THE ENGINEER'S LENS
2017-18

CASE SCHOOL OF ENGINEERING

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CASE WESTERN RESERVE
UNIVERSITY

THE ENGINEER'S LENS

Annual Report 2017-18

SEEING THE WORLD THROUGH THE **ENGINEER'S LENS**

As engineers, we're aware that we see the world differently. We don't simply marvel at feats, we learn from them—we dig in and investigate how they're accomplished and use what we've learned to create better solutions to the problems we're tackling.

We don't simply wonder, "what if?" or "wouldn't that be nice?" We get tactical—we measure the distance we are from the goal and set up strategies to bring us closer. We have confidence that each idea can be brought to life with the right amount of care, attention and persistence.

We don't become dissuaded by failure. We wear each misstep as a badge of honor, knowing it helps us better frame the right solution.

This lens through which we view the world is one of our greatest strengths. Here at the Case School of Engineering, it allows us to usher in the new era of connected devices via the IoT, it guides us through the creation of more personalized medical care through deep-learning computer algorithms, it encourages us to look up toward the future of electric air vehicles, and it shows us the way to better develop and inspire the next generation of innovators.

I invite you to explore the world we see through our lens—it's one of perseverance, dedication and a deep desire to make this world a better place for everyone.

Venkataramanan "Ragu" Balakrishnan
Charles H. Phipps Dean, Case School of Engineering
Case Western Reserve University

LEADING THE IOT

Meet Nick Barendt, Internet of Things (IoT) expert and champion, and inaugural executive director for Case Western Reserve's Institute for Smart, Secure and Connected Systems (ISSACS). Get inspired by how he's planning to lead the university's vision for industrial IoT innovations.

What are your primary charges and goals as ISSACS executive director?

I'm focused on fostering collaborations across the university and with our external partners—those in industry, nonprofit groups, economic development organizations and other community conversations. I'm also here to help increase research grant proposals in this space. I'm also working with our peers at Cleveland State University and other partners on the IoT Collaborative (read more about the collaborative, a partnership between CWRU and CSU supported by the Cleveland Foundation, on page 7). In that space, I'm helping provide alignment and collaboration around all of the region's various IoT initiatives.

What is your background?

I'm a Case electrical engineering and computer science double alum. After graduating, I worked at Nordson in the electronics industry. I then spent time in the test and measurement world, and then went out and did some startups and consulted, where I developed expertise in elements of the cloud infrastructure and deployment. Then I became a partner at the software firm LeanDog and led the design and delivery studio. I've also been an adjunct faculty member at Case School of Engineering for a while and have developed and been teaching a course on the IoT (read more on page 6).

What attracted you to the ISSACS executive director position?

I think ISSACS is, in many ways, a startup in a really interesting area. There's this convergence of technology—the IoT is a big tent of technology, from digital transformation to engineering and software disciplines. But without the other aspects of business, law, medicine, social science and other areas where these technologies are deployed, we're only solving a technical problem. That's why we're focused on a technology-plus approach—with this convergence of medicine and technology, or business and technology, we are going to see some amazing things happen in the next few years. I'm fascinated by the way ISSACS is approaching this—developing really broadly rounded teams from a convergent research topic area.

What's an example of this in action?

We recently met with GE Lighting to discuss taking the campus's Nord Greenway space, which GE Lighting is providing the lighting for—including donating their LightGrid node technology so that together we can turn that space into an IoT living lab. And by that I mean we're thinking about the societal, neighborhood and community pieces along with the technology. In a traditional lighting approach, you would install lighting on poles to brighten a walkway. Perhaps in the modern era, you would use LED lighting to be more energy-efficient. But from a community engagement standpoint, you could set up a lighting network that is capable of decreasing brightness when the lights aren't needed in order to decrease light pollution. At the same time, you can build a network infrastructure to deploy other sensing technologies such as air quality monitoring, noise, things like that. GE is interested in continuing to develop smarter lighting, and we're excited to partner with them to do so.

How is Northeast Ohio, with its roots in manufacturing, positioned to be a leader in this space? Why here?

We know how to make things, right? Whether it's automotive or welding machines or durable goods or medical devices, we know how to make things at scale. We have the manufacturing and supply-chain capabilities. The piece that might be missing is we need broader talent in this area to help traditional manufacturers begin to think about how to adapt their products to move from selling a thing—which becomes a commodity—to selling a thing plus value-added services, to selling an outcome model.

How does a university play a role in the advancement of the IoT sector?

A university is very focused on training the next generation of engineers, scientists and business leaders—creating that talent pipeline to support these industries. There's also research opportunities to work with industry partners that wouldn't fit into a consultant's typical area of expertise, that are too cutting-edge from a technical standpoint or are too niche that the expertise doesn't exists outside of the university's walls. Universities are here for the long haul. It's one of the critical assets of a region, a research university's capabilities, because of that long tenure.

ISSACS is focused more on industrial applications of the IoT. What does that mean and how is that different from commercial applications?

The consumer side—your Nest thermostat, your Fitbit—those are great and impactful. But the industrial IoT, the IIoT, which we would describe as things in industry: manufacturing, health care, energy and smart cities and infrastructure—the economic impact of those areas dwarfs the consumer IoT opportunity by a factor of two or more. What it means to deploy these technologies for health care in the hospital or home health care—assistive technologies to allow senior citizens to remain at home but still be connected to the health care system via remote capabilities—or in factories for increased automation capabilities, the economic impact is enormous. As we think about replacing and augmenting our aging infrastructure in the U.S. and around the world—our water systems, roads, bridges—they all have huge opportunity areas for the IIoT.

What projects with regional partners is ISSACS engaging with currently?

We've had conversations with the Ohio Turnpike Commission as they are rolling out their smart, connected system on a section of the turnpike to help them with some of their challenges. We're also talking with the Cleveland water department about smartly tackling water loss. ISSACS and Cleveland State are also involved in conversations with [Cleveland-based business incubator] BioEnterprise and a number of other organizations around the opioid crisis and how we can integrate disparate pools of data to identify opportunities for intervention. Those are just a few of the fascinating conversations we've had in the last few weeks. There's so much potential here.

What gets you the most excited about ISSACS and IoT opportunities?

There's so much; many of the technology pieces are really cool. But then looking at the opportunities from an economic development standpoint for Northeast Ohio, for the university's convergent research area to grow our research capabilities doing really cool, cutting-edge work with high impact in health care, manufacturing and social sectors is really exciting to me. That idea that we'll be generating startups out of a lot of this work in the next few years, there's student entrepreneurial opportunities in here, I find that really exciting.

LIGHTING THE FUTURE OF THE IOT

From your smartphone or from any internet-connected computer, or from an Amazon Cloud app, you can turn on the desk lamp sitting in your home or office, swipe across a slider to adjust its hue—red, orange, yellow, green, blue or purple—and adjust its brightness. With its connectivity, you can check these levels while you're away from the house to see if a family member has adjusted the lighting locally. You can even plug in a camera or set a loop for the light to dim and brighten on a schedule.

Would you ever actually need to do any of this? Likely not. But the multi-chromatic, touchscreen-sporting, small tabletop lamp, rocking a 3-D printed shade, and lovingly referred to as "the world's most over-engineered lamp," isn't really about building and remotely controlling a lamp. It's at the center of the jointly offered EECS 377 technical elective course "Introduction to Connected Devices," which shows students how to harness the power of the Internet of Things (IoT).

The course is a robust, comprehensive survey of what it takes to design and build a device that is connected to the internet: everything from the hardware to the behind-the-scenes code to the touch-screen interface of the user is covered in this undergraduate course that is jointly offered to Case Western Reserve and Cleveland State students—part of the partnership between the two universities via the IoT Collaborative.

"We're covering it all, from user experience and design to getting something on Amazon Cloud to HTML templates to analytics, load testing, firmware updates, security, mobile development, Bluetooth Low Energy and everything in between," said course co-instructor Nick Barendt (see page 4), who team-teaches the class with Nigamanth Sridhar, dean of the College of Graduate Studies at Cleveland State. The class's centerpiece lamp offers an approachable and manageable way to break down the sometimes daunting subject matter of connected technology and to get students thinking about systems-level properties. "Is the device secure? Or can someone hack in and change the color of your lamp light," said Barendt. "Is your system scalable—can 10,000 users log on at once? One million? And what about capturing user data—which interface do they use most frequently, which color light do they prefer and what brightness?"

The class offers the students hands-on lessons for each step along the way and allows them to synthesize those individual learning components into the whole system. Barendt developed the comprehensive course with colleagues at LeanDog and because it covers the spectrum of a multidisciplinary team at a real-world software firm, the syllabus crams a lot in.

But the students thrived on the rapid pace of the content and challenges and couldn't wait to integrate even more functionality. For their final project for the course, students created their own next-gen for the lamp: everything from making it function with Google Home and Alexa to having the light change color when your bus is close to your stop.

"On the last day of class, I had so many students come up to me and say 'This was the most amazing class I've ever taken,'" said Barendt. "That means a lot to me. That means we're doing a good job of training the next generation of tech leaders."

Case Western Reserve and Cleveland State universities launch IoT Collaborative

A $1.75-million Cleveland Foundation award to the two institutions helps advance the industrial Internet of Things

Case Western Reserve and Cleveland State universities have combined their expertise in data science, systems engineering and public policy to focus on turning Northeast Ohio into the capital of the industrial Internet of Things (IoT).

With a $1.75 million grant from the Cleveland Foundation to establish the IoT Collaborative, the universities aim to transform the region into a national model of collaboration, research, technology transfer, workforce development and community infrastructure in the industrial IoT space.

According to the initiative's leaders, Cleveland's strong manufacturing resources, thriving health care sector and booming startup landscape make it well-positioned to lead innovations in IoT in manufacturing, energy, infrastructure and health.

Research endeavors are already underway across these four focal pillars, from examining how implementing a smart-grid could drive economic growth in Cleveland, to efforts to improve infrastructure monitoring and traffic flow, to advancing tele-health capabilities. On the manufacturing front, Robert Gao, the Cady Staley Professor of Engineering and chair of the Department of Mechanical and Aerospace Engineering, is leading an NSF-funded effort to help small- to mid-sized manufacturers adapt to IoT connectivity.

This latest grant in 2018 brings the Cleveland Foundation's support of the collaborative to more than $2 million, which will help attract top academic talent, create research labs and establish an organizational infrastructure.

The collaborative links Case Western Reserve's Institute for Smart, Secure and Connected Systems (ISSACS) with Cleveland State's Center for IoT Innovation (CITI). ISSACS leverages Case Western Reserve's strengths in sensors and electronics, networks and communications, systems and control, data science and analytics, which complements Cleveland State's expertise in public policy, law and urban studies.

Learn more at case.edu/issacs.

A Diagnosis Right at Hand—and Up in the Cloud

One drop of blood. Taken by a physician with a point-of-care device, which instantly processes the sample so the physician and patient can discuss the results moments after the test is taken. A treatment plan and follow-up appointments are scheduled—reminders are texted to the patient.

No transferring samples to labs. No waiting. No need to track a patient down days or even weeks later to discuss the results. And no paper files. Through a wirelessly connected device, the results are recorded in a cloud-based, centralized, nationwide database of medical records to be accessed by both physician and patient, as well as to analyze population trends and treatment success.

That's the vision Umut Gurkan, assistant professor of mechanical and aerospace engineering, has for diagnosis and treatment protocols in so-called "mobile-first" nations—places like Nigeria, Uganda, India and Thailand that have leap-frogged over traditional desktop-computer-based systems and wired networks to do the majority of their work and connectivity exclusively on mobile phones and other wirelessly connected devices. These places often do not have the infrastructure in place to replicate the United States' centralized lab model for disease diagnosis.

Gurkan is the inventor of a point-of-care device that can rapidly screen for sickle cell disease and other hemoglobin disorders, which are currently one of the greatest health care challenges in many parts of Africa and Asia. His test is able to wirelessly connect to a cloud database, where disease metrics can be tracked. Such a system deployed in the field would allow a doctor instant access to results for patients, continue communications with them for follow-up care through mobile phones, and minimize the need for any paper files. Gurkan has already tested the efficacy of his test in the United States, Nigeria, Uganda, India and Thailand.

With the help of a National Institutes of Health (NIH) R21 grant, Gurkan is working with the University of Nebraska on the next step—to develop and link the point-of-care device to a universal electronic medical record that can be used across an entire country. In collaboration with eHealth Africa, they are working on a pilot program in Kano State in Nigeria, where the burden of sickle cell disease is the highest in the world.

At the same time, he's worked with a team to combine the sickle cell point-of-care diagnosis device with a similar system for detecting malaria, also developed at Case Western Reserve by School of Medicine assistant professor of international health Brian Grimberg. The rapid malaria detection device—called the Magneto-Optical Detector (MOD)—requires only one drop of blood for an instant malaria diagnosis. Both technologies have been licensed by Hemex Health, which has combined them into one platform to simultaneously assess patients for both diseases. The University of Nebraska, the International Foundation Against Infectious Disease in Nigeria and eHeath Africa are collaborating on the project. The combined remote diagnostic system—called SMART (Sickle and Malaria Accurate Remote Testing)—is capable of uploading results to a centralized cloud-based electronic medical record to track and monitor patients over time. This data collection may help researchers better understand the relationship between these two diseases. Gurkan is also working to expand the test to include screening for diabetes as well.

Gurkan received a planning grant from Case Western Reserve's Institute for Smart, Secure and Connected Systems (ISSACS) that enabled him to organize workshops and meetings, and collect the preliminary data needed to apply to the Vodafone Americas Foundation Wireless Innovation competition—where the SMART platform won first prize.

Learn more at hemexhealth.com/smart.

Electrical Engineering and Computer Science's **Xusheng Xiao** received a National Science Foundation (NSF) grant to enhance mobile app security.

A REAL UPDATE FOR A VIRTUAL WORLD

The Virtual Worlds Lab within the Department of Electrical Engineering and Computer Science got a real-world update and expansion this year, thanks to the generous support of alumnus **Kevin Kranzusch (CWR '90)**.

The University of Akron, Ocius Technologies and Case Western Reserve received a **$1.5 million grant** from the Defense Advanced Research Projects Agency (DARPA) to explore how computationally intensive engineering and physics problems can be more rapidly solved using new types of analog computers. Case Western Reserve's **Soumyajit Mandal** has joined the research team for the phase II award, following a successful phase I effort that explored analog co-processors with a focus on simulation and design.

A DIFFERENT KIND OF TECH SUPPORT

Case School of Engineering's efforts in the digital domain were bolstered by generous alumni support this year, including a gift from double alumnus and craigslist founder **Craig Newmark (CIT '65, GRS '77, computer science)**, who pledged $100,00 to help launch a new Women in Tech initiative at his alma mater that concentrates on providing resources and networking opportunities to female students interested in computer science.

Alum **Tom Baker (CIT '64)** provided $20,000 to refresh the 56-seat Nord computer lab with Dell's latest thin clients—lightweight computers that connect to virtual desktops, letting users log into their personalized accounts and access their files anywhere, while allowing the operating system and software to be securely and consistently updated remotely.

Tien-Li Chia (GRS '85, systems and control engineering), president of ControlSoft Inc., gave $40,000 to the school's Institute for Smart, Secure and Connected Systems (ISSACS) to bolster the initiative's IoT endeavors.

And **Bob Herbold (GRS '68, computer science)**, alum and former Microsoft COO, who has previously given more than $4 million in support of digital endeavors at the school, has endowed a fellowship for Case Western Reserve undergraduate students to continue at the institution to pursue their master's degree in computer science.

Case Western Reserve, Cleveland State and Mercyhurst universities have formed the **North Coast Cyber Research and Training Alliance** to develop cybersecurity education, research and training programs in Northeast Ohio and western Pennsylvania.

127 new devices globally connect to the internet every second

There were 3.8 billion IoT devices in 2014; **34 billion devices** are forecasted to be connected to the internet worldwide by 2020

<1% of data captured is used by decision makers

Industrial IoT (IIoT) will dwarf consumer IoT applications by **2-3x**

up to **$11 trillion** will be spent worldwide on IoT solutions by 2025

TAKING ON THE IOT

The Internet of Things (IoT) is the network of billions of physical devices that contain embedded technology to communicate with each other and interact over the internet. It includes factory automation and technology that monitors agricultural production, transportation, utility infrastructures and even patients remotely.

100% of industrial manufacturers say IoT is key to drive digital business transformation

BUT

66% of organizations think they aren't moving fast enough regarding IoT

AND

only 33% have a holistic IoT strategy in place

Connected to industry, including engagement with **38 alumni** serving on our Silicon Valley advisory group, who work at companies like Google, Apple, Y Combinator, NVIDIA and Yelp, as well as serial technology entrepreneurs and academics

Institute for Smart, Secure and Connected Devices (ISSACS)

Case Western Reserve created the Institute for Smart, Secure and Connected Systems (ISSACS) in 2016 to empower faculty, students and partners to conduct research and catalyze breakthroughs in the IIoT space. The institute leverages the university's strengths in basic science and engineering, as well as health-oriented fields, business, humanities and social sciences. It leads initiatives in data science, cybersecurity, networks, embedded systems and more.

$8 million+ raised in faculty endowments since 2016

51 Case Western Reserve faculty members

6 initial research pilot projects have been funded via ISSACS to drive IoT innovations, including point-of-care medical devices and smart fire fighting

4 main research thrusts:

ENERGY | HEALTH | MANUFACTURING | INFRASTRUCTURE/ SMART CITIES

IoT Collaborative

To further extend the impact and the pace of breakthroughs in the industrial IoT (IIoT), Case Western Reserve and Cleveland State universities have partnered to launch the IoT Collaborative (IOTC) in 2018—combining their expertise to turn Northeast Ohio into the capital of the IIoT.

Nearly $2M in funding from the Cleveland Foundation

Nearly $1M in grants and $12M in philanthropic gifts

Collaborating with **36 companies**

3 demonstration projects underway:

- Utilizing ground penetrating radar to monitor subsurface utilities
- Collaborating with Cleveland's Hough neighborhood to identify their greatest community needs and explore IOT solutions
- Pooling data to identify interventions in the opiod crisis

Cited data sources can be found at engineering.case.edu/report-17-18-data-sources.

MACHINE-GUIDED PRECISION MEDICINE

Biomedical engineering researchers are using machine-learning algorithms and clinical imaging scans to improve diagnosis and guide better treatment plans for a range of diseases, from cancer to heart failure to Alzheimer's.

Mankind and machines have come a long way since Archimedes rocked the ancient Greek world by experimenting with pulleys and levers. Our tools are more sophisticated than ever—driven by computing power that has, by some estimates, seen a trillion-fold increase since the advent of the first computers in the mid-1950s.

Add the proliferation of big data and large numbers of imaging studies to the mix, and the environment is ripe for a new generation of smart machines capable of helping human users in unprecedented ways. Biomedical engineers at Case Western Reserve University are looking to pack that high-tech toolkit with a fleet of machine-learning algorithms that can help clinicians make more accurate diagnoses and guide more effective treatment plans.

DATA-DRIVEN DIAGNOSES

Simply put, machine-learning and deep-learning computer programs recognize patterns in imaging scans and make predictions based on that information, says Anant Madabhushi, the F. Alex Nason II Professor of Biomedical Engineering at Case Western Reserve and director of the university's Center for Computational Imaging and Personalized Diagnostics (CCIPD).

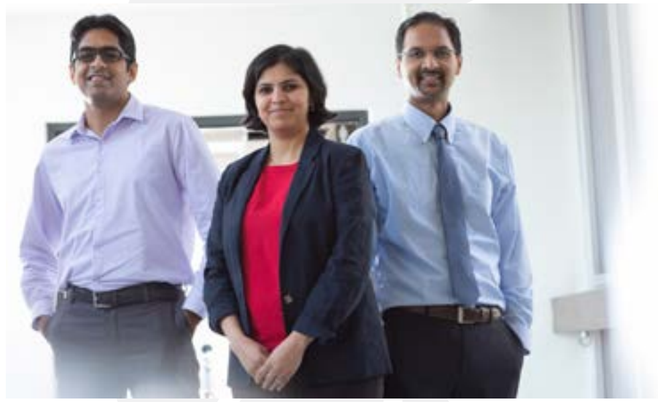
Madabhushi and his center are pioneering the use of these programs in health care, applying their predictive power to better diagnose and treat a whole host of diseases.

The researchers **build their algorithms based on data from routinely acquired medical images, typically MRI or CT scans or digitized tissue slides**, which they say contain a treasure trove of information invisible to the human eye.

Some conditions are notoriously tricky to identify based on images alone. For instance, **97 percent of lung nodules are benign, Madabhushi says, but it's difficult for radiologists to tell harmless nodules from tumors** based on the visual information from a scan.

"So you err on the side of caution," he says. "You order additional tests like follow-up CT scans and biopsies —it's expensive and invasive." By identifying quantitative patterns, he says, these decision tools could help radiologists do a better job differentiating these very similar-looking pathologies.

Similarly, radiation necrosis in the brain—a benign condition that results from radiation treatment—is nearly impossible to visually distinguish from a recurrent brain tumor on routine imaging. Pallavi Tiwari, CCIPD member and assistant professor of biomedical engineering, has developed an algorithm that outperformed expert clinicians in telling the difference. On their own, the two **neuroradiologists in the original study accurately diagnosed cancer about 50 percent of the time. But when they teamed up with Tiwari's algorithm, they spotted 95 percent of cancer recurrences**.



SATISH VISWANATH, PALLAVI TIWARI AND ANANT MADABHUSHI

"If you can know upfront what's going to work best for the patient, at every step, you are personalizing the treatment plan. That's where these programs are going to have the biggest impact."

-PALLAVI TIWARI

While these diagnostic programs are sometimes framed as competitors for their human counterparts, Tiwari's study highlights the power of the human-machine combo. "You can't teach computers everything," she says. **"But if we can bring human experience together with what computers can do, it's a powerful combination."**

In collaboration with clinicians at Cleveland Clinic this year, Tiwari received a three-year $200,000 grant from the Dana Foundation. She also received a $577,000 Department of Defense grant to continue testing and validating the algorithm's performance on multi-institutional studies.

The center's growing army of algorithms is not limited to cancer. Researchers published a study this year in *PLOS ONE* documenting an algorithm's 97-percent accuracy in predicting pending heart failure, and they're applying the approach to diagnosing Alzheimer's earlier and predicting the progression of kidney disease.

THE RIGHT TREATMENT, RIGHT AWAY

The ability to predict a disease's aggression level is just as critical as making a quick, accurate diagnosis in the first place, Madabhushi says.

This year, the center secured grants of more than $6 million from the National Cancer Institute and almost $2 million from the Department of Defense to support developing algorithms to predict the aggressiveness of lung, prostate and brain, as well as head and neck cancers. The center is collaborating with Cleveland Clinic, University Hospitals, the Louis Stokes VA Medical Center, and also industry partner Inspirata Inc.

And, with funding from the U.S.–India Science and Technology Endowment Fund, the center is partnering with the Tata Memorial Centre in Mumbai to develop a predictive algorithm based on digitized tissue slides to help identify aggression in breast cancer to determine which patients will benefit from chemotherapy and which will not.

By predicting success based on solid, quantitative information, doctors can put patients on the right treatment track from the start, according to Satish Viswanath, center member and assistant professor of biomedical engineering. Viswanath specializes in applying predictive image analysis approaches to gastrointestinal diseases like colorectal cancers and inflammatory bowel conditions like Crohn's disease.

"For instance, in Crohn's, therapies right now follow a stepped approach," he says, as doctors gradually ramp up the level of intervention as the disease progresses. "In aggressive disease presentations, you have a disease that's progressing while the more conservative treatment isn't helping. If you can tell who will benefit from more aggressive therapy up front, you can skip unnecessary and unhelpful treatments and improve the patient's outcome."

The researchers' ultimate goal is to create a more precise approach to health care. For many diseases, **lack of predictive guidance forces doctors to take a "kitchen sink" approach to treatment, Madabhushi says, in which the same treatment plan is applied across the board**, leaving clinicians to react if it's not effective. Precision medicine can be more proactive, personalized and informed.

"If you can know upfront what's going to work best for the patient, at every step, you are personalizing the treatment plan," Tiwari says. "That's where these programs are going to have the biggest impact."

Learn more about the center's work at **engineering.case.edu/ccipd**.

HEALTH HIGHLIGHTS

Case Western Reserve will be able to ramp up its research initiatives in computational imaging, machine learning and personalized medicine thanks to a pair of generous alumni. **Jayendra (Jay)** (GRS '84, computer engineering) and **Harita Patel** (GRS '83, computer engineering) committed $500,000 to the university's Center for Computational Imaging and Personalized Diagnostics, led by Anant Madabhushi, the F. Alex Nason Professor II of Biomedical Engineering.

The California couple—who met at the Case School of Engineering in graduate school before going on to successful careers at Apple—have long been supporters of Madabhushi's work, which uses predictive algorithms built on routinely acquired medical images to more quickly diagnose and predict response to treatment for a host of diseases, from cancers to heart failure to Alzheimer's and more. (Read more about the center's efforts on page 12). Thanks to their gift, the center will be able to expand its research into new disease areas.

Dustin Tyler, the Kent H. Smith Professor of Biomedical Engineering, and post-doctoral researcher **Emily Graczyk** conducted the first known study of how amputees use advanced sensory-enabled protheses at home—subjects reported stronger feelings of social connection and an improved sense of well-being.

Seven promising pieces of biomedical engineering technology took a step closer to commercialization with the help of funding from the university's **Case-Coulter Translational Research Partnership**. More than $1.1 million was awarded to support the following projects:

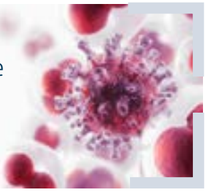
- A molecular imaging agent for surgical resection of invasive brain tumors
- A decision support tool for lung nodule risk prediction on screening CT
- Point-of-care device for monitoring and diagnosing oral cancer
- A minimally invasive direct current nerve block
- An ablation catheter with imaging for better treatment of atrial fibrillation
- Point-of-care device for diagnosis of cystic fibrosis in newborns
- Oropharynx appliance to maintain airway patency

Consider it a blow to the idea of multi-tasking: **Roberto Fernández Galán**, assistant professor of electrical engineering and computer science, discovered a new pattern in neural activity that shows that as some brain networks speed up, others slow down—suggesting that not all of the brain's networks can operate at once.

Buzzworthy: Biomedical engineering researchers found unlikely inspiration for a new technique to more successfully place neural implants: the mosquito. Rigid, metallic devices can sometimes damage soft, sensitive tissue. But the means by which these pests bite their victims could hold the secret to smoother insertion, according to post-doctoral researcher **Andrew Shoffstall** and Associate Professor **Jeffrey Capadona**.

Researchers received a $1.8M grant from the **Department of Defense** to develop an implantable muscle stimulator to improve muscular health and prevent atrophy-related pressure ulcers and deep tissue injuries that can affect patients with spinal cord injuries.

A new MRI contrast agent that pinpoints breast cancers early and differentiates between aggressive and slow-growing types was developed by **Zheng-Rong Lu**, the M. Frank Rudy and Margaret Dormiter Rudy Professor of Biomedical Engineering.



Student teams in a first-year seminar class about engineering solutions for resource-challenged communities built six solar-powered phototherapy devices designed to treat jaundice in off-the -grid villages.

What if we could stop pain at the source? Researchers at Case Western Reserve received a $2M grant from the NIH to refine the pain-management component of the electric nerve-block device they've developed, and to investigate how the technology could be used to treat asthma and heart failure.

Dominique Durand, the Elmer Lincoln Lindseth Professor of Biomedical Engineering, developed carbon nanotube yarn electrodes capable of recording neural activity. These biocompatible wires could help advance electroceutical treatments, which aim to sidestep unwanted side effects by monitoring and manipulating individual nerves.

Sixteen future field-leading scholars began their journey toward earning their PhD in biomedical engineering thanks to the generous support of **Robert (CIT '52) and Brenda Aiken.**

The couple launched the Aiken Strategic Initiative last year with a $20 million gift. In addition to supporting translational research to help move promising discoveries toward clinical use, the Aiken's gift provided support for graduate student fellowships. The first 16 Aiken fellows started their programs this year, contributing to the cutting-edge research happening in labs across campus exploring novel MRI techniques, tissue engineering, computational pathology and more.

Biomedical Engineering's **Eben Alsberg** developed a tissue engineering technique that coaxes a patient's own stem cells to assemble into stackable rings that could be used to build artificial tracheas.

ADVANCING POINT-OF-CARE TECHNOLOGY

Researchers at Case Western Reserve are leading the charge to make health care quicker, cheaper and more personalized.

Point-of-care (POC) devices allow physicians to perform tests, make diagnoses and monitor patients in person in a matter of minutes, skipping the lab and the lag time.
These devices have the potential to dramatically improve the delivery of care in countries with localized medical systems where a lack of infrastructure complicates the flow of care.

There are currently no FDA-approved POC devices for monitoring patients with a spectrum of blood coagulation disorders.

CLOT CHIP

developed by engineering's **Pedram Mohseni**, detects blood clotting ability 95 times faster than current methods using just

1 drop of blood

Received **$150,000+** in funding from the American Heart Association

Health tech company XaTec Inc. raised **$9.1M** to support Clot Chip's development

500M people live with a hemoglobin disorder worldwide

HEME CHIP

70%
of sickle-cell-related deaths in Africa could be prevented with early detection

Developed by engineering faculty member **Umut Gurkan** for the rapid diagnosis of sickle cell disease (read more on page 10)
$2-per-screening, provides results in 10 minutes

2M+ units of platelets are transfused annually in the U.S.
Limited by 5-day shelf life and need for refrigeration

SYNTHOPLATE

Shelf-stable artificial platelets developed by biomedical engineering's **Anirban Sen Gupta** that can treat

traumatic injuries or break up life-threatening clots

Supported by
$1M DOD grant
and more than
$4M in NIH
and other funding

Oral squamous cell carcinoma is the 6th most common cancer in the world

BETA DEFENSIN INDEX TECHNOLOGY

Handheld device developed by **Umut Gurkan** in collaboration with CWRU's School of Dental Medicine, uses a new biomarker to rapidly

diagnose and monitor oral cancer

Delivers results in
15 minutes

in any dental clinic as part of a regular checkup

Almost half the world's population is at risk for malaria

MAGNETO-OPTICAL DETECTION FOR MALARIA (MOD)

Developed by the School of Medicine's **Brian Grimberg**, detects malaria in

1 minute

(Read how this device has been coupled with Gurkan's HemeChip into a POC powerhouse on page 8)

There are zero POC screening options for neurodegenerative disorders like Alzheimer's

BIO-CONJUGATED, SINGLE-USE BIOSENSORS

Developed by chemical engineering's **Chung-Chiun "C.C." Liu**, the sensors could provide the foundation for handheld sensors to detect biomarkers of

Alzheimer's disease

Cited data sources can be found at engineering.case.edu/report-17-18-data-sources.

GIVING STUDENT IDEAS A BOOST

The Student Project Fund at the Larry Sears and Sally Zlotnick Sears think[box] offers students unprecedented access to financial assistance to help them pursue their innovation dreams. Through this unique program, all Case Western Reserve students can apply for awards of up to $2,500 to assist them in turning their ideas into realities—including entrepreneurial pursuits, team projects, design competitions, personal projects and more. Realizing that college students frequently have ideas that are bigger than their budgets would allow them to actualize, the funds are intended to help cover the cost of materials, equipment, manufacturing costs and related expenses that would otherwise be out of reach. Projects can be on any topic. This year's project fund was made available thanks to the generous support of the Reinberger Foundation.

Meet some recent recipients of the Student Project Fund and learn what they've built, why they're passionate about innovating and how the fund and Sears think[box] have had an impact on their lives.

Jiajie Hu, a graduate student pursuing his PhD in civil engineering, used the student project fund to build his own 3-D concrete printer.

"My advisor recommended I use the 3-D printer and 3-D scanner in Sears think[box], and I was so impressed and inspired by the 3-D polymer printer there. I applied to the Student Project Fund to use that inspiration to invent a 3-D concrete printer for construction applications. The space and the funds allowed me to pursue something I couldn't have even imagined before."

"Without the funds, we wouldn't have been able to create two models of the vaccine storage carrier for our trip to Uganda. The funds gave my team one less thing to worry about during the prototyping process—the financial limitation. It encouraged my design team to focus on the bigger picture without constraints. We were able to experiment with different ideas to implement."

Alan Chen, a fourth-year macromolecular science and engineering major who's planning to attend medical school after graduation, is a member of the Global Health Design Collaborative, an undergraduate student organization at Case Western Reserve that works with Makerere University to develop solutions for identified needs in rural Uganda. Alan's team sought to design a vaccine carrier that can safely store and maintain vaccines at the proper temperature without refrigeration. The team utilized student project funds to develop and 3-D print two different prototypes that were then field-tested.

"I first came to Sears think[box] out of curiosity and to make a gift for my mom. Sears think[box] offered me the equipment to bring my ideas to real life, a place to be creative, and a common space for me to meet other like-minded people. Having all of these offerings in one place is what makes think[box] so unique. With the student project fund, I was able to develop an early prototype and gather early data, and now I've filed a provisional patent on the technology and hope to pursue a full patent."

Prince Gosh, a senior majoring in mechanical and aerospace engineering, tapped into the student project fund to prototype a device he's dubbed a "dielectric barrier discharge plasma actuator," which is a thin, flexible electrode that uses electric fields to control the flow of air—and could potentially make wind turbines more efficient. Gosh has been innovating since the first grade, when he invented a state-science-fair-winning entry of a shoe that had a touch sensor near the big toe to alert wearers if they put their shoe on the wrong foot.

Junior **Emily Long**, an electrical engineering and cognitive science double-major with a minor in biomedical engineering, joined the student group Global Health Design Collaborative. The club uses Sears think[box] for all of its brainstorming and prototyping, and Emily helped her team apply to the project fund to develop a durable, cost-effective, handheld pulse oximeter that provides vital information for the rapid identification of pulmonary infection, such as pneumonia, and is designed specifically for pediatric use in low-resource areas.

" I was attracted to Case Western Reserve because of its research and design opportunities and facilities, but what differentiated it from other schools for me was its focus on global citizenship and innovation for the good of others. When I first started using Sears think[box], it introduced me to the real world of innovating. Just having access to the equipment and resources there changed how I and my group approach design challenges and solutions. It's allowed us to design and prototype faster and more efficiently than we could otherwise. The student project fund allowed us to purchase vital prototyping and testing materials, and we received valuable feedback on our design and already have ideas for the next iteration. We fully intend to continue to use think[box] resources for our next generation of the prototype."

"With the help of the Student Project Fund and equipment at think[box], I was able to purchase the material and electronic components needed to prototype and verify my design, which I modified several times after issues were revealed from the prototype. The end result was a peer-reviewed conference paper I wrote that was published in the proceedings of the IEEE International Conference on Robotics and Automation, a highly competitive flagship robotics conference. I plan to continue improving the device and will frequently be visiting think[box] to do so."

Xiangyi Cheng, a mechanical engineering PhD student who works in Assistant Professor Kiju Lee's robotics lab and with clinical advisor Yehoshua N. Laker from the departments of emergency medicine at Long Island Jewish Forest Hills and Staten Island University Hospital, used her award to build a robotic endotracheal intubation device called IntuBot.

Mengyao "Alice" Li is a veteran innovator. She's been inventing since she was 9 years old, when she got tired of getting out of bed to turn off the light—and risking ghosts attacking her along the way—so she rigged up a pulley system out of string, scotch tape and paper towels to flip the light switch from her bed. She continued inventing, and went on to major in mechanical engineering, graduating this past spring. Alice used her award from the student project fund to build scenery for her theater groups, both the Players' Theatre Group and CWRU Footlighters.

"I first heard about Sears think[box] in the fall of my first year. I was working on a prop chainsaw for the CWRU Footlighters' theater production of *Evil Dead: The Musical*, and I needed access to a hot glue gun. Someone pointed me toward think[box], the chainsaw turned out great, and I applied to be a student worker at think[box], which is when I realized the enormous amount of opportunities available to me there. I started exploring all the equipment, and the immense diversity of tools available to me expanded my horizons, allowing me to experiment with new manufacturing processes and create things I wouldn't have the time or precision for otherwise."

Turner Montgomery, a senior biomedical engineering student, was inspired by his mother—who was diagnosed with a rare autoimmune disease shortly after he was born. When he started college, he began to dig deeper into her condition, and made a startling discovery: she had been misdiagnosed. When she received a new diagnosis of muscular dystrophy, Montgomery applied to the Student Project Fund and used the award to build an assistive device called an EMG machine to help her with physical therapy to treat her condition.

"Sears think[box] allowed me to explore the way I thought about the limitations of my creativity. I had always wanted to build, but was too afraid to do so. There's a distinct feeling of intimidation when getting your feet wet in physical and practical technology as an engineering student. I did not grow up building robots or tinkering with various devices. I personally believe that it was this stereotype of typical engineers that held me back from trying it myself, since I was so afraid to fail. Think[box] inspires and encourages users to create projects of all shapes and sizes, no matter your background. It's a pressure-free environment where you can develop and practice any skill, and I appreciated this immensely. Their resources, both in terms of people and materials, helped me achieve a level of prototyping competence that I am proud of."

"I've worked on so many projects at Sears think[box] over so many years, and it's such a part of the fabric of my life at this point, that there isn't a defining thread other than think[box] itself. It's a great resource that's been a huge part of my experience at Case Western Reserve, and I'm proud to be a part of it in turn."

Kristina Collins, an electrical engineering graduate student who worked at Sears think[box] as an undergrad, had a case study she co-wrote on the use of public makerspaces for multidisciplinary projects accepted for publication at the International Symposium for Academic Makerspaces, which was hosted by Sears think[box] at Case Western Reserve in 2017. She used the Student Project Fund to cover the registration fee so she and her co-authors could attend the conference.

INNOVATION HIGHLIGHTS

Case Western Reserve ranked **13th in the country**—ahead of Harvard, Georgia Tech and the University of Chicago—in a new study by the Brookings Institution on research universities' effectiveness in translating research breakthroughs into commercial success.

NEW CWRU STARTUP COMPETITION

With the support of university trustee and venture capitalist **Bob Pavey**, the university launched a new competition for startup businesses that include at least one current Case Western Reserve student or recent alumnus. The Morgenthaler-Pavey Startup Competition—which gives entrants a chance to win up to $25,000—was designed to find and support high-potential startup companies coming out of the university, while simultaneously training students to evaluate and ultimately invest in these types of ventures. Learn more at mpstartup.com.

A FASHIONABLE INNOVATION

Engineering and Management student innovator **Chioma Onukwuire**—who graduated spring 2018—was selected by RAW Artists Cleveland to exhibit clothing from her African fashion business, CHIMU, at their ENVISION showcase at the House of Blues this past March. Onukwuire developed an online platform to make it easier for individuals in the United States to purchase traditional African clothing. Onukwuire collaborates with seamstresses in Africa on the various designs, then buys their work in bulk and sells and ships it in the United States—making for lower prices, online purchasing and easier returns.

CHIOMA ONUKWUIRE (SEATED, RIGHT)

The university was ranked in the **top 50** of worldwide universities granted U.S. utility patents in 2017, according to a compilation by the National Academy of Inventors and the Intellectual Property Owners Association.

Three Case Western Reserve student inventor-entrepreneurs, **Xyla Foxlin**, **Andrew Dupuis** and **Matt Campagna**, showcased their companies before members of the U.S. Congress and other visitors at the CES on The Hill annual event.

SHOWING OFF INNOVATION AT CES

For the fifth-straight year, Case Western Reserve showed some of its best innovations from students, faculty and alumni at CES 2018 in Las Vegas, including self-powered "smart building" sensors, a low-cost, hand-held blood analysis device and more among its 10 booths at the Eureka Park display area. CES, considered the world's premier consumer technologies show, draws tens of thousands of thought leaders, inventors, investors, companies and consumers to multiple days of innovation and media buzz.

The new **Case Angel Network**, started by university alumni and faculty, seeks to invest directly in promising startup businesses that include university students, graduates, staff, faculty and supporters.

20

Case Western Reserve was ranked among the world's **top 20** universities for innovation impact by the multidisciplinary journal *Nature* in 2017.

SEARS THINK[BOX]:
AN ECOSYSTEM OF INNOVATION

The Larry Sears and Sally Zlotnick Sears think[box] is celebrating its seventh year serving as the epicenter of Case Western Reserve University's ecosystem of innovation. From a 2,500-square-foot experiment to a 50,000-square-foot innovator's paradise in the Richey-Mixon Building, Sears think[box] has become one of the most-used facilities on campus and one of the most well-respected university-based innovation centers in the world.

Largest open-access, university-based innovation center in the world

50,000 SQUARE FEET

More than $50M invested in Sears think[box]'s physical structure, operations and ongoing activities

#1 most-used facility by university researchers

Sears think[box] was a significant factor in choosing CWRU — said **64%** of student users

$10.1M raised by startups utilizing Sears think[box] and CWRU LaunchNET services

188 student projects have received more than $250,000 in project fund money since 2014

1 of 8 founding members of the Higher Education Makerspaces Initiative (with Berkeley, CMU, Georgia Tech, MIT, Olin, Stanford and Yale)

More than $2M in prototyping and fabrication equipment

29 3-D PRINTERS

4 LASER CUTTERS

4,770 high-resolution parts 3-D printed annually (plus thousands more printed on our desktop 3-D printers each year)

1/1,000th OF AN INCH ACCURACY ON OUR TOP-OF-THE-LINE WATER JET CUTTER

CWRU student users come from **376 academic programs**

118 How to Think[box] classes offered since 2016

22% growth in visits since 2015

70,000+ annual visits

Open **60+ hours per week** during the school year

AN AVERAGE OF **1,400 VISITORS** TOURED MONTHLY

CARS TAKE FLIGHT

Mechanical and aerospace engineering researcher Vikas Prakash is developing structural battery systems that will help power the next generation of electric air vehicles.

We've wanted them since long before we went "back to the future" in 1985—in fact, enterprising inventors have been tinkering with designs for flying cars as far back as the mid 1800s.

Now researchers at Case Western Reserve University are helping to get these futuristic rides out of our imaginations and into the skies.

Vikas Prakash, a professor of mechanical and aerospace engineering, is confident that the ability to hail an air taxi is right around the corner. And he's not the only one—Uber unveiled the design it would like to see take to the sky this spring. And in addition to the ride-share giant, a number of other companies, governments and federal agencies are scrambling to get in on the personal air travel game.

In fact, **NASA is doubling down on the next generation of transportation, and Prakash received a $1.3-million grant from the agency to focus on developing new battery systems capable of powering these electric air vehicles (EAVs)**, which is part of a $10-million effort shared by a consortium of U.S. universities, each focused on tackling different challenges in getting EAVs airborne.

THE PERKS OF FLIGHT

Why the fervor around flying cars? (Other than their inherent awesomeness?) Shifting some of our transportation skyward could come with numerous benefits, Prakash says, from reducing carbon emissions to easing road congestion to simply saving people tremendous amounts of time.

"These vehicles could also be indispensable to FEMA for providing immediate relief in areas cut off by natural disasters."

"Flying from one place to another is just more direct. Envision for a minute—available lanes for flying cars would be in three dimensions instead of today's two," he says. "People could cut their commutes considerably. And powering these vehicles with batteries cuts down on noise and air pollution as well."

And that's just civilian applications. The military is keen to use EAVs for surveillance and supply deployment. "These vehicles could also be indispensable to FEMA for providing immediate relief in areas cut off by natural disasters," Prakash adds.

So if people have been designing flying cars for centuries, what's the holdup?

The power problem comes down to a pretty simple equation, Prakash says: flight takes a sizable amount of energy. Current battery packs have lower energy density than jet fuel per unit of weight, so if you want to add energy using batteries, you also have to add mass—too much mass for efficient flight.

So the challenge is to add battery power while minimizing additional weight. Prakash intends to achieve this balance by building structural batteries—power packs built into the vehicle's structure that multitask by bearing load and providing energy.

"Traditional design has one component doing one job," he says. "If we can make something that can carry a structural load and provide some energy functionality too, we start winning because we're adding power without adding too much mass."

BUILT-IN BATTERIES

This two-for-one approach has applications that extend beyond EAVs, Prakash says. These types of built-in batteries could help power any kind of hybrid or electric vehicle. He says researchers around the world are even exploring the concept in stationary structures like office buildings and military applications like bullet-proof vests with built-in battery packs that power devices and protect the wearer.

There are many challenges that come with trying to embed a battery system into a vehicle's fuselage or wings, Prakash says. First, the battery packs and the composite materials they inhabit must still be robust enough to withstand the physical stressors of flight, particularly the impact of landing. In addition, all the electrical connections have to stay in place through that somewhat jarring process.

"There's a lot of applied science behind all this—you can't just take battery cells and put them inside the structure," Prakash says. "There are so many discrete components and the structure is always vibrating during flight."

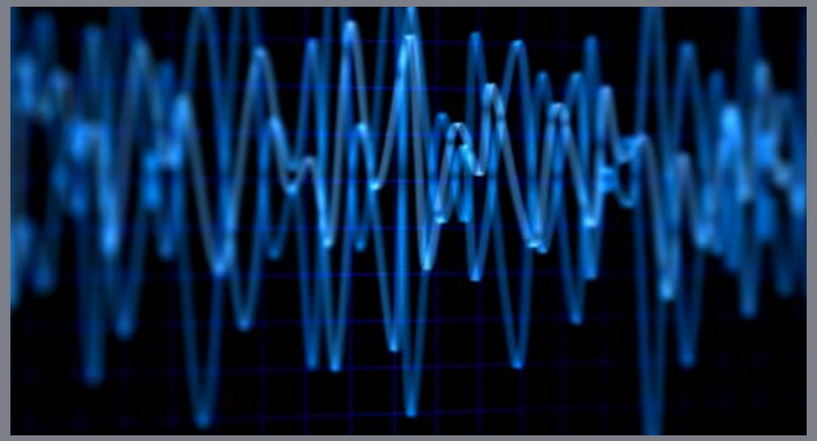
Prakash and his team are also exploring 3-D printed aerospace batteries that are safe, flexible and can be fabricated in the exact shape of a host structure—like a wing—rather than lining up multiple battery cells. This technique simplifies the embedded battery cell architecture and boosts pack-level efficiency. And 3-D printability makes it easier to scale up manufacturing.

Prakash's work on NASA's EAV charge is an extension of his research and commercialization efforts under the Partnership for Research in Energy Storage and Integration for Defense and Space Exploration (PRESIDES), part of Case Western Reserve's Great Lakes Energy Institute. (Learn more about GLEI on page 30.) He is also working on projects in collaboration with Wright-Patterson Air Force Base in Dayton, Ohio, that aim to refine structural battery technology for applications in hybrid propulsion vehicles.

There are certainly plenty of engineering challenges—and some public perception ones too—to overcome before fleets of autonomous air taxis are awaiting our business. But according to Prakash, the flying cars of the future aren't too far removed from the present.

Learn more about this project at engineering.case.edu/air-taxi.

ENERGY + MATERIALS HIGHLIGHTS



Pint-sized signal detection powerhouses

The ultra-tiny drumheads developed by engineering researchers at Case Western Reserve may be 100,000 times thinner than the human ear, but they can detect signals across a much wider range.

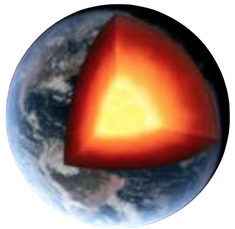
Tiny is the new big deal. Electronic devices have been trending smaller for decades, and the challenge with the constant cycle of downsizing is making sure ultra-small components are not only robust, but also keep reducing power consumption and improving sensitivity at ever-smaller sizes.

Researchers led by Philip Feng, the Theodore L. & Dana J. Schroeder Associate Professor of Electrical Engineering and Computer Science at Case Western Reserve, have made a big breakthrough in this small space: they've developed atomically thin drumhead transducers that are tens of trillions times smaller in volume than the human eardrum, but capable of sensing signals at ranges well beyond human hearing.

Made from atomic layers of semiconductor crystals, they can sense or "hear" radio frequency signals across the highest reported dynamic range—which is the range of radio wave oscillations between the highest and lowest detectable levels—for vibrating transducers of their type. The dynamic ranges of Feng's thin atomic layer drumheads are comparable to the ranges cats can hear.

While not designed for any specific technology currently on the market, these new components will likely contribute to making the next generation of ultra-low-power communications and sensory devices smaller and with greater detection and tuning range. The research was published in *Science Advances* and has been featured by *IEEE Spectrum, ASME Mechanical Engineering, NSF Science360* and other news outlets.

Learn more at engineering.case.edu/atomically-thin-drumheads.



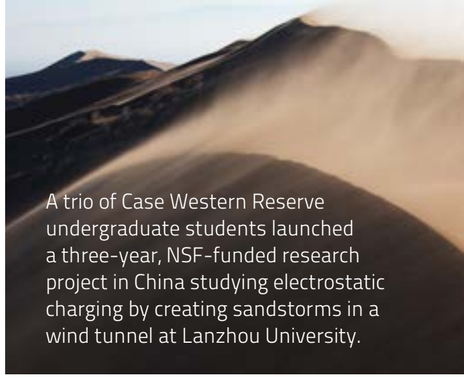
According to a team of Case Western Reserve scientists, including **Matthew Willard**, associate professor of materials science and engineering, there's a problem with the Earth's solid inner core: the 760-mile wide ball of crystallized metal shouldn't exist. The team challenged current models that explain the core's formation, pointing out a gap in the supercooling process they call the "inner-core nucleation paradox." So how did the core solidify? **Read the team's theories at** engineering.case.edu/core.

Student innovator **Prince Ghosh** pitched his wind-tech startup Boundary Labs at the finals of the U.S. Department of Energy-sponsored Switched On: Student Innovations in Cleantech contest.

Big investment in small materials: **Alp Sehirlioglu,** assistant professor of materials science and engineering, received an NSF CAREER award to support his work developing self-assembled, higher-dimensional superstructures—essentially, manipulating how groups of naturally arranged atoms come together to control a material's properties. He also received a $1.2-million grant from the Air Force Office of Scientific Research (AFOSR) to explore the nanostructures of atomically thin 2-D oxides, and he is part of a team of researchers led by Purdue University that has been awarded $7.5 million from the AFOSR to study piezoelectric energetic materials.

Julie Renner, assistant professor of chemical and biomolecular engineering, is working with researchers at the University of Arkansas on a $2.4-million NSF project to develop more energy-efficient fertilizer.

A new type of solar cell technology called passivated emitter rear cell (PERC) promises higher efficiency and energy yield. But will the perks of PERC cells last for the long-haul? Researchers at the university's SDLE Research Center received a $1.47 million grant from the U.S. Department of Energy SunShot Initiative to test these cells under accelerated and real-world conditions to see how they stand up over time.



A trio of Case Western Reserve undergraduate students launched a three-year, NSF-funded research project in China studying electrostatic charging by creating sandstorms in a wind tunnel at Lanzhou University.

Mark De Guire and **Arthur Heuer**, associate professor and emeritus professor in the Department of Materials Science and Engineering, received a Department of Energy grant to study solid oxide fuel cells under harsh conditions—aiming to extend the lifetime performance of these energy-efficient conversion devices. This brings the total DOE investment in the project to more than $1.1 million. The project has attracted more than $2.8 million in total funding since it began in 2009.

Civil engineering researchers offered their recommendations to LEEDCo to shore up the proposed foundation design for the world's first freshwater wind farm being developed off the coast of Lake Erie.

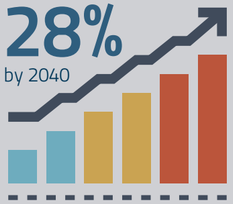
GREAT LAKES ENERGY INSTITUTE
celebrates 10 years

Climate change. An aging grid. Finite stores of fossil fuels. Increased energy needs of a growing population.

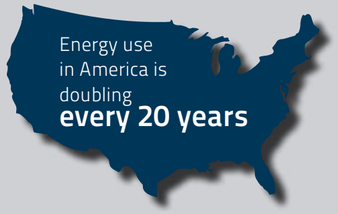
The world's energy-related challenges are as numerous as they are serious. In response, the university launched the Great Lakes Energy Institute (GLEI) in 2008 with an initial $3M grant from the Cleveland Foundation to lead the creation of breakthroughs in advanced energy research. Since then, GLEI has brought together more than 100 faculty researchers, attracted nearly $100 million in research funding—including more than $10M in ARPA-E funding—and engaged more than 100 industry partners.

Helping solve the world's most pressing energy challenges

Total world energy consumption is expected to increase **28%** by 2040



>80% of U.S. energy and **77%** of the world's energy comes from fossil fuels



30% of energy used in commercial buildings is wasted

16/17 warmest years on record have occurred since 2001

We're harnessing the changing energy landscape to create a more sustainable future.

SOLAR ENERGY

The cost of solar panels has dropped **80%** since 2008

A new solar energy device is installed in an American home every **3.2 minutes**

Our 900-site Global Sun Farm Network has the ability to put solar cell technologies through 25+ years of testing in a fraction of the time

WIND POWER

A single wind turbine can create enough energy to power as many as **300** American homes

We have 3 research wind turbines that are capable of generating **1.325 mega watts**

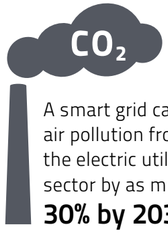
Plus we're helping refine the foundations for a **$126M, 6-turbine** wind farm on Lake Erie

STORAGE

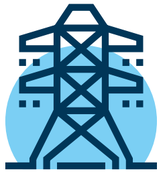
The global energy storage market will **increase 6X** between now and 2030

We received **$10.75M** from the DOE to establish a research center dedicated to identifying new battery chemistries for better storage

GRID TECHNOLOGY



A smart grid can cut air pollution from the electric utility sector by as much as **30% by 2030**



Our **campus-wide living lab** with solar installations, wind turbine, sun farm and battery systems are all linked via a transactive control system to better optimize a smarter grid.

AND EDUCATION INITIATIVES

>30 energy-related courses

40 energy ambassadors created through the ThinkEnergy student fellows program

Learn more at energy.case.edu.

Cited data sources can be found at engineering.case.edu/report-17-18-data-sources.

CHEMICAL GAME-CHANGER

Meet Assistant Professor Christine Duval.
New to the faculty of the Department of Chemical and Biomolecular Engineering, she's upending traditional chemical separation by developing custom materials that can perform highly selective separations in minutes. Learn more about her unique approach and how she's advocating for other women in engineering.

What is the focus of your research?

My lab develops advanced materials to perform chemical separations, and we design them to be highly selective. These materials, typically resins or membranes, can be used to selectively bind contaminants for environmental remediation and wastewater treatment; purification of medical isotopes for cancer radiotherapies and for nuclear forensic analysis.

What makes a material 'highly selective' and what benefits does that selectivity bring?

Highly selective materials have a high preference for binding or permeating one type of analyte over other competing ions that may be in solution. For industry applications, these materials save money and time because they only concentrate the desired product. In our group, we design selective materials that perform separations as rapidly as possible. In medical isotope production, it is necessary to perform fast separations because the desired product is a radioisotope with a short half-life—the product is literally decaying away. In terms of nuclear forensics, performing fast separations shortens the sample analysis timeline, which means government agencies can make better informed decisions and plan their response.

Is 'nuclear forensics' as cool as it sounds?

It is pretty flashy. The goal is basically the same as normal forensics, except the investigation is targeting someone who might be smuggling nuclear materials or who is working with them in a way they did not declare to international agencies. Let's say you're an IAEA inspector and you're checking some nuclear site that claims it's only enriching uranium for nuclear power and not making any weapons. Using radiation detection techniques to inform nuclear forensic analysis, we can show, with scientific evidence, whether or not a facility—or country—is in compliance with international law. My lab develops schemes to rapidly purify and separate actinides or fission products found in the environment.

How is your approach to separation materials different from what everyone else is doing?

The traditional approach to radiochemical separations is more one-size-fits-all. A lot of people take an off-the-shelf separation material and adjust the process variables to fit the characteristics of the material. Often times, that means adjusting the pH, adding oxidizing or reducing agents, or undergoing buffer exchanges to get the analyte in the proper form for the resin—wasting time, money and resources. On top of that, for multicomponent mixtures, it may require several columns in series to purify the product. In the situations we're thinking about, like post-detonation nuclear forensics, the radiochemists have a limited timeline to test the air, water and soil before passing their findings to government officials. The timeline is crucial, so you can't spend two days doing sample preparation. Our approach is to design custom separation materials that only bind the desired radionuclide. By doing this, we're reducing consumables and processing steps in order to do the separation as fast as possible—we're targeting minutes. If you want easy material synthesis you can buy the commercial resins, but you'll spend all your time on workup. Or you can spend time developing a material that's selective for your desired radionuclide in a given set of conditions, so when you actually deploy it, it does the job quickly.

What got you interested in engineering in the first place and what led you to focus on separation materials?

I liked my high school chemistry classes, so my brother suggested I think about chemical engineering when I was applying to colleges. He's an engineer himself—computer science—and a feminist, so he was happy to try and recruit a woman into the field. When I was an undergrad at the University of Connecticut, I was doing fuel cell research, specifically purifying hydrogen via gas separation with membranes. I got the research bug while I was there—I really liked working with membranes and I knew I wanted to stick with them in grad school. But when I arrived at Clemson University for graduate school, the lab I joined was in between active membrane projects. I ended up working on a radiation detection project, which was my introduction to nuclear forensics. As it turns out, I love nuclear forensics and radiation detection, so I've stuck with that.

You also worked in industry before grad school. Can you share some details about that experience?

When I was an undergrad, I got involved with an innovation accelerator program at the Connecticut Center for Entrepreneurship and Innovation, where I was part of a team that developed business plans for high-tech startups. I worked there for a few years and at the end of my third accelerator cycle, one of the companies I consulted for offered to hire me for a few months before I went to grad school. I did marketing for them—everything from making websites and brochures to digging up sales leads.

How did your time in industry impact your approach to research?

It's helped me have a more practical approach. You can have a membrane that performs the world's most elegant separation, but if it costs a million dollars per membrane, it's never going to go anywhere and it's never going to solve any problems outside of your lab. After working with startups and watching the commercialization process up close, I began to think of my separation schemes and materials in terms of a product that can be commercialized someday. In my lab, we aim to synthesize our separation materials from chemicals that are inexpensive and readily available on the market.

You mentioned the scarcity of women engineers as a factor when you started considering your career. Can you share some of your experiences as a women in STEM?

I hit a lot of the typical hurdles every woman in STEM does. I went to meetings, I brought up my opinion and, often, it wasn't well accepted. Then my male colleague brought up the same opinion and suddenly, it was accepted. There was a strong trend with one of my friends: we published the same amount, we both won a lot of external awards, we were well-respected within our department, but a lot of times, my accomplishments would be tamped down compared to his. I realized I had to be my own advocate in graduate school because I started seeing these patterns of behavior and they started affecting me. If I didn't find my own support system, I wouldn't have made it to where I am now.

What advice do you give upcoming female engineers about navigating their STEM careers?

As advisor of Case Western Reserve's chapter of Phi Sigma Ro, a national sorority for women in engineering, I get a lot of opportunities to talk about these issues with our students. As a faculty member, when any students encounter inherent biases, it's important to validate what they're feeling. It's easy for a student who may be encountering these things, these biases, in the classroom, the lab or at work, to feel like they are over-reacting. I tell students that it's important to acknowledge what's happening—if you're not aware of it, you're not going to know how to respond. I encourage them to advocate for themselves and to find supportive people in their classes. As a student, I made friends with other women who were pursuing their PhDs and realized they were having similar experiences—I wasn't alone.

What aspect of your research are you most excited about?

I'm proud of all the work going on in my lab, but I'm particularly excited about growing our efforts in purifying medical isotopes for targeted alpha therapy. As a chemical engineering undergrad, you are told that you can do anything with your degree, and for me, I got into engineering because I wanted to help people and make a difference. With any sort of involvement in medicine, you're directly helping people. That'd be a fun place to make an impact.

MORE RESEARCH HIGHLIGHTS

WALKING THE WALK
A research team including **Roger Quinn**, the Arthur P. Armington Professor of Engineering in the Department of Mechanical and Aerospace Engineering; **Ronald Triolo**, professor of biomedical engineering and executive director of the Advanced Platform Technology Center; and **Musa Audu**, research associate professor of biomedical engineering, received a $1-million NSF grant to develop a hybrid neuroprosthetic walking system for people paralyzed by spinal cord injuries.

Kiju Lee, assistant professor of mechanical and aerospace engineering, has designed a robot with a gentler touch. Inspired by origami artwork, her 3-D printed flexible robot is soft—and safe—enough to work side-by-side with humans on the manufacturing floor or perform delicate surgical procedures. Its paper-esque properties also make it lighter than its traditional robot counterparts, making it ideal for work in outer space. **Learn more at engineering.case.edu/origami-inspired-robot.**

RAPID-FIRE SCREENING
Polymer researchers at Case Western Reserve developed a faster way to test flame retardants in plastics. Thanks to project lead **Taneisha Deans**, who began her career at Case Western Reserve as a high school student in the university's Polymer Envoys program, a dozen materials can be screened for flame retardancy in an afternoon—work that used to take an entire semester. Deans developed the technique as part of her PhD thesis while working in the lab of department chair **David Schiraldi**.

Organismal engineering: post-doctoral researcher **Vickie Webster-Wood** and her team coined a new name for the emerging engineering field in bio-inspired robotics. **Learn more at engineering.case.edu/news/mapping-out-biorobotic-future.**

Mario Garcia-Sanz, professor of electrical engineering and computer science, published his third book: *Robust Control Engineering: Practical QFT Solutions*, with more than 600 pages about robust control theory and industrial and space applications he has developed during the last 25 years.

Ya-Ting Liao, assistant professor of mechanical and aerospace engineering, received a grant from the NSF and the federal Center for the Advancement of Science in Space to study how fires behave in confined spaces in microgravity. Her team will conduct experiments on the International Space Station, examining how flame spreads within walls. They will also perform numerical simulations to complement the experimental data, aiming to help improve building designs and fire safety codes back home on Earth.
Learn more at engineering.case.edu/flame-spread-space.

Civil engineering researchers put four highway berm materials and four pieces of compaction equipment to the test for a total field study of 16 different combinations. They discovered crushed limestone performed on par with recycled asphalt pavement and that a side-mounted roller has the edge when it comes to better compaction. The team's work was included in the *Journal of Cold Regions Engineering*. Learn more at engineering.case.edu/berming.

FIRE FOCUS
Case Western Reserve hosted a Symposium on Advanced Fire Science and Technology in 2017, attracting nationally recognized speakers and fire science experts from the FAA, NASA, NIST, the U.S. Air Force, UL, American University, North Carolina State University, the University of Dayton and more.

OUR NEW DEAN

Meet Venkataramanan "Ragu" Balakrishnan. The accomplished researcher in system and control theory joined the Case School of Engineering as dean on Sept. 1, 2018. Balakrishnan spent 24 years as a faculty member at Purdue University, where he held multiple leadership roles, including most recently serving as head of the School of Electrical and Computer Engineering—one of the nation's top programs and Purdue's largest academic unit. Under his direction, it underwent significant transformation, including a dramatic growth in undergraduate enrollment, research funding and faculty diversity.

Can you summarize your career up to this point?

I earned my undergraduate degree at the Indian Institute of Technology in Madras, then came to the United States and earned two master's degrees and a PhD in electrical engineering from Stanford. Afterward, I worked as a postdoctoral researcher at Stanford, the California Institute of Technology and the University of Maryland. I then joined the Purdue faculty in 1994 and, not long after receiving tenure, I became interested in serving the school, so I began volunteering and eventually was tasked with overseeing graduate admissions for the school, then strategic initiatives, and then education, before moving into a role at the College of Engineering as associate dean of research. I then served as the head of the School of Electrical and Computer Engineering for nine years before coming here.

It's been a fun ride, and I've made many friends along the way. I've also learned that you can't please everybody all the time, so when making decisions with limited resources, it's essential to have a set of consistent principles and policies that embody those principles; to apply them consistently; and to communicate why you made the decisions you made. That's my style: to be direct and transparent.

What has been the highlight of your career to date?

When I left my last position as head of ECE at Purdue, the faculty size was around 100, with about a third of them hired under my tenure. That means I've had substantial influence in shaping a very important component of an organization, which is the faculty, and I am particularly proud of the success of these more recent faculty members. Another highlight has been my continuing appreciation and support of experiential education; this is why I am very excited by all the activities surrounding Sears think[box].

You made some very impressive accomplishments at your school at Purdue—significantly increasing research expenditures, undergraduate enrollment, diversity of students and faculty, curricular advancements—how did you create such success?

We all want to have clear goals and march straight toward them. But quite often these goals depend on external factors—like being able to bring resources into the picture—which are not always under your control. For example, while I am proud of the increase of the number of Purdue electrical and computer engineering faculty, I can't claim full credit for it. The entire engineering school was growing, and what I did was advocate for my department to fully participate in that opportunity. I also utilized having an open line of communication with the dean to pitch important initiatives, such as diversity goals. In the end, a quarter of the faculty we hired were women. In this and in all things, my strategy has been to have bold goals that are generated with the community at large—the students, faculty, staff and alumni—but also to realize that sometimes you have limited control over how much progress can be made. I've tried to be strategic as well as opportunistic, and also sensible.

What made you interested in being dean of the Case School of Engineering?

What I particularly liked about Case Western Reserve was, in conversations with the president and provost, department heads, senior faculty and junior faculty, I definitely found a sense of hunger and desire to be even better than we are now. It was also very clear to me that there was enormous trust in and responsibility placed with school leadership, and that was very attractive to me. Also the school's reputation in engineering is quite strong. Additionally, with resources like Sears think[box] and CWRU LaunchNet, it was clear to me that Case Western Reserve cares deeply about the student experience. I was also told that the weather in Cleveland is perfect all through the year and rivals California's, and that was a big factor as well.

What are you most excited about?

I'm most excited about the opportunity to work with such an impressive community of faculty, staff, students and alumni. First, though, I do want to take time to talk with everyone to get a better picture of their thoughts and needs before fully developing my strategy. I'm especially looking forward to meeting alumni, and getting them even more engaged as partners with us in working toward a greater good. I'm also interested to explore the integration of Sears think[box] with the experiential learning component of the curriculum. And I'm excited to see what we can do on the graduate student recruitment side to increase the number of students.

What do you think the greatest challenges will be?

I believe the school's graduate program rankings underreport the quality that is here and my sense is there is much that can be done to remedy this. One of the first steps we need to take is to grow the graduate student numbers. And that directly comes down to resources. I'm hopeful there are some creative ideas that I can implement to move resources around to bring more graduate students into the program. I think that translates not only into the rankings—which is not an end in itself—but a means to bring even more great people into the fold.

What do you like most about Cleveland so far?

So far, I am most appreciative of how nice and friendly everyone has been. I am quite humbled by their welcome. It's simply been a pleasure coming here. Also the city of Cleveland, in contrast to the small town I came from, has many more options for entertainment—I have been pleasantly surprised by the variety and quality of the cuisine in Cleveland. I also appreciate all the opportunities to be in nature. Overall, I'm very excited to be here.

What are your hopes for the next five years?

I would like to have a transformative, positive impact on the graduate program without compromising on any of the other wonderful accomplishments of the school thus far. I believe there are some course corrections we can make to help the school be more appreciated for the strengths it has.

ALUMNUS CHARLES H. PHIPPS ENDOWS DEAN'S POSITION

Charles H. Phipps (CIT '49) has committed $5 million to endow the dean's position at the Case School of Engineering. The endowment will provide new Dean Venkataramanan "Ragu" Balakrishnan resources for research opportunities, strategic initiatives and transformative ideas.

Phipps graduated from the Case Institute of Technology in 1949 with a degree in electrical engineering and went on to work at General Electric, Motorola and Texas Instruments before consulting and then becoming a partner at a high-tech venture capital firm. Long a generous benefactor to the university, Phipps's deanship endowment is his third major gift to the school.

SCHOOL HIGHLIGHTS

NEW PEER ADVISING PROGRAM

The engineering school launched a new peer advising program this fall to complement the academic advising offered by faculty in the school's seven departments. The 11 new peer advisors are all senior engineering students representing all engineering departments, and are available to undergraduate students on a drop-in basis Monday through Friday, 9 a.m. to 5 p.m. Peer advisors can assist their fellow students at all stages of their college careers—helping them review major and minor choices, declare majors, review academic requirements, and navigate dropping and adding courses, as well as offering recommendations and identification of other campus resources.

Case Western Reserve University, in partnership with the National Academy of Engineering, hosted climate change experts **Michael Mann**, **Stephen Palumbi** and **V. "Ram" Ramaswamy** in the spring for a community event exploring the effects of climate change on Earth's lands, seas and atmosphere.

ANANT MADABHUSHI

THINK BEYOND SPEAKER SERIES

In the fall of 2017, the school launched the Think Beyond Speaker Series, an opportunity for alumni and friends to hear from notable faculty members, alumni and other speakers on cutting-edge research and topics. The first event featured biomedical engineering faculty members **Dustin Tyler** and **Mark Griswold** exploring "Touch: Visualizing the Human Evolution of Technology." The event was hosted at the home of **Aarti (GRS '88, computer science)** and **Asheem (CIT '86, GRS '88, computer engineering) Chandna** in California.

In March 2018, appropriately on "Pi day," the father of algorithm analysis, **Don Knuth (CIT '60)**, participated in an in-person "All Questions Answered" session to share and discuss moments from his life and career as a mathematician and pioneering computer scientist.

The most recent event, featuring **Anant Madabhushi**, faculty director of the Center for Computational Imaging and Personalized Diagnostics, explored the power of big data to create more personalized medical treatments. The event was hosted by **Jay (GRS '84, computer engineering)** and **Harita (GRS '83, computer engineering) Patel**, also in California.

TEACHING LAB RENOVATION SUPPORT

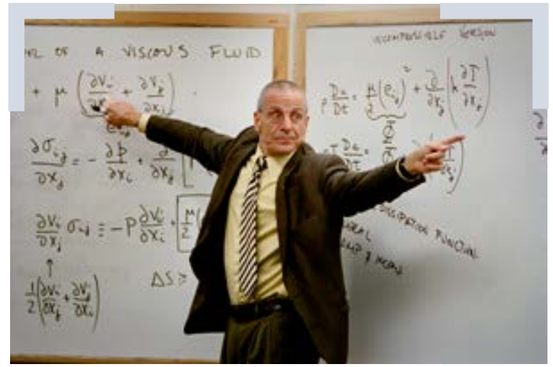
The engineering school is receiving a matching gift from the university for important teaching space renovations across campus, thanks to the generous support of alumni and friends who contributed $1 million to see upgrades done in the civil engineering, chemical engineering and materials science and engineering departments.

The new William M. (CIT '64) and Mary Jane James Lecture Hall in chemical engineering will come thanks to a lead $250,000 gift from the James family. A new concrete lab in civil engineering was made possible by the support of the Rollin M. Gerstacker Foundation and alumna Gina Beim (GRS '87, systems and control engineering, MBA '04).

And James R. (CIT '65) and Linda Venner supported laboratory renovations at the dean's discretion, allowing these projects to be undertaken, along with updates to the entryway and teaching laboratory in materials science and engineering—a project initially supported by a gift from Robert Smialek (CIT '65, GRS '67, '70) and a pledge from Jennie Hwang (GRS '76).

NAMING BECKMAN SCHOLARS

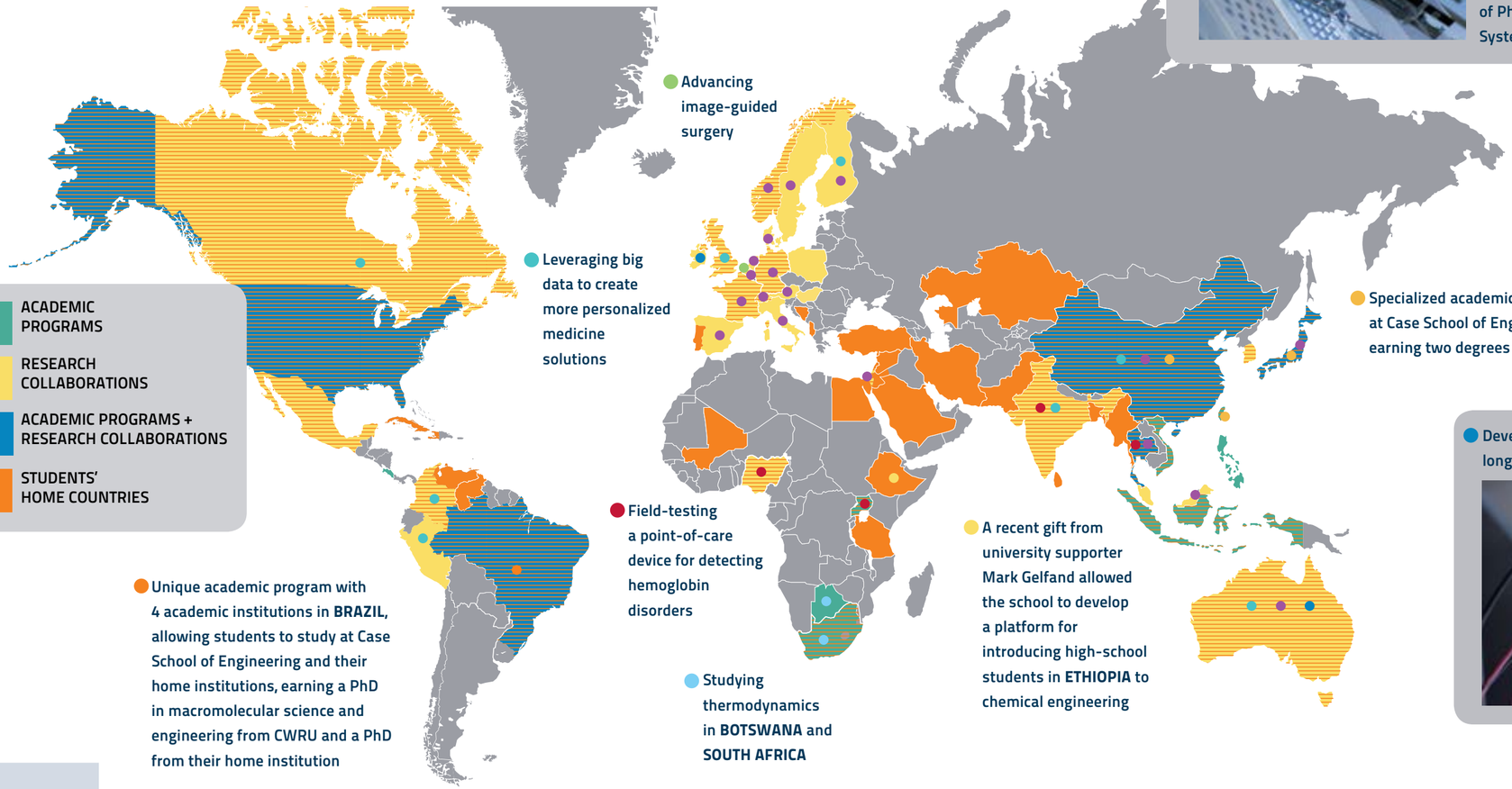
One of only 12 institutions chosen nationally this year, Case Western Reserve University was selected by the **Arnold and Mabel Beckman Foundation** to offer research grants and mentorship to exceptional undergraduate students in chemistry and the biological sciences. The Beckman Scholars Awards will go to six students—two each over the next three years—who are majoring in biology, chemistry, biochemistry, nutrition, biomedical engineering or chemical and biomolecular engineering. The Arnold and Mabel Beckman Foundation provides grants to researchers and nonprofit research institutions to promote scientific discoveries—especially work that leads to new research methods, instruments and materials.



Alumnus **Richard Mueller (CWRU '95)** donated $25,000 to the Case Alumni Association to establish the Joseph M. Prahl Scholarship Fund for undergraduate students. Mueller made the generous donation upon hearing the news of the death of mechanical and engineering beloved professor **Joseph Prahl**, who was his undergraduate advisor. Prahl passed away in April 2018.

OUR GLOBAL PARTNERSHIPS

From study abroad options to unique dual-degree programs that span continents, from research collaborations that pull in partners from all time zones to field-testing translational technologies across hemispheres, the Case School of Engineering may be Cleveland-based, but it creates far-reaching connections that spark innovation all over the world.



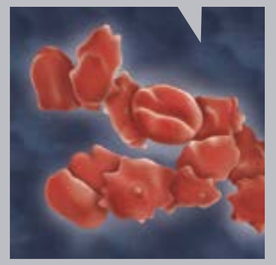
MEDIA MENTIONS

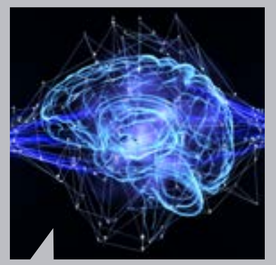
Atomically thin drumheads that hold promise for advanced electronics developed by researchers at Case Western Reserve make headlines in *ENGADGET* and *IEEE SPECTRUM*.

A deep-learning algorithm developed by biomedical engineering researchers at Case Western Reserve outperforms human doctors in making diagnoses and was named one of the "5 COOLEST THINGS ON EARTH THIS WEEK" BY *GE REPORTS*.

CNET: "But that's not their only potential benefit if Dustin Tyler's research pans out. The professor of biomedical engineering at Case Western Reserve University is developing a technique that could trick the brain into thinking sensations are coming from the missing, flesh-and-blood hand."

On his blog, **NIH DIRECTOR FRANCIS COLLINS** highlighted red blood cell research by Case Western Reserve Assistant Professor Umut Gurkan and his team's BioArt Competition-winning illustration of the effects of toxic mercury on blood cells.

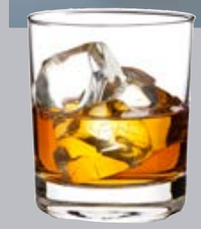




MEDGADET: Carbon nanotubes spun into yarn work to stimulate neurons inside the brain.

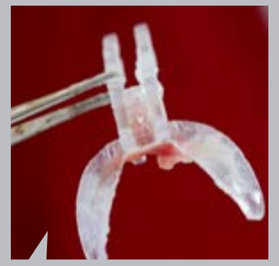
NEW ATLAS: "'I don't have any doubt,' [Vikas Prakash] says. 'In a few years, you will be able to call an air taxi from Uber or someone else to travel maybe 100 miles in a vehicle with two other people. I'm very excited about this.'"

Case Western Reserve mechanical and aerospace engineering professor Vikas Prakash tells the *SMITHSONIAN'S AIR & SPACE MAGAZINE* what it'll take to get flying cars off the ground.



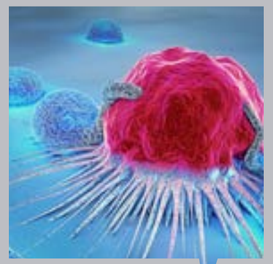
Cheers! Chemical and biomolecular engineering department chair Daniel Lacks comments on the chemistry behind mixing water and whiskey to improve flavor in *THE WASHINGTON POST*.

The **U.S. DEPARTMENT OF ENERGY** highlights the SDLE Research Center's use of advanced imaging techniques and statistical analysis to improve the lifespan of solar photovoltaic cells as one of its Success Stories.



SCIENCE FRIDAY: "Vickie Webster-Wood of Case Western Reserve University, who has experimented with the sea-slug-muscle robots, says the aqueous origins of the muscles point to underwater applications, perhaps environmental monitoring, or hunting down leaks in an oil pipeline."

NEW ATLAS: Soft origami tower robot keeps things light on the assembly line and in space



U.S. NEWS & WORLD REPORT profiled Case Western Reserve University's campus and featured Case Western Reserve University biomedical engineering research on how computerized image analysis could improve cancer diagnosis and treatment.

MEDGADGET: New contrast agent points out tumors, helps identify how aggressive they are.

THE ATLANTIC: "'Mixed reality allows students to see where the professor is directing their attention and allows the professor to see how the students are approaching the body and get a sense of who might need a bit more guidance.'"

FORTUNE: "Augmented and mixed reality aren't just for gaming. Case Western Reserve University and the Cleveland Clinic are designing programs that use Microsoft's HoloLens to teach med students anatomy."

A brain-computer interface developed at Case Western Reserve that helps reconnect the mind to paralyzed muscles was featured in *THE ECONOMIST*, *THE DAILY BEAST*, *BLOOMBERG BUSINESS WEEK* and *CNN*.

FACULTY AWARDS AND ACCOLADES

WEI LIN

Chris Yuan, associate professor of mechanical and aerospace engineering, won **first place in the Reusable Abstractions of Manufacturing Processes national research competition**.

David Schiraldi, chair of the Department of Macromolecular Science and Engineering and the Peter A. Asseff Professor, won the **Polymeric Materials: Science and Engineering Division Distinguished Service Award**, and was named **editor-in-chief of the journal *Silicon***.

Umut Gurkan, assistant professor of mechanical and aerospace engineering, **Birnur Akkaya**, a visiting scholar, and **Courtney Fleming**, a Cleveland Institute of Art student, were named among the **winners of the Federation of American Societies for Experimental Biology's sixth annual BioArt Competition** for their illustration depicting the impact of mercury exposure on red blood cells. **Gurkan** and other researchers from Case Western Reserve also **won the Vodafone Americas Foundation Wireless Innovation Project Competition** with their Sickle and Malaria Accurate Remote Testing (SMART) system.

Lisa Camp, associate dean for strategic initiatives, was **named to the inaugural class of America Makes Ambassadors** in recognition of dedication to the America Makes mission of advancing innovation in additive manufacturing.

Wei Lin, professor of electrical engineering and computer science, has been named a **fellow of the Institute of Electrical and Electronics Engineers (IEEE)** in recognition of his contributions to nonlinear control systems.

Michael Hore, assistant professor of macromolecular science and engineering, received a **Young Investigator Award** from the American Chemical Society's Polymer Materials Science and Engineering Division.

James T'ien, the Leonard Case Jr. Professor of Engineering in the Department of Mechanical and Aerospace Engineering, was elected to the **inaugural class of fellows of the Combustion Institute**.

Mario Garcia-Sanz, professor of electrical engineering and computer science, was **appointed as a program director at the Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E)**, where he will focus on projects related to advanced control engineering, wind energy systems, renewable and conventional power generation, electrical distribution systems, smart grid technologies, and water treatment plants and networks.

Anant Madabhushi, the F. Alex Nason Professor II of Biomedical Engineering, received the **2017 IEEE (Institute of Electrical and Electronics Engineers) Engineering in Medicine and Biology Society (EMBS) Technical Achievement Award** for contributions in computer-aided diagnosis, pattern recognition, machine learning and image analysis tools for diagnosis, prognosis and treatment response prediction of disease from digital pathology and radiographic images.

JAMES T'IEN

CLARE RIMNAC AND DWIGHT DAVY

The Department of Mechanical and Aerospace Engineering's **Clare Rimnac**, the Wilbert J. Austin Professor of Engineering, and Professor Emeritus **Dwight Davy** have been inducted into the inaugural class of **fellows of the Orthopaedic Research Society**.

Robert Gao, the Cady Staley Professor of Engineering and chair of the Department of Mechanical and Aerospace Engineering, received the American Society of Mechanical Engineers' 2018 **Blackall Machine Tool and Gage Award** and was named co-recipient of the **Hideo Hanafusa Outstanding Investigator Award** by the 2018 International Symposium on Flexible Automation.

YeongAe Heo, assistant professor of civil engineering, was named an American Society of Civil Engineers (ASCE) **ExCEED Fellow** and was selected as the ASCE SEI (Structural Engineering Institute) Codes and Standards Activities Division committee's **Young Professional member**.

James Basilion, professor of biomedical engineering and radiology, was elected **president of the World Molecular Imaging Society**.

Pedram Mohseni, professor of electrical engineering and computer science, was appointed an **associate editor** of the ***IEEE Solid-State Circuits Letters***—the newest publication of the IEEE Solid-State Circuits Society.

Vikas Prakash, professor of mechanical and aerospace engineering, received the **Society of Experimental Mechanics 2018 Peterson Award**.

Rigoberto Advincula, professor of macromolecular science and engineering, was **elected to membership in the National Academy of Science and Technology, Philippines**.

Andrew Rollins, professor of biomedical engineering, was appointed section **editor for biomedical imaging** for the new Elsevier journal, ***Current Opinion in Biomedical Engineering***.

A. Bolu Ajiboye, assistant professor of biomedical engineering, and **Robert Kirsch**, the Allen H. and Constance T. Ford Professor and Chair of Biomedical Engineering, received **first place in the 2018 International Annual Brain Computer Interface Research Award competition**.

STUDENT AWARDS AND ACCOLADES

CWRUbotix, Case Western Reserve's robotics team, impressed on the national stage this year. The club sent three teams to the National Robotics Challenge, winning first in the combat competition and fourth for their mini-sumo robot. The team also placed fourth overall at NASA's annual Robotic Mining Competition, securing a top spot out of 44 other collegiate teams.

Graduate students from the Department of Materials Science and Engineering earned accolades at conferences across the country:

- **Zhe Ren** and **Aaron Washburn** won first- and second-place poster awards at the 29th American Society for Metals (ASM)-Heat Treating Conference.
- **Will Huddleston** won a student poster contest at the American Ceramic Society's Electronic Materials and Applications Conference in January with a poster titled, "Freeze casting of LAGP for 3D textured solid-state structural electrolytes."
- PhD student **Henry Neilson** won a first-place award for his research at the Materials Science and Technology (MS&T) meeting in Pittsburgh.

The Case Western Reserve University **Motorsports team** and their baja off-road vehicle placed first in acceleration and overall dynamic at the Midnight Mayhem racing event in Louisville, Ky.

Case Western Reserve University student entrepreneurs won Infy Maker Awards from the Infosys Foundation: **Matthew Campagna**, an undergraduate computer engineering major and co-founder of Reflexion Interactive Technologies LLC; and **Pavel Galchenko**, an undergraduate studying biochemistry and applied data science, founder of RVS Rubber Solutions.

Mousa Younesi, a PhD student in the Department of Mechanical and Aerospace Engineering, won an Acta Student Award for his contribution to the manuscript, "Heparinized collagen sutures for sustained delivery of PDGF-BB: Delivery profile and effects on tendon derived cell In-Vitro," which appeared in the journal *Acta BioMaterialia*.

Madeleine Harris, **Aaron Mann**, **Nicholas Merchant-Wells** and **Jack Worsham**, all civil engineering undergraduate students, won first prize in the Ohio Water Environment Association (OWEA) 2018 Student Design Competition

A team of undergraduate students from Case Western Reserve won the **American Society of Civil Engineers Sustainable Development Award** at the EPA's P3 National Sustainable Design Expo for developing an electrical incinerator for hazardous medical waste disposal designed for use in Uganda.

Case Western Reserve undergraduates took first place in the Cleveland Medical Hackathon for CrasBand—a wrist device that monitors a person's cardiac health.

Case Western Reserve student-led startups **Path Robotics** and **Boundary Robotics** took the top two spots at the LaunchTown Entrepreneurship Awards.

Chemical engineering and chemistry major **Zane Ostoin** won the Ohio Co-op Education Association's Cool Co-op Award.

Xinyou Ke, a PhD candidate in the Department of Mechanical and Aerospace Engineering, was awarded the 2018 ECS F.M. Becket Summer Fellowship by the Electrochemical Society.

ADMINISTRATION

Case Western Reserve University

Barbara R. Snyder
President

Ben Vinson III
Provost and Executive Vice President

Case School of Engineering

Venkataramanan "Ragu" Balakrishnan
Charles H. Phipps Dean

Marc Buchner
Associate Dean, Academics
Associate Professor,
Electrical Engineering and Computer Science

Christian Zorman
Associate Dean, Research
Professor,
Electrical Engineering and Computer Science

Lisa A. Camp
Associate Dean, Strategic Initiatives

Daniel M. Ducoff
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

FACULTY

AS OF OCT. 1, 2018

Biomedical Engineering

Robert F. Kirsch
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

Cameron McIntyre
*Professor**

P. Hunter Peckham
Distinguished University Professor and Donnell Institute Professor of Engineering

Andrew M. Rollins
Professor

Gerald M. Saidel
Professor

Nicole Seiberlich
Elmer Lincoln Lindseth Associate Professor of Biomedical Engineering

Anirban Sen Gupta
Professor

Sam E. Senyo
Assistant Professor

Pallavi Tiwari
*Assistant Professor**

Dustin J. Tyler
Kent H. Smith Professor of Engineering II

Satish Viswanath
*Assistant Professor**

Horst von Recum
Professor

David L. Wilson
Robert J. Herbold Professor

Xin Yu
Professor

Chemical and Biomolecular Engineering

Daniel J. Lacks
Chair and C. Benson Branch Professor of Chemical Engineering

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

Harihara Baskaran
Professor

Christine Duval
Assistant Professor

Donald L. Feke
Distinguished University Professor and Vice Provost

Burcu Gurkan
Assistant Professor

Uziel Landau
Professor

Chung-Chiun "C.C." Liu
Distinguished University Professor and Wallace R. Persons Professor of Sensor Technology and Control

**School of Medicine campus*

Chemical and Biomolecular Engineering, *continued*

Heidi B. Martin
Associate Professor

Julie Renner
Climo Assistant Professor

R. Mohan Sankaran
Goodrich Professor for Engineering Innovation

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

Civil Engineering

Xiangwu "David" Zeng
Chair and Frank H. Neff Professor

Christian Carloni
Associate Professor

YeongAe Heo
Assistant Professor

Yue Li
Professor

Michael Pollino
Associate Professor

Kurt R. Rhoads
Assistant Professor

Adel S. Saada
Professor

Katie Wheaton
Instructor

Xiong "Bill" Yu
Professor

Huichun "Judy" Zhang
Associate Professor

Electrical Engineering and Computer Science

James D. McGuffin-Cawley
Interim Chair and Arthur S. Holden Jr. Professor in Engineering

Venkataramanan "Ragu" Balakrishnan
Charles H. Phipps Dean and Professor

M. Cenk Cavusoglu
Associate Chair and Nord Professor of Engineering

Jing Li
Associate Chair and Professor

Erman Ayday
Assistant Professor

Marcus R. Buchner
Associate Dean of Academics and Associate Professor

Vira Chankong
Associate Professor

Harold Connamacher
Assistant Professor

Philip X.L. Feng
Theodore L. & Dana J. Schroeder Associate Professor in Computer Science & Engineering

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Assistant Professor

Mario Garcia-Sanz
Professor

Evren Gurkan-Cavusoglu
Assistant Professor

Ming-Chun Huang
Assistant Professor

Mehmet Koyuturk
Andrew R. Jennings Professor in the Computing Sciences

Electrical Engineering and Computer Science, continued

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Professor

Pan Li
Associate Professor

Vincenzo Liberatore
Associate Professor

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Professor

Kenneth A. Loparo
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Behnam Malakooti
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Soumyajit Mandal
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Veale Professor of Wireless Health Innovation

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Distinguished University Professor and Herbert Henry Dow Professor of Science and Engineering

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Brian Maxwell
Assistant Professor

Vikas Prakash
Professor

Roger D. Quinn
Arthur P. Armington Professor of Engineering

Clare M. Rimnac
Distinguished University Professor and Wilbert J. Austin Professor of Engineering

Fumiaki Takahashi
Professor

Chris Yingchun Yuan
Associate Professor

NOT PICTURED

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

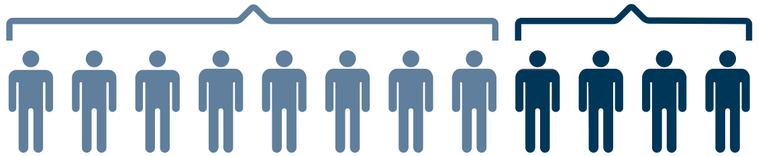
AT A GLANCE

Student Enrollment Fall 2018

2,223 Total*

1,484
Declared undergraduate engineering students

739
Graduate and professional-degree students



*In addition, 718 undergraduate students expressed interest in engineering majors but are not expected to declare majors until the end of their sophomore year.

FY 2018 Full-time faculty

122

FY 2018 Total revenue

$106.9 million

FY 2018 Research, training and grant revenue

$47.7 million

FY 2018 Fundraising

Total: $51.4 million

In FY2018, the Case Alumni Foundation/Association provided $2.8 million from annual and endowed gifts to the Case School of Engineering.

Technology Transfer

In FY2018 Case School of Engineering faculty contributed to:

115 invention disclosures
5.13 times the national per-dollar proficiency average*

212 patent applications
9.88 times the national per-dollar proficiency average*

20 deals with industry
3.04 times the national per-dollar proficiency average*

3 startup companies
2.82 times the national per-dollar proficiency average*

*AUTM U.S. Licensing Activity Survey, FY16 (latest data available)

U.S. News & World Report rankings

50th
for engineering graduate schools*

43th
for undergraduate engineering programs**

18th
for graduate biomedical engineering programs*

14th
for undergraduate biomedical engineering programs**

*published spring 2018

**published fall 2018

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Majors

Bachelor of Science in Engineering (BSE)
Available majors:
Aerospace Engineering
Biomedical Engineering
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical Engineering
Engineering Physics
General Engineering
Materials Science and Engineering
Mechanical Engineering
Polymer Science and Engineering
Systems and Control Engineering

Bachelor of Science (BS)
Available majors:
Computer Science
Data Science and Analytics

Bachelor of Arts (BA)
Available majors:
Computer Science

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

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

Centers and Institutes

Advanced Manufacturing and Mechanical Reliability Center
Advanced Platform Technology Center
Center for Advanced Polymer Processing
Center for Advanced Science and Engineering for Carbon
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Center for Computational Imaging and Personalized Diagnostics
Center for Control and Energy Systems
Center for Layered Polymeric Systems (CLiPS)
Center for the Evaluation of Implant Performance
Cleveland Functional Electrical Stimulation Center
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Microfabrication Laboratory
Neural Engineering Center
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University Marketing and Communications p. 14, Mengyao "Alice" Li p. 20, Chioma Onukwuire p. 22, CES p. 23, Annie O'Neill p. 38, Umut Gurkan p. 42 {blood cells}, Microsoft p. 43 {HoloLens}, CWRU Motorsports p. 46 {Baja car}

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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_3355-2018