ENGINEERING
Momentum
Across Disciplines. Across the World® // **FALL 2017**

IS THE FUTURE OF ENERGY STUCK IN THE PAST?

Washington University in St. Louis

Snapshot //

Chemical Engineering undergraduate students analyzing the operation of pumps and a distillation column in the Unit Ops lab.

DEVON HILL

From the dean //

Dear friends,

Traditionally, science and math have been the two key pillars of Engineering. Science afforded the understanding of fundamental processes of the physical world, and mathematics provided quantitative modeling that would predict the effect of interventions and constructions. Engineering education built upon these skills typically provided in high school and grew them to greater sophistication.

But then, enter computation.

The influence of computing on our world in general and engineering in particular cannot be overstated. The impact of computation on everyday life ranges everywhere from the powerful computers many carry in their pockets — otherwise known as smartphones — to the embedding of artificial intelligence in systems ranging from hotel reservations to intensive care units. It is this ubiquity of computing and the demand for support and development that has resulted in a severe shortage of computer science professionals.

According to Code.org, there will be an estimated 1 million more computing jobs than applicants who can fill them by 2020. There are also more than 500,000 open computing jobs nationwide, but fewer than 43,000 computer science students graduated into the workforce in 2016.

The effect on engineering is even greater. Whereas earlier generations would create simplified approximate models of systems that could be analytically represented and thus analyzed, current practice also asks and answers questions through simulation. And while solutions derived from first principles are satisfying, more and more solutions to design problems are found through computation on "big data" leveraging earlier observations and experiments.

The net result of this trend is that educational instruction at all levels must make computational instruction fundamental. As you will read in these pages, this past October, Washington University and the Engineering school hosted the CSforALL national summit dedicated to teaching computing targeted at mostly K-12 opportunities (read more on pg. 22). It was an inspirational meeting, demonstrating successful efforts in all types of schools and programs, ranging from urban city public schools to private high school experiences. And they really mean CS for *all* — one of my favorite presentations was by Technolochicas, an organization dedicated to getting young Latinas engaged in computing.

Here at WashU, we have also dramatically expanded CS education for our undergraduates. Significantly, we teach the same introductory computing courses to all students, be they STEM or humanities or business majors. To do so required creating an engaging curriculum that does not presume one will be a practicing computer scientist upon graduation. Rather we are educating the future generation, at the college level, about the nature of computing and programming.

In the future you will hear more about the further integration of computing into our engineering undergraduate curriculum. Our engineering students of all disciplines should be able to innovate, explore and solve problems through the tools of computing as easily as they do so with mathematics. This will expand both their opportunities and their impact.

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FALL 2017

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THE BUZZ

#WashUengineers

Lizzy Crist named 2017 NCAA Woman of the Year

NCAA PHOTO

WashU BME graduate Lizzy Crist was named the 2017 NCAA Woman of the Year. Crist is the second student-athlete from WashU to win the award, joining 2012 winner Elizabeth Phillips. She is also the fifth NCAA Division III student-athlete to claim the honor.

"I am still letting it all sink in. I really want my teammates to know that I could not have done this without them. I am so thankful to have had my four years at WashU and to have been surrounded by so many incredible people."

New school video

An engineer answers the question "What's next?"

See how we are changing the future of engineering today: engineering.wustl.edu

Donna Williams retires after 45 years of service to WashU Engineering

For more than four decades, Donna Williams offered guidance, inspiration and support to a diverse student body, recognizing the need to provide each individual with the care they require and deserve.

1984 #tbt

Aug 21 @washuengineers
Engineers are always prepared! Safety first! #SolarEclipse2017

Jul 28 @setton_lab
Happy for #nsf fellow Marcos Barcellona to be accepted as a T32 affiliate fellow in #mechanobiology

Jun 9 @washuengineers
MilliporeSigma CEO Udit Batra visited us in May to tour engineering labs & dedicate Brauer Hall's second floor. Yes, he now owns a #WashU tie!

First day of class

School news //

Spartan Makerspace will foster innovation and entrepreneurship

To give Washington University students enhanced opportunities to learn by working with their hands, Spartan has pledged $1 million to create the Spartan Light Metal Products Makerspace. The cutting-edge facility will be centrally located on the ground floor of Henry A. and Elvira H. Jubel Hall, which was named in 2013 with a substantial commitment from the Jubel family through the Henry A. Jubel Foundation. Jubel Hall, part of the university's east end transformation project, will be completed in 2019 and will house the Department of Mechanical Engineering & Materials Science.

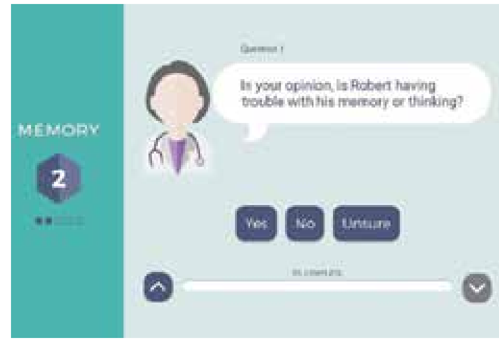
The Spartan Makerspace will transform the way students and faculty members interact with their subject matter in many areas of study. Its state-of-the-art resources will include 3-D printers and scanners, plasma cutters, computer-controlled milling machines, and lathes for cutting metal. Such tools can be used to create everything from tech products and biomedical devices to sculptures and architectural mock-ups.

"The makerspace will accelerate innovation and entrepreneurship across Washington University," says Philip Bayly, chair of mechanical engineering and the Lilyan and E. Lisle Hughes Professor. "It will provide a place where innovators can bring to life designs for addressing society's challenges.

"The Spartan Makerspace will provide students and faculty with sophisticated fabrication capabilities that will allow them to have an even greater impact on our world."

Written by Kelly Marksbury

Testing begins for student-created app to aid Alzheimer's diagnosis



With the aim of streamlining the diagnosis of Alzheimer's disease, a student-led team has designed an online app to help doctors more quickly evaluate patients. The app is being tested at WashU School of Medicine.

"This app is not meant to replace the visit with the physician," said MD/PhD student Robert Chen, who co-leads the student group known as Memento that designed the app. "It is meant to help physicians have more information about the patient before they are evaluated in person. With additional reliable and clinically relevant information in the hands of physicians beforehand, the hope is that physicians can make a diagnosis more quickly and confidently, and spend the extra time building a treatment plan and answering questions from patients and caregivers in the face of a devastating diagnosis."

The app consists of 60 to 100 questions for a patient's caregiver to answer on an iPad before the patient sees a dementia specialist.

East End *Transformation*

In May 2017, WashU began the largest capital project in the recent history of the Danforth Campus, transforming the east end to align with the university's core academic mission of groundbreaking discovery, research and teaching. The plan includes two new Engineering academic buildings.


July 2017


August 2017


October 2017

CRETE House debuts at Solar Decathlon 2017

WASHU PHOTOS

Concrete is the most widely used construction material in the world. Billions of tons are produced annually.

But for the 2017 Solar Decathlon, "we wanted to demonstrate a new approach," said Dylan Weber Callahan, a master's candidate in both architecture and construction management at Washington University in St. Louis. "We wanted to show that concrete could be used in more sustainable ways."

Over the past two years, more than 100 students from the Sam Fox School of Design & Visual Arts, the School of Engineering & Applied Science and the International Center for Energy, Environment and Sustainability (InCEES) have worked with industry partners to design, fabricate and construct CRETE House.

The solar-powered, 995-square-foot residence — which was assembled on the university's North Campus — is built almost entirely from pre-cast concrete. Water coils embedded within the floors and ceiling, rather than a traditional HVAC system, provide heating and cooling. Large gutters foster shade and direct run-off to a hydroponic garden capable of feeding residents for much of the year.

"Concrete is extremely durable, so we have a very resilient house," said Ethan Miller, a master's candidate in architecture and construction management. "We also took into account, in the steel connections, seismic forces, so that this house will not only be able to withstand tornados and hurricanes, but also earthquakes."

Sponsored by the U.S. Department of Energy, the biennial Solar Decathlon challenges university teams from around the world to design and build full-size, energy-efficient houses. This year's competition took place Oct. 5-15 in Denver.

Students spent several weeks at North Campus, completing initial assembly and testing and refining systems. In September, they took the house back apart, drove the components to Denver and reassembled the house on site. After the competition, CRETE House will be permanently installed at the university's Tyson Research Center as a residence for visiting scientists.

"Concrete is typically used on larger commercial projects," Callahan concluded. "Yet the material's durability, thermal properties and ubiquity could also hold the key to making residential construction more sustainable.

"We wanted to create a catalyst for how concrete might be used more efficiently in the future."

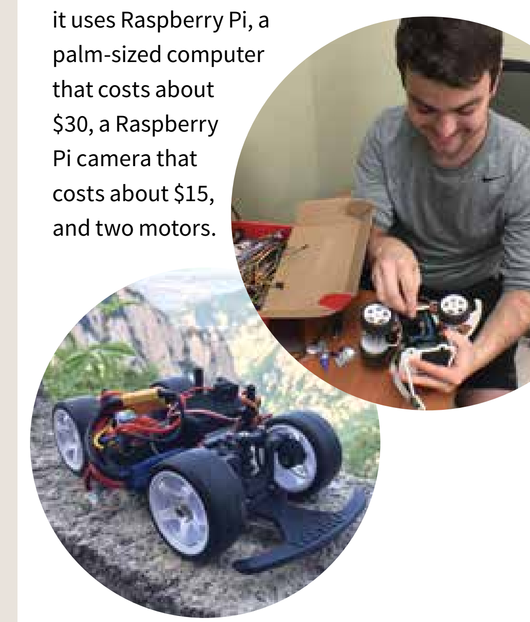
WashU Engineering-designed autonomous car inspired by insects

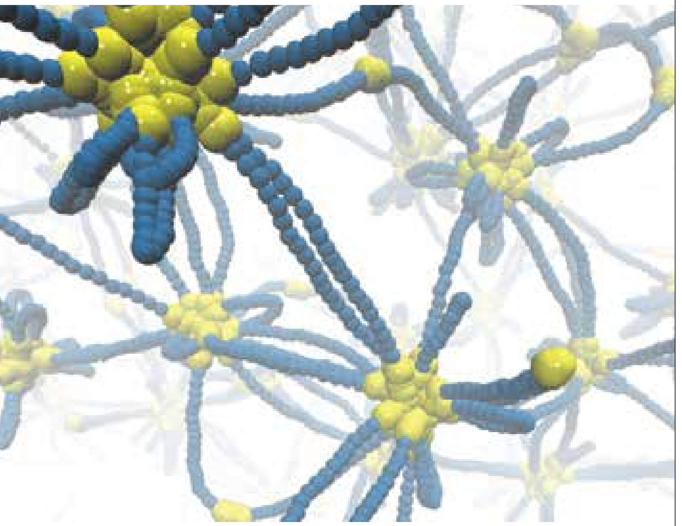
A team of five students placed among the top 10 teams in an international robotics competition for its low-cost autonomous vehicle design inspired by the movements of insects.

Members of the team were working to develop a low-cost, self-driving vehicle design in the lab of Xuan "Silvia" Zhang, assistant professor of electrical engineering, who accompanied the team to China as faculty adviser.

"One of the original objectives of this project was to see if we could make this in a very affordable manner," Zhang said. "You can buy an expensive robotic experiment setup that's ready-made, but to make this affordable, on one hand, it presented some interesting constraints that we had to work with as engineers. With extra constraints, there is more room for innovation and design. On the other hand, we want to be able to open source the entire platform so that other people can replicate it. In the end, that's a limitation, but we also tried to embrace this as a challenge."

The team's autonomous car, called the FlowBot, is about 4 inches by 7 inches and is inspired by the way insects use an optical flow method to navigate and avoid obstacles in an agile manner. The base model is called the Pi car because it uses Raspberry Pi, a palm-sized computer that costs about $30, a Raspberry Pi camera that costs about $15, and two motors.





Pushing science and engineering to create new soft materials

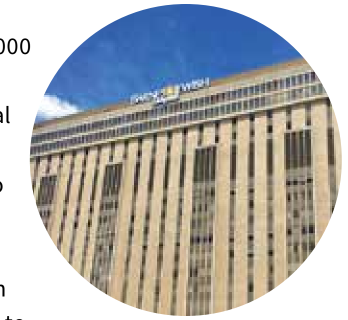
Engineering new materials holds enormous potential to improve and advance the global community. Breakthroughs in medicine, defense and clean energy could be achieved by designing polymeric materials with a whole host of abilities and properties.

To push this emerging field forward, the National Science Foundation (NSF) set up an initiative called Designing Materials to Revolutionize and Engineer our Future (DMREF). In August, DMREF awarded a four-year, $1.4 million grant to a team consisting of researchers from the engineering schools of Washington University and Duke University. The initiative awards grants to researchers at the forefront of materials advancement, enabling them to push science, stretch their imaginations in the quest to streamline the development of new soft materials, and predict and tune their properties for both existing and novel applications.

"You can imagine making an adhesive that will also have the strength of steel," said Rohit Pappu, the Edwin H. Murty Professor of Engineering at WashU. "Or perhaps something that will flow like toothpaste but also have the potential to be used as a miniature bioreactor. We could use new materials for drug delivery, drug storage, artificial tissues and other applications we haven't thought of yet."

Written by Erika Ebsworth-Goold

WashU researchers to test anesthesiology control tower



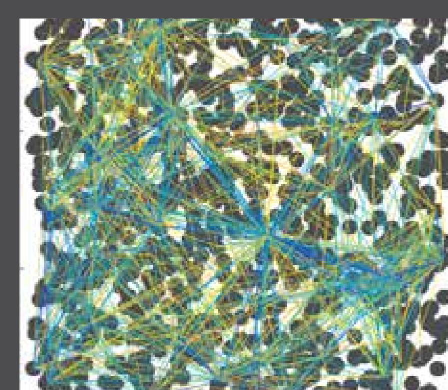
Michael Avidan, MBBCh, the Dr. Seymour and Rose T. Brown Professor of Anesthesiology at Washington University School of Medicine, and Yixin Chen, professor of computer science & engineering, are conducting a pilot study of an anesthesiology control tower to monitor patients' vital signs and other functions during surgery to prevent negative outcomes and medical errors, which lead to about 250,000 deaths in the U.S. each year.

Avidan, professor of anesthesiology and surgery and director of the Department of Anesthesiology's Institute of Quality Improvement, Research and Informatics, and chief of the Cardiothoracic Anesthesiology division, and Chen received a two-year, $300,000 grant from the National Institutes of Health to apply "big data" and information technology to monitor patient risk factors during surgery in a project called ACTFAST.

With the funding, the team is setting up a matrix of computer screens that will include one screen for each of the 48 operating rooms at Barnes-Jewish Hospital.

The screens will monitor the patients' vital signs and organs and color-code them like a stoplight: green is normal, yellow is in danger and red is urgent. Clinicians monitoring the screens will be able to determine what is wrong with the patient and notify the clinicians in the operating room immediately.

AI implications: Engineer's model lays groundwork for machine-learning device

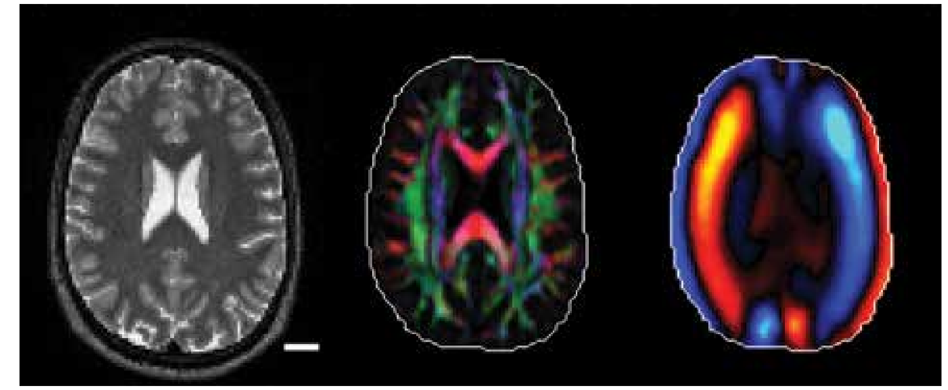


Elijah Thimsen, assistant professor of energy, environmental & chemical engineering, and his collaborators have developed a model in which to test existing theories about how electrons move through nanomaterials. This model may lay the foundation for using nanomaterials in a machine learning device.

"When one builds devices out of nanomaterials, they don't always behave like they would for a bulk material," Thimsen said. "One of the things that changes dramatically is the way in which these electrons move through material, called the electron transport mechanism, but it's not well understood how that happens."

Thimsen and his team based the model on an unusual theory that every nanoparticle in a network is a node that is connected to every other node, not only its immediate neighbors. Equally unusual is that the current flowing through the nodes doesn't necessarily occupy the spaces between the nodes — it needs only to pass through the nodes themselves. This behavior, which is predicted by the model, produces experimentally observable current hotspots at the nanoscale, Thimsen said.

Measuring with and against the grain



Researchers with the School of Engineering & Applied Science and the School of Medicine plan to use magnetic resonance imaging and focused ultrasound to better study the anisotropic behavior of brain tissue during trauma and mechanical stress.

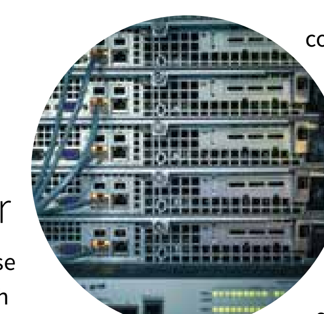
"What we eventually want to do in brain trauma prevention is develop computer simulations which can tell us how the injury occurs, what parts of the brain get injured and what preventative measures might make a difference," said Phil Bayly, the Lilyan & E. Lisle Hughes Professor of Mechanical Engineering at the School of Engineering & Applied Science. "To do that, you have to have a good mechanical model, and to make that, you must have good measurements of a variety of factors, including anisotropy."

The National Science Foundation recently awarded Bayly and his collaborators a three-year $467,000 grant to develop and validate the new measurement method.

Working with Hong Chen, assistant professor of biomedical engineering and assistant professor of radiation oncology at the School of Medicine, and Joel Garbow, professor of radiology at the School of Medicine, Bayly plans to use focused ultrasound to remotely and non-invasively apply a force deep in the tissue, and then measure how the resulting acoustic waves travel. The researchers will repeat this in a variety of materials, including collagen and fibrin gels that have been magnetically aligned to mimic the anisotropy of natural tissues.

Written by Erika Ebsworth-Goold

WashU engineers to study best way to maximize computer's power



When you type a word or phrase into a search engine, the search goes to many processors looking for the answer in an activity called parallel computing. A team of computer engineers at WashU is seeking the best way to take advantage of parallel computing to maximize its power and potential.

In one grant, Benjamin Moseley, Kunal Agrawal and I-Ting Angelina Lee, all faculty in computer science & engineering, received a four-year, $650,000 grant to find a way to schedule jobs so that the parallel computing process runs fairly and efficiently.

Parallel computing, which is now the standard in computing, uses at least two processors, or cores, simultaneously to solve a single problem. A desktop computer generally has eight cores, while a data center would have computers with 128 or 256 cores on one chip, said Moseley, the principal investigator.

"We want to use the processing power and deliver good quality of service," said Moseley, an applied mathematician. "This would result in more results, so users could do more work, and reduced variance of time it takes to receive results."

Study in *Nature:* Engineers find better way to detect nanoparticles

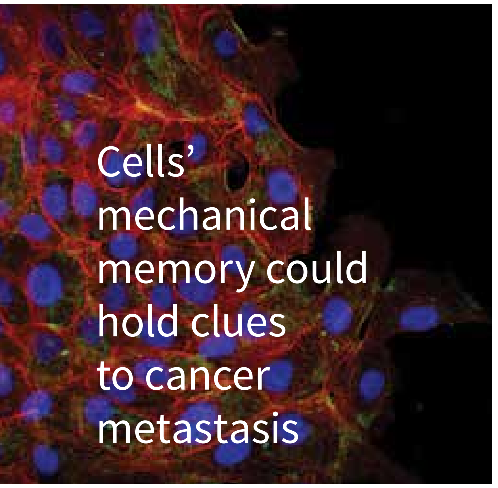
It's long been thought that two's company and three's a crowd. But electrical and systems engineers at WashU and their collaborators have shown that the addition of a third nanoscatterer, complementing two "tuning" nanoscatterers, to a photonics resonator makes for a fascinating physics party.

Specifically, the two tuning nanoscatterers set the resonator at an "exceptional point," a special state of a system at which unusual phenomena may occur. The third nanoscatterer perturbs the system, and like a nasty playground bully, the smaller it is, the more response it gets.

The WashU team, led by Lan Yang, the Edwin H. & Florence G. Skinner Professor of Electrical & Systems Engineering, has made major strides recently in the study and manipulation of light. The team's most recent discovery of the sensing capability of microresonators could have impacts in the creation of biomedical devices, electronics and biohazard detection devices.

"It's challenging to detect nanoscale objects, such as nanoparticles," Yang said. "If the object is very small, it introduces little perturbation to a sensing system. We utilize an unusual topological feature associated with exceptional points of a physical system to enhance the response of an optical sensor to very small perturbations, such as those introduced by nanoscale objects."

Written by Tony Fitzpatrick



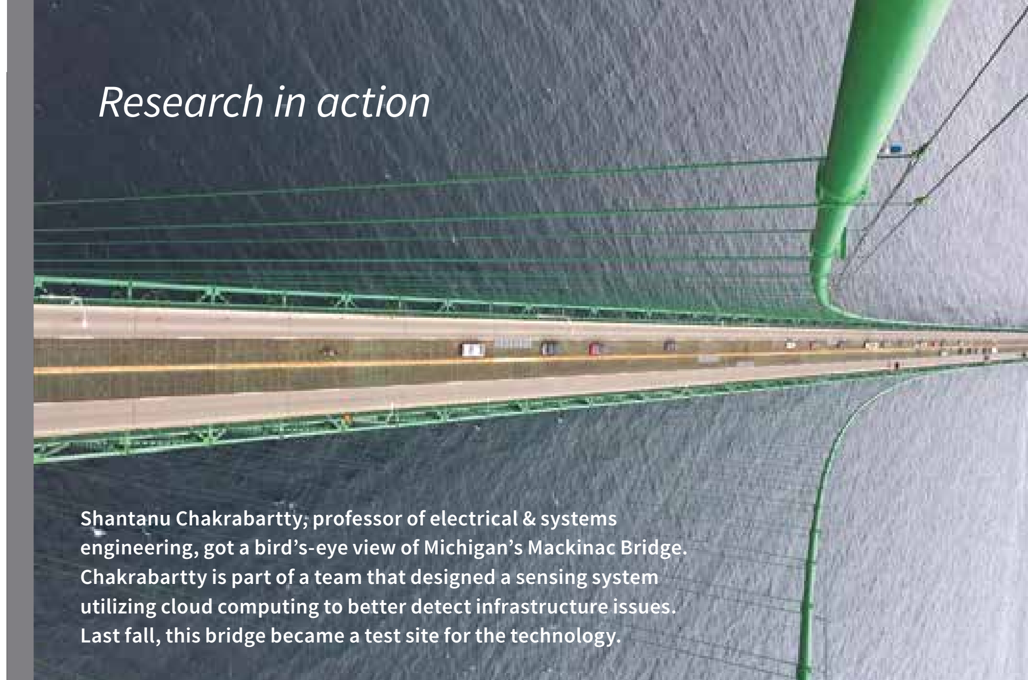
Cells' mechanical memory could hold clues to cancer metastasis

In the body, cells move around to form organs during development; to heal wounds; and when they metastasize from cancerous tumors. A mechanical engineer at Washington University in St. Louis found that cells remember the properties they had in their first environment for several days after they move to another in a process called mechanical memory.

Amit Pathak, assistant professor of mechanical engineering & materials science, spent three years using mechanobiology and materials science to find answers to these questions: If cells sit in one environment and move to another one, do they remember the first one, and do they inherit any of the properties of the first environment? The results of the research, conducted in collaboration with Gregory Longmore, professor of medicine in the Department of Internal Medicine's Medical Oncology division at Washington University School of Medicine, were available in advanced online publication Sept. 8 in *Biomaterials*.

To prove his hypothesis, Pathak created a device from which he can measure how long the cells' memory lasts in the new environment. The device, which has a U.S. patent pending, has two sides divided by a barrier. Samila Nasrollahi, a graduate student in Pathak's lab, placed cells in the stiff side of the device, a similar environment as a malignant tumor. After a few days, she removed the barrier, and the cells quickly invaded the other side of the device, which is a soft environment.

Research in action



Shantanu Chakrabartty, professor of electrical & systems engineering, got a bird's-eye view of Michigan's Mackinac Bridge. Chakrabartty is part of a team that designed a sensing system utilizing cloud computing to better detect infrastructure issues. Last fall, this bridge became a test site for the technology.

Study casts doubt on the warming implications of brown carbon aerosol from wildfires

As devastating wildfires continue to rage in the western U.S. and Canada, a team of environmental engineers has discovered that light-absorbing organic particulate matter, also known as brown carbon aerosol, in wildfire smoke loses its ability to absorb sunlight the longer it remains in the atmosphere.

Rajan Chakrabarty, assistant professor, and Brent Williams, the Raymond R. Tucker Distinguished InCEES Career Development Associate Professor, both aerosol scientists in the Department of Energy, Environmental & Chemical Engineering, and their labs found that brown carbon aerosol changes its properties from light-absorbing to light-scattering the longer it remains in the atmosphere. When it is first emitted, the smoke is brown and has a warming effect on the atmosphere. But over several days in the atmosphere, the smoke gradually turns white and has a significantly reduced warming effect. The resulting white smoke roughly contributes to about a 46 percent reduction in light absorption compared with the brown smoke.

"Our study casts doubts on the warming implications of brown carbon," Chakrabarty said. "If this life cycle analysis is not taken into account, climate models could very well give rise to overestimated values of warming due to these aerosols."

Results of the research were published in early online publication in *Environmental Science & Technology Letters* Sept. 21, 2017.

Chakrabarty, Williams and their lab members made the discovery by burning peatland fuels, acquired from different regions of Alaska with the help of the U.S. Forest Service, in their combustion chamber. Smoldering peat fires in the Boreal forests are a major source of organic aerosol and carbon emissions. In a unique simulated environment, the team studied the changes in the physics, chemistry, optical properties and composition of the brown carbon smoke over several days. By exposing the smoke plumes to ultraviolet radiation and oxidants, such as ozone, in a photochemical reactor, they could mimic the natural effects in the atmosphere.

A sodium surprise

Irregular heartbeat — or arrhythmia — can have sudden and often fatal consequences. A biomedical engineering team at WashU examining molecular behavior in cardiac tissue recently made a surprising discovery that could someday impact treatment of the life-threatening condition.

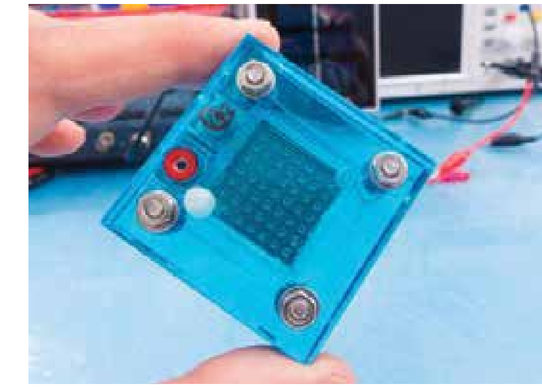
"It was a fun finding, not at all what we expected to see," said Jonathan Silva, assistant professor of biomedical engineering.

Silva and his team study sodium ion channels — tiny proteins in cardiac muscle that electrically control a heartbeat — and how they interact with molecules that could affect their performance. In new research, recently published by the *Journal of General Physiology*, Silva worked with collaborators to take a closer look at the sodium ion channels responsible for creating the electrical signal that makes the heartbeat: Zoltan Varga at the University of Debrecen in Hungary, and Jeanne M. Nerbonne, Alumni Endowed Professor of Molecular Biology and Pharmacology and Director of the Center for Cardiovascular Research at Washington University School of Medicine.

"Sodium channels aren't made out of just one part," Silva said. "The main portion is a really big protein made up of more than 2,000 amino acids, and then there are smaller proteins called beta subunits that attach to it. We wanted to understand what the differences were in how the beta subunits controlled the channel."

Written by Erika Ebsworth-Goold

Creating longer-lasting fuel cells



An engineering team at WashU has developed a new way to take a look at the rate at which oxidation occurs. Using fluorescence spectroscopy inside the fuel cell, they are able to probe the formation of the chemicals responsible for the oxidation, namely free radicals, during operation. The technique could be a game changer when it comes to understanding how the cells break down and designing mitigation strategies that would extend the fuel cell's lifetime.

"If you buy a device — a car, a cellphone — you want it to last as long as possible," said Vijay Ramani, the Roma B. and Raymond H. Wittcoff Distinguished Professor of Environment & Energy.

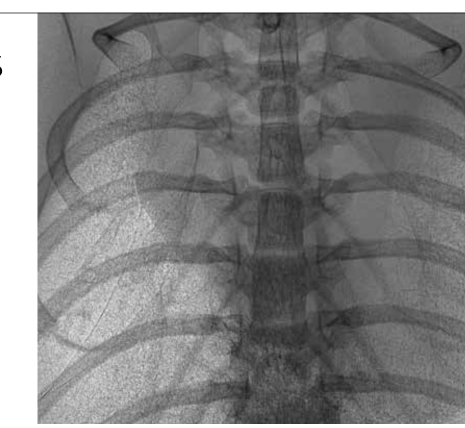
"Unfortunately, components in a fuel cell can degrade, and it's not an easy fix. What our new research does is really shed light on one of the modes by which these devices can fail, allowing us to figure out methods so we can improve the lifetime of devices that use these fuel cells."

The research, published this summer in the journal *ChemSusChem*, is the first to use an in situ approach to examine the fuel cell's inner membranes. A fluorescent dye is incorporated and used as a marker to ascertain the rate at which damaging free radicals are generated during operation.

"By using fluorescence spectroscopy in conjunction with an optical fiber, we can quantify the oxidative free radicals generated inside the fuel cell, which work to break down the membranes," said Yunzhu Zhang, a doctoral candidate in Ramani's lab and study co-author.

Written by Erika Ebsworth-Goold

A better look at the lungs



The National Institutes of Health awarded a biomedical engineer a four-year, $1.7 million grant to attempt to develop a new way to image airflow in lungs. If such research proves successful, it someday could make diagnoses of lung disease considerably more expeditious, easy and cost-effective.

A team of engineers and radiologists at WashU hopes to develop a new X-ray technique to better see airflow in the lungs.

"There is a great clinical need for being able to image ventilation; however, there's really no easy way to image ventilation in vivo right now. So the purpose of this project is to develop a new technique," said Mark Anastasio, professor of biomedical engineering.

Physicians currently use CT scans and MRI to image airflow — or ventilation — in the lungs. Both methods require the patient to inhale a contrast agent, a procedure that can cause complications. Additionally, such methods require expensive equipment that limits their widespread use.

Anastasio will use sophisticated modeling and machine learning to develop new tech that would enable airflow imaging with a single X-ray image. The method would take less time and not require contrast inhalation beforehand. It potentially would be a less expensive, more efficient way to get a better look at how air circulates through the lungs.

"We believe this rapid imaging approach will allow earlier diagnosis of a whole host of lung conditions, including COPD and even lung cancer," Anastasio said.

Written by Erika Ebsworth-Goold

Test uses nanotechnology to quickly diagnose Zika virus

Currently, testing for Zika requires that a blood sample be refrigerated and shipped to a medical center or laboratory, delaying diagnosis and possible treatment. Although the new proof-of-concept technology has yet to be produced for use in medical situations, the test's results can be determined in minutes. Further, the materials required for the test do not require refrigeration and may be applicable in testing for other emerging infectious diseases.

Findings from the small study — from Washington University School of Medicine and the School of Engineering & Applied Science — are available online in the journal *Advanced Biosystems*.

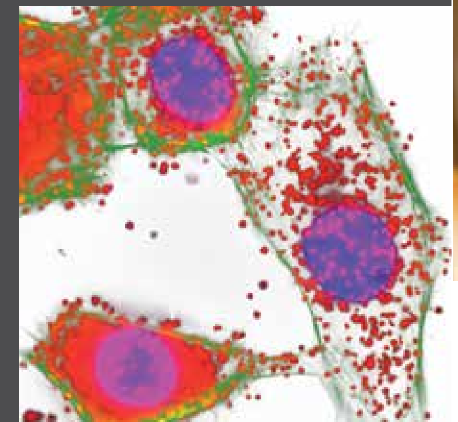
The researchers tested blood samples taken from four people who had been infected with Zika virus and compared it to blood from five people known not to have the virus. Blood from Zika-infected patients tested positive, but blood from Zika-negative controls did not. The assay produced no false-positive results.

Among the reasons such a test is needed, according to the researchers, is that many people infected with Zika don't know they're infected. Although symptoms include fever, joint pain, muscle pain and rash, many people don't feel ill after being bitten by an infected mosquito. Testing is particularly important for pregnant women because Zika infection can cause congenital Zika syndrome, which contributes to several neurologic problems in the fetus or newborn infant.

That strategy requires inexpensive, easy-to-use and easy-to-transport tests. Kharasch, the Russell D. and Mary B. Shelden Professor of Anesthesiology, collaborated with Srikanth Singamaneni, associate professor of mechanical engineering & materials science, and Jeremiah J. Morrissey, research professor of anesthesiology, to create the test, which uses gold nanorods mounted on paper to detect Zika infection within a few minutes.

Written by Jim Dryden

Biomedical engineer combines data, algorithms to understand HER2 breast cancer gene

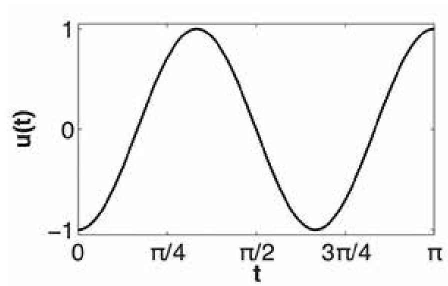


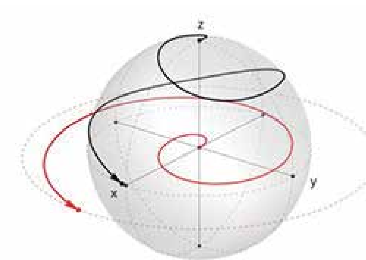
Kristen Naegle, assistant professor of biomedical engineering, applied her unique computational skills to look at the HER2 gene. HER2-positive breast cancers are aggressive and spread faster than other types. Researchers have found that too much protein is made from the HER2 gene — called overexpression — in 20 percent of all breast cancers, making HER2 a valuable target for potential personalized treatment methods for this type of breast cancer.

To determine why HER2-positive cancers are more aggressive, Naegle analyzed measurements from a previous study that isolated signaling molecules in a HER2-overexpressing breast cell line and a normal breast cell.

"We use mathematical approaches to find similarities in the data," Naegle said. "For this dataset, we looked at how signaling molecules are most related to each other in the normal cells, compared to how they are related to each other in the HER2-overexpressing cells. We looked for relationships that are drastically different in the two cell types to understand how signaling is altered. Despite the fact that individual molecules are highly similar to each other across cell types, we found that small changes in signaling dynamics led to very large changes in the relationships uncovered between groups of signaling molecules."

WashU engineer develops key mathematical formula for driving quantum experiments



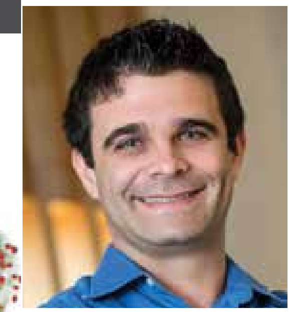


Jr-Shin Li , the Das Family Career Development Distinguished Associate Professor, and his collaborators have derived a mathematical formula to design broadband pulse sequences to excite a population of nuclear spins over a wide band of frequencies. Such a broadband excitation leads to enhanced signal or sensitivity in diverse quantum experiments across fields from protein spectroscopy to quantum optics.

The research, the first to find that designing the pulse can be done analytically, was published in *Nature Communications* Sept. 5.

"This design problem is traditionally done by purely numerical optimization," Li said. "Because one has to design a common input — a magnetic field to excite many, many particles — the problem is challenging. In many cases in numerical optimization, the algorithms fail to converge or take enormous amounts of time to get a feasible solution."

Eleven new faculty join WashU Engineering











BIOMEDICAL ENGINEERING

Nathaniel Huebsch, assistant professor

» PhD, engineering science and medical engineering, Harvard University

» Huebsch's research focus is in basic and translational stem cell mechanobiology, with specific focus on hydrogels to control cell-mediated tissue repair, and 3-D heart-on-a-chip models derived from human induced pluripotent stem cells.

Michael Vahey, assistant professor

» PhD, SM, electrical engineering and computer science, Massachusetts Institute of Technology

» Vahey's research has been in live imaging of the influenza A virus assembly; in vitro reconstitution of membrane budding by influenza virus proteins; microfluidic technologies for membrane reconstitution; and miotic spindle assembly in confined volumes.

COMPUTER SCIENCE & ENGINEERING

Sanjoy Baruah, professor

» PhD, MS, computer science, University of Texas, Austin

» Baruah's research is in scheduling theory; real-time and safety-critical system design; computer networks; resource allocation and sharing in distributed computing environments.

Ayan Chakrabarti, assistant professor

» PhD, SM, engineering sciences, Harvard University

» Chakrabarti's research focuses on computer vision, computational photography and machine learning. Using tools from machine learning, he works to develop efficient and reliable visual inference algorithms, as well as new high-capability cameras and visual sensors.

Chien-Ju Ho, assistant professor

» PhD, computer science, University of California, Los Angeles

» Ho's research centers on the design and analysis of human-in-the-loop systems, with a focus on acquiring and utilizing human-generated data. The research spans and draws from the fields of machine learning, algorithmic economics, optimization, and online behavioral social science.

Ulugbek Kamilov, assistant professor

» PhD, electrical engineering, École Polytechnique Fédérale de Lausanne, Switzerland

» Kamilov joins the ESE and CSE departments. Kamilov's research areas are developing new techniques for computational imaging in biomedical and industrial applications. His broader research interests include signal and image processing, convex and nonconvex optimization, statistical inference, and machine learning.

Brian Kocoloski, assistant professor

» PhD, computer science, University of Pittsburgh

» Kocoloski's research seeks to make it easier to efficiently use large parallel computers. His work has been primarily focused in system software, where he has designed operating systems and virtualization mechanisms to improve the scalability of tightly synchronized parallel workloads.

William Yeoh, assistant professor

» PhD, MS, computer science, University of Southern California

» Yeoh's research focuses on artificial intelligence with an emphasis on developing optimization algorithms for agent-based systems. His primary expertise is in distributed constraint optimization, where his goal is to develop and deploy such algorithms in smart grid and smart home applications.

ELECTRICAL & SYSTEMS ENGINEERING

Chuan Wang, assistant professor

» PhD, electrical engineering, University of Southern California

» Wang's research interests include flexible and stretchable electronics for display, sensing and energy harvesting applications, as well as low-cost and scalable inkjet printing processes for microfabrication of flexible electronics.

Shen Zeng, assistant professor

» PhD, engineering, University of Stuttgart

» Zeng's research focuses on systems theoretic methods for the study of complex and large-scale dynamical systems. Zeng in particular seeks to develop computational methods that will efficiently utilize the abundance of available data for both systems analysis and controller synthesis.

ENERGY, ENVIRONMENTAL & CHEMICAL ENGINEERING

Peng Bai, assistant professor

» PhD, mechanical engineering, Tsinghua University

» Bai's research focuses on the mechanism and control of lithium dendrite growths; asymmetrical reaction kinetics at battery nanoparticles; dual-mode lithium-brominel seawater flow battery; mixed ion-electron transfer kinetics of core-shell nanomaterials.

Q&A with Lori Setton

Chair of the Department of Biomedical Engineering and the Lucy & Stanley Lopata Distinguished Professor of Biomedical Engineering

RON KLEIN

What have you learned about the department you didn't know before?

I learned that the department and the university have a supportive culture and climate for entrepreneurship and tech transfer. I had no idea before I came here that there would be so many resources and such a deep commitment to really rapidly translating ideas into inventions.

What are your goals as chair?

I am eager to build upon the traditions of research excellence at WashU BME in cardiac bioengineering, medical imaging, neuroengineering from devices to systems, and in molecular and cellular engineering. At the same time, we have an opportunity to expand our strengths in regenerative bioengineering in partnership with the School of Medicine. So I expect to make faculty hires that will take on leadership roles to shape and define BME for the future.

For a student who studies biomedical engineering, what can the future hold?

It is widely known that biomedical engineering is one of the few engineering disciplines that continues to grow and expand at all levels. The interest in hiring our students is only growing, and the ability to generate new industries, new market sectors and new products is only increasing, particularly as the health-care sector becomes an even larger part of our economy. Biomedical engineering is at the bottom of what I think will be a very long growth curve.

> We have to respect and understand that many of these engineering undergraduate degrees are not even 25 years old, and employers are just beginning to understand the value that this pool of graduates is providing.

What challenges do biomedical engineering students face, and how is the department preparing them for those challenges?

We don't yet fully understand the world that our students are going to inhabit even 15 or 20 years from now. Technology is evolving so quickly. Even global economies are changing on the order of five to 10 years. We are trying to prepare students to be capable, competitive and successful in almost any enterprise and in the future. I think we have to ensure that they are excellent communicators, are fearless in mastering new disciplines, and they are self-motivated and can work independently. I think biomedical engineering does a great job of preparing them with these talents and skills.

What are the challenges for women in the biomedical engineering field?

There are always constituents who are underrepresented, underserved and undervalued. Women in biomedical engineering definitely feel that at the professional level and at the academic faculty level. In my time in academia, I've watched the representation of women students in BME grow from about 20 percent to our current level of 50 percent at the undergraduate level. I like to think that their experience now, with half of their class being female, is pretty positive and that they feel like they have a community that they can work with to complete problem sets, design projects and where they get support in lab research. But I certainly don't think that women either in professions or in academics have that same sense of community right now. Essential to my happiness and retention in academia has been a small but close-knit group of female mentors that have served me well throughout my career. I have needed them as sounding boards to process responses to my scholarship, evaluations, opportunities and simply daily life.

Big on my agenda, and I think on the whole school's agenda, is to increase representation of under-represented minorities. I've just stepped into this chair role, but I'm starting to talk about what we can do to broaden diversity. We created the Chair's Fellowship, which creates incentives for under-represented students when they sign up for graduate school at WashU. We have also begun to create opportunities through WashU's many NIH training grants to support broader professional development for minority students.

What is your role with the Biomedical Engineering Society?

I am currently president of BMES. The 50th anniversary is in 2018, so we're preparing for one big birthday party. It is important for me to contribute to BMES, a wonderful community of colleagues and scholars that has historically been the home for everything related to biomedical engineering education. That community is where we recruit our faculty candidates and students and share best practices. Part of what I've been working toward is to make it the go-to home for continued professional learning, and a first step has been contributing to the generation of the 10th BMES industry chapter here in St. Louis, now enjoying its first year.

What do you consider your biggest accomplishment so far?

I think my greatest accomplishment is graduating many, many students and mentoring a large number of post-docs who have remained invigorated by research, both academic and corporate research, and have remained engaged in advancing knowledge at some level. I think I've had about 20 PhD students and more than 20 post-docs, and I now enjoy seeing them spread their knowledge and influence nationally.

2015

JOINED THE WASHU ENGINEERING FACULTY FROM DUKE UNIVERSITY

SHE HAS MENTORED MORE THAN 40 DOCTORAL AND POSTDOCTORAL TRAINEES IN HER LAB

$25M

RESEARCH FUNDING FOR HER WORK AND 170 PAPERS IN PEER-REVIEWED JOURNALS

Son Justin Guliak, Lori Setton, Farshid Guilak and daughter Dina Guilak

COLUMBIA UNIVERSITY

EARNED MASTER'S AND DOCTORAL DEGREES IN MECHANICAL ENGINEERING FROM COLUMBIA UNIVERSITY

Follow Lori's research and learn more about exciting news at WashU BME: @setton_lab

Setton named chair of WashU biomedical engineering

Lori Setton, a renowned researcher into the role of the degeneration and repair of musculoskeletal tissues, was named chair of the Department of Biomedical Engineering effective Aug. 1.

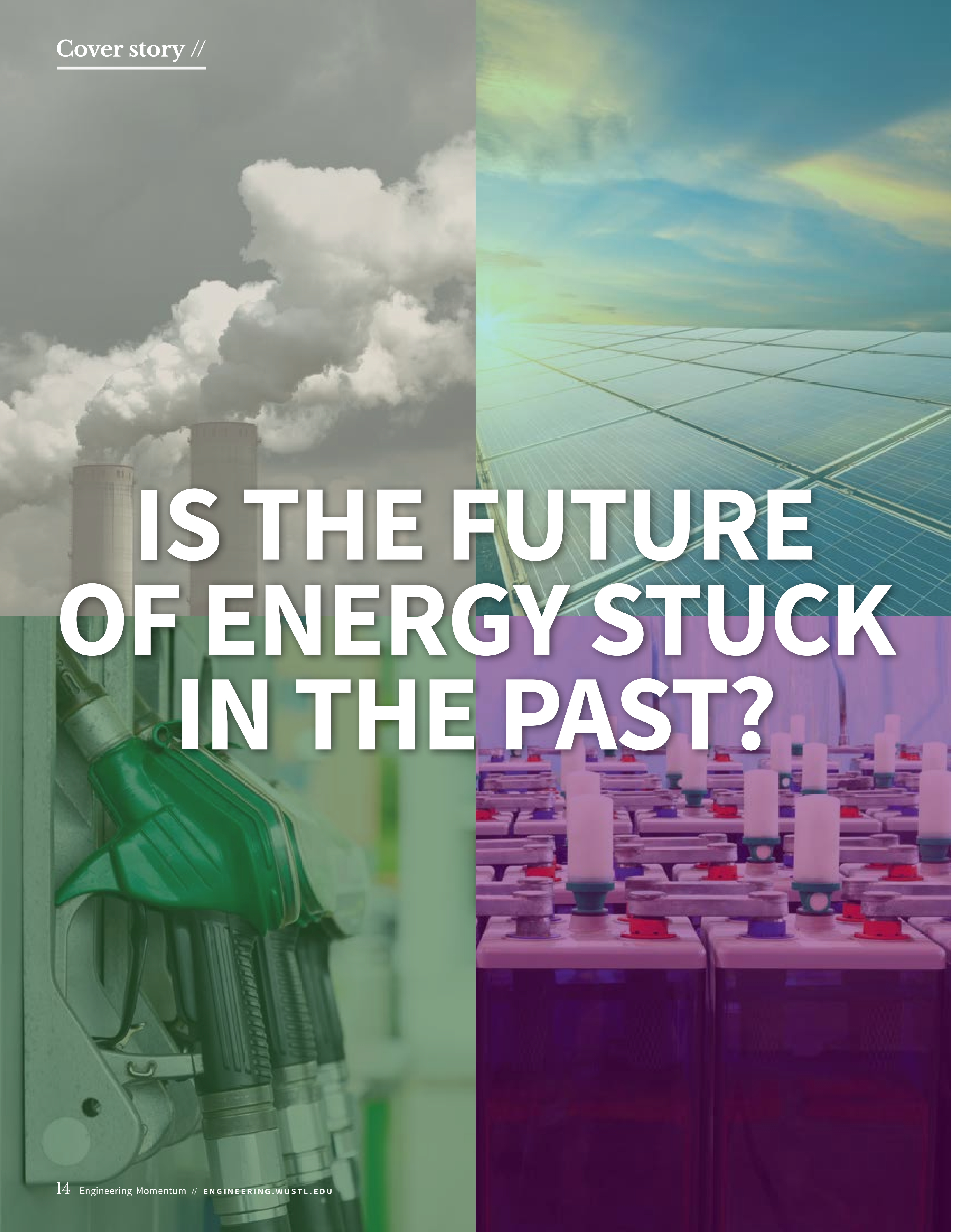
Setton's research blends tools from mechanical engineering, materials synthesis and cell and molecular biology to advance use of biomaterials designed to deliver bioactive cells or drugs to treat musculoskeletal diseases such as arthritis and herniated disks.

"We are quite fortunate to have someone as talented and qualified as Dr. Lori Setton already at Washington University," said Aaron Bobick, dean of the School of Engineering & Applied Science and the James M. McKelvey Professor. "Lori is not only a tremendous scholar and researcher, she is also a leader within the biomedical engineering community, serving as the Biomedical Engineering Society president. I very much look forward to working with Lori as we work closely to achieve her great aspirations for the department."

Setton's work includes creating new biomaterials that promote regeneration of degenerating intervertebral discs; creating new drug depots to slowly release inflammatory inhibitors in arthritis and disc diseases; and revealing novel relationships between disease development and the onset of pain and dysfunction. At the start of Setton's research career in the 1990s, she was one of a few to tackle how mechanical loading and biological factors contribute to disc disorders and back pain, a field we now know as mechanobiology.

She is a fellow of the Biomedical Engineering Society (BMES) and of the American Institute of Biological and Medical Engineering and earned a Presidential Early Career Award from Scientists and Engineers (PECASE) in 1997.

Setton has been recognized for her commitment to increasing diversity in the engineering student body as the first recipient of a doctoral research mentor award at Duke and for leading a partnership between the Biomedical Engineering Society and National Society for Black Engineers (NSBE) as BMES president.



IS THE FUTURE OF ENERGY STUCK IN THE PAST?

In the days after Hurricane Maria ravaged Puerto Rico, most of the U.S. territory had no running water or electricity. Damaged roads, harbors and airports hampered relief efforts. What's more, without power, the vast majority of cell towers and land lines were inoperable, meaning communications were all but cut off. Gas stations were running out of fuel, forcing people to ride bicycles or walk for miles in search of a fill-up.

The unfolding humanitarian disaster was a reminder not only of nature's power, but of modern society's dependence on electricity and fuel, for everything from refrigeration to transportation.

Written by REBECCA BOYLE

Jeff Phillips, who earned a bachelor's degree in mechanical engineering in 1981 and now is a senior program manager at the Electric Power Research Institute who formerly worked for Royal Dutch Shell

View of Puerto Rico from space days after Hurricane Maria.

"Fossil fuels offer something very unique: energy where you want it, when you want it, in all times in all places. That's unprecedented," said Richard Axelbaum, the Stifel & Quinette Jens Professor of Environmental Engineering Science. "How do you replace something that is available to you at all times in all places, with things that aren't available to you at all times and in all places? That's the challenge facing us."

Modern society developed in large part because of relatively easy, cheap access to fossil fuels, Axelbaum argues. And the world is still using those resources, based on technologies first developed more than a century ago. From efforts to improve automobile fuel economy to reducing emissions at electrical power plants, the future of energy is inherently still in the past, according to School of Engineering & Applied Science experts. Replacing atmosphere-warming coal and crude oil, or eliminating their emissions — and doing so in a way that minimizes disruption to daily life and commerce — is not going to be easy. But the university is on the forefront of efforts to do so.

Researchers are growing bacteria to produce biofuels that can use existing pipelines and infrastructure; designing new batteries and storage tanks that can harness the power of the wind and the sun; and building technology that not only diverts carbon dioxide from the atmosphere, but allows it to be used anew. Dramatically reducing carbon dioxide emissions to levels agreed upon in the Paris climate accord will not happen without dramatically changing the way we imagine and use energy, experts say.

"You can't get there by tweaking today's technologies. It won't happen," said Jeff Phillips, who earned a bachelor's degree in mechanical engineering in 1981 and now is a senior program manager at the Electric Power Research Institute who formerly worked for Royal Dutch Shell. "There needs to be a fundamental shift in the way we use fossil fuels and reducing the cost of low-

> "There needs to be a fundamental shift in the way we use fossil fuels and reducing the cost of low-carbon energy sources like wind and solar and nuclear."
>
> — JEFF PHILLIPS

carbon energy sources like wind and solar and nuclear. WashU is actively involved in many areas helping to bring about this fundamental shift and move toward revolutionary approaches in how to harness and use energy."

Coal

Even in 2017, the vast majority of the energy that powers computers, moves cars and drives society is derived from some form of combustion. In a power plant, coal or natural gas (or nuclear decay) is used to warm water, generating steam that spins a turbine to produce electricity. In a car, an internal combustion engine burns gasoline with air, which expands to push a piston that turns a crankshaft, which turns the wheels.

Most power plants are designed and built to last at least three to five decades, and power plant operators expect to recoup their construction costs over many years. In the United States, natural gas production has spiked while coal-burning has declined, but developing economies in China, India and elsewhere are still reliant on coal. That's one reason why Axelbaum focuses on making it cleaner to use. He is working on pressurized oxy-combustion, a method of recovering the latent heat in a power plant's steamy smokestack and using it to increase the

Richard Axelbaum

WHITNEY CURTIS

> “It’s going to be very hard to internationally ask people to double the cost of electricity or use unreliable sources of energy, so we need to think about how to bring the price down. This new technology allows us to do that.”
>
> — RICHARD AXELBAUM

THE COAL SHARE OF TOTAL WORLD ENERGY CONSUMPTION IS EXPECTED TO DECLINE SIGNIFICANTLY, **from 27% in 2015 to 22% in 2040.**

efficiency of the plant while virtually eliminating all emissions. The pressurized carbon dioxide (CO_2) can later be injected deep underground, preventing it from escaping into the atmosphere and worsening global warming. Axelbaum has received more than $8 million from the Department of Energy (DOE) to develop the technology, which is being tested in a large, three-story experimental facility on campus and studied on the International Space Station, where microgravity allows for detailed studies of combustion. He says his method cuts the cost of carbon capture in half.

“It’s difficult to expect developing countries to pay double for their electricity, or use unreliable sources of energy, so we need to think about how to bring the price of clean energy down. This new technology allows us to do that,” he said.

Prices are a concern in the U.S. as well as developing countries. But the cost of increasing access to energy may be one developing economies are willing to bear. Britain and France have announced intended rules that will bar automakers from selling petroleum-based cars after 2040, and China is considering similar rules, according to Vijay Ramani, the Roma B. & Raymond H. Wittcoff Distinguished University Professor of Environment & Energy. And in India, the government is stepping in to electrify the nation.

On Sept. 25, Indian Prime Minister Narendra Modi launched a 163.2 billion-rupee (US$2.5 billion) program to ensure electricity for every household by March 2019. It will focus on helping people, including residents of more than 3,000 un-electrified villages, obtain “last-mile” electricity connections at no cost.

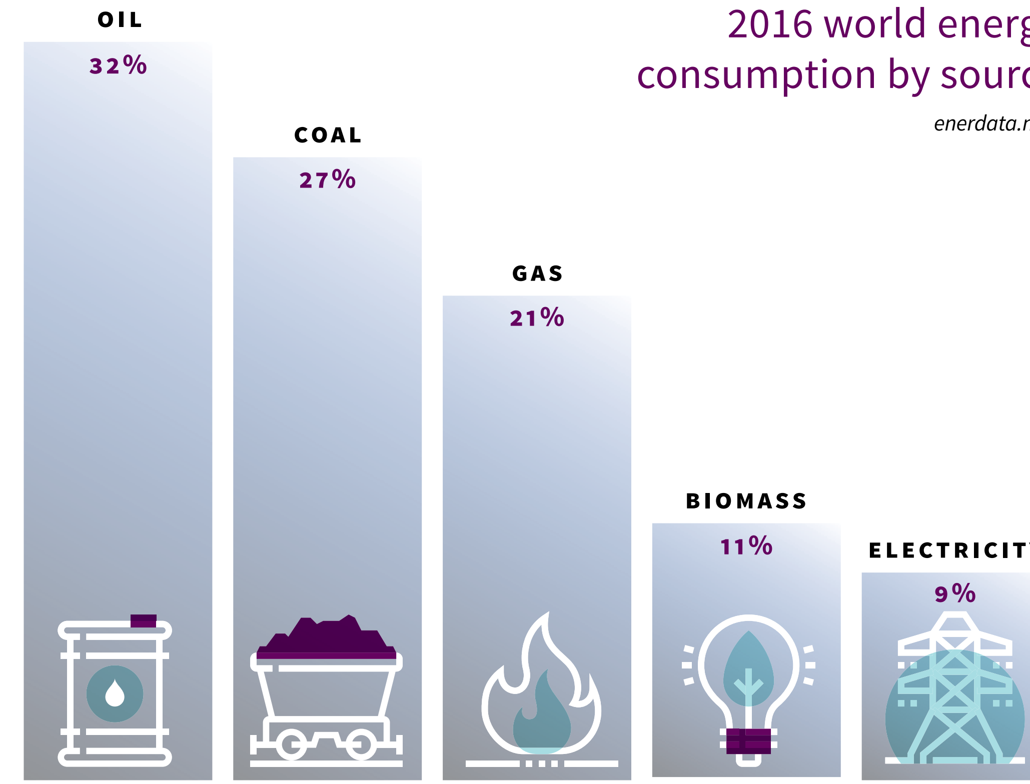
Still, replacing giant pieces of the power grid is often more expensive than building them right in the first place. In that case, Axelbaum’s pressurized oxy-combustion and other forms of carbon capture, storage and utilization can help.

But the next generation will face a different sort of challenge, down to their very bones, Phillips says. Power plants are not designed to switch on and off, and when they are forced to do so, they can break down more easily. The metals that make up a power plant, from ventilation and tubing to the turbine blades themselves, expand and contract as they heat and cool. This causes damage due to a phenomenon known as thermal fatigue.

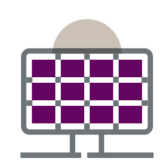
“These old plants we have today were designed assuming they were going to run around the clock,” Phillips said. “But if we say, ‘Actually, new power plants that are going to use fossil fuels are going to go up and down like a yo-yo,’ we need to be able to handle that. It really comes down to developing materials that have a better ability to withstand temperature swings.”

2016 world energy consumption by source

enerdata.net



Renewables



In the near future, those on-off temperature swings may become more common, as coal-fired power plants will only be needed according to the whims of nature. Pratim Biswas, assistant vice chancellor of international programs, chair of the Department of Energy, Environmental & Chemical Engineering and the Lucy & Stanley Lopata Professor, is working on technology that bridges the old and the new.

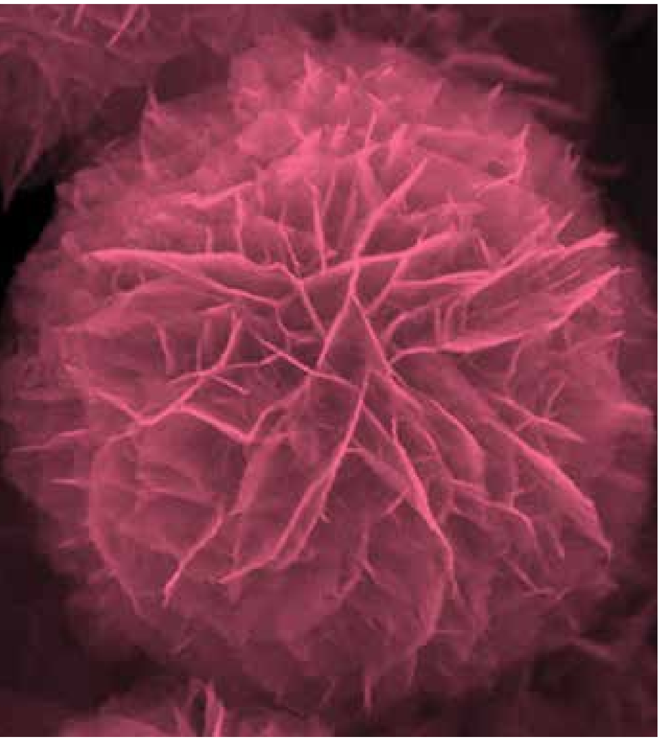
In the past few years, a new class of solar energy devices called perovskite cells, which are hybrids of organic and inorganic material, has revolutionized solar energy research. Previous generations of solar panels were made from silicon, which remains expensive, but perovskite cells could make solar panels a feasible option for anyone, Biswas said. They would be lower-cost and higher-efficiency, but right now, they don’t last as long as traditional photovoltaic cells.

“A key requirement in this case is that systems be more stable, so they last for

IN OCTOBER 2017, ST. LOUIS JOINED 46 OTHER CITIES ACROSS THE U.S. COMMITTING TO **100% clean energy by 2035.**

Pratim Biswas (right) with a PhD student

RON KLEIN



In Pratim Biswas' lab, researchers are creating tiny particles and pairing them with catalysts to speed reactions between CO_2 and sunlight.

RON KLEIN

RENEWABLES ARE THE WORLD'S FASTEST-GROWING ENERGY SOURCE, WITH CONSUMPTION INCREASING BY AN AVERAGE

2.3% a year between 2015 and 2040.

15 to 20 years on the roof of a building," Biswas said. "They are not there as of yet. We are exploring techniques to make perovskite solar cells that are more stable."

Meanwhile, there are other ways to harness the sun's energy for power generation. Biswas is building novel materials that can capture carbon dioxide emitted from power plants and use energy from the sun to turn it into a product that can be used again. It may sound revolutionary, but it's what nature already does, Biswas pointed out.

"It's carbon recycling, but in an engineered, faster manner," he said. "Carbon is recycled by plants and trees, but it is slow."

As an aerosol scientist, Biswas focuses on tiny particles that remain airborne and can contribute to global warming. His lab's aerosol reactors engineer tiny particles and pair them with chemical catalysts, which can speed up reactions between CO_2 and sunlight. The engineered particles are deposited as thin films through which air flows. When activated by sunlight, the particles trap the carbon dioxide molecules and can convert them into compounds such as simple hydrocarbons or alcohols that can be used later. Biswas' lab is filled with artificial-sunlight lamps shining on thin films filled with aerosols.

Biswas said the technology already works, but large-scale progress has been limited by policy. The U.S. does not control carbon dioxide emissions, and regulations put in place by the Obama administration face legal challenges. With tighter carbon emission rules, power utilities would have an incentive to invest in the technology, but for now it remains expensive, Biswas said.

"If regulations stepped up, this could be utilized," he said. "In countries such as India and China, where there are regulations, this is where our partnerships through the McDonnell Academy Global Energy and Environment Partnership (MAGEEP) come in handy. There needs to be a global willingness to address the CO_2 issue in the most significant manner possible."

Biofuels

U.S. regulations have called for improvements in fuel economy, specifically for cars, which are still a leading cause of carbon dioxide emissions around the world. But so far, no one has come up with a replacement for gasoline that is cheap, easy to transport, fast to fill up and efficient to burn, said Fuzhong Zhang, associate professor of energy, environmental & chemical engineering and director of the Biomolecular Engineering and Synthetic Biology Laboratory.

"We need replacements with properties similar to fuels that we pump into buses, airplanes, cars and trucks," he said. "We also need the fuel replacements to be produced from cheap and renewable feedstock. But how to convert cheap and renewable feedstock to fuels like we already use is a challenge."

Although ethanol has been produced by fermenting corn and used as an additive in combustion engines, it's corrosive to both existing engines and transportation pipelines. Butanol, another form of alcohol that is less corrosive and was believed to be a better replacement than ethanol, can only replace gasoline in limited quantities and provides less combustion heat than gasoline.

> "We need replacements with properties similar to fuels that we pump into buses, airplanes, cars and trucks."
>
> — FUZHONG ZHANG

"We want to go to a gas station, and in one minute, put enough energy in our cars to drive 300 miles," Axelbaum said. "It's taken for granted, but that's an unbelievable capability that we have. Fossil fuels have gotten us used to a lifestyle that's very hard to give up, but they are also very hard to replace."

Zhang is working on another organic solution: Engineering bacteria to convert sustainable resources to chemicals such as petroleum-derived gasoline, diesel and jet fuels.

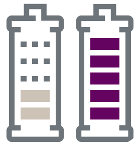
"We collaborate with other WashU labs to develop processes that can convert waste biomass from agriculture into simple chemicals or sugars, and then the engineered bacteria will be able to eat them," Zhang said. "The bacteria will at the same time produce better fuels that can be directly used in current engines without further modification. We also develop methods to control these bacteria so that they would grow and do their job efficiently and robustly, in large fermenters with thousands of tons of scale."

In addition to studying the waste-conversion process, Zhang is modifying the genomes of several types of bacteria to produce new forms of materials and various chemicals with novel properties. Ideally, their advanced fuels would be pumped through the existing oil and gasoline infrastructure. One day, motorists could pull up to a pump and inject their cars not with gasoline derived from the Paleozoic, but from decidedly modern microbes.

Fuzhong Zhang

RON KLEIN

Storage

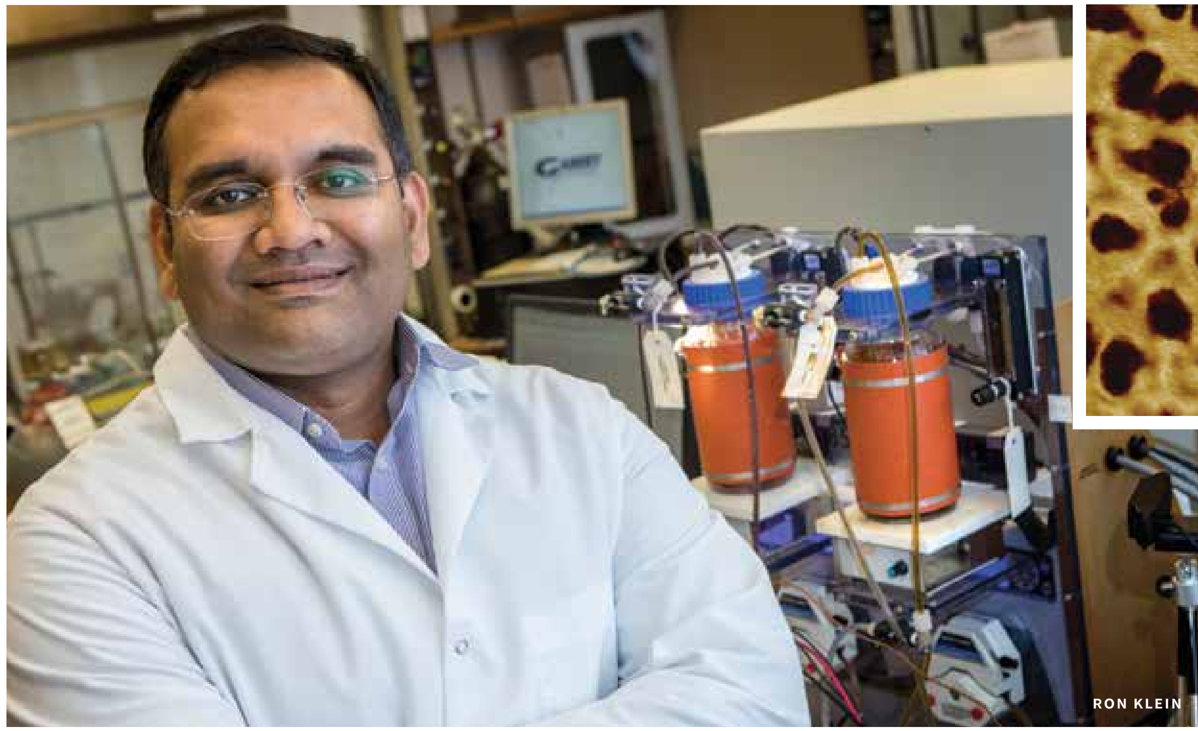


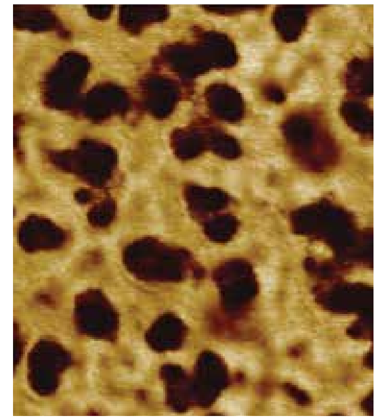
The batteries in bacteria-burning cars will also likely look different in a few years, Ramani said. Basic car batteries have not changed much since cars were invented; indeed, the fundamentals of battery technology have not changed much since the 18th century, he said. Advances in lithium-ion batteries, which pack a high-density punch in a small size and are rechargeable, have enabled the explosion of personal tech. But for cars and, more importantly, the power grid, batteries have a long way to go.

Today, more than 35 percent of energy use in the U.S. comes from petroleum-based sources, Ramani said, quoting estimates from the U.S. Department of Energy. Of that, about 72 percent is in transportation.

"We need to electrify the transportation sector. It has to be done," he said.

MORE THAN 35 PERCENT OF ENERGY USE IN THE U.S. COMES FROM PETROLEUM-BASED SOURCES





RON KLEIN

Vijay Ramani

> "Ultimately, money may be the main barrier — and the main driver — for moving the future of energy out of the past."
>
> — VIJAY RAMANI

The biggest advantage would be eliminating distributed sources of emissions, he adds.

"It's really hard to regulate CO_2 out of a tailpipe. But then you're shifting the emission to a power plant, where the electricity is being generated. And then you can envision a way to capture it," Ramani said.

Automakers are designing improved batteries that would make electric cars more affordable, increasing their presence on American roads. Electric cars represent about 1 percent of the U.S. auto market, Ramani says. He is working with Nissan to design more efficient and durable fuel cells, which could be used in fuel cell electric vehicles or as a range extender in electronic cars such as the Nissan Leaf.

Even if all cars were electric, the energy sector would need new battery technologies. Renewable energy, especially wind and solar, is intermittent, so power plants would need some kind of backup for times when the wind is not blowing or the sun is obscured.

"If you want a really high level of penetration, you need a buffer, and that's storage," Ramani said.

He and his colleagues are working on what's known as a redox flow battery. At its heart, a flow battery's energy comes from dissolved metals that are stored outside the battery, rather than solid chemicals like lithium-metal oxides or lead-oxide that are stored inside. They require huge tanks of liquid — but at a solar or wind farm, space is generally not a problem. Each tank would contain a battery and two tanks — each full of a particular type of dissolved metal salt. In one example, a flow battery contains iron and chromium salts, which are dissolved in acid. When pumped through the battery, the iron will accept (or lose) an electron. While the chromium will lose (or accept) an electron, the amount of charge stored scales with the concentration of the salt and the size of the truck. The flow of charge can be reversed again and again, Ramani said.

"If you use elements like iron and chromium, they never degrade," Ramani said. "They will last as long as you want it to. The design lifetime for these batteries is about 20-25 years. There is really no downside to it, but we are still not there on cost."

Ultimately, money may be the main barrier — and the main driver — for moving the future of energy out of the past, Ramani said. Future energy breakthroughs will be driven in part by technology, and in part by policies that force change. Unlike fossil fuels, they may not be cheap — but someday, they might be just as abundant.

"There's a saying in the energy industry: No power is more expensive than no power," Phillips said. "The folks in areas that have been hit by a hurricane definitely agree with that. They would probably pay virtually any price for a chance to charge up their cellphones. So I would say reliability is even more important than cost."

Students in the UMSL/WashU Joint Undergraduate Engineering Program

WHITNEY CURTIS

Boeing boosts scholarship support for Engineering students

Continuing years of generous giving to Washington University in St. Louis and to the University of Missouri-St. Louis, The Boeing Co. has pledged $1.5 million over five years to support scholarships for undergraduate Engineering students.

The funds will create a group of Boeing Scholars by supporting 12 scholarships per year for WashU undergraduate Engineering students; 16 scholarships per year to students in the University of Missouri-St. Louis and Washington University in St. Louis Joint Undergraduate Engineering Program; and 12 scholarships per year for students in the WashU Summer Engineering Fellowship Program.

The new pledge brings Boeing's total contribution to the *Leading Together* campaign to more than $6.8 million.

"Boeing is committed to inspiring and preparing the next generation of innovators through scholarship support for exceptional young engineering students of all backgrounds," said Kristin Robertson, vice president and chief engineer, Strike, Surveillance & Mobility. "We are honored to partner with Washington University in St. Louis and the University of Missouri-St. Louis to help prepare today's students to become the engineering leaders of tomorrow."

The $1.5 million in new funding is in addition to the annual funding that Boeing already provides for engineering scholarships at Washington University and the University of Missouri-St. Louis. Boeing has an active mentor program at both universities, providing students with inspiration, professional advice and world-class experiences.

Summer fellowship scholar

WASHU PHOTO

"Boeing's support of the School of Engineering & Applied Science and of WashU over the past 70 years has been instrumental to the growth of the Engineering school and the success of our undergraduate students, who represent some of the best in the world," said Aaron F. Bobick, dean of the School of Engineering & Applied Science and the James M. McKelvey Professor. "These scholarships will allow us to continue to increase diversity among our student body, while producing well-qualified graduates for potential careers with Boeing."

Watch the livestream from the CSforALL Summit 2017: csforallconsortium.org

CSforALL Summit brings corporate leaders, region's educators to WashU

With more than 600,000 tech jobs in the United States going unfilled every year and up to 1 million expected by 2020, the U.S. government launched the Computer Science for All initiative in 2016 to provide all K-12 students in the U.S. with the skills they need for the tech-driven economy. In mid-October, more than 700 educators, corporations, elected officials and university representatives joined forces at Washington University in St. Louis over two days to commit to making computer science education available to all students to prepare them to fill those jobs and to compete in the new economy.

The CSforALL Summit brought in about 300 teachers and administrators from school districts from Missouri and Southern Illinois to provide them the tools to incorporate computer science into all aspects of the curriculum beyond computer science classes. On the second day, more than 400 leaders from such corporate giants as Apple Inc., Facebook, Cartoon Network, The Boeing Co. and Mastercard, and organizations including Girls Scouts of the USA, committed funds to help the initiative move forward. The initiative also has the support of universities in the region.

In 2016, CSforALL held its inaugural summit at The White House. Then-President Barack Obama launched the initiative, which proposed $4 billion in funding for states and $100 million to train teachers, expand access to high-quality instructional materials and build regional partnerships with industry and higher education institutions.

"I strongly believe every child has to have the opportunity to learn this critical skill," Obama said in a September 2017 teleconference. "It's becoming fundamental just like reading, writing and math. We are inundated with technology, and I don't want our young people to just be consumers, I want them to be producers of this technology and to understand it, to feel that they're controlling it, as opposed to it controlling them."

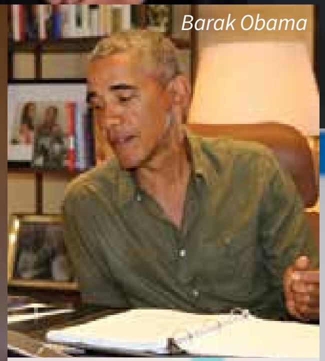
Written by **BETH MILLER**

Photos by **WHITNEY CURTIS**

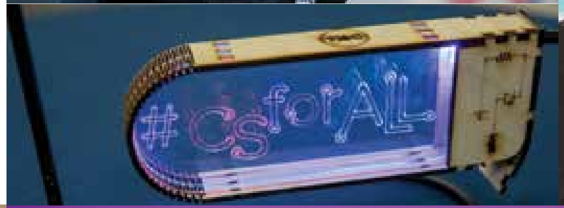
Christina Miller, president of Cartoon Network, and Megan Smith, third U.S. CTO; CEO, shift7

Michael Evans, TEALS graduate; Jim Evans, superintendent, Beattyville Schools; Kevin Wang, TEALS

David Karandish



Barak Obama



WashU Engineering Dean Aaron Bobick

Ruthe Farmer, chief evangelist for CSforALL; Brenda Wilkerson, president and CEO, Anita Borg Institute for Women and Technology

Educators from around the U.S. attended the summit

Holden Thorp, provost, WashU

iLuminate

Randy Jones, also known as the cowboy from the Village People

Student feature //

ArchHacks 2017 took place Oct. 27-29 on the WashU Danforth Campus.

48 hours @ArchHacks

Photos by **JERRY NAUNHEIM**

A timeline of two WashU Engineering students and how they spent the weekend at a hackathon

Junior, computer science undergraduate student

Jack

Jack's team designed Barcode, a system designed to prevent drivers who have had too much to drink from accessing car keys. The locker-type system would use a built-in ethanol sensor to measure blood alcohol content. If below the legal limit, the locker will unlock, providing access to car keys. But if above the legal limit, the locker will remain locked and will recommend alternative transportation.

FRIDAY

6:00 PM
Gave the MLH intro speech

7:30 PM
Went to my friend's birthday dinner (with 3/4 of my team)

10:00 PM
Went to hang out at Michael's apartment

MIDNIGHT
Started brainstorming

2:00 AM
Decided on Barcode

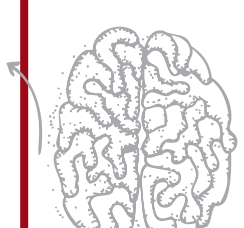
2:15 AM
Started the front-end development

3:18 AM
Finished the CSS

4:48 AM
Finished the HTML

5:00 AM
Went to sleep

MLH stands for Major League Hacking



SATURDAY

NOON
Got lunch with the team

1:00 PM
Started the Javascript

1:01 PM
Realized I dislike Javascript (JS)

1:02 PM
Realized that my team dislikes JS more than I do

1:03 PM
Started the JS, knowing I would do it all

2:07 PM
We got a bunch of cookies (I had at least four)

3:36 PM
Finished all of the log in and out functions

6:00 PM
Dinner break!

6:45 PM
Began merging hardware with software

7:00 PM
Ran into our first bug — our core designs were different

8:00 PM
I won the argument, and made the hardware guy change his code, so I didn't have to change mine

SUNDAY

10:00 PM
Actually began the merge

10:01 PM - 5:00 AM
Finished merge

5:34 AM
I put the page on AWS and submitted on devpost

6:22 AM
Went to sleep and woke up just in time for judging!

Master's student in computer science

Cancan

Cancan's team developed ChouChou, an easy-to-use and inexpensive sensor-application kit that monitors the humidity level of a baby's diaper and sends real-time data to parents' phones so they know when it's time for a change.

FRIDAY

4:30 PM
I checked in and grabbed some free stuff. The Android-robot key chain is really cute.

6 PM
Networked with companies about summer intern opportunities

10:30 PM
Went to a workshop about a framework that we finally decided to not use

11 PM
One of my teammates started working on hardware (wiring and stuff). Another teammate started with the front end, and I started with the back-end (database).

SATURDAY

12:30 AM
We ran into a fatal issue that the data cannot transfer from the hardware to database through Bluetooth

2:30 AM
Database is set up, front-end view is being built, we just can't get data in

4:00 AM
Went to sleep, desperately

8:30 AM
Woke up

9 AM
Found an alternate solution to the hardware problem

12:30 PM
After three hours of non-stop coding, I can't continue anymore. I went to get lunch.

5 PM
We got our main page done

8 PM
I've been working on our data visualization codes for two hours. It's time to get my sixth cup of coffee today!

11:45 PM
Our three data visualizations are finally made. The only step left is to integrate them into our application and connect with real-time data

3 AM
Our project requires to nest web application into mobile form. But our CSS file (which controls the UI) keeps running into problems so we spend hours on debugging and adjusting.

5 AM
We finally fixed all bugs.

SUNDAY

9:30 AM
Woke up

10 AM
Waiting at our table to demo for judges

10:45 AM
Closing ceremony

NOON
My group didn't win any prize, but I learned so much from the past 40ish hours about coding, teamwork, design concepts and have a better understanding of how much I can accomplish in 40 hours.

ArchHacks 2017

300 STUDENTS

66 PROJECTS

WINNERS
View the list of winners and all the projects: archhacks2017.devpost.com

Greg Hyslop

DEVON HILL

Leading change

Written by BETH MILLER

As chief technology officer of The Boeing Co., Greg Hyslop oversees some 45,000 engineers who develop high-performance aircraft and space vehicles that change the world.

It's a tall order, not only because of the effect of Boeing's products on society, but also because of the scope of his position, leading the technical team of the world's largest aerospace company, and the need to take on his one overarching challenge: to find what needs to change and lead that change. Yet it's a role Hyslop is managing deftly after advancing through various leadership positions over his 35-year career with the company.

While Hyslop's titles of CTO and senior vice president of the company's Engineering, Test & Technology organization may indicate he is waist-deep in the technical aspects of the business, he says technology is only part of what makes the company work.

"As CTO, I have to be looking for what we need to be doing for the future, the technologies that will define the future for us and who we need to be working with," says Hyslop, who earned a doctorate in systems science & mathematics from the School of Engineering & Applied Science at Washington University in St. Louis in 1989. "You can't do technology without the people element. That's how it comes together."

People are the key to change, says Hyslop, who is working to build a network of people throughout the company. After 31 years in Boeing's defense operations in St. Louis, Dallas and Huntsville, Alabama, and the past four in corporate roles, Hyslop has unique insight into the connections that need to be made among employees on the defense, space, services and commercial sides of Boeing's business.

> "As CTO, I have to be looking for what we need to be doing for the future, the technologies that will define the future for us and who we need to be working with."
>
> — GREG HYSLOP

"I feel like I'm a matchmaker," he says. "If I'm in a meeting with a lot of people, and I see two people I know, I'll tell them they need to know each other and introduce them to build those connections. That has been a fun part of being in the corporate jobs to be able to see that, because then cool things really start to happen."

That network of people includes longtime employees as well as the next generation.

"Because of the function of engineering, I am looking at who we are bringing in and how that meshes with where we need to be technologically for the future," he says. "That's when the magic happens — when you've got people with experience working with people who are new and have new ideas. How do we successfully preserve the knowledge and experience of the people who'll be retiring and get that knowledge to the generation that's coming in?"

Boeing partners with top engineering schools such as the School of Engineering & Applied Science to bring in the next generation of engineers who will meet some of its challenges. More than 1,200 Engineering alumni are Boeing employees, and one-fourth of master's students are Boeing teammates, continuing a longstanding partnership between the school and the company, which includes joint research projects, a mentorship program, scholarships, internships and support of the Boeing Patent Challenge.

New ideas and staying ahead technologically are other keys to leading change in a global corporation with nearly 140,000 employees responsible for the safety of 4.5 million people who travel on Boeing airplanes and communicate via more than 60 Boeing satellites in orbit, Hyslop says.

THE BOEING CO.

Hyslop at the Paris Air Show in 2017

"For us to stay competitive, there are things we have to change — in how we do things, how we design airplanes, how we build airplanes, and a number of things for us to stay on top," he says. "Technologically, artificial intelligence will change our industry and change the world, and we have to be ready for that in aerospace."

Hyslop foresees a future with more autonomous vehicles and aircraft.

"In a lot of ways, having autonomous things flying is easier than autonomous things driving, because there is less to worry about in the air than on the ground," he said. "I think that will change our industry. I think we're about to enter another golden era of aerospace. There is so much technology that is developing so quickly in some of these areas that it is going to change life as we know it."

> "There is so much technology that is developing so quickly in some of these areas that it is going to change life as we know it."
>
> — GREG HYSLOP

To continue its quest to stay ahead technologically, earlier this year the company launched Boeing HorizonX, an initiative under Hyslop's direction that invests in early-stage businesses and startups developing emerging technologies that complement Boeing's goals, seeks new business opportunities for the company's aerospace technology and assesses disruptive innovations and business strategies. Already, HorizonX has invested in several companies, including several that develop augmented or virtual reality and one that develops alternative propulsion aircraft, and has partnered with several other international companies that collectively have expertise in cutting-edge fields such as augmented or virtual reality, alternative propulsion aircraft and artificial intelligence.

In addition, Boeing recently announced plans to acquire Aurora Flight Sciences, a firm that specializes in autonomous systems technologies that enable advanced robotic aircraft for future aerospace applications and vehicles. The company also is sponsoring the GoFly Prize, a $2 million competition to prompt creation of flying objects, such as jet packs, hoverboards and drones to transport individuals. Hyslop said in news reports that the idea is a good opportunity for small teams with limited resources, for the company to attract new talent and for the United States to continue as the leader in aerospace innovation.

With Hyslop's responsibilities comes an innate sense of the love of learning and discovery, which he has had since his graduate student days under the direction of TJ Tarn, now senior professor of electrical & systems engineering at WashU and director of the Center for Quantum Information Science and Technology at Tsinghua University in Beijing. Hyslop earned the doctorate while working full-time at what was then McDonnell Douglas, now part of Boeing, and supporting a young family.

DEVON HILL

Chancellor Mark S. Wrighton, Greg Hyslop and Dean Aaron Bobick before the Engineering Graduation Ceremony May 18, 2017

Read Hyslop's graduation speech:
engineering.wustl.edu/hyslop2017

Education:

BS, Electrical Engineering, University of Nebraska, 1980

MS, Mathematics, University of Nebraska, 1982

DSc, Systems Science & Mathematics, Washington University in St. Louis, 1989

Heroes:

Winnie the Pooh, Hagrid

"I always appreciated that they had my best interest in mind as I went through the program," Hyslop says. "There was a strong sense of community at WashU and a strong tie to St. Louis, but they showed that you can think bigger than St. Louis and not lose the deep connection to the city."

Though Hyslop has close ties to and a love for St. Louis, he is a native of Nebraska. He earned a bachelor's degree in electrical engineering and a master's in mathematics from the University of Nebraska and serves on the university's Engineering College Advisory Board. In addition, he is a member of the Aeronautics Committee of the NASA Advisory Council, an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a member of the Board of Trustees of the AIAA Foundation.

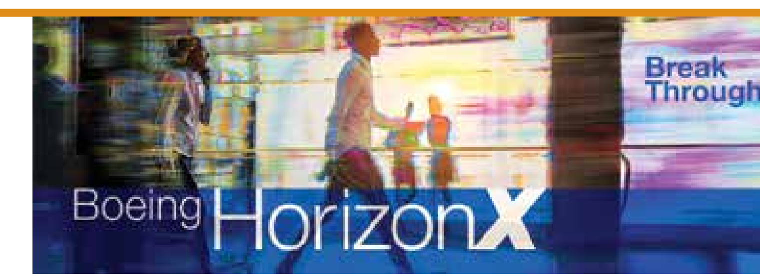
When he's not working, Hyslop and his wife, Fiona, enjoy gardening at their home in the Seattle area. In addition, he has three adult daughters and four granddaughters he visits whenever he can.

Hyslop has had several opportunities to give back to WashU Engineering, first as an adjunct professor for seven years, which he said he enjoyed so much he would consider teaching as a second career, and most recently, as the May 2017 Engineering Commencement speaker. In his speech, Hyslop encouraged graduates to maintain their sense of wonder and discovery throughout their lives.

"If you're able to, it will nurture your curiosity, preserve your humility and make you a better leader," he told graduates. "Keeping that sense of wonder and curiosity means you will welcome surprise, you relish what is new, you are constantly learning and are open to new insights."

What is Boeing HorizonX?

Boeing HorizonX functions as a pathfinder organization for Boeing. The team makes targeted investments in new ventures and startups; seeks unique business opportunities for the company's aerospace technology; and assesses disruptive innovations and business strategies.



Karl Zelik


JOHN RUSSELL/VANDERBILT UNIVERSITY

Written by **BETH MILLER**

As one of four active brothers growing up in Pittsburgh, Karl Zelik frequently had stitches and broken bones. That experience built the foundation for his career as a mechanical and biomedical engineer at Vanderbilt University who has a passion for assistive technology that could help millions of people living with pain and disability.

Zelik, who earned bachelor's and master's degrees in biomedical engineering at the School of Engineering & Applied Science in 2007, now is an assistant professor of mechanical engineering, of biomedical engineering, and of physical medicine and rehabilitation at Vanderbilt, where he runs the Biomechanics & Assistive Technology Laboratory. His ultimate goals are to restore health, mobility and independence to people with disabilities, to prevent injuries that cause physical disabilities, and to enhance human capabilities beyond biological limits.

In July, Zelik and his team debuted "smart underwear," a garment designed to prevent low-back strain and pain in those who perform repetitive lifting, twisting or leaning. More than 80 percent of U.S. adults will experience low-back pain, costing $30 billion in medical expenses and more than $100 billion annually in lost wages and productivity.

Zelik's interest in a solution for this also is a personal one — repetitive lifting of his 2-year-old son brought a new awareness of the common affliction.

"I started thinking about whether there was some sort of wearable technology that could fit into an everyday lifestyle, something that was not heavy, not obtrusive and not expensive," Zelik says. "As I learned more about the biomechanics of leaning and lifting tasks and why there are high forces on the spine, I discovered that it was theoretically possible to create a clothing-like exoskeleton that could offload the low back. Then by integrating sensors and electronics into the clothing, low-back assistance could be engaged or disengaged as needed, by tapping the garment or using a smartphone app we developed."

> "One of my mottos is 'fail frequently' — I tell that to all of the students in my lab ... It often takes a lot of failure to uncover new engineering solutions or advance scientific understanding."
>
> — KARL ZELIK

Zelik challenged his students to develop prototypes, which have since shown in their lab tests the ability to reduce low-back muscle activity during repetitive lifting and leaning movements. The lab plans to continue its research into the undergarment's design and effectiveness before moving to clinical research and potentially commercialization.

Zelik's experience in developing medical devices and prosthetic limbs came while earning a doctorate in mechanical engineering at the University of Michigan. After a two-year postdoctoral fellowship in Rome, Zelik and his wife, Tiffany, moved to Nashville, where he has been on the Vanderbilt faculty since 2014. In his first three years, he has received the International Society of Biomechanics' Promising Scientist Award, its highest award to researchers early in their careers, and the American Society of Biomechanics' Young Scientist Post-doctoral Award. He also has funding from the National Institutes of Health, the National Science Foundation, industry, foundations and institutional research funds from Vanderbilt, which recently built a 3,000-square-foot state-of-the-art motion analysis lab for Zelik and his colleague, Michael Goldfarb, a world leader in wearable robotics.

Zelik credits the opportunities he had at WashU — both as a student in the John B. Ervin Scholars Program and the Enterprise Holdings Scholars Program and as an All-American track-and-field athlete — for how he mentors students in his own lab. Although his senior design project didn't work, he learned more about engineering, problem-solving and perseverance than if it had succeeded, he says.

"One of my mottos is 'fail frequently' — I tell that to all of the students in my lab," he says. "Particularly for undergrads, as long as they are learning things and developing new skills, it's not always important that their project succeed in the traditional sense. It often takes a lot of failure to uncover new engineering solutions or advance scientific understanding."

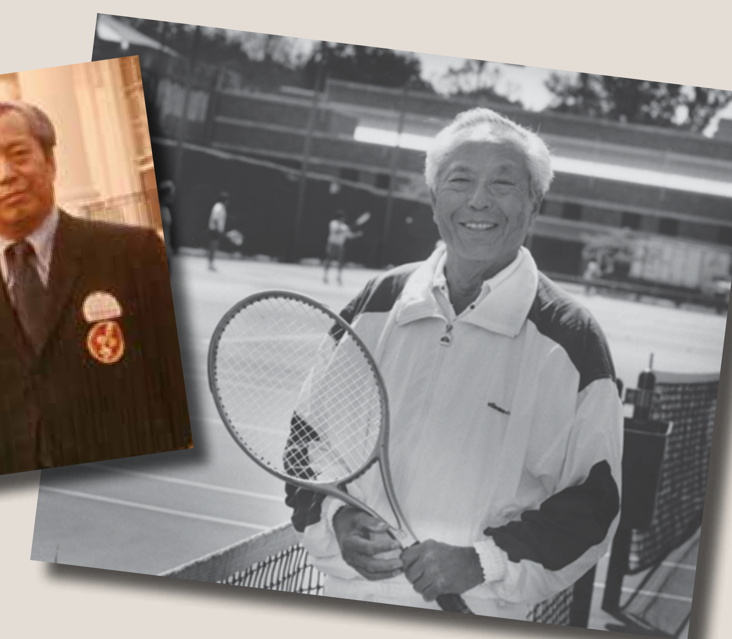
Generosity

Written by **RACHEL "RILEY" ROSENFIELD, MD**

When I found out that I was accepted at Washington University, I was thrilled. The biomedical engineering program was everything I'd been hoping for, the campus was beautiful, and there was a great sense of community from the students. There was only one problem — finances. My family was going to help me, but only if the cost was equivalent to my state university. I'd already been accepted as a Woodward Scholar, but it was still out of reach.

The generosity of the Tao family helped push WashU into being financially feasible for me. I was fortunate to meet Bill and Anne several times during my time at school at the scholarship dinner, and they were always so warm and welcoming. While at school, I made amazing friends, was very involved with EnCouncil, and had a great springboard into post-collegiate life, first as a consultant with Accenture for a few years, and now as an emergency medicine physician. The generosity of people like Bill and Anne Tao encourages us to pay it forward, both emotionally and financially.


Rachel Rosenfield earned bachelor's degrees in applied science and biomedical engineering from the School of Engineering & Applied Science in 2008 and an MD from the University of Illinois at Chicago. She is an emergency medicine physician at Littleton Adventist Hospital in Littleton, Colorado.



William K.Y. Tao

William K.Y. Tao has made significant contributions to the School of Engineering & Applied Science since he earned a master's in mechanical engineering from Washington University in St. Louis in 1950. He established the university's first annual named scholarship program in 1974 in the School of Engineering. Today all of the university's schools have named scholarship programs.

After earning a master's degree at WashU, he became a full-time instructor in Engineering. He continued as an affiliate professor after starting his own engineering consulting business, William Tao & Associates Inc., in 1956. Since 1965, he also has been an affiliate professor at the Sam Fox School of Design & Visual Arts.

Respect for education, embedded in his upbringing in China, remains a key element in his personal philosophy. Recognized internationally as a leader in engineering systems design, Tao is responsible for many innovative, energy-effective concepts and applications. A trustee emeritus, Tao formerly served on the National Council for the School of Engineering & Applied Science. He received a Distinguished Alumni Award in 1971, an Engineering Alumni Achievement Award in 1982, and the William Greenleaf Eliot Society Annual Search Award in 1990. In addition, he received an honorary Doctor of Science degree in 1997.

Tao, who turned 100 this year, has received numerous additional honors for his professional achievements, humanitarian work and community service. He and his wife, Anne, reside in St. Louis. They have three sons and six grandchildren.

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Congrats, Class of 2017!

PHOTOS BY DEVON HILL