “But you need graphene composites that are not just conductive but also mechanically durable.”

Getting that combination of strength, toughness, and conductivity in a composite can be tricky. Pure graphene is stiff and conductive, but it is hard to integrate into a composite readily, and it leads to brittle composites. Conversely, when graphene sheets are functionalized to integrate into the matrix robustly, they become tougher but lose some of the conductivity of pure graphene. “There is a trade-off there,” Brinson says. “The goal is to find something in the ‘Goldilocks regime,’ with both superior mechanical performance and requisite conductivity.”

Recently, Brinson and Putz have worked with Jiaxing Huang to create a sandwich composite, layering Huang’s crumpled graphene particles between two pieces of their layered graphene paper. The resulting structure could provide the best of both worlds—a stiff, strong outer layer with lower conductivity, paired with a highly conductive, mechanically weak inner layer.

The ability to create tailored materials at several length scales may provide insight into strong, layered materials made in nature, such as bone or an armored fish with an exceptionally pierce-resistant outer shell. “We want to learn from functional layers in biological structures, like the armored fish, and learn to recreate them,” Putz says. “In the next 10 years, using our unique capability to make tuned layered structures, we will create functional materials with tunable property gradients to satisfy specific application needs.”

M Sarah Ostman



DESIGN *for* AMERICA TACKLES URBAN FLOODING

Many cities in the Great Lakes region experience frequent flooding, and area homeowners may face property damage, health problems, and other potential repercussions. Design for America, a Northwestern-founded student initiative that creates local and social impact through interdisciplinary design, is on the case. In August 40 DFA members from colleges around the country connected with the Center for Neighborhood Technology (1) and community members in Midlothian, Illinois (2), to learn more about urban flooding and conduct in-home research and interviews with flood victims (3, 4). After interviewing homeowners, activists, and experts from the American Red Cross (5), the students regrouped at McCormick's Ford Motor Company Engineering Design Center and brainstormed design solutions to help communities prepare for, respond to, and recover from flooding (6, 7, 8). Ideas included a grassroots flood-alert system, a smoke alarm-like device for overflow drains, and a "Ziploc bag for your couch."

"It was a powerful experience to meet directly with flood victims, and those from the community felt incredibly grateful that their stories were heard," said Sami Nerenberg, DFA's program administrator. "Design for America will continue to work with the CNT to help amplify the issues related to urban flooding."



Alumni Profile: **Alicia Boler-Davis**



As senior vice president of global quality and global customer experience for General Motors, Alicia Boler-Davis ('91) travels the world to ensure excitement and reliability each time customers step inside their vehicles.

Back in the late 1980s, however, Boler-Davis was a typical undergraduate, undecided about her future and overwhelmed by classwork. She loved chemistry, but an internship at a chemical company convinced her that she wouldn't be satisfied working alone in a lab. She was challenged by the difficult chemical engineering curriculum and by juggling a full course load with a part-time job. Tough it out, she told herself—a mantra that also helped her rise in a male-dominated industry and pioneer a more customer-focused culture in a century-old company.

"Throughout my career I have always gone back to the memory of when I was in school and found ways to overcome challenges, when I had setbacks and persevered," she says. "You have the greatest opportunity to contribute when you stretch yourself."

It helped that Boler-Davis was always focused: she knew she wanted to be an engineer from an early age. Growing up in Michigan, she excelled in math and science. In high school she participated in a six-week engineering program at what was then the General Motors Institute, taking college-level courses, visiting plants and laboratories, and picturing herself as an engineer.

Boler-Davis chose Northwestern because of its location and its reputation with minorities in engineering. She participated in the program that eventually became EXCEL, where students interested in minority issues come to campus the summer before freshman year to get a head start.

"I built relationships from the moment I stepped on campus," she says. She chose to major in chemical engineering and met several alumni who were successful in research and development and in sales. "I loved that you could do many things with a chemical engineering degree, because I wasn't exactly sure what I wanted to

do," she says. "And I loved organic chemistry"—a comment rarely heard in the halls of Tech.

In her free time Boler-Davis could be found at the beach with friends, cheering at Wildcat football games, and serving as chairwoman of the National Society of Black Engineers, an early chance to develop leadership skills. "I found you don't just tell people what to do. You need to figure out how to get them to buy into what you're trying to do," she says. "That has helped me tremendously in the workplace. You don't know you're getting those tools in your toolbox until you have to use them, and then you find out you're very well prepared."

Northwestern's wide curriculum honed her whole-brain engineering skills with classes in sociology and African art. "My goal was always to be a balanced engineer who had strong technical skills but who also had great interpersonal skills," she says.

She joined General Motors as a manufacturing engineer in 1994 after spending a few years as an engineer for pharmaceutical and food companies, and she traveled the country to help with new tooling product launches. But in order to learn more about GM operations, she asked for an assignment in a plant—an unpopular choice for many engineers because of the demanding people-oriented work.

After a year working on production and launch schedules, Boler-Davis became a plant production supervisor in charge of 50 employees. Approaching the job as an engineer, she created lists of daily duties but learned that in a plant where problems arose quickly and needed to be solved immediately, she needed a new approach.

"I wasn't just an engineer anymore. It was less about me and more about what I was able to get done with my team," she says. "I had to be an effective leader to communicate what needed to happen each day."

Boler-Davis found she was good at being a plant supervisor—she liked the people, the pace, the challenges—and by putting in long hours and making data-driven decisions she continued moving up the ranks until she became the first African American female plant manager in 2007.

"When I was moving up at GM, there were very few female plant managers," she says. "There were no African American females at all in leadership roles. Some people had the reaction, 'Wow, you're a woman and you're black; what

can you do?' But once they get over that initial reaction, they judge you on your capabilities. People knew I delivered results and did it by engaging the team." Several more women have since followed Boler-Davis into leadership roles at GM.

In her current role Boler-Davis travels the world to examine customers' every touch point with GM to ensure the company is exceeding expectations. Her role combines product design and development with the consumer experience of the product, which has helped her

improve GM's customer awareness. "I see the full value chain from concept to production to ownership to when the customer is back in the market for another vehicle," she says. "It is huge to see that and be able to affect our next products." Boler-Davis has observed a "transformation" among GM employees, who are now "passionate around delivering great products and experience for our customers." The redesigned Chevrolet Impala earned *Consumer Reports'* highest score among sedans, a rare feat for an American car.

When she's not working, Boler-Davis spends time with her husband and two sons, volunteering in the community, and traveling, including visits to Evanston for Homecoming.

Her success motivates her to keep moving forward. Her next goal is to help refine GM's global strategy before implementation.

"I'm excited to have this opportunity," she says. "I have a lot to do."  Emily Ayshford

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GIVING REPORT

Alumni and friends are an essential part of the McCormick network: they provide opportunities, guidance, and support for faculty and students on many different levels. Within the past year more than 1,300 McCormick alumni and friends made gifts that will help students and faculty pursue educational and research opportunities at the intersection of global challenges and the knowledge required to solve them. Thank you.

Peter Barris ('74), a member of the University's Board of Trustees, and his wife, **Adrienne Barris**, have given \$5 million to endow a professorship in the Department of Electrical Engineering and Computer Science.

Northwestern trustee **David A. Sachs** ('81) and his wife, **Karen Richards Sachs**, also have made a \$5 million gift, which will endow a professorship in the Department of Industrial Engineering and Management Sciences.

With technology pervading virtually every aspect of life today, these endowed professorships will strengthen McCormick's emphasis on computer science and systems and add momentum to the school's innovative scholarship and teaching. Expanding the reach of computer science and systems across the University's campuses and a variety of disciplines, they will increasingly affect the overall research enterprise at Northwestern.

Other major gifts include the following:

Bill Gantz, past chair of the McCormick Advisory Council, and **Bob Shaw** ('70, KSM '81) and his wife, **Charlene Shaw** (WCAS '70), made gifts to establish a translational fellows program, a McCormick collaboration with the Feinberg School of Medicine and the University's Innovation and New Ventures Office.

Barry MacLean established an endowed fund to benefit programming at the interface of art and engineering, including the Data as Art class (featured on page 20).

Mary Meister ('98) and her husband, **Ethan Meister**, and **Boris Vuchic** (PhD '95) made gifts toward the construction of a new Energy Materials Laboratory housed in the Department of Materials Science and Engineering.

Greg Merchant (PhD '90) established an endowed fund to benefit the Department of Engineering Sciences and Applied Mathematics.

Todd (WCAS '87) and **Ruth Warren** established the Warren Fellows in the Department of Electrical Engineering and Computer Science. The fellowships will provide competitive graduate aid packages.

Three funds to honor retired professors were established with support from McCormick faculty and alumni:

An endowed lecture series in honor of **Jan Achenbach**, Walter P. Murphy and Distinguished McCormick School Professor Emeritus of Civil and Environmental Engineering, Engineering Sciences and Applied Mathematics, and Mechanical Engineering

An endowed lecture series in honor of **Ted Belytschko**, Walter P. Murphy Professor Emeritus of Computation Mechanics and Civil and Environmental Engineering

An endowed graduate fellowship fund in honor of **Johannes and Julia Weertman**, Walter P. Murphy Professors Emeriti of Materials Science and Engineering

Other alumni made generous commitments to remember Northwestern and McCormick through their estate plans. If you would like to make a gift to McCormick, please contact Ben Porter, senior director of development, at 847-467-5212.

CLASS NOTES

1950s

Harry Grounds ('59, MS '60), a professional engineer in Minnesota and Wisconsin, specializes in the protection of water resources. He recently wrote *Marie's Vineyard*, a tale of spies, intrigue, and romance that begins and ends at a vineyard near Thomas Jefferson's Monticello.

Thomas E. Reimer ('59) wrote his third novel, *Pitchfork Murders* (Virtualbookworm.com Publishing, 2012).

1960s

Charles A. Wentz Jr. (PhD '62) was named to the board of directors of the Lessie Bates Davis Neighborhood House, a United Methodist Church community center in East St. Louis, Illinois.

Bruce Bingman ('67, PhD '71, Nav '71) was named chief physicist for the Naval Nuclear Propulsion Program, where he is responsible for the design and safe operation of all reactors in the nuclear-powered ships of the US Navy. Bingman, a lifelong competitive sailor, was awarded the Marcia B. Grosvenor Award for outstanding volunteer services in furthering the sport of sailboat racing. He has promoted offshore sailing while serving in many positions with US Sailing, including as chair of the National Offshore Council and a member of the board of directors.

Send us your news!

Please email your news to magazine@mccormick.northwestern.edu.

Bill Kroll ('67, MS '71) relinquished his role as chairman and CEO of Matheson-Trigas Inc. to become executive chairman of its board. In addition to his duties as executive chairman, he will become senior managing director of TNSC and will be responsible for global mergers and acquisitions, electronics research and development, and the corporation's metalorganic chemical vapor deposition equipment business, which serves the compound semiconductor field.

Robert P. Wayman ('67, KSM '69) is a director of Textura Corporation, which completed its initial public offering on June 7.

Richard A. Laruffa (MS '68), project manager and director of Jacobs Engineering, was appointed to the board of trustees of New Jersey's Sussex County Community College.

1970s

Raymond N. Wareham ('70) joined Rockefeller & Company in April 2012 as a managing director. He advises high-net-worth individuals, families, trusts, endowments, and foundations.

William H. Bowman Jr. ('71), CEO of U.S. Inspect, was named senior consultant with Training Associates, a consulting firm in Westborough, Massachusetts.

Richard W. Sevcik (MS '71), president of Sevcik Consulting, a consulting firm for semiconductor companies, was appointed to the board of directors of Liquidmetal Technologies.

Tuncer B. Edil (MS '73), a professor of civil and environmental engineering at the University of Wisconsin-Madison, received the American Society of Civil Engineers' 2013 Karl Terzaghi Award.

Richard A. Zellmer ('73) has retired after 33 years from the practice of radiology. He specialized in interventional radiology, fluoroscopy, and nuclear medicine. His practice was one of the first in the suburbs of Atlanta to offer balloon angioplasty, vascular stenting, and tumor embolization.

William F. Yearout Jr. ('75, KSM '82) joined Korte Company to assist in healthcare development.

Joshua Jacobs ('77) was named president of the American Academy of Orthopaedic Surgeons.

Mark D. Grover (MS '78, PhD '82), a full-time senior software developer at DeLorme Publishing, was elected to a four-year term as a commissioner for the third district of Cumberland County, Maine.

Vince Petrie ('79) retired after nearly 33 years as an engineer in the phone industry. He worked for GTE Automatic Electric, Pacific Telephone, and AT&T.

Virginia M. Rometty ('79), president, chairman, and CEO of IBM, was ranked number one on *Fortune's* 50 Most Powerful Women in Business list.

1980s

K. Ravi Kumar (PhD '81), professor at the University of Southern California's Marshall School of Business, was appointed dean of the College of Business at Nanyang Technological University in Singapore.

David Evan Thomas ('81) is a composer, program annotator, choral singer, pianist, and conductor. In November 2012 two of his works premiered. *Tales of the Sierra Madre* was commissioned by Eugenia Smith Cline (BSM '81) for her New Jersey-based quintet, the Monmouth Winds, an ensemble that also includes horn player **Richard Sachs** ('67, GC '75). An oratorio, *The First Apostle*, received its first performance by the choirs of Houston's Christ Church Cathedral, with soloists and chamber orchestra.

Kevin E. Comolli ('82) is the founding partner of Accel London, whose tech fund raised \$475 million in eight weeks.

William H. Cork ('82, WCAS '82) was promoted to global chief technology officer and executive vice president of the medical device division of Fresenius Kabi in Lake Zurich, Illinois. He is responsible for research and development, quality, intellectual property, and the automatic blood process business unit. Fresenius Kabi is a \$16 billion global medical device and pharmaceutical corporation.

Yogi R. Bhardwaj (MEM '83) is chair of Royal Group International, a worldwide organization involved in the distribution of medical and beauty products, agricultural products and exports, water purification technology, mining, hotels, and real estate.

Darren R. Gilbert ('83, KSM '89) was named business development manager for North America at DianaPlantSciences in Portland, Oregon.

Annetta M. Hewko ('83, KSM '88), vice president of global strategy and programs at Susan G. Komen for the Cure, was appointed president of the Tourette Syndrome Association.

Catherine Greener ('84) joined Xanterra, a national and state park concessioner, as vice president of sustainability. Greener is accountable for the company's sustainability initiatives in the areas of energy, water and waste management, pollution prevention, cuisine, and design.

Mark E. Mowinski ('84) joined Alliant Insurance Services in Chicago as a producer and vice president.

Ajay Bansal (MS '85, KSM '88), former CFO of Complete Genomics, was appointed CFO of Onconova Therapeutics.

Ruby Rachael Chandy (MS '85), president of industrial business at Pall Corporation, was elected to the board of directors at AMETEK, a global manufacturer of electronic instruments.

CLASS NOTES

Teresa Duncan Cox ('85), a trade adviser to the Obama administration and trustee at Ohlone Community College, spoke in April at the Alpha Kappa Alpha sorority's Day at the Capitol in Sacramento.

Mark Axland ('86, MS '90) licensed an invention to be sold by Stanley Tools.

John Patrick Murphy (MS '87), vice president/general manager at Johnson Controls, was promoted to president of the company's global workplace solutions business unit.

Bradley Eames Bodell ('88, KSM '95), former vice president of global technology and operations for MetLife, has been named senior vice president and chief information officer for CNO Financial Group in Carmel, Indiana.

Andrew P. Armacost ('89), professor at the US Air Force Academy, was appointed dean of the faculty and nominated by President Barack Obama for promotion to the rank of brigadier general.

Tanguy Rene Cosmao (MS '89) was appointed president of Statoil in Azerbaijan. He previously served as the company's vice president of area development.

Jenifer Serafin Kennedy (MS '89, PhD '91) is the cofounder of JustRight Surgical, which has raised more than \$10 million in investment capital. The company recently received FDA approval for its Surgical Vessel Sealing System.

Alfred C. Li (PhD '89) has been named a TAPPI fellow. He has worked at USG Corporation for the past 13 years and is currently on the process team for the Gypsum Panels Laboratory, where he is working to help develop innovative and sustainable wallboard manufacturing processes.

1990s

Alicia S. Boler-Davis ('91), former vice president of global quality and global customer experience with General Motors, has been promoted to senior vice president, expanding her customer experience role from a US position to an international one. (See story on page 42.)

William James Krueger (MEM '92, KSM '92) was named senior vice president of manufacturing, purchasing, and supply management for Nissan North America.

Robert Nowakowski ('92) returned to his position as a senior staff engineer at Qualcomm in December 2012 after a one-year leave of absence as a Navy reservist. Nowakowski was director of training for the Combined Joint Task Force—Horn of Africa in Djibouti.

Paul J. Brown (MEM '94, KSM '94), former president of brands and commercial services for Hilton Worldwide, was named CEO of Arby's Restaurant Group.

Mircea Tipescu (MS '94) was elected shareholder at Chicago's Brinks Hofer Gilson & Lione, one of the nation's largest intellectual property law firms. His practice includes patent litigation, counseling, and prosecution. Tipescu has represented clients in federal courts, as well as at the United States International Trade Commission.

Julius Voloria (MEM '95, KSM '95), formerly with Microsoft, was appointed vice president of sales and marketing for Kolbe Corporation.

Drew Berg ('96) was promoted in January to principal at Diversified Trust Company, a comprehensive wealth management firm based in the Southeast. Berg, a chartered financial analyst, leads the firm's institutional advisory services team, is a member of the investment strategy committee, and heads up portfolio management for the Nashville office.

Rajarao Jammy (PhD '96) has joined Intermolecular as senior vice president and general manager of the semiconductor group.

LONDON ALUMNI EVENT

On July 11, McCormick and the Northwestern Alumni Association hosted "Creativity and Innovation at Northwestern" at the the Royal Society in London. The cocktail reception brought together alumni from across Northwestern, and Dean Julio M. Ottino gave remarks on a range of new initiatives that bring together students and faculty to develop new ideas. Attendees included (clockwise from top left)

1. Cherine and Taher Helmy, parents of Lara Helmy (McC '06) and Samir Helmy (McC '15), with Dean Ottino
2. Joseph Liu (WCAS '00)
3. Mary Johnson (WCAS '04)
4. Jason Trost (WCAS '03) and Dean Ottino
5. Alex Riemer (MMM '07) and Nathan Freeman (McC '04)
6. Jason Navarette (McC '99)
7. Karen Pelham (KSM '86)



Kyle Oyama ('98) was promoted to lieutenant colonel in the US Air Force in May, when he also earned a doctorate in systems engineering from the University of Virginia. In the fall Oyama joined the faculty at the Air Force Institute of Technology in Ohio.

2000s

Matthew Fortney ('01, L'06), an attorney at Quarles & Brady, was named a 2012 "Rising Star" by *Wisconsin Super Lawyers*. He specializes in real estate.

Ashik Mohan (MS '02) and his wife, Jenelle, in March launched Born of Sound, a way to visualize sound as it would look if it could be seen in nature. The company offers personalized art derived from sounds that have meaning to the sound creators.

Boo B. Aaron Khoo (PhD '03) was appointed director of engineering at 9Slides, a developer of online presentation platforms. The firm is headquartered in Redmond, Washington.

Agnella Izzo Matic (MS '04, PhD '07) founded AIM Biomedical Consulting in Chicago. The firm specializes in medical writing, independent research, and teaching. A former assistant professor of otolaryngology at Northwestern, she worked at the University for more than a decade, researching solutions for emerging biomedical problems.

John Marszalek (MS '05) began a new position as an engineer and medical device reviewer with the Food and Drug Administration's neurological and physical medicine group in Silver Spring, Maryland.

Birju Shah ('05) joined Google X to lead its wearable computing division. Shah earned his MBA and the Patrick J. McGovern Entrepreneurship Award from MIT Sloan School of Management in 2012. Shah is also the chairman of sugarcrew.com, a leading social network for diabetic patients.

Danai Eric Brooks (MEM '06, KSM '06) was appointed executive vice president and COO of Dyadic International, a global biotechnology company.

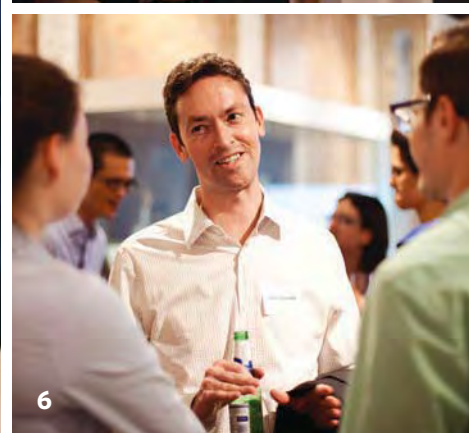
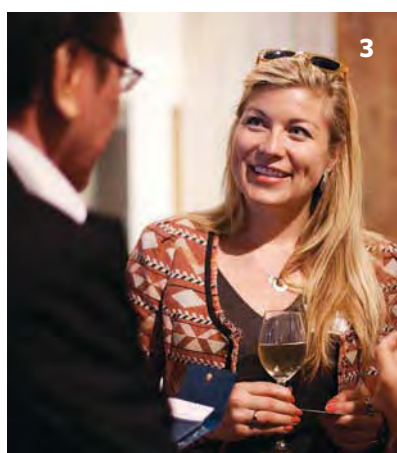
Douglas Alexander Stone (MPDD '07) was promoted to senior vice president of innovation at Maddock Douglas in Elmhurst, Illinois.

Michael Parrott ('09) has been promoted to senior associate consultant at Mars & Company, a global management consulting firm specializing in business strategy and operational improvement.

2010s

Jessica L. Irons (MEM '12) became a marketing specialist at Sonoco Protective Solutions in Arlington Heights, Illinois, in 2011. Her article "Think Inside the Box: Design for Manufacturing and Assembly" was published in *Appliance Design* magazine. The technical article highlights the benefits of design for manufacturing and assembly, an up-and-coming concept in the product design world.

Timi Chu ('13) received the 2013 Senior Woman's Service Award from the Alumnae of Northwestern University. Chu was a volunteer coordinator for AmeriCorps and a teaching assistant for Project EXCITE. In 2011 she founded Book Buddies, a program to develop literacy skills through individual reading opportunities. She is now a software engineer at McMaster-Carr in Elmhurst, Illinois.



CLASS NOTES

In Memoriam

Eric G. Yondorf '43
 Benjamin H. Moon '44
 George F. Dvorak '45
 Robert E. Noyes '45
 Arthur R. Whale '45
 Conrad W. Petersen '46
 Irwin S. Sylvan '46
 John A. Cedervall '47
 John J. Pederson '47
 Harry F. Schweitzer '47
 Jeanne Popp Aitchison '48
 Stanley A. Gorski '48
 Clotworthy Birnie Jr. '49
 Richard S. Davis '49
 Kenneth E. Weaver '49
 James N. Yamasaki '49
 Ralph W. Golterman '50
 Charles J. Homan '50
 George R. Smith '53
 Franklyn E. Larson '57
 Wesley O. Pipes Jr. '59
 David F. Wood '59
 Roger E. Johnsen '60
 Richard A. Volz '60
 Suzanne Winings '60
 Kenneth E. Knutel '62
 Ralph A. Warren '69
 Russell W. Neuhaus '73
 Bradley Jeffries '84
 Dmitri A. Teplov '15

In Memoriam: Jacques Denavit

Jacques Denavit (MS '53), a professor of mechanical and nuclear engineering at Northwestern from 1958 to 1982, died in September at age 82. A pioneer in the computer simulation of plasmas, Denavit published numerous scientific articles and was named a fellow of the American Physical Society. He made important contributions to the fields of inertial confinement fusion and high-intensity short-pulse laser-matter interaction. His 1964 book *Kinematic Synthesis of Linkages*, coauthored with Richard Hartenberg, introduced the mathematics (the Denavit-Hartenberg parameters) still used for describing robotic motion. After leaving Northwestern he worked as a research physicist at Lawrence Livermore National Laboratory until 1993.

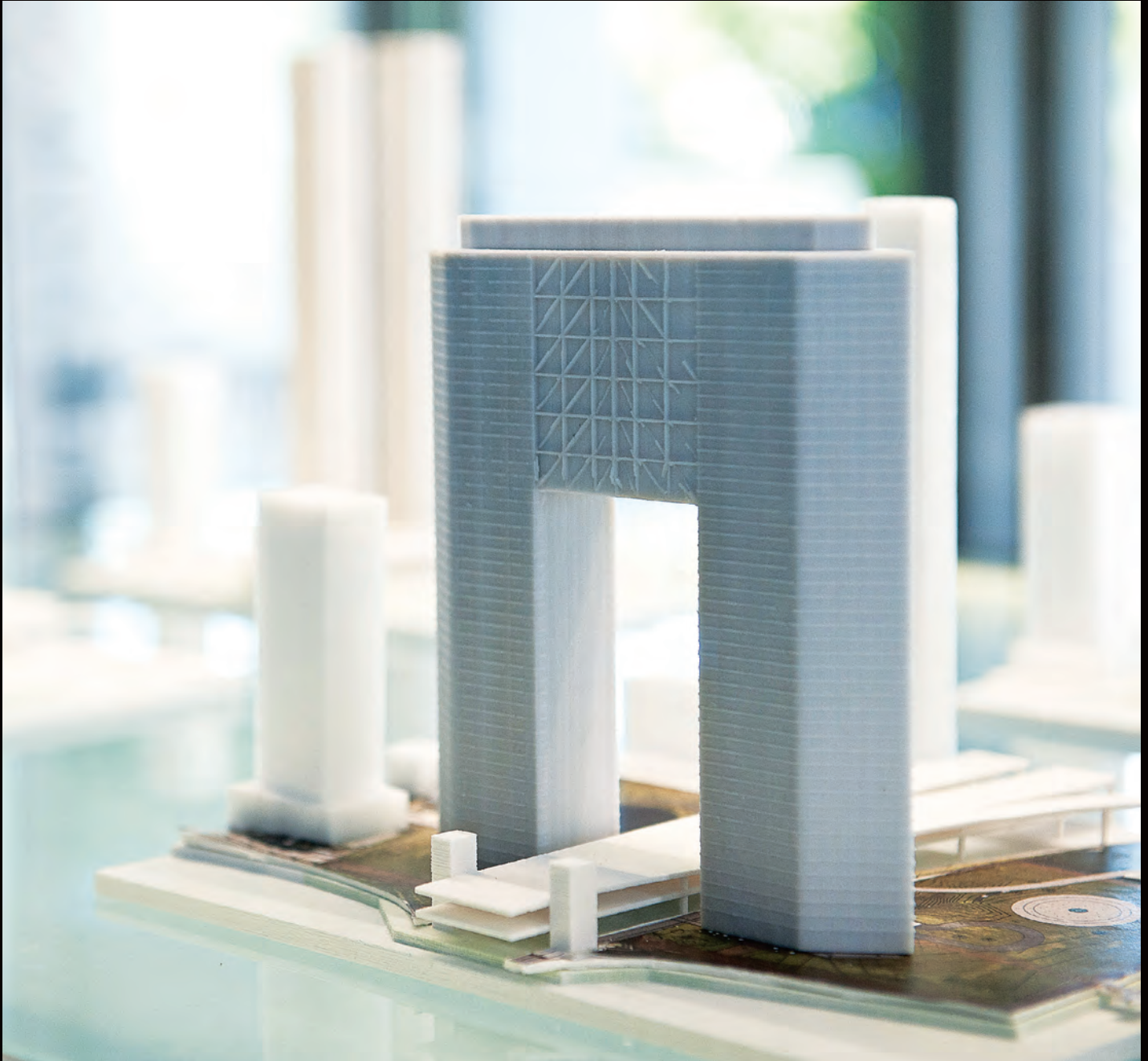
In Memoriam: Albert Rubenstein

Albert Harold Rubenstein, Walter P. Murphy Professor Emeritus of Industrial Engineering and Management Sciences, died April 13 at age 90. A dedicated academic, adviser, and consultant who spent more than four decades at McCormick, Rubenstein was known for his pioneering work in engineering management as well as a commitment to bringing his field to the forefront at the University. Rubenstein founded the Master in Engineering Management program in 1976 and directed it until 1992. He also established two research centers at Northwestern, the Program on Management of Research, Development, and Innovation and the Center for Information and Telecommunication Technology. After retiring from Northwestern, Rubenstein moved to Washington, DC, in 2004, remaining active in research and consulting.

PHOTOGRAPHY: C. JASON BROWN

More than 30 faculty, alumni, and friends of McCormick gathered September 11 for "A Celebration of Art and Engineering." The event, hosted by Barry MacLean (right), president and CEO of MacLean-Fogg Company, celebrated McCormick's research and education initiatives that intersect both engineering and the arts and humanities, including the Architectural Engineering and Design certificate program and McCormick's partnership with the Art Institute of Chicago. Guests toured MacLean's collection of Southeast Asian art and heard faculty presentations from McCormick and the School of the Art Institute of Chicago.





the art of engineering

How would you design 1.8 million square feet? This past spring, undergraduates in the Architectural Engineering and Design program were tasked with designing a mixed-use high-rise development for downtown Chicago. The result? Skyscrapers featuring a combination of hotel rooms and luxury apartments, printed in miniature on McCormick's Z450 3D printer. The project was the culmination of the six-course certificate program, which prepares engineering students for collaborative careers in the building industry—as architects, structural designers, builders, project managers, or developers. In addition to coursework, the program offers students the opportunity to work abroad every two years in a renowned architect's studio. Integrating creativity, design methods, history, and research, the program is directed by Laurence Booth, Richard Halpern/RISE International Distinguished Architect in Residence and design principal of Booth Hansen Associates.

**Robert R. McCormick School
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Northwestern University**
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A Northwestern weather balloon flying 97,000 feet above Earth captured amazing images last May—and collected valuable information for a team of McCormick undergrads. Interested in how solar cells behave at high altitudes, the team outfitted the weather balloon with a solar cell, a variety of sensors, a video camera, and a GPS unit. The balloon traveled 40 miles before touching down near Knox, Indiana, where the team retrieved the payload intact. Their findings: the solar cell performed best at around 50,000 feet.