CASE SCHOOL OF ENGINEERING 2016-17 ANNUAL REPORT

the way >> FORWARD

CASE SCHOOL
OF ENGINEERING
CASE WESTERN RESERVE
UNIVERSITY

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Progress: it's our path, not our destination.

Innovation and discovery have no last stop—that's part of what makes being an engineer so exciting. Every nugget of new knowledge, every eureka moment, every promising piece of technology is a step forward on the journey toward a better world.

From harnessing the decisive power of big data, to reconnecting the brain to paralyzed muscles, to driving economic development by advancing the Internet of Things, to creating a thriving ecosystem to foster student entrepreneurs, we're forging new paths of progress in energy, human health, smarter cities and so much more.

Each achievement is a step worth celebrating, and the road ahead is teeming with new possibilities. Thank you for coming this far with us, and I hope you'll continue the journey with us as we push ahead.

James McGuffin-Cawley

INTERIM DEAN, CASE SCHOOL OF ENGINEERING

ARTHUR S. HOLDEN JR. PROFESSOR OF ENGINEERING

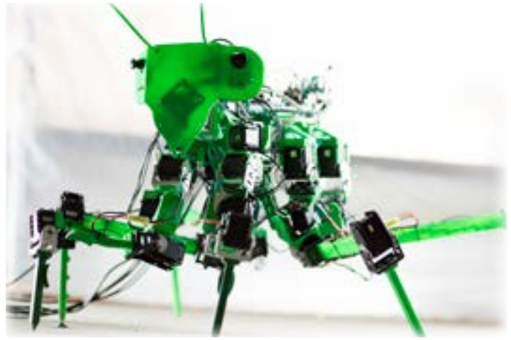
FIRED UP: mechanical and aerospace engineering researchers James T'ien and Ya-Ting Liao teamed up with NASA to perform Saffire III—the latest in a series of experiments to explore **how flames spread in outer space**.

STATIC ELECTRICITY is more than a laundry-based nuisance—the same force behind clinging clothes can cause serious safety hazards on the manufacturing floor. Chemical engineering's Daniel Lacks and Mohan Sankaran received NSF funding to **unravel the secrets of triboelectric charging**, the common but little understood phenomenon behind the shock that follows shuffling across a carpet and touching a doorknob.

SMARTER MANUFACTURING: Robert Gao, the Cady Staley Professor of Engineering and chair of the mechanical and aerospace engineering department, is working with a team of researchers from Pennsylvania State University, GE Global Research and Microsoft to help make factory machinery smarter. The team is working on a Digital Manufacturing and Design Innovation Institute-funded project to develop a **smart sensor system that uses cloud computing** to enable manufacturing machinery to monitor for and diagnose the root cause of problems and predict the remaining useful life of the machinery automatically.

Robotics Roundup

MANTISBOT, a six-legged, 29-degree-of-freedom robot based on the biomechanics of a praying mantis, is helping test a newly developed synthetic nervous system controller that provides a more natural posture and locomotion. The project is a collaboration between mechanical and aerospace engineering professor Roger Quinn and biology professor Roy Ritzmann. The animal-like control system could lead to robots with more natural agility, making them well suited for use in rough terrain such as farms, disaster sites or even on other planets.



TOP FINISHES: Undergraduate student robotics team **CWRUbotix** won first place for its combat robot at the National Robotics Challenge. The team also placed fifth out of almost 50 teams at NASA's Robotics Mining Competition and earned first place for its Systems Engineering Paper and second for its Systems Engineering Presentation.

WORM-LIKE ROBOTS: Three new prototypes of these bio-inspired machines—one made of fabric, one using a shape-memory alloy and one that doubles the number of steering motors—will help researchers better understand **scalability, material selection and degrees of freedom in soft robotics**. The robots were developed by mechanical and aerospace engineering faculty members Roger Quinn and Kathryn Daltorio with biology professor Hillel Chiel.

AUTONOMOUS SNOWPLOW: Case Western Reserve students took home first place at the seventh annual **Autonomous Snowplow Competition**. Learn more at **engineering.case.edu/autonomous-snowplow-win-2017**.

THE BIOHYBRID ROBOT developed last year at Case Western Reserve took another important step forward with the introduction of organic motor-control from neurons to control motion. Designed with isolated muscles from a sea slug fixed to a 3-D printed body, the tiny robot originally needed external electrical stimulation to cause muscle contraction. The upgrade incorporates a cluster of nerve cells to provide **autonomous control of the muscle**.

BUILDING BLOCKS long used by psychologists to assess cognitive skills are going digital, thanks to Kiju Lee, assistant professor of mechanical and aerospace engineering, who is **embedding the blocks with technology to help provide a clearer view of problems** a child or adult may suffer due to developmental disabilities, brain trauma or dementia. The sensor-embedded blocks can detect hyperactivity and reveal the problem-solving strategies used by each subject, as well as detect performance accuracy and the time taken to complete each task. Learn more at **engineering.case.edu/blocks-cognition**.

FAST READS

CHARGED UP: Next-generation lithium-ion batteries are key to advancing the electric vehicles of the future. Chris Yingchun Yuan, associate professor of mechanical and aerospace engineering, is investigating how to manufacture the technology more sustainably, and he's developing other green battery innovations for future use.

Cleveland-based pop artist Rachel Latina painted a vibrant mural in the main entrance of the A.W. Smith Building, home to the university's Department of Chemical and Biomolecular Engineering. Depicting female engineers on a bright, blocky background, the artwork celebrates women in engineering.

A record-setting

$50

million raised

with support from around the world

10 countries

40 states represented

Case School of Engineering hits $50-million fundraising mark

Thanks to the generous support of more than 3,000 alumni and friends, the **Case School of Engineering raised a record-breaking $51.2 million this year**. The total is nearly $17 million more than last year's all-time record.

The gifts included everything from aid for student groups and teams, to student fellowships and scholarships, such as the commitment by Syrian native and double undergraduate alumnus **Amr Salahieh (CWRU '89, '90)** to support an undergraduate biomedical engineering student from a country in crisis; a generous gift from **David (CIT '74) and Sandy Gorka**, who donated to support undergraduate scholarships for women in engineering; and a gift from **Tien-li Chia (GRS '82, '85**, systems and control engineering) to provide fellowships to graduate students in electrical engineering and computer science. The university's Master of Engineering and Management program got a boost from **Alan (GRS '62, mechanical engineering, MGT '65, organizational behavior) and Lynn Wagner** in honor of the role engineering and management education played in his career. Biomedical engineering received a generous pledge from **Robert M. (CIT '52) and Brenda Aiken** (read more on page 32), and labs and facilities also received crucial funding, including a commitment from **Malcolm Cooke**, associate professor of mechanical and aerospace engineering, to support the future of the Larry Sears and Sally Zlotnick Sears think[box], where he currently serves as executive director.

3,062 donors

63 gifts from young alumni

$4,562,525 toward scholarships

THE POWER OF PREDICTION

Case Western Reserve University researchers are using hard data to take the guess-work out of decision-making in medicine, manufacturing, infrastructure planning and more.

The city of Flint, Mich., made headlines in 2014 when its government attempted to save money by sourcing drinking water from the Flint River. That water ended up corroding the pipes, leading to hazardous levels of lead in the drinking water, plunging the city into a massive water crisis. Flint's plight proves how dangerous it is to make decisions based purely on financial considerations—and it also demonstrates the need for better decision-making tools when it comes to city infrastructure.

Ten years ago, the Cleveland Water Department noticed that whenever they experienced a frigid winter, they also faced a much higher incidence of water main breaks. But was there really a connection, and if so, what would be the best way of handling the issue—repair the broken pipes, or replace them? The Cleveland Water Department manages more than 5,000 miles of water mains and serves 73 cities, so the wrong choice could lead to incredible trouble and expense.

The Cleveland Water Department asked Xiong "Bill" Yu, professor of civil engineering at Case Western Reserve University, to carry out data-driven research to help the city make the right decisions. **This year, Yu and his team received a $2.5-million Critical Resilient Interdependent Infrastructure Systems and Processes grant from the National Science Foundation (NSF) to tackle the issue**. The Spokane, Wash., water department is also on board, giving the team plenty of data to build a robust decision model.

A key component of the research is the engineering model, which will consider the different conditions that lead to the deterioration of pipes, like corrosion, internal loading, frost load—and even snow removal procedures, since salt can corrode pipes. "Then the algorithm determines how quickly the infrastructure will deteriorate over time," says Yu. "This allows us to predict which section along a geographic area has a greater chance of failure." This model will **help the city make decisions on whether to fix a pipe or replace it depending on not only the financial cost, but also by factoring in more qualitative costs** like potential inconvenience to the neighborhood's inhabitants, safety issues and traffic considerations.

"This [model] allows us to predict which section along a geographic area has a greater chance of failure."

XIONG "BILL" YU

As the Flint crisis demonstrated, water delivery decisions raise social issues, and these need to be accounted for in the model as well. "Low-income neighborhoods, with older pipe infrastructure and decades of disrepair may demand different approaches to respond in an effective way," says Francisca García-Cobián Richter, a research assistant professor at the Jack, Joseph and Morton Mandel School of Applied Social Sciences at Case Western Reserve. "Without paying attention to contextual needs, policies and practices at the water department level will only continue to increase the inequalities in health and economic opportunity that low-income communities face."

The team aims to have a workable model completed by the end of the four-year project. Yue Li, associate professor of civil engineering at Case Western Reserve and collaborator on the project, hopes that decision-makers around the world will combine the data that comes from this research with their existing knowledge to improve the health of cities—and their inhabitants. The interdisciplinary team at Case Western Reserve also includes Justin Gallagher, assistant professor of economics, who will investigate the sustainable financial model for water pipeline management.

A better prognosis

While Yu, Li and their team are proving that data can help improve infrastructure, other researchers at Case Western Reserve are also building algorithms that have a direct impact on people's health.

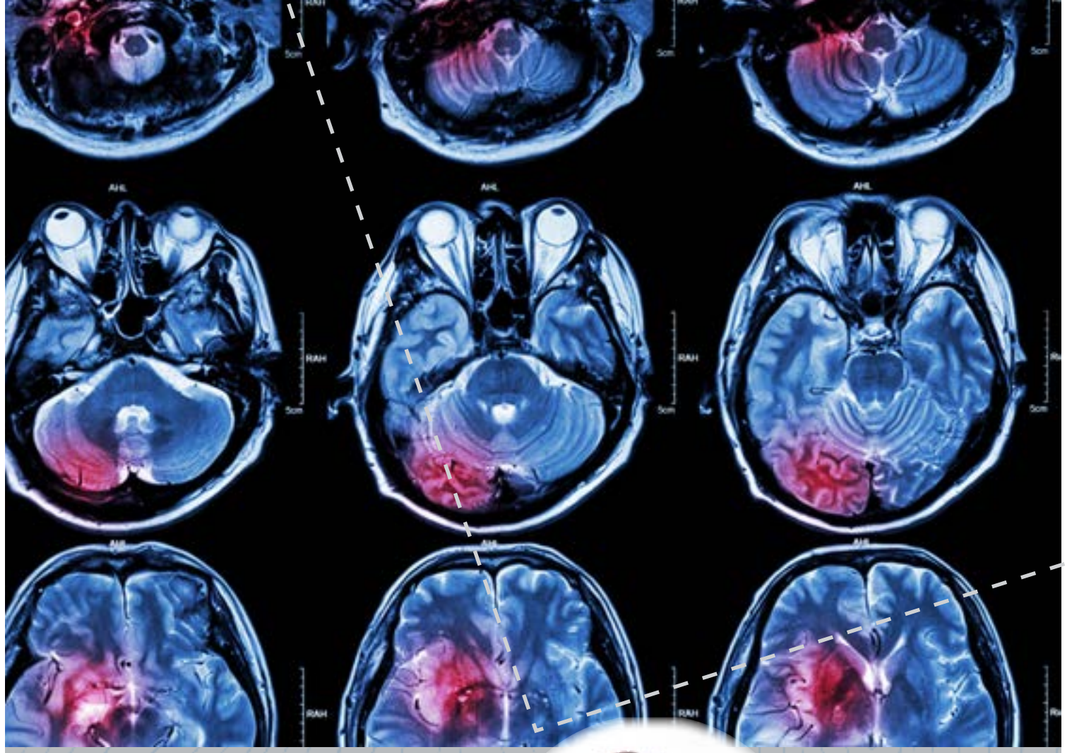
Even the most skilled neuroradiologists have difficulty detecting the minute differences between a potentially fatal cancer recurrence and a confounding yet benign side effect of radiation. That's why biomedical engineering researchers at Case Western Reserve are developing machine learning techniques that can help medical professionals—and patients—in this life-and-death scenario.

Imagine a patient has been treated for brain cancer. They've gone through surgery, radiation and chemotherapy, and are finally on the mend. Then they visit their oncologist for a follow-up and get a phone call a few days later: The doctor spotted something suspicious on the MRI, and will need to perform a biopsy to determine whether it's a recurrence of the cancer or radiation necrosis, which is dead tissue that can result from radiation therapy.

"Unfortunately, these two conditions look very, very similar on standard readings of routine MRI," says Pallavi Tiwari, an assistant professor of biomedical engineering at Case Western Reserve. "There's no way to tell unless a surgeon goes back in and does another biopsy, or goes in and takes out whatever they see. Which means that for patients who don't actually have a tumor, it's absolutely unnecessary." It's also traumatic to a patient who has been through so much already.

Says Tiwari, "The idea was, can we use routinely acquired MRI scans where clinicians find it difficult to distinguish radiation effects from tumor recurrence, and build machine learning algorithms using those scans to mine information that is perhaps not visually appreciable, but is there—and then **use these models to predict whether a patient has a benign side effect of radiation or a true tumor recurrence?**"

The answer is yes. The team had neuroradiologists examine the MRI scans in these two situations, and these medical professionals were accurate less than 50 percent of the time—indicative of just how difficult the situation is for medical professionals. On the other hand, **the algorithm built by the team is close to 90-percent accurate in distinguishing between the two conditions.** Tiwari stresses that the system will serve as decision support for neuroradiologists, not as a replacement for human expertise and intuition. The team published its findings in the *American Journal of Neuroradiology* last fall.



"The idea was, can we use routinely acquired MRI scans ... and build algorithms ... and then use these models to predict whether a patient has a benign side effect of radiation or a true tumor recurrence?"

PALLAVI TIWARI

The next challenge is to prove the validity of the software algorithms across different hospitals. For example, it may turn out that the software works for data from one hospital, but not from another due to differences in the equipment they're using. **The team is now collaborating with eight institutions in the United States as well as one in China to test the robustness of the system.**

Once the team validates the algorithm's accuracy using retrospective data, they'll deploy it in a clinical setting and analyze whether the network helps neuroradiologists make better calls when it comes to diagnosing cancer recurrence versus radiation necrosis. If the technique proves to be superior to other diagnostic modalities, **"It would be a huge advantage to be able to make a diagnosis right then and there and begin your treatment planning,"** says Lisa Rogers, medical director of the neuro-oncology program at University Hospitals Cleveland Medical Center and a professor of neurology at Case Western Reserve University School of Medicine**.** "It would help avoid subsequent advanced imaging or surgeries where they're not needed."

A similar use of algorithms may also be able to help patients with breast cancer: **A team of researchers has developed a deep learning network that can identify areas of breast cancer from routinely acquired tissue slides**.

The researchers had pathologists mark areas of cancer on routinely acquired slides, and then used these to train the computer to identify cancerous regions. The computer proved to be 100-percent accurate in identifying the exact amount of cancer and the exact location of cancer on the digitized slides. "As you can imagine, this would be a huge deal for pathologists because it could obviate a large part of the very laborious work they've got to do," says Anant Madabhushi, the F. Alex Nason Professor II of Biomedical Engineering and director of the Center for Computational Imaging and Personalized Diagnostics at Case Western Reserve. It would also let pathologists focus their efforts on those patients who do have cancer, instead of examining slides under a microscope.

According to the team's study in *Scientific Reports*, the network learned so quickly that it was soon able to tease out benign regions within the pathologists' marked up areas. "The pathologists had done their best to mark up the primary cancer, but it's tough to do," says Madabhushi. "It became evident—and the pathologists acknowledge this—that the network was indeed refining their markups. That was quite astounding."

Another breakthrough Madabhushi's group has made has been to use the pattern-recognition artificial intelligence to figure out how aggressive a patient's cancer is, predict the patient's long-term outcome, and therefore determine what the best course of treatment would be—which would spare patients from having to undergo treatments they don't need.

This network is faster than humans, more accurate than humans, and will be able to work nights and weekends analyzing slides—but Madabhushi points out that integrating human interpretation with machine interpretation could create even better results than either one alone.

Material benefits

Faster-than-the-human brain computations are also helping materials science researchers amp up their predictive powers in terms of testing the longevity of materials and coming up with entirely new alloys.

Many environmentally conscious consumers and businesses are investing in solar power, which is good news for the Earth. But if solar panels peter out before their 20- or 25-year product warranty is up, consumers could lose confidence. How can manufacturers predict how long solar panels will last when the technology is still so young?

"We were able to develop models that let us predict how yellow the material will turn after so many hours of exposure to UV light and humidity, and how hazy the material will become."

LAURA BRUCKMAN

Companies that make solar panels, consumers that have solar panels on their homes, owners of solar panel farms, and banks that finance these systems all have a vested interest in knowing exactly how long they can expect their investment to last. So a **team of researchers from Case Western Reserve is using data science to predict how the weather will impact the lifetime of the materials that make up solar panels**.

Because manufacturers can't leave their products outside for 20 years to test them before going to market, right now they use what Ken Boyce, director of energy and power technologies at the safety consulting and certification company UL, calls a "sledgehammer program" to predict the longevity of the materials: They use standard tests, but increase the length of time or the harshness of the conditions just to be extra sure their products can take the punishment. "We're trying to be a lot more surgical in the way we address that," says Boyce.

According to scientists at Case Western Reserve's SDLE Research Center, big data can be used in tandem with accelerated and real-world testing for more refined results. A **team of researchers led by Laura Bruckman, a research associate professor at the SDLE Research Center, completed a successful pilot study** in collaboration with scientists at Gebze Technical University in Turkey (the results of which were published earlier this year in *PLOS One*) where they were able to **test the concept of using data analytics to evaluate how PET degrades when exposed to the environment**. PET is a polymer that's used in the backsheet of a photovoltaic module; the backsheet protects people from electrocution and protects the internal workings of the module from UV light, humidity and other environmental hazards. "We were able to develop models that let us predict how yellow the material will turn after so many hours of exposure to UV light and humidity, and how hazy the material will become," says Bruckman. "Those performance properties are pretty simple to monitor, and they also give you an indication of whether the material is starting to break down."

The SDLE Research Center **received a $1.3-million SunShot grant from the U.S. Department of Energy on the heels of the successful pilot work to expand the research**. A photovoltaic (PV) module in San Diego is exposed to much different weather conditions than one in Ohio, so the team is gathering data from PV modules all over the world and using weather records to extrapolate how well the polymeric backsheets—which each contain PET—will fare in different regions. This will help the industry make the right decisions about which materials to use depending on where the panels will operate—not to mention save money and boost consumer confidence in solar power.

Another project that's using data to replace the arduous trial-and-error process is **employing predictive modeling to create better soft magnetic alloys for power electronics**. "If we can use computational methods to help us understand and improve materials, then we can save a lot of time and effort compared to the Edisonian way of making things, testing them, and then redesigning our idea based on the results that we get," says Matthew Willard, an associate professor of materials science and engineering at Case Western Reserve. Better alloys can benefit many industries, from the automotive industry to the military.

Matthew Willard, associate professor of materials science, is developing algorithms to create better alloys.

NASA is interested in developing new soft magnetic alloys to use in their hybrid electric aircraft, so they reached out to Willard, who received a $1.6-million grant from the NSF to work on the problem. Alloys already exist that work well in this application, but the lighter and more magnetic the alloy, the more efficient the aircraft will be. "We spend a lot of time here casting magnetic alloys and fabricating them into components," says Randy Bowman, a materials research engineer in the High Temperature and Smart Alloys Branch at NASA Glenn Research Center. "It would be nicer if we had an analytical basis to guide alloy development."

In Willard's model, the researcher theorizes what composition of elements might work well in an alloy, and then the computer system predicts the properties that can be expected from that composition. Says Willard, "If we find something that's both stable and has good magnetic properties, then that is something we're going to make."

While the model does the predicting, the human touch is needed to brainstorm different combinations of elements to test. "I told my team that if we predict something that no one in their right mind, from my perspective, would come up with, and it has good properties, then that would be a big win," says Willard. "It would mean we have completely broken the mold of what a guy like me would come up with."

That's what predictive technology is all about: Helping people go beyond the ordinary, make better decisions faster, and improve lives.

Driving the Internet's Next Wave

Strong manufacturing resources. Some of the world's top health care systems. A booming startup landscape—Northeast Ohio's got it all. Now, Case Western Reserve and Cleveland State universities are joining forces to leverage the region's rustbelt revival and turn Cleveland into the capital of the industrial IoT.

Case Western Reserve University had firm footing in the first wave of the internet as one of the original nodes on the ARPANET—a Department-of-Defense-run 1980s-era computer network that served as a kind of proto-internet. Silicon Valley became the geographic home of the first two waves as the internet—and the seemingly countless websites, apps and devices that connect to it—took shape. According to researchers at Case Western Reserve and its academic colleague just down the street in downtown Cleveland, Cleveland State University, **Northeast Ohio is primed to lead the next wave in the Industrial Internet of Things (IIoT)**.

The two universities are teaming up to make that happen by launching an initiative they call the **IoT Collaborative that will pool their academic and research resources together with a variety of local industry partners and governments**. The universities' two presidents, Barbara R. Snyder of Case Western Reserve and Cleveland State's Ronald M. Berkman, formalized the partnership by signing a memorandum of understanding this year. And they kicked off the project with the help of a planning grant from the Cleveland Foundation, giving the research teams and their partners in the City of Cleveland the first tools they needed to start building their vision for Cleveland's IIoT future.

The grand plan to create an ecosystem of IIoT innovation rolled out of Case Western Reserve's launch of its Internet-of-Things (IoT)-dedicated Institute for Smart, Secure and Connected Systems, or ISSACS for short. As that initiative came together under the leadership of the Case School of Engineering, it became clear to everyone involved that the IoT was bigger than one school-based institute, according to Kenneth Loparo, Nord Professor in the Department of Electrical Engineering and Computer Science and one of the project leads. "We wanted to think more broadly—regionally, nationally, even internationally," he says. "We knew Cleveland State had strengths in this area, so rather than having two institutions potentially competing in the same space, we decided a team effort might allow us to do something even bigger than either could accomplish on its own."

Going Big (and Broad)

The traditional approach to research is to focus on one thing and dive deep, says Lisa Camp, associate dean of strategic initiatives at the Case School of Engineering at Case Western Reserve. While researchers could easily focus on singular elements of IIoT technology development, like cyber security or sensor technology, **Camp says the IIoT is too broad for a siloed approach to work effectively**. "This isn't something that's just going to impact manufacturing lines or just city infrastructure or just the way we manage health care," she says. "This is something that touches on behavioral sciences, community activities, urban issues and education, medicine and nursing, and more. We're talking about entirely new business models—it really has the potential to upend things."

"We're talking about entirely new business models—it really has the potential to upend things."

LISA CAMP

So what exactly is the IIoT? While cool gizmos like smart thermostats and refrigerators that text you when you're out of milk may capture the headlines when it comes to the Internet of Things, they're not the innovations that are going to drive the future of IoT, according to Loparo. The real innovations that pack market-shifting impact will come on an industrial scale, so that's where Case Western Reserve and Cleveland State are focusing their efforts, leveraging each school's particular strengths to **advance IIoT initiatives in four key areas: manufacturing, smart cities and infrastructure, health care and energy**.

A More Connected Society

Both Case Western Reserve and Cleveland State bring particular sets of expertise to the partnership, working together to advance IIoT projects across all four main platforms. It's an ambitious approach, but Camp says that's part of the systematic nature of IIoT. "You can't really study these areas in isolation," she says. "You can't really talk about manufacturing without addressing infrastructure. You can't work on infrastructure and ignore energy. What's more, if you solve one problem with the IIoT, that solution is applicable in those other spaces, so there's a flow of solutions going back and forth between these four pillars."

And what exactly does the IIoT in action look like? Loparo describes it as a natural step in the evolution of digital technology. He explains it in waves: "We started with something more efficiency-focused," he says—essentially creating machines and devices to accomplish tasks faster and better than humans can on their own. "**Next we're trying to make the devices smarter—rather than just collecting data, we want them to have on-board abilities to analyze that data and even manage how they operate**." The next wave? According to Loparo, it's a system that's totally autonomous with a focus on outcomes, not just function.

"It's about sensing, actuation, data, analytics, communications and networking, and, ultimately, feedback control and decision-making that manages that industrial process so it can produce the most reliable products with the highest quality, at the cheapest economic cost."

KENNETH LOPARO

"In our conversations with industry, we keep hearing similar feedback," says Nigamanth Sridhar, dean of the College of Graduate Studies and professor of electrical engineering and computer science at Cleveland State. "One statistic that keeps coming up from all the major companies that are working on initiatives in this space is that less than 1 percent of the data they're collecting is actually being used." All the components are there to take the IIoT to the next level: "That's the next big milestone," says Sridhar. "How to integrate all these sensors and networks and ask the right questions that can change that data into actionable intelligence."

In practice, that next wave has powerful applications in everyday life. **"Industrial IoT will make infrastructure monitoring and repairing faster and more efficient,"** says David Zeng, the Frank H. Neff Professor and chair of Case Western Reserve's Department of Civil Engineering, who is leading the university's efforts on the smart infrastructure front.

"Imagine a water leak in a home that's detected instantly by sensor technology," says Camp. "What if your infrastructure could communicate to your utility in real-time—detecting and even fixing problems before there's any damage?"

The IIoT also has the potential to improve how cities themselves run—from improved traffic flows to better connecting citizens to resources they need.

On the manufacturing front, the IIoT has the ability to connect the process in a way that far surpasses and leverages human capabilities. "It's about sensing, actuation, data, analytics, communications and networking, and, ultimately, feedback control and decision-making that manages that industrial process so it can produce the most reliable products with the highest quality, at the cheapest economic cost," says Loparo.

"Attaining that trifecta, practically perfecting the process demands IIoT at its core."

In energy applications, IIoT brings that level of connection to a grid, creating a system that's far more nimble and adaptive than today's energy infrastructure. (Read more about Case Western Reserve and Cleveland State's collaboration on microgrid development on page 37.) "The IIoT enables a more resilient energy infrastructure that can operate grid-connected, but will also have the ability to operate in an islanded or grid-disconnected mode to keep critical loads operating even if the system upstream is down due to a blackout caused by a storm," Loparo says.

In health and medicine, IIoT applications range from improving tele-health capabilities to integrating mankind with machines in unprecedented ways. Dustin Tyler, the Kent Hale Smith Professor of Biomedical Engineering at Case Western Reserve, is leading an initiative in collaboration with the university's Interactive Commons that **combines the IIoT, advances in prosthetics and augmented reality to digitize sensory information**.

"Through the IIoT, humans themselves could be agents and sensors in the system … which could make huge impacts in human health and more."

DUSTIN TYLER

Tyler has pioneered advanced prosthetic systems that restore sensation to amputees. He says the IIoT has the potential to build on that work, using network-connected sensor technology and robotics to virtually put humans practically anywhere: **allowing an engineer to repair a deep-sea oil rig safely from shore, or an expert surgeon to conduct an operation from another continent**. The work is in its earliest stages, but the possibilities could radically alter human beings' connection to technology.

"Through the IIoT, humans themselves could be agents and sensors in the system, creating a truly symbiotic relationship between humans and machines, which could make huge impacts in human health and more," Tyler says.

According to the researchers, **universities are uniquely positioned to drive these types of disruptive innovations**. And they're focused on bringing those advances to the here and now with the help of the IoT Collaborative's industry and government partners. Civil engineering researchers are already using real data from the City of Cleveland Division of Water to build computer models to help guide better infrastructure decisions (read more on page 6). Researchers will be working directly with local small and mid-sized manufacturers on implementing IIoT solutions. And urban affairs experts are working directly with city and regional economic development operations like BioEnterprise, Team NEO and Cleveland's Health-Tech Corridor to hone these opportunities. "Academics, public entities, private companies—all three coming together in true partnership is what we see as the real power behind this initiative," says Sridhar.

The Academic Edge

Both universities hope to grow the collaboration to include more of Northeast Ohio's academic institutions. "We want to use this collaboration as a model for bringing in other institutions like Kent State University and Akron University, our community college partners and other private college partners like John Carroll University. We want to build a true, integrated public-private partnership that will be an economic engine for the entire region," says Loparo.

The economic opportunity is tremendous—according to a report in *McKinsey Quarterly*, industrial IoT will far surpass its consumer-based counterpart by 2025, to the tune of $5.3 trillion invested in factories and cities versus $1.9 trillion in the consumer sector. According to the collaboration's partners, Cleveland should be at the center of that boom.

While "economic development" seems to fall in the realm of the private sector, universities are particularly well-suited to drive those initiatives. "The fact is that the institutions can provide the ecosystem by which the public and private sectors can flourish simultaneously," says Loparo. "It's about stimulating the region with deep academic and analytical strengths that then become an attraction for businesses, small and large, that want to plant themselves in that ecosystem because the academic institutions provide the nutrient that's absolutely essentially for them to grow and develop."

"When you think about **economic development, you certainly think about job creation and workforce development—those are important factors. But there's also a knowledge creation element**, and that's where universities can lead," adds Sridhar.

Universities also bring a sense of stability to the table that most private companies just can't match, Sridhar says. "Universities are anchors," he says. "When an investment gets made, it's not something that's done lightly or reassigned easily, which provides a certain sustainability."

The IIoT Capital of the World

As academic institutions are ideally suited to anchor sweeping initiatives like the IoT Collaborative, Cleveland is a natural home for the next wave of IoT innovation, according to Loparo. "We are, and always have been, an industrial city," he says. "Manufacturing is what put us on the map in the beginning, and, while we may have shifted to smaller and medium-sized plants, it's still important here."

And health care? Cleveland is home to some of the biggest names in the business: Cleveland Clinic, University Hospitals Cleveland Medical Center, the Louis Stokes Cleveland VA Medical Center and MetroHealth Medical Center. "Where's a better place to do health care?" Loparo asks of a city that saw some $200 million in investments from health care companies in 2016, according to an industry report from BioEnterprise. Cleveland also boasts clean energy resources and a city government that's already declared the collaborative an "important pillar" to its own Smart Communities Initiative dedicated to transforming Cleveland into a smart city.

And while the collaborators are focused on building an IIoT ecosystem unique to Cleveland, they anticipate the work will have further-reaching impacts on the field. "Cleveland is not so big that it's unwieldy, but it's not so small that you're not going to have lessons learned across the country," Camp says.

And that's exactly what the collaborators hope to build: a **proving ground that will not only drive economic growth in Cleveland but provide valuable IIoT solutions to the industry as a whole**. "We're taking a systems approach from the start," Loparo says. "It's not just about the technology and devices, or the networking and communications, or the data—it's about the seamless integration of all these entities, where, from end to end, the total is much greater than the sum of its parts."

EXPLORING NEW SPACES

New biomedical engineering teaching lab gives undergraduates plenty of space for exploration

Biomedical engineering students have a new space in which to bring their lessons to life. The undergraduate teaching lab located on the ground floor of the Wickenden Building includes a computer and instrumentation lab as well as a biomaterials-focused wet lab. Students have access to a range of equipment, including incubators, centrifuges, bio-hoods, chemical fume hoods, oscilloscopes, fluorescent microscopes and more—all of the tools they need to gain a better understanding of how the biomedical technologies and innovations they work with interact with living tissue.

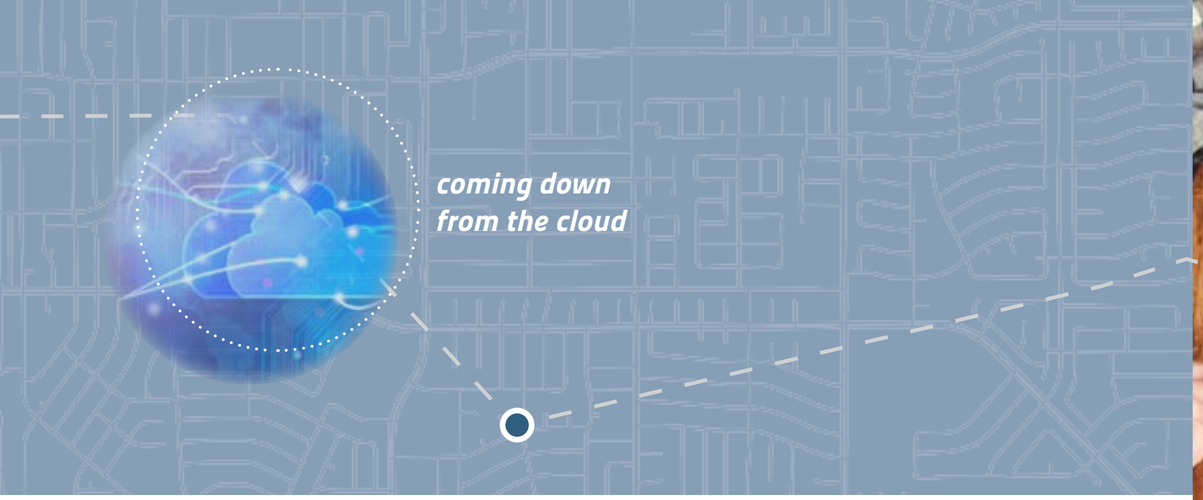
New suite of civil engineering labs provides room for rock-solid experimentation

Civil engineering students and faculty have a new, state-of-the-art space in which to study and make discoveries—a suite of renovated labs dedicated to geotechnical engineering education and research. The suite includes the Frank E. Gerace Geotechnical Teaching Lab, the Warren C. Gibson Library, the Saada Family Geotechnical Research Labs and the Richard A. Saada Intelligent Geosystems Lab.

New Sears think[box] floor adds dedicated space for student projects

Case Western Reserve University's Larry Sears and Sally Zlotnick Sears think[box] will provide 50,000 square feet of ideation and creation resources to the campus and local community. The **opening of the innovation center's fifth floor gives special access to the university's student project groups and design teams**. The university Rocket Team, Robotics Club, Baja Team and Design, Build, Fly organizations now have dedicated bays in which to tinker and perfect their projects. The new floor also includes office spaces for student startups like Parihug (read more on page 38) and RVS Rubber Solutions.

And thanks to one generous alumnus, one of those student groups had even more resources. **Larry Enterline (CIT '74)** donated $25,000 to support the Baja Team, which allowed it to hit the road for one of the most successful seasons in the organization's history.



coming down from the cloud

home computing with a residential hub

Researchers win NSF funding to bring our data back home

Engineering researcher Michael Rabinovich received an NSF grant to explore using ultra-broadband technology to establish residential data hubs.

We live at home, but our information doesn't. Thanks to cloud storage, our files, photos and so many other digital odds and ends are kept elsewhere—easily accessible anytime from anywhere with an internet connection. But the downside to this accessibility? We've got information everywhere—photos on social media sites like Facebook and Instagram, collaborative files on Google Drive and chains of correspondences housed in various email services. Using a hodge-podge of service providers means users rely heavily on others to maintain and protect their data. And new, high-profile security breaches continue to make headlines, indicating that keeping our data in the hands of others can be risky business.

Computer science researchers at Case Western Reserve University think keeping our digital footprints a little closer to home could keep information safer.

Michael Rabinovich, professor of electrical engineering and computer science, received a National Science Foundation grant to explore using ultra-broadband technology to establish residential data hubs, allowing users to organize their digital lives around the same hub where they organize their physical lives: their residences. Bandwidth of tens of megabits per second is common-place and advances in fiber-to-the-home technology are poised to make unprecedented storage capacity available. Rabinovich and his team will test whether these advances can be used to shift storage to home-based networks, giving people more control over their information.

Generous donations provide free technology camps to local students

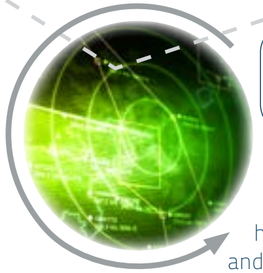
Thanks to the generous support of the Case School of Engineering Gelfand Engineering and Technology Education Fund, the Abington Foundation, the White Foundation, Cognizant, the Char and Chuck Fowler Family Foundation and Rockwell Automation, Case Western Reserve was able to **host eight free Techie Camps**.

Last summer, **165 elementary and middle school students from Cleveland-area public school districts** attended the week-long technology camps, which included activities in programming, 3-D printing, robotics and app development.

With support from the Cleveland Foundation, the university also hosted a **high-school coding camp**, which gave 20 Cleveland-area students the chance to learn the programming language C#.

SETTING THE STANDARD:

The Business-Higher Education Forum highlighted Case Western Reserve's undergraduate minor in applied data science as a national model for collaboration between academia and industry partners. Check out the case study at **engineering.case.edu/data-science-case-study**.

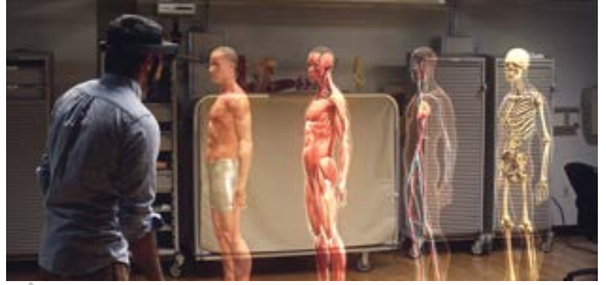


BEST OF BOTH:
COMPUTER SCIENTISTS EXPLORE DIGITAL-ANALOG HYBRID COMPUTING

It may seem like we're living in a digital world, but when it comes to computing, analog signals still have a place among all those ones and zeros, according to computer science researchers at Case Western Reserve University.

While digital computer performance is hitting fundamental limitations, **analog transistors are actually getting faster—making them a good fit for wireless communication, imaging and radar applications**.

Soumyajit Mandal, assistant professor of electrical engineering and computer science, received grants from the NSF and DARPA to develop high-speed analog co-processors. His team hopes to scale up and develop analog computation units that can be integrated into digital computational architectures, creating a seamless hybrid computer system.



HoloAnatomy, the mixed-reality app developed by Case Western Reserve and Cleveland Clinic that allows Microsoft HoloLens users to see arrangements of organs, bones and blood vessels inside of the body, snagged top honors:

- A 2016 Jackson Hole Science Media Award
- A 2017 Digital Edge Award
- Named among Medgadget's Best Medical Technologies of 2016
- One of five finalists in the U.S. Department of Education EdSim Challenge

Learn more at **engineering.case.edu/HoloAnatomy-honors**.

Remesh—a startup company co-founded by Case Western Reserve University engineering graduate student Aaron Slodov—raised $3.8 million in funding to advance its market research software. Learn more at **engineering.case.edu/Remesh-angel-investment**.

PHOTON TO PHOTON:
Researchers awarded $2M NSF grant to advance quantum communications

Scientists think they may have found a new hiding place for data: tiny particles of light called photons. These elementary particles are linked to each other through a phenomenon known as quantum entanglement: change one photon and its partner changes too, no matter the distance between. Hitching digital information to them could be a safer, more secure way to transmit—and to thwart hackers.

A multidisciplinary team of researchers led by the University of Rochester, including Philip Feng, associate professor of computer science and electrical engineering at Case Western Reserve, received a $2-million grant from the National Science Foundation to explore creating systems that use quantum entanglement for communication. Specifically, Feng's team will build chip-sized quantum photonic processors that could interface with fiber-optic links to send and receive quantum information.

Learn more at engineering.case.edu/Feng-NSF-quantum-photonics.

Alum helps expand Virtual Worlds Lab

Case Western Reserve's Virtual Worlds Lab is getting a total, real-world makeover thanks to the generous support of Kevin Kranzusch (CWR '90), computer engineering alumnus and vice president of system software at Silicon-Valley-based high-performance computing company NVidia Corp.

Kranzusch's $150,000 gift expands and remodels the lab to better fit with student needs in computer gaming technology, virtual and augmented reality, and artificial intelligence. The expanded capabilities also support the university's research and education in the Internet of Things.

combining video games and electrical stimulation

Advancing therapy for those with cerebral palsy and stroke by pairing sensor technology with video games

A challenge therapists face when treating patients with hand disabilities due to hemiplegia—such as victims of stroke and those with cerebral palsy—is getting enough therapeutic time in. When a patient isn't able to open or close their hand due to such a disability, the best-practice approach would be daily therapy sessions where the patient completes hundreds of reps in each. Frequently, however, sessions occur once or twice weekly. Therapists ask patients to supplement with at-home practice, but for many patients, this isn't possible.

But what if the therapy included electrical stimulation to help patients open their hands? And what if instead of hundreds of monotonous repetitions, they were playing video games? That's the solution Michael Fu, assistant professor of electrical engineering and computer science, has helped devise.

During a Mentored Clinical Research Scholars (KL2) program with Case Western Reserve's Clinical and Translational Science Awards Program, Fu met up physical medicine and rehabilitation faculty members Jayme Knutson and John Chae. Knutson, a senior staff scientist at MetroHealth Medical Center, and Chae, chair of physical medicine and rehabilitation at MetroHealth, developed an **electrical stimulation glove that allows stroke patients to practice opening their paralyzed hand by controlling the motion by opening their gloved functional hand**. Stimulators attached to the paralyzed hand relayed the movement, mimicking the motion. The device was an important step toward better at-home practice, but patients needed more guidance—and interest—in what motions they should be practicing.

Fu developed **a series of video games that require important and varying movements for therapy**, from the opening of the hand in a Pong-like paddle game to the nuances of movement in a path-tracing game, the speed of movement built into a skeeball game, and the subtle twists of moving a marble through a block maze. The games take patients through a range of motions and make the therapy more appealing—and therefore more likely to be completed—for the required one hour a day.

Fu received grants from the NIH and the Pedal-with-Pete Foundation to conduct initial studies in children with cerebral palsy with Cleveland Clinic Children's Hospital for Rehabilitation. He also received a Target Challenge grant from the New England Pediatric Device Consortium to help commercialize the system. His team has converted the prototype to a wireless system, has adapted the video games for tablets and is talking with companies to license the product.

improving at-home therapy for hand disabilities

Student startup develops a better way to screen for concussions

In high school, current Case Western Reserve junior Matt Campagna witnessed the impact of a mis-diagnosed concussion first-hand. Campagna's friend Matt Roda slammed headfirst into the boards during a hockey game but was cleared for continued play because he was able to correctly answer three questions—"Where are you? What year is it? Who is the president?" A few days later, his doctor diagnosed Roda with a severe concussion and he missed two months of school while recovering.

Inspired to protect other athletes from traumatic brain injury, the two student entrepreneurs, along with a third friend, Patrick Walsh, made it their business to better detect concussions. They **founded Reflexion Interactive Technologies and developed the Reflexion Edge—a portable 2-by-6-foot touch screen that can evaluate athletes not only for severe concussions, but also for early and mild concussions**—the ones that most frequently go undiagnosed.

Athletes interact with light patterns on the screen, which assess the player's cognitive function. In 30 seconds, the device measures complex correlated functions such as peripheral awareness, depth perception and memory—simultaneously—which are used to determine if the athlete has a concussion.

Because the device is fast and portable— it collapses into a case the size of a duffle bag and deploys in minutes—it is designed for athletes to use each week, regardless of any suspicion of a concussion. **Data from each session is saved so athletic trainers, coaches and physical therapists can identify even the slightest change in a player's performance**. The Edge can even help in the rehabilitation process with restoring cognitive function.

In January 2017, Campagna demonstrated the Edge to attendees at CES, the world's largest technology trade show. He's placed in top spots at South by Southwest's Student Startup Madness (read more on page 38), the Cleveland Medical Hackathon and Pitch U. To meet such successes, **Campagna has taken full advantage of university student entrepreneurial resources such as Sears think[box], CWRU LaunchNet and the IP Venture Clinic**.

Campagna and his friends Roda and Walsh successfully completed a clinical study with the Pennsylvania State University Center for Sport Concussion Research and have begun another. They've hired software developers and hope to launch the product in 2018. Learn more at **engineering.case.edu/meet-our-innovators/Reflexion.**

Restoring movement for MS and stroke patients

More than five years ago, Robert Bush's multiple sclerosis (MS) took away his ability to walk. Around the same time, Joseph McGlynn suffered a stroke that seriously impaired his left side. Yet the two **both were able to stand and walk again, thanks to technology designed by a research group with members from Case Western Reserve University**, the Advanced Platform Technology Center, the Functional Electrical Stimulation Center and the Louis Stokes Cleveland Veterans Affairs Medical Center.

"I could barely take two steps," said Bush, who **researchers believe is the world's first MS patient to "test-drive" an implanted functional electrical stimulation (FES) system**. The proof-of-feasibility test lasted 90 days. "At the end, I was walking down the hallway," said Bush. "To me, it was monumental."

McGlynn could walk with a cane, but not easily. **With the technology switched on, he covered far more ground and his pace became twice as fast over his 30-week study**. "It's helped with balance and confidence," said McGlynn. "I'm confident now that I can walk without stumbling and falling."

The neural stimulation system could be the foundation for a long-term, implanted assistive system to restore independence to those with MS or who have suffered a stroke. Learn more, and watch videos of Bush and McGlynn using the system at **engineering.case.edu/neural-stimulation-stroke-MS**.

Controlling diseases in our crops

Two Case Western Reserve engineering researchers are exploring innovative ways to fight against the damaging effects of diseases on plants that lead to crop failure and starvation.

Michael Hore, assistant professor of macromolecular science and engineering, received a $500,000 NSF CAREER award to unravel how nanoparticles move through a tight pore—a process known as translocation—which is how plant viruses can spread. Hore's approach combines theory, computer simulations and experiments to develop a virus mimic—nanoparticles with polymers attached to the surface.

"If we can understand how these nanoparticles move through pores, it may provide a way to fight plant infections," Hore said. "It would also enable us to purify water by designing a membrane to preferentially filter out particles, such as a virus, that we don't want."

In another study, a research group led by **biomedical engineering's Nicole Steinmetz, the George J. Picha Designated Professor in Biomaterials, are applying drug-delivery technology to agriculture to control parasitic roundworms more effectively and safely**. The tiny roundworms, or nematodes, cause an estimated $157 billion in crop failures worldwide each year, largely because they're beyond the reach of pesticides. The chemicals disperse poorly into soil, while the parasites feed at plant roots well below the surface.

By using plant viruses to deliver the pesticide, it's able to better diffuse into the soil, simultaneously decreasing the risk of leaching and runoff, reducing the amount of chemicals in the crops and reducing the cost to treat them.

$20 million gift creates strategic initiative for research, scholarship and faculty leadership

One of the largest gifts in the school's history supports biomedical engineering

With a generous $20 million gift to launch the Aiken Strategic Initiative, Robert (CIT '52) and Brenda Aiken have given the Department of Biomedical Engineering at Case Western Reserve University new resources to help it attract the best and brightest faculty and students and enable them to thrive.

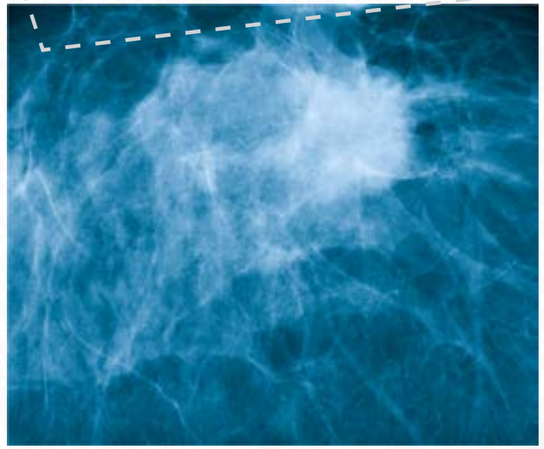
The Aikens have been long-time supporters of the biomedical engineering department—they've made a Case Western Reserve **biomedical engineering education possible for 28 students through the Aiken Scholarship Program**, which they established in 2008. With this most recent commitment, they extend their support to generations of future biomedical engineering students and faculty with an even broader impact. The Aiken Strategic Initiative reaches across the department, including **a translational research fund that will foster collaborations between clinicians and engineering researchers** on translational projects with the potential to impact patient care, and **scholarship support to attract students of the highest caliber**.

A new implantable drug-delivery system developed by biomedical engineering's Horst von Recum is activated by the acidic environment surrounding a tumor to provide sustained drug release without damaging healthy tissue.

Gene therapy to prevent vision loss

Recently developed nanoparticles could be the key to preventing vision loss from inherited eye disease. The gene-carrying nanoparticles home in on target cells and prevent vision loss in one of the most common causes of blindness in children. The research team, led by Zheng-Rong Lu, the M. Frank Rudy and Margaret Domiter Rudy Professor of Biomedical Engineering, believes the approach also could deliver any type of gene to treat inherited visual disorders. Learn more at **engineering.case.edu/drug-delivery-vision**.

A new imaging agent developed at Case Western Reserve has tested capable of determining which prostate cancers are aggressive and metastatic, potentially helping doctors determine the best treatment plan.



Using imaging, AI and big data to take on cancer—one patient at a time

Understanding the unique nuances of disease and creating individualized treatment plans could be the key to better combating cancer. At Case Western Reserve, the Center for Computational Imaging and Personalized Diagnostics, led by Anant Madabhushi, the F. Alex Nason II Professor of Biomedical Engineering, has made strides in combining digital imaging and artificial intelligence to personalize treatments for cancer. New discoveries from patterns of disease arrangement on tissue slides of ER+ breast cancer could help determine the most appropriate treatment plan for each woman. And a discovery on the risk for biochemical recurrence after a radical prostatectomy could lead to important guidance on each prostate cancer patient's post-treatment management. Read the whole story at **engineering.case.edu/CCIPD2016-17**.

DOD grant for TBI and stroke

A $1.65M Department of Defense grant will help Case Western Reserve and University of Kansas researchers continue developing a neural prosthesis to restore some motor function to those who have suffered a traumatic brain injury. The prosthesis, called a brain-machine-brain interface, records signals from one part of the brain, processes them in real time, then bridges the injury by stimulating a second part of the brain that had lost connectivity. The three-year grant, co-led by professor of electrical engineering and computer science Pedram Mohseni, will allow the research team to assess whether the implant can help make permanent repairs and then be removed. The team also is assessing the device for stroke patients. Learn more at **engineering.case.edu/TBI-prosthetics**.

By building their battery using inexpensive materials, Robert Savinell and his team are making the device more cost-effective and safer.

Researchers win ARPA-E funding to advance flow battery based on iron and water

Mother Nature's variability is a major stumbling block to the mass adoption of renewable energy sources that hinge on weather: wind and solar.

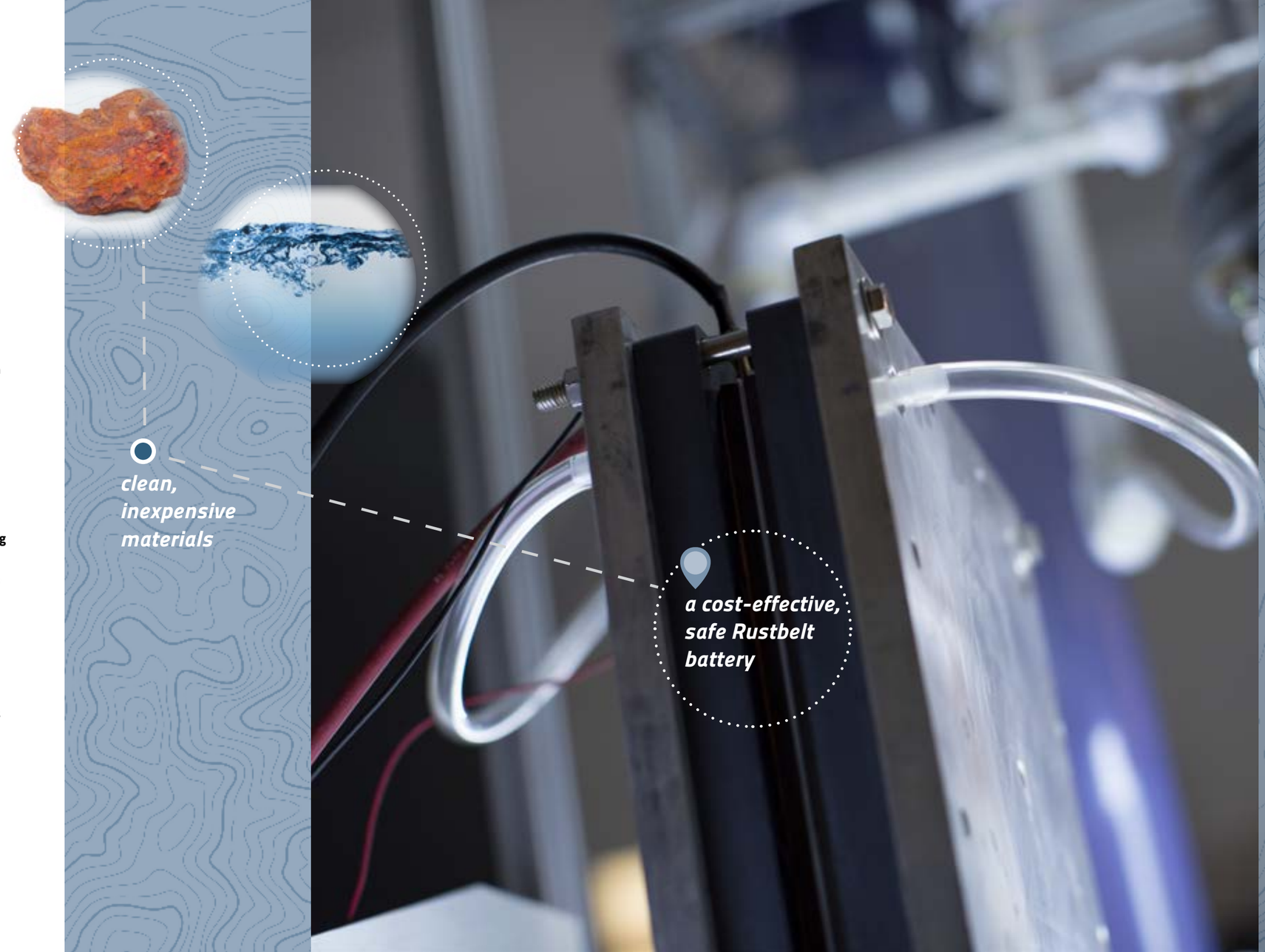
So the research community is on the hunt for a missing link of sorts: something that can hold the energy generated by intermittent natural sources and disperse it as needed. The additional challenge is that this technological bridge between supply and demand must be cost-effective enough to make renewables competitive with traditional power. **Chemical engineering researchers at Case Western Reserve have developed an iron-based flow battery that could provide cleaner, cheaper power during generation ebbs and flows, and they received $1.7 million in federal funding to build a near-commercial-sized prototype and put their idea to the test**.

Robert Savinell, Distinguished University Professor and the George S. Dively Professor of Chemical Engineering, has been developing this "rustbelt" battery for five years. This new award brings the **total U.S. Department of Energy's Advanced Research Projects Agency-Energy—or ARPA-E—funding for the project to $3.25 million**.

By building their battery using inexpensive materials like iron and water, Savinell and his team are making the device more cost-effective and safer than other electrochemical alternatives that rely on costlier and sometimes toxic components.

The team is currently building a 1-kilowatt prototype system that will be able to provide enough power to run a small window air conditioner, large-screen LCD TV, Xbox 360 gaming system and a lamp with a 100-watt incandescent bulb for six hours.

Learn more at **engineering.case.edu/flow-battery-prototype**.



Powered up: Vikas Prakash, professor of mechanical and aerospace engineering, received a $1.3-million grant from NASA to develop battery systems for next-generation electric air vehicles.

Marija Prica, assistant professor in the Department of Electrical Engineering and Computer Science, served a one-year term as a visiting scholar at the Federal Energy Regulatory Commission. She advised and counseled the commission staff on emerging trends in distributed energy resources and their impact on reliability of the bulk power system and economic influence on wholesale markets.

DOE funding to help double the life of thin-film solar cells

According to the Department of Energy, the average cost of solar photovoltaic (PV) panels has dropped more than 60 percent since 2010, and in the same time frame, the cost of a solar electric system has fallen by about 50 percent. These market shifts put solar on the path to being competitive with its traditional energy counterparts.

But interfaces in solar cells—essentially the points where the different material layers connect—are particularly vulnerable to degradation. **Researchers at Case Western Reserve are developing a powerful method to change these interfaces from delicate to durable: using interfacial modifiers (IMFs) made from a special coating to extend the lifespan of PV components,** making them even more cost-effective. They received a U.S. Department of Energy SunShot Initiative Award to find a way to make this promising technology hearty enough for industry to take advantage of its potential in crystalline silicon PV panels, and even in digital display technology.

The team, led by SDLE Research Center Director and Kyocera Professor of Ceramics in the Department of Materials Science and Engineering Roger French, Ina Martin, director of the MORE Center and adjunct professor of materials science, and Timothy Peshek, adjunct professor of materials science, is **testing the method on thin-film solar cells, coating them with a capping layer, which could double the life expectancy to 25 years, making them comparable to silicon-based cells**. They're experimenting with a family of compounds called organofunctional silanes, which are widely used to protect fiber optics.

Learn more at **engineering.case.edu/thin-film-solar**.

Residents of Musanze, a rural village in Rwanda, have access to safe, renewable solar energy—and the know-how to keep the system up and running—thanks to a team of engineering students and faculty from Case Western Reserve. Learn more at **engineering.case.edu/Rwanda-solar-panel-installation.**

RETHINKING THE GRID:

Universities team up to explore how advanced energy can drive economic development

The grid is a massive collection of energy infrastructure organized around a central generation point, like a power plant, with distribution arms reaching out like the spokes on a wheel to thousands, even millions, of users. A microgrid, on the other hand, reimagines the energy wheel as a decentralized system that, when disconnected from the main grid, relies on a local supply of energy distributed to a much smaller network of users. It can plug into the full grid, but importantly, can function independently.

Energy experts think these microgrids could make energy delivery cleaner and more secure, with added benefits of helping support more reliable energy delivery to main grid customers during times of high demand and driving economic development in the cities and regions they serve.

Case Western Reserve University's Great Lakes Energy Institute will collaborate with Cleveland State University on a Cleveland Foundation-funded study to examine just how the city might benefit from this shift in energy delivery by leveraging assets like proximity to offshore wind resources and access to cost-competitive natural gas to create business opportunities.

Case Western Reserve University student innovator Pavel Galchenko won $50,000 for his startup RVS Rubber Solutions by winning the Midwest Regional portion of the Clean Energy Trust Challenge, took home a $10,000 prize in the Infosys Foundation Infy Maker Awards, and competed in the finals of the Lee Kuan Yew Global Business Plan Competition. The sophomore, who is studying biochemistry and applied data science, has developed technology that extracts rubber and steel from a tire's largest and most-difficult-to-recycle component—the body ply.

student CEOs

Case Western Reserve student entrepreneurs take top spots in South by Southwest business competition

Parihug and Reflexion Technologies place second and third, respectively, at SXSW Student Startup Madness.

For two Case Western Reserve University undergrads, spring break 2017 was serious business.

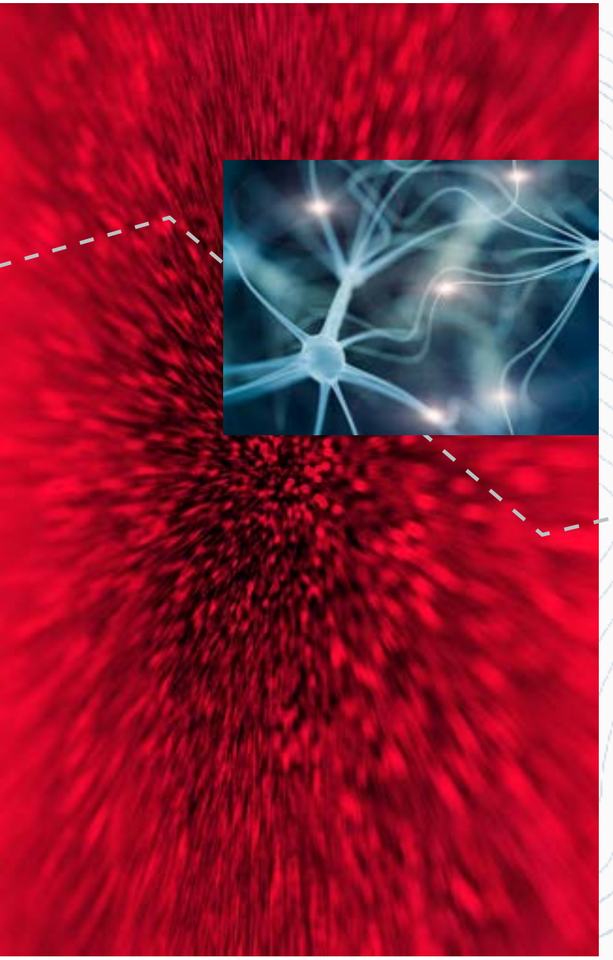
While many of their college-age peers were jetting off to the beach, Xyla Foxlin and Matt Campagna headed to Austin, Texas, to pitch their startup companies to a panel of world-class judges for a chance to win thousands of dollars in funding at South by Southwest's Student Startup Madness competition. Not only did they compete with some of the best young innovators from across the country, **they captured two of the three top spots: Foxlin took second place for her digital-hug-sending startup Parihug, and Campagna came in third with his sideline concussion detecting device, the Reflexion Edge**.

Foxlin, a senior majoring in mechanical and aerospace engineering, impressed the panel with her high-tech take on plush toys. Pari is a cuddly stuffed animal tricked out with state-of-the-art sensors that detects hugs and then transmits those warm fuzzy feelings via vibrations to its pair in another location. She's won thousands of dollars and loads of accolades from business competitions across the country since launching Parihug in 2015, raised more than $50,000 on Kickstarter, and plans to start shipping her first round of pre-ordered Pari this year. **Her company also got the attention of Microsoft executives, which landed her in a national TV ad campaign for the company's Surface laptop**.

Inspired by a high school friend's hard hit on ice during a hockey game, Campagna co-founded Reflexion Technologies LLC with two high school friends. The trio developed a device that can be deployed on the sidelines and screen for concussions in as little as 30 seconds (read more about the technology on page 30). **The Edge has been raking in prize funding as well, including a third-place finish at the Cleveland Medical Hackathon and second place at PITCH U earlier this year**. The team is starting field tests, aiming to get it to market next fall.

Learn more at **engineering.case.edu/SXSW-Startup-Madness**.

winning big at business



Four pieces of biomedical technology took a step closer to market by garnering licensing agreements with top companies

From mind to market: companies license technology invented in Case Western Reserve labs for further development

Four pieces of biomedical technology developed by engineering researchers at Case Western Reserve took a step closer to market by garnering licensing agreements with top companies.

ICBM Medical Inc. signed an exclusive license agreement with the university to further develop biosensor technology invented by Distinguished University Professor C.C. Liu, the Wallace R. Persons Professor of Sensor Technology and Control in Case Western Reserve's Department of Chemical and Biomolecular Engineering. The technology holds promise in providing low-cost, rapid patient screening and monitoring for a range of critical clinical conditions, from prostate cancer to concussions.

Health product startup Hemex licensed the HemeChip, a device capable of rapid diagnosis of sickle cell disease developed by Umut Gurkan, assistant professor of mechanical and aerospace engineering, and his team.

XaTek, a new Cleveland-based company, licensed the technology for ClotChip—a portable microsensor that can assess the clotting ability of a person's blood 95 times faster than current methods, using only a single drop of blood at the point of care. The device was developed by Pedram Mohseni, professor of electrical engineering and computer science at Case Western Reserve, and Michael Suster, senior research associate.

In addition, the **university and Halyard Health Inc. signed an exclusive research agreement to collaboratively develop pain-blocking neuromodulation technology** invented by Research Assistant Professor of Biomedical Engineering Niloy Bhadra and Professor of Orthopedics Kevin Kilgore, in the university's School of Medicine.

Learn more at **engineering.case.edu/licensing-2017**.

Embedded entrepreneur: Student-turned-CEO one of four innovators chosen to participate in DOE program at Argonne National Lab

He's gone from experimenting on the family grill to honing his invention at one of the country's premier research labs: **Felipe Gomez del Campo, a Case Western Reserve graduate student and CEO behind a jet-fuel-saving startup, was chosen to participate in a new two-year entrepreneurship program at the U.S. Department of Energy's (DOE) Argonne National Laboratory** in Lemont, Ill.

He is one of four young innovators from across the country selected as part of the **inaugural cohort of the DOE's Chain Reaction Innovations program**, where they'll embed at Argonne for two years to access the lab's scientific expertise, world-class facilities and mentorship opportunities to develop their innovative technologies.

Gomez del Campo will use the program to advance his fuel-injection device, which uses plasma to help jet engines burn more efficiently.

Learn more at **engineering.case.edu/Gomez-del-Campo-CRI**.

Bolstering Innovation

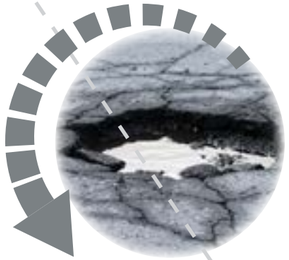
Case Western Reserve University's Larry Sears and Sally Zlotnick Sears think[box] continues to pack more valuable resources for budding entrepreneurs into its 50,000-square-feet of innovation space, thanks to the support of a number of generous donors.

Alumnus and long-time Sears think[box] supporter Barry Romich (CIT '67) endowed the executive director position at the innovation center, providing lasting support for leadership of the facility.

The center of Case Western Reserve's ecosystem of innovation also celebrated the opening of its fifth floor—the Eric T. Nord Project Space Floor—which serves as a homebase for a number of student groups, including the university's Baja team, rocket club, Design Build Fly group, robotics team and more. These student innovators, and others across campus, also received additional opportunities to fund their ideas through the renewal of the Sears think[box] Student Project Fund and the establishment of the Z-Fund.

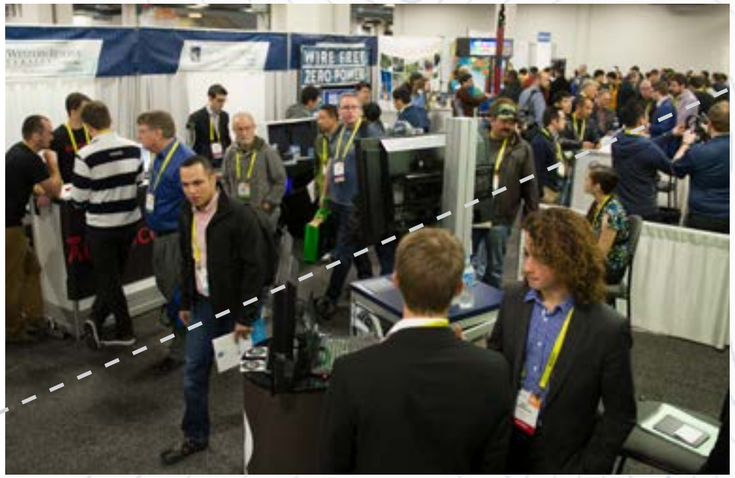
The Sears think[box] Student Project Fund, renewed thanks to the support of the Codrington Foundation, and Fran and Jules Belkin, offers awards up to $2,500 to undergraduate and graduate students. Alumnus and longtime Hyland Software executive Miguel Zubizarreta (CWR '90) built on the support of the Student Project Fund by launching the Z-Fund, which awards annual grants ranging from $2,500 to $25,000 to students to help move their ideas from early-stage prototypes to more fully realized products.

Engineering students Andrew Dupuis and Xyla Foxlin launched **"Beauty and the Bolt," a YouTube channel dedicated to proving anyone can be an engineer**. The channel's high-energy videos and tutorials run the gamut from how-to basics on skills like soldering and sawing for beginners to next-level, don't-try-this-at-home projects that show the full range of what engineering can do, and that there's no one way an engineer should look, act or dress. Check them out at **beautyandthebolt.com**.



Case Western Reserve University alumni are working with faculty mentor João Maia, associate professor of macromolecular science and engineering, to perfect their non-Newtonian-fluid-based pothole patch and pitch their innovation to cities looking to repair pock-marked roads.

NeuroRadVision, imaging software that distinguishes between recurrent brain tumors and benign radiation side effects, won first place in the collegiate division of the Medical Capital Innovation Competition. The software was developed by a team of researchers at Case Western Reserve University led by Pallavi Tiwari, assistant professor of biomedical engineering, and including Anant Madabhushi, the F. Alex Nason Professor II of Biomedical Engineering. Learn more at **engineering.case.edu/NeuroRadVision-innovation-competition**.

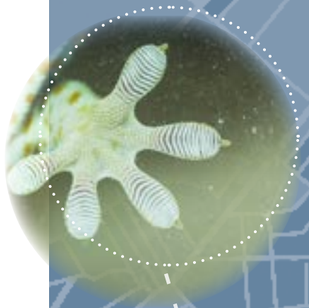


Case Western Reserve University packed 10 booths with student, alumni and faculty startups at CES 2017. Big ideas on display included a sideline test for concussions, a low-cost maker machine, digital hug-transmitting plush toys and more. Learn more at **engineering.case.edu/CES-2017**.

Buzz around Sears think[box] helped drive undergraduate applications to Case Western Reserve University to an all time-record. The university's 50,000-square-foot innovation center was also tapped to **host the 2017 International Symposium on Academic Makerspaces** and was chosen to receive free commercial licenses of the SolidWorks CAD software as a **SolidWorks Incubator site** (joining institutions such as MIT and Northwestern). To date, Sears think[box] and CWRU LaunchNet have supported more than **100 student startups in raising more than $10 million** in external funding and sales.

Because the adhesive holds over such a wide range of temperatures, the inventors say it's a great fit for a variety of applications in environments prone to drastic temperature swings, including use in outer space.

Scientists draw inspiration from nature to create dry adhesive that holds strong in extreme temperatures.



gecko-inspired adhesive

holding strong in extremes

Geckos are natural climbers, and a perfect storm of science gives these little lizards their wall-walking abilities. Gecko toes are specially designed to defy gravity—they're coated with a field of microscopic hairs known as setae and even tinier hairs called spatulae, which are so small that they kick up a molecular-level attraction known as van der Waals forces between the gecko and the surface it's traversing, allowing it to stick sideways and even hang upside down.

Using carbon nanotubes to replicate the microscopic hairs, a team of scientists from Case Western Reserve University led by Liming Dai, the Kent Hale Smith Professor in the Department of Macromolecular Science and Engineering, **developed a dry adhesive that maintains its bonds even in the most extreme temperatures**.

Most adhesives fail in the face of drastic temperature shifts. But the **nanotube-based material developed by Dai and his collaborators stays just as sticky in temperatures as cold as liquid nitrogen or as hot as molten silver**, and it actually gets stickier as things heat up.

Because the adhesive holds over such a wide range of temperatures, the inventors say it's a great fit for a variety of applications in environments prone to drastic temperature swings, including use in outer space. The bonding agent also conducts heat and electricity, which means it could have additional applications in enhancing the performance of electronics at high temperatures.

Learn more at **engineering.case.edu/dry-adhesive**.

MORE DURABLE IMPLANTS:

Improving performance through surface engineering

Cobalt–chromium alloys are frequently chosen for medical implants replacing hips and other load-bearing joints. Recently, however, these alloys have come under scrutiny for adverse effects they may have on human health because of decomposing wear debris.

Researchers in the departments of materials science and engineering, biomedical engineering, and mechanical and aerospace engineering are working together to develop new methods of surface engineering based on low-temperature carburization and low-temperature nitridation to improve implant performance by reducing wear and corrosion.

REAKING THE MOLD:
esearcher Bo Li wins NSF CAREER award
optimize additive manufacturing of metal

Additive manufacturing has the potential to produce complex metal components quickly and cost-effectively, but the resulting parts are often of lower strength and fatigue faster than their traditionally molded counterparts.

Bo Li, assistant professor of mechanical and aerospace engineering, **received a National Science Foundation Faculty Early CAREER Development award** to develop theoretical analysis and computational tools to understand what's going wrong in the process.

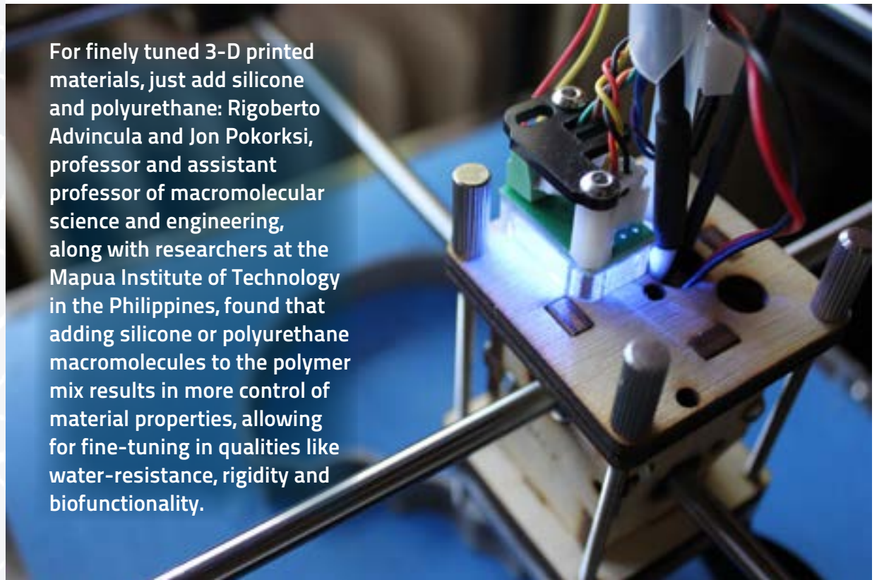
For metals, additive manufacturing typically uses a laser or electronic beam that melts powdered metals on a bed into the shape of the desired part. Li theorizes that multiple variables are at play in causing defects in the microstructure of printed metals, including powder quality, temperature and the speed and pathway at which the laser is fired—making it difficult to pinpoint the problem.

Li's lab will develop analytical tools and numerical simulations to address the multiple conditions in question. By running thousands of simulations concurrently in the design space, Li hopes to predict quantitatively what combinations of metals, processing parameters and more will lead to the optimal product.

Learn more at **engineering.case.edu/CAREER-2017**.

Case Western Reserve macromolecular science and engineering researchers were part of an MIT-lead team of scientists examining how to reduce the number of defective loops in polymer chains. Fewer loops mean stronger polymer networks and more durable materials for manufacturers.

Jon Pokorski and Michael Hore, both assistant professors in the Department of Macromolecular Science and Engineering; Nicole Steinmetz, the George J. Picha Designated Professor of Biomaterials; and Phoebe Stewart, professor of pharmacology at the Case Western Reserve School of Medicine, made the cover of the *Journal of the American Chemical Society*'s March issue with their study "Polymer Structure and Conformation Alter the Antigenicity of Virus-like Particle–Polymer Conjugates," which examined how water-soluble polymers improved the performance of biotherapeutics.



For finely tuned 3-D printed materials, just add silicone and polyurethane: Rigoberto Advincula and Jon Pokorksi, professor and assistant professor of macromolecular science and engineering, along with researchers at the Mapua Institute of Technology in the Philippines, found that adding silicone or polyurethane macromolecules to the polymer mix results in more control of material properties, allowing for fine-tuning in qualities like water-resistance, rigidity and biofunctionality.

MAKING NATIONAL HEADLINES

Huffington Post

"Building a Nation of Makers" article highlights Case Western Reserve University's Sears think[box] among academic innovation centers contributing to advancing the maker movement.

"With innovation, colleges fill the skills gap"

New York Times highlights Case Western Reserve University's minor in applied data science among academic programs developed based on feedback from employers.

Popular Science

"Created by researchers at Case Western Reserve University, the [biohybrid] robot is a pioneer of sorts, an early foray into a kind of biomechanical creature, hopefully one with a longer functional lifespan than purely electric machines."

Student entrepreneur and his concussion-detecting device featured in ***Forbes***.

Case Western Reserve student innovator Matt Campagna shares his experience at CES 2017 on *ideastream's Sound of Ideas*.

National Geographic

"[Mark] Griswold and his colleagues at Case Western Reserve University and Cleveland Clinic set out to design a program for HoloLens that would revolutionise anatomy lessons."

Chicago Sun-Times

"A next-generation artificial hand is letting two amputees tell the difference between a soft or firm touch—like holding a child without squeezing too tightly. It's another step toward developing prosthetics that can feel."

U.S. News & World Report highlights Sears think[box] as a driver of the maker movement.

"Groundbreaking" technology restores movement in paralyzed man

Smithsonian Magazine

"Researchers from Case Western Reserve University and the Cleveland Functional Electrical Stimulation Center revealed a brain implant system that allows a paralyzed man to move his arm and hand with just his thoughts."

CNN

"A man paralyzed from his shoulders down has regained use of his right hand with the aid of an experimental prosthetic that replaces lost connections between the brain and the muscles."

BrainGate clinical trial participant Bill Kochevar using injury-bridging technology developed by a research team led by Case Western Reserve University researchers Robert Kirsch, chair of biomedical engineering, and A. Bolu Ajiboye, assistant professor of biomedical engineering.

Inside Edition

Severely Paralyzed Man Moves Arm With the Power of His Thoughts

NPR

"The system Kochevar uses has taken scientists more than a decade to develop. Yet it's still limited to research labs and depends on wires that penetrate the skull and skin, Kirsch says.
'I think what we've done, though, is shown that we can put this all together and it's feasible,' Kirsch says.
'We can actually record signals from his brain, determine what he's trying to do and make that happen.'"

Engadget

"Researchers used tech to bypass a quadriplegic patient's severed spinal cord, helping him move his own hand with his mind and feed himself without aid."

ABC News

Brain implants help paralyzed man drink coffee on his own for 1st time in years

BBC News

"Bill Kochevar, who was paralysed in a cycling accident, said he was 'wowed' to regain control of his right arm. Researchers say this is the first time anyone has been able to restore brain-controlled reaching and grasping in a person with complete paralysis."

Faculty Accolades

Five Case Western Reserve University faculty members were inducted as **fellows of the American Institute for Medical and Biological Engineering** (AIMBE): **Cenk Cavusoglu,** professor of electrical engineering and computer science; **Jeffrey Capadona**, associate professor of biomedical engineering; **Nicole Steinmetz**, the George J. Picha Designated Professor in Biomaterials; **Dustin Tyler**, the Kent H. Smith Professor of Engineering II; and **Nicholas Ziats**, professor of pathology, biomedical engineering and anatomy.

Ica Manas-Zloczower, Distinguished University Professor and the Thomas W. and Nancy P. Seitz Professor of Advanced Materials and Energy in the Department of Macromolecular Science and Engineering, won the **Fred E. Schwab Education Award from the Society of Plastics Engineers.**

YeongAe Heo

YeongAe Heo, assistant professor of civil engineering, was selected as an **early-career research fellow of the National Academies of Science, Engineering and Medicine's Gulf Research Program**. Heo will use the fellowship to advance her work in preventing hydrocarbon release and other societal and environmental impacts that result from the failure of oil and gas infrastructure systems.

Jennifer L.W. Carter, assistant professor of materials science and engineering, received the **Bradley Stoughton Award for Young Teachers from ASM**.

Eric Baer, Distinguished University Professor and the Herbert Henry Dow Professor of Science and Engineering in the Department of Macromolecular Science and Engineering, received the **James L. White Innovation Award from the Polymer Processing Society**.

Mechanical and aerospace engineering department chair **Robert Gao**, the Cady Staley Professor of Engineering, was **elected to the Academy of Fellows of the International Academy for Production Engineering, known as CIRP,** the French acronym for the organization.

Civil engineering professor **Xiong "Bill" Yu** was elected to **fellowship in the American Society of Civil Engineers**.

From left to right: AIMBE fellows Dustin Tyler, Cenk Cavusoglu, Nicole Steinmetz, Jeffrey Capadona and Nicholas Ziats.

Professor of electrical engineering and computer science **Christian Zorman was elected a fellow of the American Vacuum Society**.

Clare Rimnac, the Wilbert J. Austin Professor of Engineering in the Department of Mechanical and Aerospace Engineering, **received the ORS/ OREF Distinguished Investigator Award from the Orthopaedic Research Society and Orthopaedic Research and Education Foundation**.

Anant Madabhushi, the F. Alex Nason Professor II of Biomedical Engineering, won the **IEEE Engineering in Medicine and Biology Society (EMBS) Technical Achievement Award** and was invited to be a **standing member of the National Institutes of Health Biodata Management and Analysis study section**.

Julie Renner, assistant professor in the Department of Chemical and Biomolecular Engineering, was awarded an **ECS Toyota Young Investigator Fellowship**.

Rigoberto Advincula, professor of macromolecular science and engineering, was **elected to the World Economic Forum Council for the Future of Advanced Materials** and was named **editor-in-chief of** ***MRS Communications***.

Dominique Durand, the Elmer Lincoln Lindseth Professor of Biomedical Engineering, was **elected North American representative to the IEEE-EMBS**.

Kenneth Loparo, the Nord Professor in the Department of Electrical Engineering and Computer Science, was named a **life fellow of the IEEE**.

Alp Sehirlioglu, the Warren E. Rupp Assistant Professor in the Department of Materials Science and Engineering, was appointed an **associate editor for the** ***Journal of the American Ceramic Society***.

STUDENT AWARDS

Graduate students

Mustafa Unal, mechanical and aerospace engineering: **Society for Applied Spectroscopy's Barbara Stull Graduate Student Award**, the **Federation of Analytical Chemistry and Spectroscopy Societies Student Award**, the **Coblentz Student Award and the William G. Fateley Student Award**

Joseph Toth, chemical engineering: **Fulbright Scholarship**

Nathaniel Braman, biomedical engineering: **Terry M. Speth Service Professional Memorial Scholarship for Diagnostic Imaging Research**

Jaqueline Wallat, macromolecular science and engineering: **Baxter Young Investigator Award**

Liz Stricker, chemical and biomolecular engineering: **U.S. Department of Energy Office of Science Graduate Student Research Program Award**

Kristen Van De Voorde and Kristen Wek, macromolecular science and engineering: **National Science Foundation Graduate Research Fellowships**.

Mousa Younesi, mechanical and aerospace engineering: **Society of Biomaterials Student Travel Achievement Recognition Award**

Janet Gbur, materials science and engineering: took office as **president of Microscopy Society of America student council**

Souvik Ghosh, chemical and biomolecular engineering: **2016 John Colburn and Harold Winters Student Award in Plasma Science and Technology**

William Huddleston and Kevin Pachuta, materials science and engineering: **second and third place student paper awards**, respectively, at the eighth **Electronic Materials and Applications Meeting**

Undegraduates

Michaela Cooley, senior, biomedical engineering: **Society for Biomaterials Drug Delivery Special Interest Group Student Research Award**

Evan Rose, junior, mechanical and aerospace engineering: **won the 2016 Ken Souza Memorial Research Competition**

Jamie Yu, junior, biomedical engineering: featured on **the "Women Who Reign IT"** *Medium* **account**

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Provost and Executive Vice President
Professor of Materials Science and Engineering

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Associate Professor,
Electrical Engineering and Computer Science

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Professor,
Electrical Engineering and Computer Science

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Vice Dean, External Relations
Associate Vice President, Engineering and Global Development, Case Western Reserve University

Cena Hilliard
Associate Dean, Finance and Administration

Christine Coolick
Assistant Dean,
Marketing and Communications

Deborah J. Fatica
Assistant Dean,
Division of Engineering Leadership and Professional Practice

AS OF SEPT. 1, 2017

Biomedical Engineering

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Chair and Allen H. and Constance T. Ford Professor of Biomedical Engineering

Colin Drummond
Assistant Chair and Professor

Abidemi Bolu Ajiboye
Assistant Professor

Eben Alsberg
Professor

James M. Anderson
Distinguished University Professor

James P. Basilion
*Professor**

Jeffrey R. Capadona
Associate Professor

Dominique Durand
Distinguished Research Professor and Elmer Lincoln Lindseth Professor of Biomedical Engineering

Steven J. Eppell
Associate Professor

Miklos Gratzl
Associate Professor

Kenneth J. Gustafson
Associate Professor

Efstathios "Stathis" Karathanasis
*Associate Professor**

Zheng-Rong Lu
M. Frank Rudy and Margaret Domiter Rudy Professor

Anant Madabhushi
F. Alex Nason Professor II

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Distinguished University Professor and Donnell Institute Professor of Engineering

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Professor

Gerald M. Saidel
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Viswanath Satish
*Assistant Professor**

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Elmer Lincoln Lindseth Associate Professor of Biomedical Engineering

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Associate Professor

Sam E. Senyo
Assistant Professor

Nicole F. Steinmetz
*George J. Picha Designated Professor in Biomaterials**

Pallavi Tiwari
*Assistant Professor**

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Kent H. Smith Professor of Engineering II

Horst von Recum
Professor

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Robert J. Herbold Professor

Xin Yu
Professor

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Rohan Akolkar
F. Alex Nason Associate Professor and Ohio Eminent Scholar for Advanced Energy Research

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Burcu Gurkan
Assistant Professor

Uziel Landau
Professor

**School of Medicine campus*

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Syed Qutubuddin
Professor

Julie Renner
Assistant Professor

R. Mohan Sankaran
Leonard Case Jr. Professor of Engineering

Robert Savinell
Distinguished University Professor and George S. Dively Professor of Engineering

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Assistant Professor

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Michael Pollino
Associate Professor

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Assistant Professor

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Professor

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Instructor

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Huichun "Judy" Zhang
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Jing Li
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Vira Chankong
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Harold Connamacher
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Assistant Professor

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Associate Professor

Ming-Chun Huang
Assistant Professor

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Mehmet Koyuturk
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Vincenzo Liberatore
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Professor

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Kent Hale Smith Professor

Michael J.A. Hore
Assistant Professor

Hatsuo "Ken" Ishida
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LaShanda T.J. Korley
Climo Associate Professor

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Lei Zhu
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Associate Professor

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Kiju Lee
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Bo Li
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Vikas Prakash
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Roger D. Quinn
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Wilbert J. Austin Professor of Engineering

James S. T'ien
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Fumiaki Takahashi
Professor

Chris Yingchun Yuan
Associate Professor

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Gregory S. Lee
Assistant Professor, Electrical Engineering and Computer Science

The Case School of Engineering has a proud 125-year history as one of America's top engineering schools. We are innovators and educators—tackling the world's most challenging engineering problems through groundbreaking research while balancing a rigorous academic curriculum with ample experiential learning opportunities that bring those lessons to life for tomorrow's engineers. More than 100 full-time faculty represent the best minds in their fields, and our students are among the brightest and most ambitious in the nation.
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Departments

Biomedical Engineering
Chemical and Biomolecular Engineering
Civil Engineering
Electrical Engineering and Computer Science
Macromolecular Science and Engineering
Materials Science and Engineering
Mechanical and Aerospace Engineering

Bachelor of Science in Engineering (BSE)

Available majors:
Aerospace Engineering
Biomedical Engineering
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical Engineering
Engineering Physics
Materials Science and Engineering
Mechanical Engineering
Polymer Science and Engineering
Systems and Control Engineering
Bachelor of Science in Engineering without designation

Bachelor of Science (BS)

Available majors:
Computer Science
Data Science and Analytics

Master of Science (MS)

Available majors:
Aerospace Engineering
Biomedical Engineering, with optional specialization in Translational Health Technology or Wireless Health
Chemical Engineering
Civil Engineering
Computer Engineering
Computing and Information Science
Electrical Engineering, with optional specialization in Wearable Computing or Wireless Health
Macromolecular Science and Engineering, with optional specialization in Fire Science and Engineering
Materials Science and Engineering
Mechanical Engineering, with optional specialization in Fire Science and Engineering
Systems and Control Engineering
Undesignated

Master of Engineering (ME)

Master of Engineering and Management (MEM)

Doctor of Medicine/Master of Science in Biomedical Engineering (MD/MS)

Doctor of Philosophy (PhD)

Available majors:
Aerospace Engineering
Biomedical Engineering
Chemical Engineering
Civil Engineering
Computer Engineering
Computing and Information Science
Electrical Engineering
Macromolecular Science
Materials Science and Engineering
Mechanical Engineering
Systems and Control Engineering

Doctor of Medicine/Doctor of Philosophy (MD/PhD)

Available majors:
Biomedical Engineering
Mechanical Engineering

Centers and Institutes

Advanced Manufacturing and Mechanical Reliability Center
Advanced Platform Technology Center
Case Metal Casting Laboratory
Center for Advanced Polymer Processing
Center for Advanced Science and Engineering for Carbon
Center for Biomaterials
Center for Computational Imaging and Personalized Diagnostics
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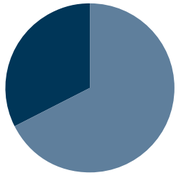
Great Lakes Energy Institute
Institute for Advanced Materials
Magnetic Materials Characterization Laboratory
Materials for Opto/Electronics Research and Education (MORE) Center
Microfabrication Laboratory
Neural Engineering Center
Nitinol Commercialization Accelerator
NSF Center for Layered Polymeric Systems (CLiPS)
Rapid Solidification Laboratory
Sears think[box]
SDLE Research Center
Swagelok Center for Surface Analysis of Materials
The Institute for Management and Engineering
Wind Energy Research and Commercialization Center
Yeager Center for Electrochemical Sciences

Student Enrollment Fall 2017

2,238 Total*



757
Graduate and professional-degree students

1,481
Declared undergraduate engineering students

*In addition, 723 undergraduate students expressed interest in engineering majors but are not expected to declare majors until the end of their sophomore year.

FY 2017 Full-time faculty

124

Total revenue

$108.1 million

Research, training and grant revenue

$50.2 million

Fundraising FY 2017

Total: $51.2 million

In FY2017, the Case Alumni Foundation/ Association provided $2.4 million from annual and endowed gifts to the Case School of Engineering.

Technology Transfer

In FY2017 Case School of Engineering faculty contributed to:

- 95 invention disclosures—4.97 times the national per-dollar proficiency average*
- 175 patent applications—9.94 times the national per-dollar proficiency average*
- 15 deals with industry—2.4 times the national per-dollar proficiency average*
- 4 startup companies —4.17 times the national per-dollar proficiency average*

*AUTM U.S. Licensing Activity Survey, FY15 (latest data available)

U.S. News & World Report rankings

50th
for engineering graduate schools*

40th
for undergraduate engineering programs**

18th
for graduate biomedical engineering programs*

14th
for undergraduate biomedical engineering programs**

*published spring 2017

**published fall 2017

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Additional Photography:
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Every effort has been made to ensure the accuracy of this report. If you have any questions or concerns, please contact Christine Coolick, assistant dean of marketing and communications, Case School of Engineering, Case Western Reserve University, 10900 Euclid Ave., Cleveland, Ohio 44106-7220; 216.368.8694; cmc174@case.edu.

UMC_3265-2017