Fall 2019

re:search

An inside look at innovation and discovery at Missouri University of Science and Technology

THE BATTLE FOR THE BRAIN

HOW RESEARCHERS ARE HELPING THE ARMY COMBAT TRAUMATIC BRAIN INJURY

MISSOURI S&T

CYBERSECURITY ACCREDITATION

Missouri S&T's leadership in cybersecurity research and education enters its second decade with the recent reaccreditation as a National Center of Academic Excellence in Information Assurance and Cyber Defense Research.

Originally accredited in 2008, S&T was the first university in Missouri to earn the accreditation, which is jointly offered by the U.S. National Security Agency (NSA) and the Department of Homeland Security (DHS). S&T was reaccredited in 2015 and again in 2019 and will hold this designation until 2024.

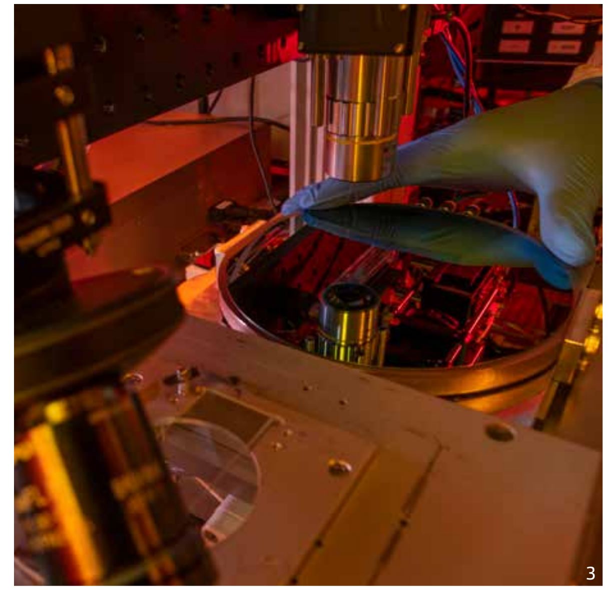
The NSA/DHS program is designed to increase understanding of information assurance and cyber defense technology, policy and practices to prevent and respond to a catastrophic cyber event. Promoting research and education in cybersecurity will reduce the vulnerabilities in national information infrastructure.

"Missouri S&T offers a unique contribution to the information assurance field with our focus on ensuring the combined cyber and physical security of the nation's electric power grid, oil, gas and water distribution systems, and transportation systems," says Bruce McMillin, interim chair and professor of computer science at S&T. "Our research focuses on the security and privacy of cyber-physical systems, cloud and mobile computing, and the internet of things."

The Missouri S&T CAE-R program emphasizes graduate education and research in three areas:

- Cybersecurity. S&T's expertise includes protective cyber-physical and mobile systems, enterprise-level information technology security, cloud and edge security, and sensor security.
- Data science. Missouri S&T researchers are exploring data mining, deep learning and artificial intelligence as they relate to urban infrastructure, image analysis, computer vision, machine learning, real-time scheduling and heuristic problem solving.
- Cyber-physical security. Research relates to physical systems that rely on computer networks, like power grids and autonomous vehicles. S&T expertise includes smart grid technology, sensing and real-time systems.

For more information about Missouri S&T's cybersecurity initiatives, visit cae.mst.edu.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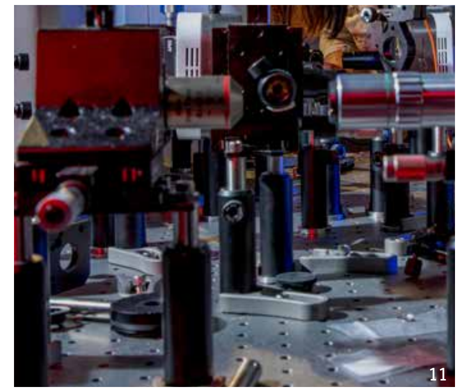
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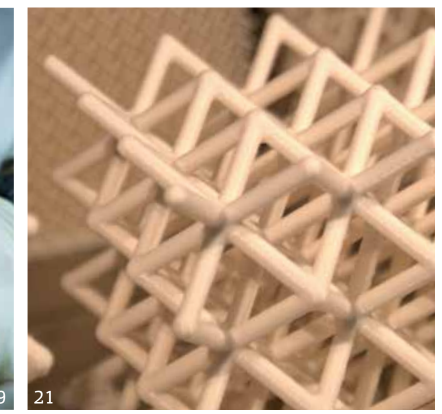
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INSIDE THIS ISSUE

BLACK HOLE IMAGER

Missouri S&T graduate **Frederick K. Baganoff**, a research scientist at MIT's Kavli Institute for Astrophysics and Space Research, was one of the scientists involved in producing the first direct images of a black hole last spring.

Baganoff and over 200 scientists worldwide collaborated on the international Event Horizon Telescope project, which captured four images of a supermassive black hole at the center of Messier 87, a galaxy in the Virgo galaxy cluster, 55 million light years from Earth.

Baganoff earned a bachelor's degree in physics from S&T in 1985. He has worked with the project since 2009 and co-authored two of the papers, "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole" and "First M87 Event Horizon Telescope Results. V. Physical Origin of the Asymmetric Ring," published in *The Astrophysical Journal Letters.*

INTELLIGENT CONTROL SYSTEMS EXPERT NAMED TO NATIONAL ACADEMY OF INVENTORS

Jagannathan Sarangapani, Rutledge-Emerson Distinguished Professor of Electrical and Computer Engineering at S&T, was named a Fellow of the National Academy of Inventors in March.

This is the highest professional distinction accorded solely to academic inventors who have demonstrated a prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development and the welfare of society.

Sarangapani holds 20 U.S. patents, and colleagues have cited his work more than 10,300 times, according to Google Scholar.

His research on intelligent control systems can be applied to aircraft control, engine control, autonomous systems and robotics, manufacturing systems, automotive and chemical process control, and more. Small businesses and large corporations such as Boeing and Caterpillar have benefitted from these technologies, and Sarangapani has encouraged students to pursue their inventions.

HOW MANY BLASTS CAN A MINE SEAL TAKE?

Kyle Perry is building a cannon to blast things like concrete blocks, hard hats and roof bolts at concrete seals in coal mine tunnels, all to test how well those seals withstand high-speed projectiles.

Through these tests, Perry hopes to determine the size and speed a projectile would need to travel to damage the seal. His work could lead to improved seal design, which translates to safer coal mines.

S&T received a $249,000 grant from the Alpha Foundation for the Improvement of Mine Safety to test seal integrity in underground tunnels that miners close off after finishing with them. The S&T Experimental Mine was chosen because of its large-scale testing facilities and expertise.

"Damaged seals could start leaking methane into the active portion of the mine," says Perry. "That could become an explosive mixture and would be dangerous for the miners."

MERGING MEDICINE AND ENGINEERING

In April, Missouri S&T hosted educators and researchers from all four University of Missouri campuses for Engineering and Health — UM System Collaborative Research Summit.

The event was part of a series of research summits designed to showcase the work being done on each campus and generate ideas for future intercampus collaboration.

During the summit, six Missouri S&T researchers spoke about their work.

Anthony Convertine, the Roberta and G. Robert Couch Assistant Professor in Materials Science and Engineering, presented "New Tricks for Old Drugs," about work at the S&T Center for Biomedical Research that involves synthesizing nanomaterials to make existing drugs work better. The work can aid in intracellular drug delivery for cancer and infectious diseases.

Julie Semon, assistant professor of biological sciences, spoke about the use of stem cells in precision medicine, including stem cells from bone marrow and adipose tissue that help with wound care. She studies stem cell biology, tissue engineering, and biological design and innovation as part of her Laboratory for Regenerative Medicine.

Krishna Kolan, a postdoctoral fellow working with **Ming Leu**, the Bailey Professor of Integrated Product Manufacturing, discussed 3-D bioprinting of stem cells with composite bio ink. Their work, which can relate to tissue engineering, regenerative medicine and transplant medicine, is conducted through the Laboratory for Regenerative Medicine.

Yun Seong Song, an assistant professor of mechanical and aerospace engineering, studies physical human-robot interaction through the Center for Biomedical Research. Current projects include motorized walking aids that provide balance assistance for older adults and make walking up and down stairs easier using a device that recycles the energy created while climbing and descending stairs.

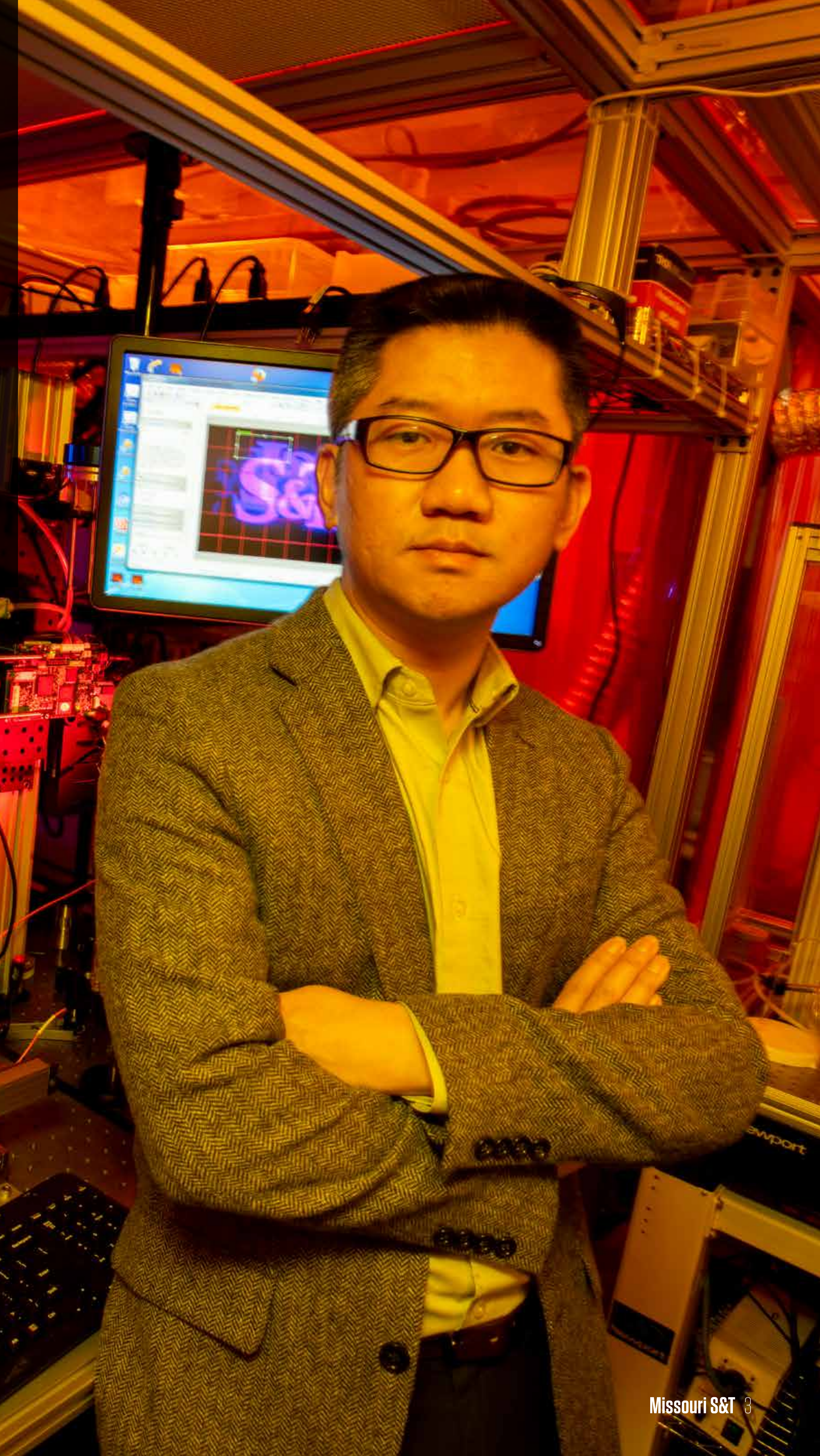
Chang-Soo Kim, professor of electrical and computer engineering, spoke about his work in the Center for Biomedical Research Intelligent Microsystems Laboratory. Ongoing research includes self-calibrating metabolite sensors, biodegradable sensors, bioactive glasses and nanomaterials.

THE FUTURE OF NANOMANUFACTURING

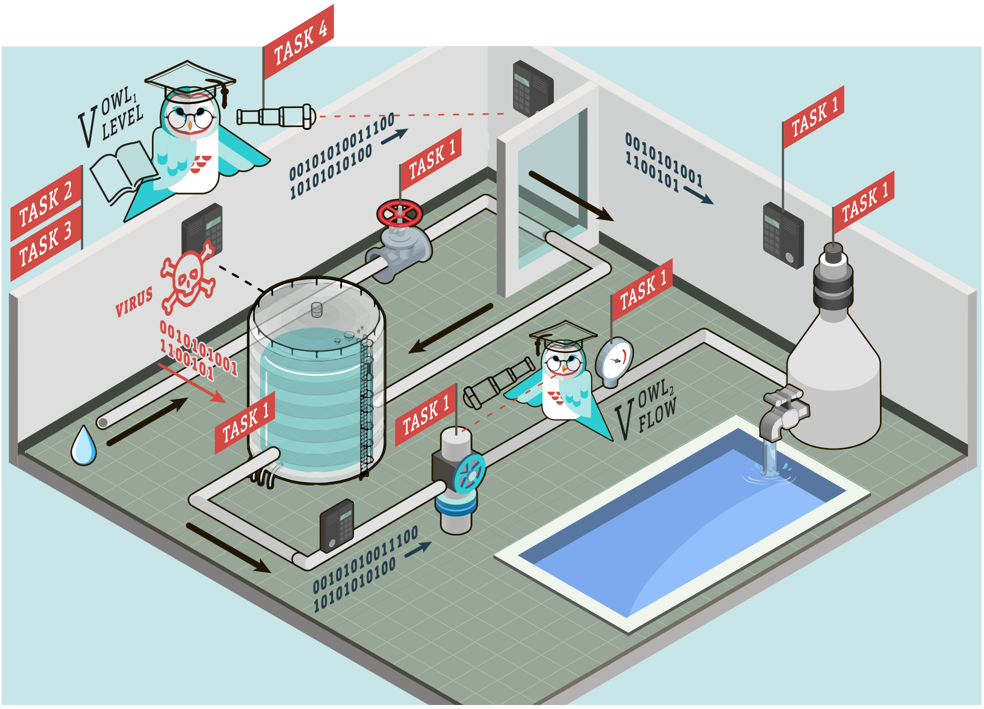
Heng Pan, assistant professor of mechanical and aerospace engineering at Missouri S&T, received a big boost from the National Science Foundation to support his efforts to create large-scale nanostructures from very small nanocrystals.

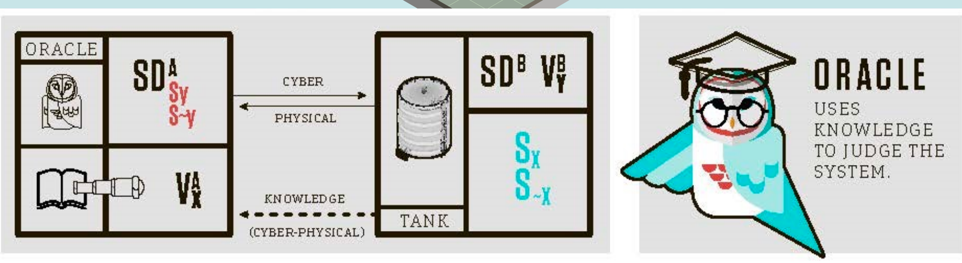
With a five-year, $500,000 NSF Faculty Early Career Development (CAREER) Award, Pan will develop a new approach for direct fabrication of functional nanostructures from multiple materials.

The research could lead to advances in solar cell and battery technology, nanophotonics (the study of how light behaves on the nanometer scale), and the development of metamaterials, which are materials engineered to exhibit properties not found in naturally occurring materials.



GUARDING CYBER-PHYSICAL SECURITY





TASK 1 Defining domains and their interaction.

TASK 2 Mathematics (prescriptive).

TASK 3 Big data (responsive).

TASK 4 State estimation.

Cyber-physical systems (CPS) — complex systems that rely on computers, like public water supply systems, electrical power grids and even autonomous vehicles — are increasingly threatened by both physical and cyber attacks.

The consequences of such an attack could be catastrophic, ranging from financial ruin to loss of life, says **Bruce McMillin**, professor and interim chair of computer science at Missouri S&T. And the myriad access points to the data contained in these systems — from smart meters and security cameras to wearable devices — only exacerbate the risks.

McMillin is leading a team of researchers with funding from a National Science Foundation grant of nearly $1 million to develop stronger safeguards for these complex systems.

"The nation's critical infrastructure is increasingly dependent on systems that use computers to control vital physical components," McMillin says. The goal of the research is to ensure that these systems do what they're supposed to do in an attack by building in defenses that make sure each component behaves and works well with others.

"The objective," McMillin says, "is to produce from untrusted components a trusted CPS that is resilient to security attacks and failures."

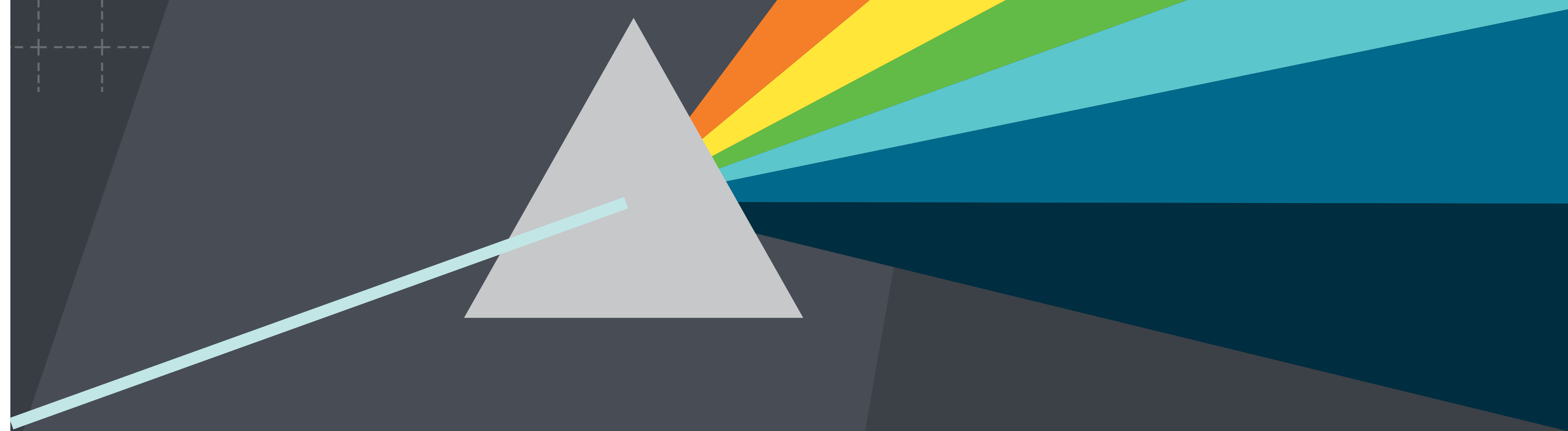
Professor **Jonathan Kimball** and assistant professor **Rui Bo**, both in electrical and computer engineering, are co-principal investigators. They're working with **Jennifer Leopold**, an associate professor of computer science, and Aditya Mathur, a Purdue University computer science professor.

The project will test the more robust cyber-physical systems on a high-fidelity water treatment system as well as an electrical power test bed to align "concepts from distributed computing, control theory, machine learning and estimation theory to synthesize a complete mitigation of the security and operational threats to a CPS," McMillin says.

Security holes will be identified and plugged automatically at system design times, then enforced during run time without relying solely on secure boundaries or firewalls, he says.

"That means treating every aspect of the CPS as its own security domain, building resilience to attacks that can come from within a secure domain."

THE SPREAD OF LIGHT



Physics researchers have discovered a new way to control light — one that produces a concentrated, optically energetic laser beam when transmitted through diffuse media like fog, biological tissue or white paint — instead of the typical lateral spread of weaker light.

The discovery from researchers at Missouri S&T and Yale University could lead to improvements in deep-tissue imaging and optogenetics, a technique that uses light to probe and manipulate cells in living tissue.

"It is commonly thought that one has little to no control over how light expands in diffuse media," says **Alexey Yamilov**, theoretical research lead and an associate professor of physics at Missouri S&T. Yamilov has a decade-long collaboration on the project with Hui Cao at Yale.

The researchers used a study of transmission eigenchannels, which are wave patterns specific to a particular sample. Yamilov says the concept was conceived in the 1980s to explain experiments with electron waves in small metal wires at very low temperatures.

But demonstration of eigenchannels eluded researchers until 2016, when Yamilov and Cao detected eigenchannels in optics. They found that unlike an ordinary laser beam that always weakens the deeper it penetrates, the eigenchannels actually bolster the energy inside the system.

The researchers had to learn how light can be transmitted through a sample of zinc oxide nanoparticles and then generate special combinations of light waves to excite specific eigenchannels. Using a spatial light modulator, they observed signatures of transverse localization, including enhanced lateral confinement and suppressed spreading of eigenchannels.

The findings have implications in condensed matter physics, acoustics and other fields that involve wave propagation and scattering.

"This work demonstrates the advantages of studying wave propagation phenomena in optical systems and offers a glimpse of a wealth of undiscovered physics," Yamilov says.

THE BATTLE FOR THE BRAIN

On a rainy day in April, researchers toured Fort Leonard Wood training sites where head or blast accidents occur.

Even if soldiers in combat survive a life-threatening trauma like a roadside IED (improvised explosive device) detonation, that experience could result in long-term, life-threatening damage. And a soldier might never be aware of it.

Hundreds of thousands of U.S. soldiers suffer from traumatic brain injury (TBI), according to a 2018 report from the Center for a New American Security. Left undiagnosed or untreated, TBI can result in later complications, including dementia, according to a 2018 study published in the American Medical Association's journal *JAMA Neurology*.

The Army estimates that 85% of all TBIs occur during training, says **Barry S. White**, executive director of the Acute Effects of Neurotrauma Consortium (AENC). Army recruits at Fort Leonard Wood, Missouri, about 30 miles southwest of Missouri S&T, endure high levels of blast overpressure — the pressure waves that come from explosions — when firing heavy weapons, White says.

Despite recent advances in brain science, little progress has been made to understand or treat TBI. "The field test to determine if a soldier may have TBI consists of, 'How many fingers am I holding up' and asking, 'Who's the president?'" says White.

"Diagnosis is still in the Model T era, and so is treatment," says Dr. **Donald L. James**, chair of the AENC board of directors and senior vice president of research and government affairs at Phelps Health, a regional health system based in Rolla.

AENC partners Phelps Health, Fort Leonard Wood, the Leonard Wood Institute (LWI, the Army base's research arm) and four universities, including Missouri S&T, recently joined together to advance diagnosis and treatment. U.S. Sen. Roy Blunt helped secure $10 million in federal funding for the initiative. The University of Missouri campuses in Columbia and Kansas City, along with Washington University in St. Louis, are also AENC members.

For the military, the earlier TBI can be detected, the better — not only for the sake of soldiers' health, but also for economic reasons. It costs the Army about $77,000 to train a single soldier, White says. The Army estimates 600 to 800 recruits at Fort Leonard Wood experience TBI each year, even though only 200 to 250 are reported.

Simplifying detection methods will make early diagnosis a possibility.

While devising a system to detect breast cancer by testing urine, **Casey Burton**, who earned a bachelor's degree and a Ph.D. in chemistry from S&T, and his advisor **Yinfa Ma**, Curators' Distinguished Teaching Professor emeritus of chemistry, found that urine containing a certain biomarker — what Burton calls a "molecular fingerprint" — detected breast cancer more accurately and safely than a mammogram. The process is also less costly, and results are available in minutes.

James, who was intrigued by the project, told Ma about a University of Utah study of student-athletes with concussions whose blood samples contained two biomarkers that indicated concussions. James encouraged Burton and Ma to expand their project to see if similar biomarkers might also indicate brain trauma.

Now director of medical research at Phelps Health and an adjunct professor of chemistry at S&T, Burton is one of seven S&T-affiliated researchers to obtain LWI funding to conduct further research into TBI.

In all, the S&T researchers have received more than $5.1 million in federal funding for their TBI research, and more could be on the way.

The facts on traumatic brain injury

- One of every 60 people in the U.S. lives with a TBI-related disability
- Every day, 137 people die in the United States because of a TBI-related injury
- At least 5.3 million Americans live with a TBI-related disability
- The number of people who sustain TBIs and do not seek treatment is unknown

Source: Brain Injury Association of America

ANALYZING SMALL MOLECULES FOR BIG RESULTS

Left: Burton earned undergraduate and graduate degrees from S&T, and now serves as an adjunct professor while working as director of medical research for Phelps Health in Rolla.

Below: Burton sits in on a briefing at the Delbert Day Cancer Institute in Rolla with staff who handle research patient intake and support

At only 28 years old, S&T chemistry graduate **Casey Burton**, director of medical research at Phelps Health in Rolla and an adjunct professor of chemistry at Missouri S&T, is poised to become a prodigious bioanalytical researcher.

His research has already led to over 20 peer-reviewed journal articles, most focused on the development of small molecule screening methods used to diagnose pathologies, particularly the bioanalysis and application of a group of urinary metabolites called pteridines that can detect cancer noninvasively.

Today, he leads a $1.24 million research project for a different urinary biomarker search. "Assessing Traumatic Brain Injury Noninvasively with Urinary Metabolites" aims to develop a simple blood or urine test to detect TBI. Burton hopes this new approach will result in a new medical device that can be deployed in the field.

This project is one of seven supported by the Acute Effects of Neurotrauma Consortium (AENC) and funded by the U.S. Army Research Laboratory through the Leonard Wood Institute. Collaboration with the Fort Leonard Wood Army training post is critical because up to 85% of military TBIs occur during training.

"Early detection and diagnosis of TBIs are essential to identify patients at risk of developing ongoing symptoms," says Burton. But current approaches to detect TBIs are inadequate, he says. Many involve cognitive assessments or advanced neuroimaging techniques that can be either subjective or impractical to use in the field.

Burton is working to identify 20 molecular biomarkers to create a "TBI fingerprint."

"These metabolic indicators are sensitive to subtle changes in the biological and physical indicators of TBI and can be measured more easily than conventional protein biomarkers," he says. "With our unique approach, we aim to determine the feasibility of using these small metabolites in urine to noninvasively detect a TBI."

The project draws on the expertise of S&T chemistry researcher **Honglan Shi**, associate chemistry professor **Paul Nam** and Dr. **Donald James**, AENC chair and senior vice president for research and government affairs at Phelps Health. Shi and Nam will develop the method and oversee the work of graduate and undergraduate students. James will help design the experiments and coordinate with Fort Leonard Wood.

In the first phase, the researchers will develop a method to analyze and identify 20 TBI biomarkers in serum and urine.

The second phase explores the feasibility of using the biomarker screening with 60 TBI patients recruited from the General Leonard Wood Army Community Hospital and a control group of 60 recruited from the 43rd Adjutant General Battalion at Fort Leonard Wood.

In phase three, the researchers will evaluate the two groups as they go through the breacher course, where they are repeatedly exposed to low-level blasts. Burton and his team will monitor short- and long-term changes in the participants' biomarker profiles in relation to individual and cumulative blast forces.

"We're in a great position to help the military and the general population by providing a better way to detect TBIs so we can focus on providing the appropriate treatment to mitigate their long-term effects," says Burton.

From left, S&T faculty researchers Catherine Johnson, Paul Nam and Honglan Shi and chemistry post-doctoral fellow Anna Pfaff discuss their TBI research in a campus lab.

SEEKING TBI THERAPIES

TBI complications — post-traumatic seizures and hydrocephalus, as well as serious cognitive and psychological impairments — can be life altering.

Paul Nam, S&T associate professor of chemistry, has joined the search for treatment. Nam is leading a $412,000 multi-disciplinary project funded through the Leonard Wood Institute to investigate the use of antioxidants to treat TBI by reducing the oxidative stress blast exposure causes in the brain.

"Our study will test the oxidative effects of controlled, open-field blasts on rats housed for antioxidant treatment in S&T's Animal Research Facility," Nam says. "Fluid and tissue samples will be biochemically analyzed to measure their oxidative stress biomarkers against control groups."

Working with Nam are **Nuran Ercal**, the Richard K. Vitek/Foundation for Chemical Research Endowed Chair in Biochemistry, who has extensive research experience studying the effects of antioxidants in living systems; **Honglan Shi**, research professor of chemistry, who specializes in bioanalysis, environmental analysis and sophisticated instrumentation applications; and **Catherine Johnson**, assistant professor of mining and explosives engineering, who is already characterizing blast models for projects with the AENC, Phelps Health and the U.S. Department of Veterans Affairs.

TO PREVENT AND PROTECT

Researcher Jie Huang is holding a prototype of his "smart helmet." Equipped with sensors, the helmet can identify when a TBI has occurred, so treatment can be quickly administered.

Missouri S&T researchers are taking an interdisciplinary approach to make traumatic brain injury (TBI) detection easier in order to speed up aid, to better model TBI injury data and even to stop TBIs before they occur.

TBIs are unfortunate but all too common occurrences during military training and deployment. Because mild TBIs often present no obvious signs of head trauma or facial lacerations, they are the most difficult to diagnose at the time of the injury, and patients often perceive the impact as mild or harmless. TBIs are cumulative, so treating a patient within the "golden hour" — the first 60 minutes after being injured — is crucial for improved long-term recovery.

Jie Huang, an assistant professor of electrical and computer engineering, is developing technology to autonomously collect and process reliable data on trauma-inducing actions. By embedding military helmets with sensors and other data-transmission technology, Huang hopes to help quickly and accurately diagnose and administer aid to mild TBI victims.

With $2.25 million in funding from the Leonard Wood Institute, Huang and his team are transforming a football helmet into a "smart-helmet" prototype. It will be equipped with fiber optic micro interferometer sensors that are activated by blunt-force impacts ranging from 3–15 on the Glasgow Coma Scale. Once activated, data is relayed wirelessly in real-time, integrating machine learning based on a decision-making framework that can detect the severity of the impact level.

"Our smart helmets will instantly warn soldiers of the severity of a concussive event in the field so that treatment can be sought immediately," says Huang. "Such a framework, with the ability to yield highly accurate predictions, will mitigate a soldier's suffering and save medical personnel's time."

Looking ahead

Fatih Dogan, a professor of ceramic engineering, is developing liquid body armor for use in helmets. His computational research combines materials processing and mechanical testing to study energy absorption and redirection.

Dogan's work also relates to the equally worrying behind-armor blunt trauma (BABT). BABTs are the non-penetrating injuries caused by the distortion and warping of body armors designed to protect the body from explosive impacts of bullets or other projectiles.

"By studying the nanostructured composite fluids, we hope to better understand impact weakening and blast-wave mitigation," says Dogan. "Multilayered viscoelastic materials — like polyurethane and rubber — could serve as ballistic and blast protection in relation to TBIs and BABT."

While the initial focus of this TBI research is on military uses, the work could one day be applied to equipment like bicycle helmets, football helmets and construction helmets.

Building models of protection

Other researchers have turned their focus on modeling injuries to better understand them and determine the best methods for healing.

Donald Wunsch, the Mary K. Finley Distinguished Professor of Electrical and Computer Engineering and director of the Applied Computational Intelligence Laboratory, is heading a team of researchers to analyze data from a TBI repository collaboratively built by the National Institutes of Health and the Department of Defense.

The team, which includes **Gayla Olbricht**, associate professor of mathematics and statistics at S&T, and **Tayo Obafemi-Ajayi**, assistant teaching professor in the cooperative engineering program at Missouri State University, will study data using unsupervised learning neural networks combined with statistics to allow for personalized medicine — medicine that is tailored for each individual patient and focuses on unique genetic profiles.

S&T researchers are also building better computer models to show the extent of injuries and damage to the brain. **Hyoung K. Lee**, associate professor of nuclear engineering at S&T, is developing a real-time computed tomography scan (CT scan) to better design and test TBI prevention gear.

Instead of using equipment that rotates around a patient, Lee's stationary CT system would sweep X-ray beams around a patient.

"The overall goal is to design a compact and fast X-ray tube that will be used for development of a stationary CT system," says Lee. "Our approach suggests that a tungsten flat emitter, a drum-shaped anode, and an electron beam focusing and steering system will allow the size of an X-ray source to be reduced while still generating the required high-intensity X-ray beam."

This could lead to a real-time CT scan — driving the field of imaging forward while allowing injuries like TBIs to be quickly diagnosed so treatment can begin.

Combining imaging and biomarkers

Jie Gao, associate professor of mechanical and aerospace engineering, is working to develop spectroscopic imaging techniques to help researchers understand fundamental biochemical alterations and their underlying mechanisms in TBI processes, as well as the effects of N-acetylcysteine amide (NACA) treatment on the injuries.

Gao is working with **Xiaodong Yang**, associate professor of mechanical and aerospace engineering, and **Nuran Ercal**, the Richard K. Vitek/ Foundation for Chemical Research Endowed Chair in Biochemistry. Yang studies spectroscopy and imaging techniques, and Ercal studies animals and oxidative stress-related disorders.

Donald Wunsch leads a team of researchers in the Applied Computational Intelligence Laboratory to study TBI data using neural networks and statistics to one day allow for medicine that is tailored to each individual patient.

UNDERSTANDING THE INVISIBLE INJURY

Research keeps professors on the cutting edge of knowledge in their fields and allows students to gain a deeper understanding of their area of study.

For students and recent graduates researching traumatic brain injury (TBI) at Missouri S&T, the work is both a passion and a duty.

S&T mining and explosives engineering graduate **Barbara Rutter** saw firsthand how blast-induced TBIs occur during her deployment to Afghanistan in 2012 with the U.S. Marine Corps Reserves.

"It got a lot more personal with me since some of the guys I deployed with are showing symptoms," says Rutter. "This work is all very near and dear to my heart."

Rutter developed her own equation for calculating impulse — the amount of pressure over time — applied to the brain during a blast. In conjunction with **Catherine Johnson**, S&T assistant professor of mining and explosives engineering, and researchers at the University of Missouri-Columbia, Rutter created a pressure-versus-impulse graph and defined the regions of mild, moderate or severe TBI in people.

"And from what I've found, the threshold is really, really low for brain injury. That surprised and scared me," says Rutter.

Because TBIs are invisible injuries, she related other physical injuries to TBI occurrence.

"You can't physically see a TBI, but other injuries could indicate the presence of one," says Rutter. "If you have lung damage or ear drum rupture, those are physical indications that you may also have a TBI."

She hopes her research can lead to faster diagnoses and treatment of TBI on the battlefield.

"I'm making it very easy for the medics to make the quick assessment," says Rutter. "They will get faster treatment to lessen and even reverse the effects of the brain injury itself."

Rutter's ultimate dream is to work on explosives with the Bureau of Alcohol, Tobacco, Firearms and Explosives. For now, she will stay at S&T as a postdoctoral scholar studying the relationship between TBI occurrence and surrounding structural damage in a blast.

Chase Sigler is just beginning his TBI research as a first-semester chemistry graduate student. Working with S&T chemistry research professor **Honglan Shi**, he is examining different biomarkers in urine to determine if their combinations could indicate a TBI.

In partnership with the Leonard Wood Institute and Phelps Health, S&T researchers will collect urine samples from military personnel going through blast training. Sigler will analyze 20 different biomarkers that he hopes will help him quantify the different stages of TBI.

"For example, one of our compounds is glucose, and if you have a high amount of glucose in urine, that could mean you have a TBI, but it probably means that you just ate a hamburger," says Sigler. "But if we get a whole panel of biomarkers, you will start to see trends that point us in the direction of TBI."

Sigler hopes to develop the method to separate the biomarkers in urine and quantify them. He will compare the military patient samples with control samples, and hopefully, discover a pattern to biomarkers in people with TBIs.

"Being able to serve my country through this — it really makes me feel wonderful," says Sigler. "I'm getting to contribute to not only the military, but also to human health in general — in making people better."

Left: S&T graduate Barbara Rutter, a former Marine, developed an equation that calculates the pressure the brain experiences during a blast and used it to build a scale of TBI severity.

Above: Chase Sigler is helping Honglan Shi identify the combination of biomarkers in urine that indicate a TBI.

CONCUSSION = TBI

The symptoms of a sports-related head injury, like concussion, may quickly fade, but the injury — a mild form of TBI — can leave behind brain impairment that lasts months or years. In recent years, concussions have become a critical public health issue for athletes at all levels.

Raelynn Twohy, a junior dual majoring in biological sciences and psychology at Missouri S&T, is working with **Amy Belfi**, an assistant professor of psychological science, to study the effects of concussion on athletes. Twohy is an undergraduate research assistant in Belfi's Music Cognition and Aesthetics Lab.

The effects of concussion — cognitive, behavioral and emotional — have gotten increasing attention from the public and scientific researchers, but also from sports organizations from the NFL to the NCAA and even youth sports leagues.

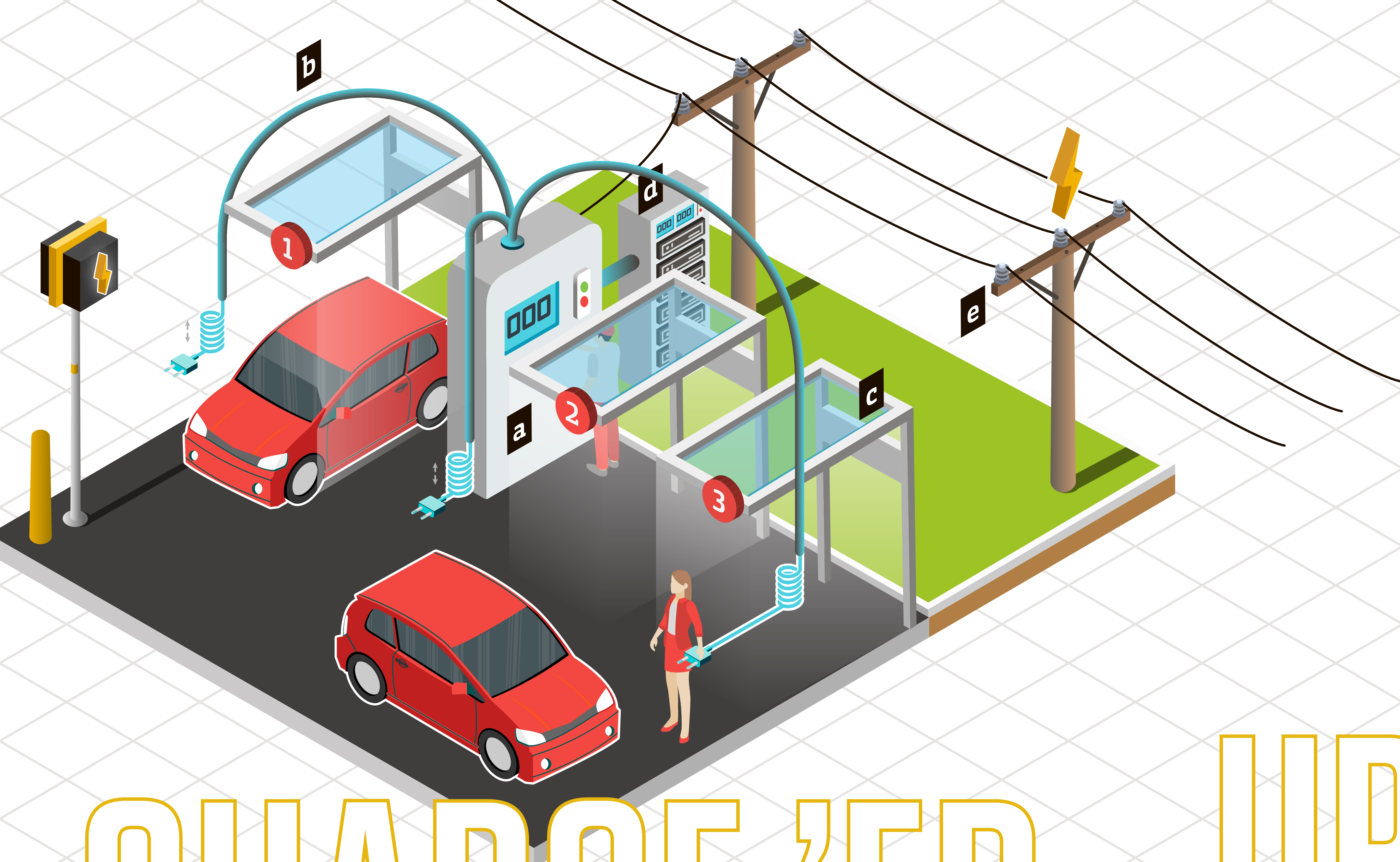
But despite the growing concern, concussions are still poorly understood, says Twohy.

"Our goal is to investigate whether the symptoms of traumatic brain injury differ based on the sport played," she says. "Our exploratory study will look for trends in college athlete concussions, including sport played, cognitive testing results and self-reported symptoms."

For the study, Twohy and Belfi are analyzing previously collected data from ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) collected by the student health center at a public university with an NCAA Division II athletics program.

The study is ongoing, but Twohy believes the research will prove her theory that specific TBI symptoms have a direct correlation to the sport that caused the injury.

In addition to her work with concussion in athletes, Twohy studies the effects of aging on autographical memory.



"People are nervous about not being able to get where they're going."

CHARGE 'ER UP

One drawback of electric vehicles (EVs) is the time it takes to charge them. But what if you could plug in your EV and fully charge it as quickly as it takes to fill up a conventional car with gasoline? Missouri S&T researchers, working with three private companies, plan to make speedy charging a reality.

"The big problem with electric vehicles is range, and it's not so much range as range anxiety. People are nervous about not being able to get where they're going," says **Jonathan Kimball**, professor of electrical and computer engineering. "With a conventional vehicle, you pull up, get gas, and in 10 minutes you're back on the road." Kimball is leading a team that received a $2.9 million matching grant from the U.S. Department of Energy to develop an extreme fast-charging system for electric cars over the next three years.

Conceptual charging station with three ports: a power converter, b cables to distribute power to vehicles, c sheltered charging location, d energy storage system (ESS), e 15 kV-class feeder that connects directly.

The project partners include Ameren, Missouri's largest electric power provider; LG Chem Michigan, a manufacturer of lithium ion batteries; and Bitrode, a St. Louis-based maker of laboratory-grade battery testing equipment.

Kimball says the group hopes to make electric cars more user-friendly by significantly reducing charging time. Most electric car chargers on the market today require anywhere from a few hours to overnight to fully charge a vehicle. Even Tesla's Supercharger stations take up to an hour to fully charge a car.

Of course, there will be challenges to building these fast charging stations. Can batteries withstand such speedy charges? Overcharging a lithium battery could lead to overheating and fire, Kimball says, and even if that scenario is avoided, the battery could still be damaged and wear out faster.

Jonghyun Park, S&T assistant professor of mechanical and aerospace engineering, joined the team to help minimize the degradation to the lithium ion batteries.

"At extreme fast charging rates, lithium-ion batteries can be damaged severely due to the limited energy transfer properties of the battery materials," he says. "This not only degrades battery performance, but also causes a short circuit that can lead to a safety issue."

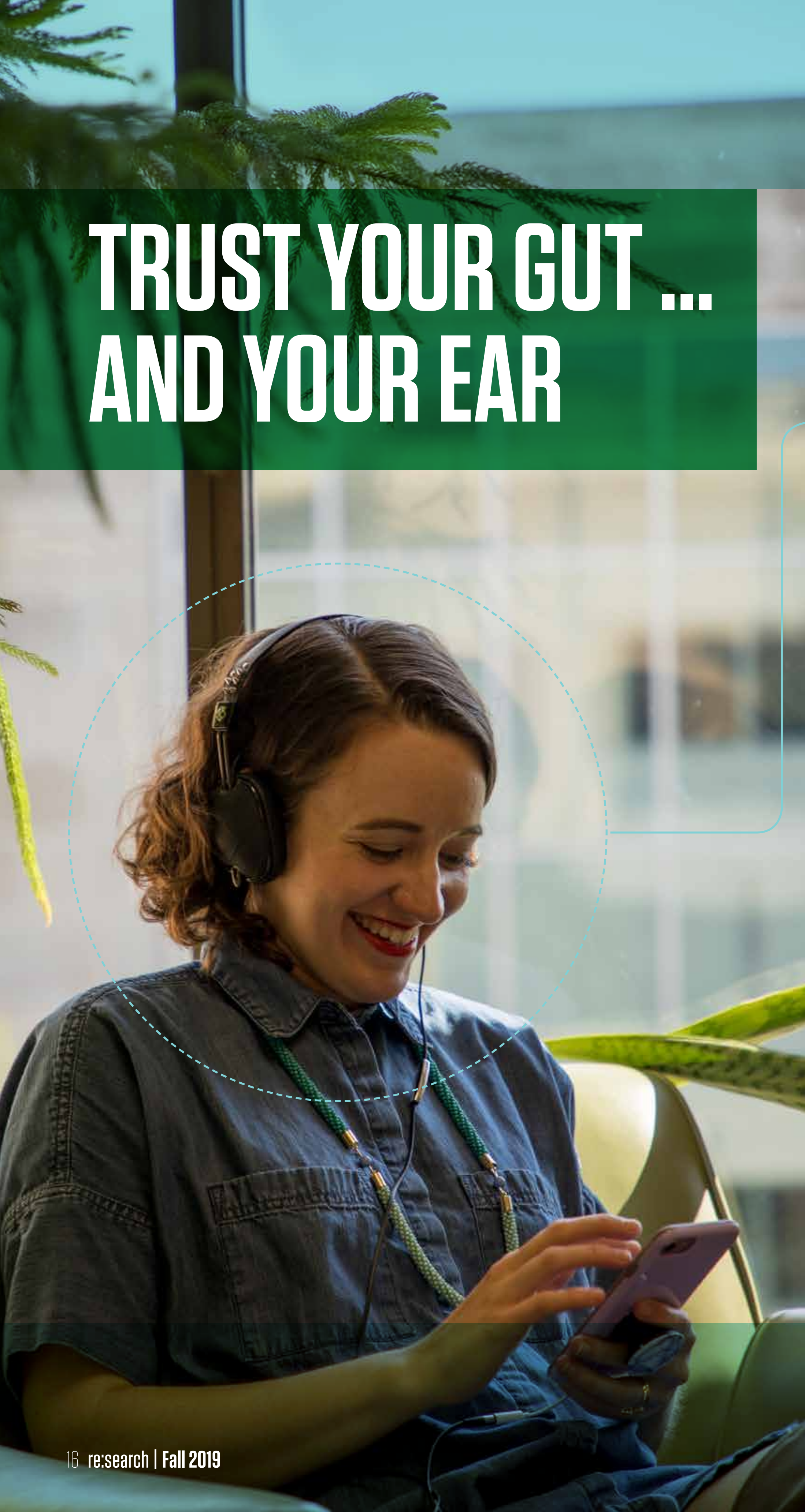
To address these challenges, the team will develop a model-based protocol for monitoring what researchers call the battery's "state of charge" and "state of health."

Quickly pulling large amounts of electricity from the power grid is another challenge, says Kimball. He estimates that charging a lithium-ion car battery in 10 minutes will take about 300 to 400 kilowatts. Several cars charging simultaneously could require more than one megawatt in needed power. In the Midwest, one megawatt hour of energy can power hundreds of homes for an hour.

Rui Bo, S&T assistant professor of electrical and computer engineering, says the sudden high current needed for fast charging would affect the power quality from the utility provider. That means it could affect other customers that also need power.

Bo and Kimball hope to bypass that instant pull on the electric grid by first connecting to a charged battery and then ramping up to connect directly to the 12-kilovolt distribution network.

The team also includes **Mehdi Ferdowsi**, professor of electrical and computer engineering, who provides broad expertise in electric-drive vehicles and their interactions with the power grid; **Pourya Shamsi**, assistant professor of electrical and computer engineering, who is experienced in high-power and medium-voltage converter design; and **Robert Landers**, Curators' Distinguished Professor of mechanical and aerospace engineering, whose expertise is in mechatronics and battery control systems.



TRUST YOUR GUT … AND YOUR EAR

Within seconds, we make personal choices daily, from what clothes to wear to what music to play in the car on the way to work. A Missouri S&T cognitive neuroscientist says these gut-level decisions are important, and that intuition tends to be accurate in revealing our true preferences.

Amy Belfi, assistant professor of psychological science, and her research team set out to determine how quickly people make accurate aesthetic decisions. Belfi studies music cognition and perception, or the ways music influences our thoughts, feelings and behaviors.

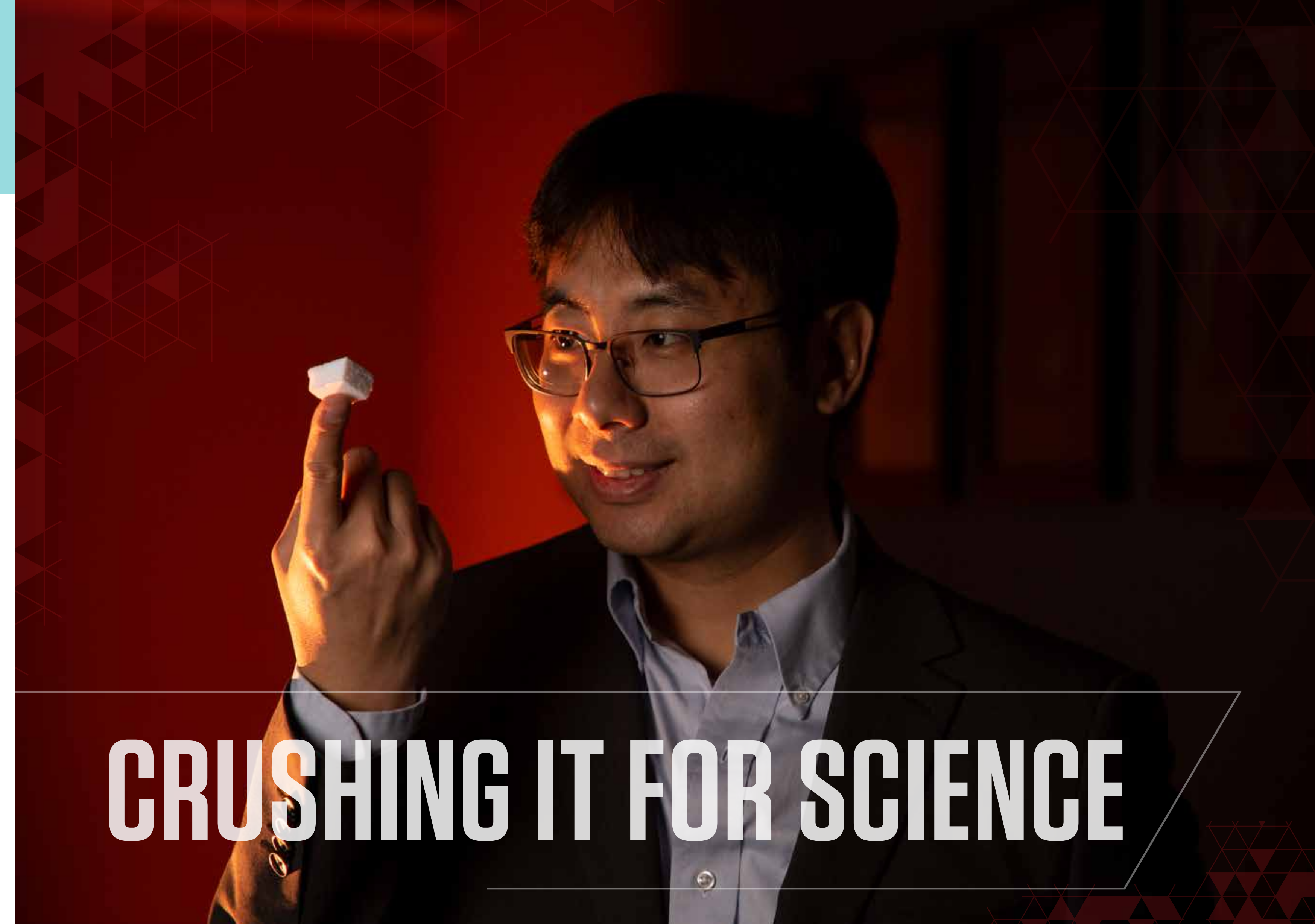
"Aesthetic judgments are subjective evaluations based on how pretty or ugly something is, or whether an observer likes or dislikes the object," says Belfi. "Intuitively, people might think aesthetic judgments require deliberate, contemplative thought."

But that isn't necessarily true, according to Belfi's research. She conducted a series of four experiments where listeners rated a variety of musical excerpts, ranging in duration from 250 milliseconds to several seconds. Musical pieces varied based on genre (classical, jazz, electronica) and familiarity of the music. Her research was published in the *Journal of Experimental Psychology: General.*

"Our experiments showed that listeners can accurately identify how much they like a piece of music quite quickly, within hundreds of milliseconds," says Belfi. "When we compared listeners' judgments of shorter excerpts to their judgments of the longest excerpts (10 seconds), they tended to match up quite closely. Listeners were accurately able to determine whether or not they would ultimately like a piece of music within 750 milliseconds. Some genres, such as electronic music, were judged even more quickly.

"Such rapid judgments represent initial gut-level decisions that are made quickly," Belfi says. "But even these initial judgments are influenced by characteristics such as genre and familiarity.

"Your initial decisions really mean something," she adds. "While limited to aesthetic judgments of music, in this case, the results of our research suggest that our intuitions tend to be quite accurate."



CRUSHING IT FOR SCIENCE

Want to build a better aerogel? You need to start by crushing them, say S&T researchers. Their findings were first published in *Soft Matter*, a Royal Society of Chemistry journal that focuses on the intersection of physics, chemistry and biology.

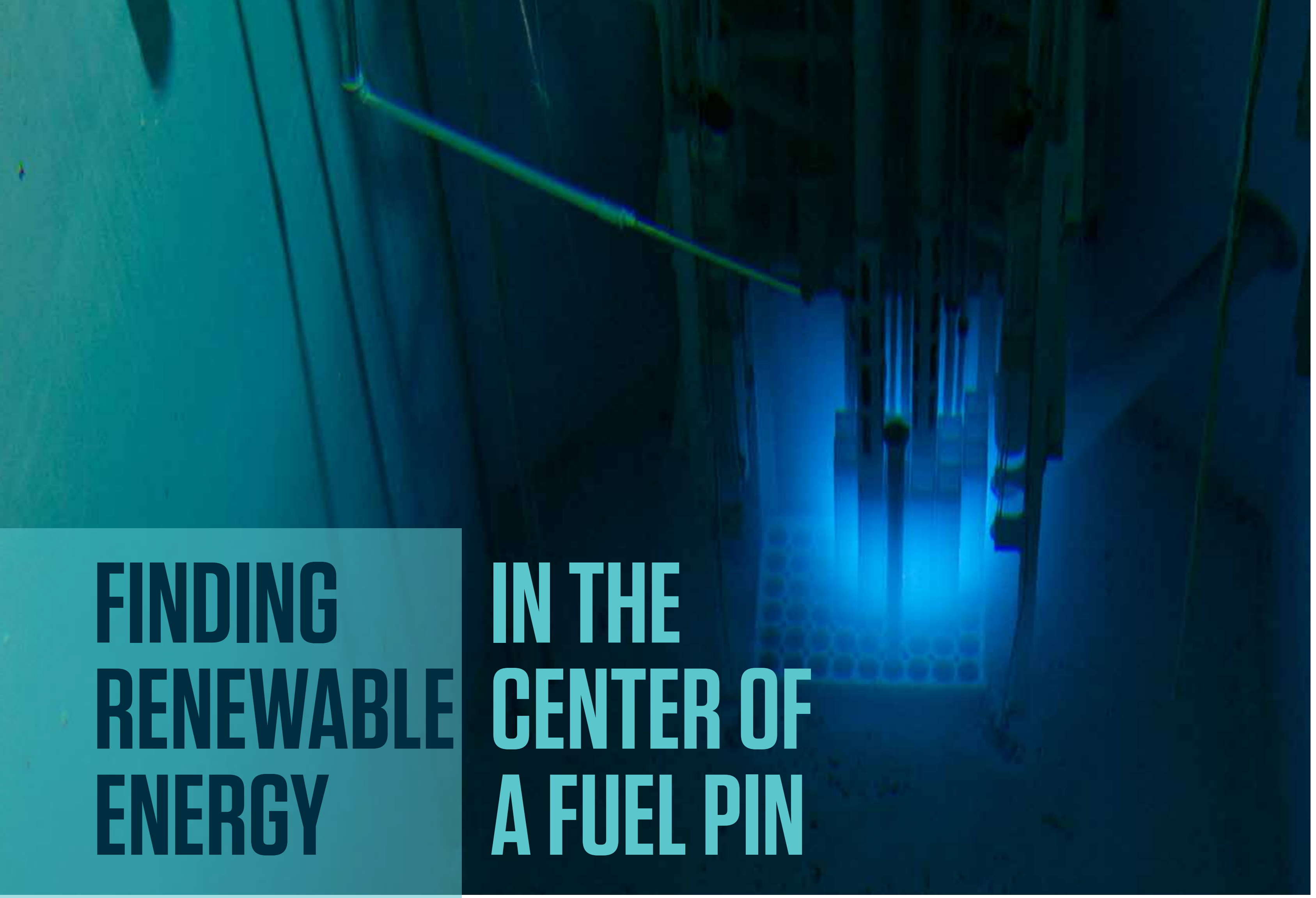
Aerogels are a diverse class of solid materials derived from a gel in which the liquid component is replaced with gas, making them lightweight and strong. The strong, flexible and ultralight materials are used in a wide variety of products, from insulation for offshore oil pipelines to parts for space missions.

By crushing and indenting aerogels, S&T researchers have gained a better grasp on their mechanical properties at the nanoparticle level as well as insight into how polymeric aerogels can fail and become deformed.

"We looked at the deformation of polyurea aerogels at a very small scale — at the building blocks themselves," says **Chenglin Wu**, assistant professor of civil, architectural and environmental engineering. "The data that we have obtained has provided, for the first time, first-hand information on nano-deformation of nanoporous polymers, and will be useful in the design, optimization and engineering of polymeric aerogel and soft nanoporous materials."

Wu and his team identified four failure modes of aerogel structures. They found that material scaling properties depended on both the relative density and the secondary particle size of the gels. That means there is not a conventional power-law relationship between the aerogels.

"Our research could be applied to areas such as energy absorption in ballistic protection to biomedical implants and drug-delivery platforms," says Wu. "This work enables the rational nanoscale-up design of nanoporous polymers for a very wide spectrum of applications ranging from ballistics to biomedicine to space exploration."



FINDING RENEWABLE ENERGY IN THE CENTER OF A FUEL PIN

> "The work relies on the pins still being highly radioactive and not decaying for too long."

The search for safe and environmentally benign renewable energy sources is one of the biggest challenges facing humanity. One source under development is the next generation of nuclear reactors and, along with them, new types of fuels.

To test the performance of these new fuels, we need new methods to investigate their structural, thermodynamic and chemical characteristics.

Joseph Graham, assistant professor of mining and nuclear engineering, has developed a microwave-sized mobile platform that can see through and image spent nuclear fuel using gamma radiation.

"It is hard to see what changes are occurring within a fuel pin when it is actively being irradiated in a nuclear reactor," says Graham, who is also director of Missouri S&T's nuclear research reactor. "Current measurement capabilities are limited to removing an active fuel rod, waiting for it to cool within a pool of water, and then scanning it or cutting it open to try to piece together what took place while it was in the reactor."

The fuel in a reactor — typically uranium — is placed into long metal tubes that are sealed and placed in a reactor. These fuel pins, often the size of a ball-point pen, undergo nuclear fission, where atoms split apart and release heat that produces electricity. Once the fuel is used up, the pins are removed from the reactor. They are still radioactive, though, so they are kept submerged in water to cool for a period of time that can vary from weeks to years.

By lowering Graham's new measuring device into the pool, researchers can begin to measure the fuel's changes throughout the pin between irradiation cycles, almost as soon as it is removed from the core.

"This device will allow us to look at the fuel right out of the oven, so to speak," says Graham. "The work relies on the pins still being highly radioactive and not decaying for too long. The fuel is like a house — at night with the lights on you can see into it, but once the lights are turned out it all becomes dark.

"We need more accident-tolerant fuels for the future, and seeing how the fuel will act while almost in situ will head us in the right direction for safety," says Graham. "With better fuels, we could help solve many challenges facing the creation of new reactors."

SAFER WATER AND MEDICATIONS THANKS TO NANOPARTICLES

Over 200,000 people die each year in the U.S. from sepsis, and an estimated 18 million worldwide. Endotoxins, which are fragments of bacterial outer membranes, trigger the septic reaction.

Sutapa Barua, assistant professor of chemical and biochemical engineering, has found a better way to remove those endotoxins from liquids.

She was awarded a federal patent in March 2018 for a method that uses polymeric nanoparticles to remove the deadly toxins from water and pharmaceutical formulations. She is working to develop a low-cost, portable bio-filtration kit to synthesize nanoparticles that can absorb water-borne toxins. Barua hopes this research will improve drug safety and increase access to clean drinking water.

The low-cost technique, as outlined in the journal *Nanotechnology*, is a one-step phase-separation method that uses a syringe pump to synthesize nanoparticles. Those polymer nanoparticles can remove endotoxins at the rate of nearly 1 million units per milliliter of water — all while using only a few micrograms of the material.

After synthesis, the particles were characterized with a transmission electron microscope and dynamic light scattering. Using a custom-made fluorescence assay, Barua was able to gauge how well the endotoxin bonded with the nanoparticles. She used the fluorescent compound BODIPY to tag the endotoxin for identification purposes.

The study "has large implications for the healthcare system, especially for those patients suffering from sepsis," the journal editors wrote. "This novel removal technique has the potential to be explored for the removal of other deadly toxins that can be found in the bloodstream from a number of different diseases."

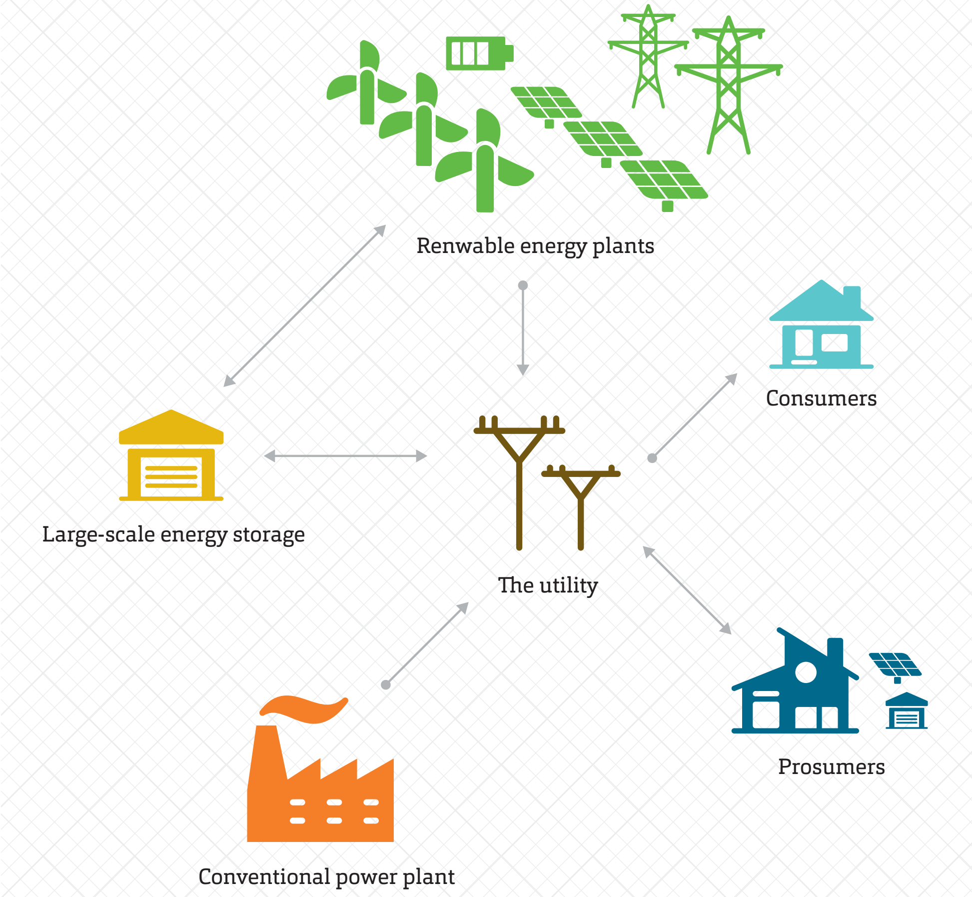
FULBRIGHT SCHOLARS

This past year, three Missouri S&T scholars earned Fulbright honors. The Fulbright program, named for the late Sen. J. William Fulbright of Arkansas, is an academic exchange program open to both faculty and students.

In January, **William Schonberg**, professor of civil, architectural and environmental engineering, began his term as Fulbright Distinguished Chair in Advanced Science and Technology at the Defence Science and Technology Group, a government agency in Melbourne. His research aims to develop mathematical models to more accurately predict how bridges, buildings and other structures can withstand a physical attack.

Daniel B. Oerther, professor of civil, architectural and environmental engineering, was selected for his fifth Fulbright award. During the 2019–20 academic year, Oerther will complete his research into reversing the spread of antimicrobial resistance at King's College London in the School of Population Health and Environmental Science as a faculty member for life sciences and medicine.

Owen Smith, a 2017 Missouri S&T physics graduate, received a scholarship grant through the Fulbright English Teaching Assistant Program to study in Russia. Smith, who minored in Russian at Missouri S&T, served as an English-language teaching assistant at a Russian university from September 2018 to June 2019.



THE AIRBNB OF THE UTILITY INDUSTRY

Could the same sharing-economy approach of companies like Uber and AirBnB work in the utility business?

A Missouri S&T researcher thinks it can, and she has developed a model for a peer-to-peer network where consumers could buy, sell and share energy.

"More consumers are yearning to use renewable energies, and energy providers are trying to fill that gap between what's already being done and what consumers want," says **Julia Morgan**, a Ph.D. student in systems engineering at Missouri S&T.

Morgan is studying how individuals who get their power from multiple sources — from solar panels and wind turbines to more conventional sources — could form communities for energy sharing among each other and local utility companies.

Morgan says that sharing communities include not only consumers of electricity, but also "prosumers" — end-users who both consume and produce electricity using their own renewable energy generators. The idea of energy sharing is to meet individual energy needs through renewable energies and to sell any excess energy within a sharing community. By sharing energy generation and demand, prosumers could see a cost savings and become more self-sufficient.

Ruwen Qin, Morgan's advisor and an associate professor of engineering management and systems engineering, says there are several benefits for both sides.

"Sharing unused generation from renewable energy sources within a community benefits all participants in the community," says Qin. "Consumers not only enjoy clean energy generated locally at a lower price than paying for the utility, but prosumers may also be able to sell the excess electricity to the community at a more attractive price."

So how close are Americans to connecting homes together to form energy sharing communities and larger systems?

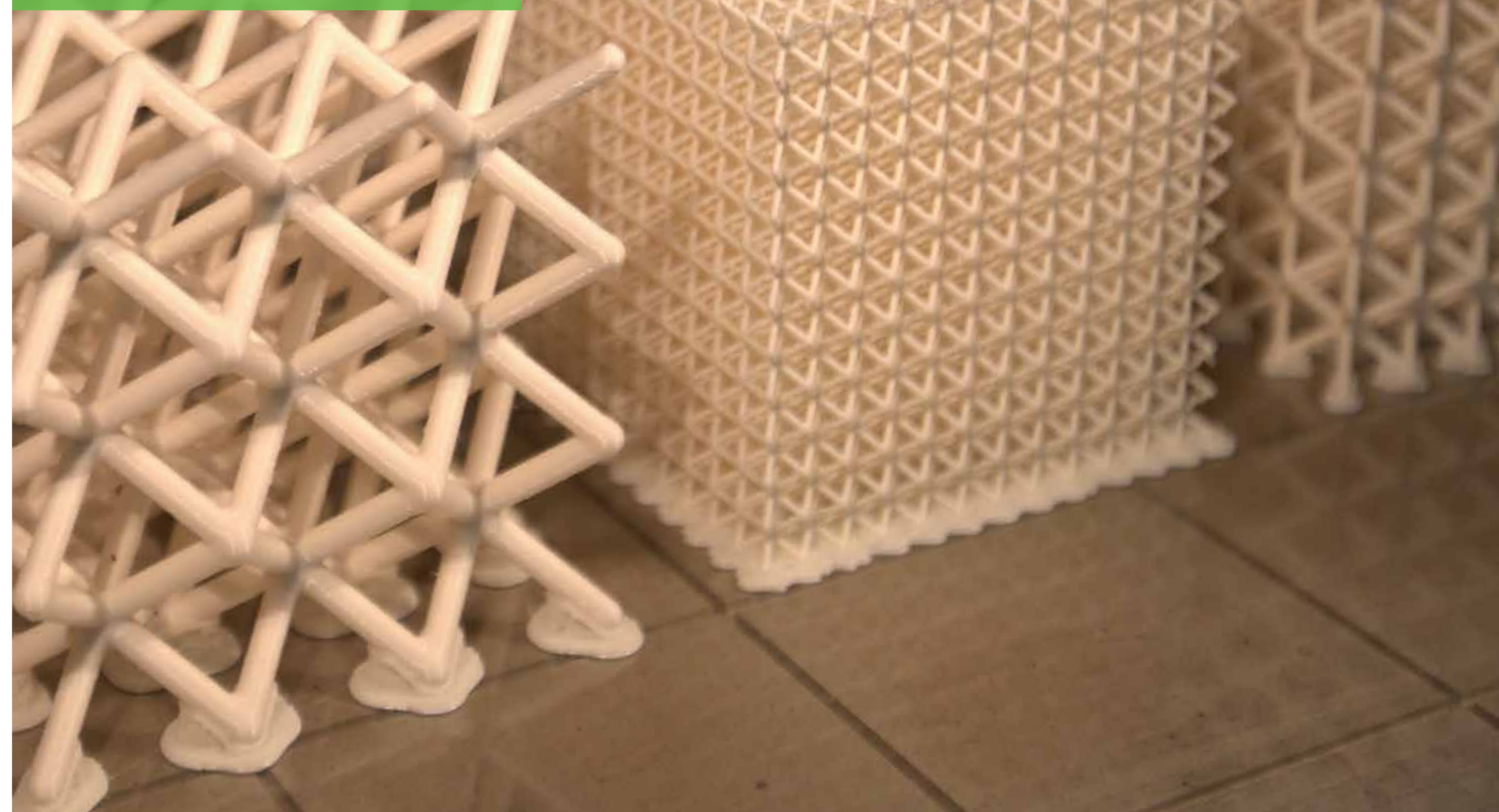
"Given that it's already happening on a small scale, I'd say we're pretty close," says Morgan. "Give it a decade, and you'll see more of that. If we can start to connect multiple communities of microgrids, they can be each other's energy backup instead of the utility company."

ADVANCING ADDITIVE MANUFACTURING AMONG LEADERS

Additive manufacturing holds promise as a speedier, less costly and more effective method to fabricate parts for industries from aerospace and automotive to healthcare and construction. But while the technological advances of this 3-D printing technique attract attention, executives in industry remain uncertain — even skeptical — about adopting the new technology in favor of traditional, time-tested approaches.

Additive Manufacturing Change Management: Best Practices, a new book co-written by **Elizabeth Cudney**, a Missouri S&T associate professor of engineering management and systems engineering, offers guidance for C-suite types uncertain of whether to join the additive manufacturing revolution or wait until its adoption becomes more widespread.

"There's often a lack of planning, a lack of understanding, a resistance to change and sometimes fear of the unknown," Cudney says. "Our hope is that this book will provide a good road map for managers to advance additive manufacturing at a faster pace."



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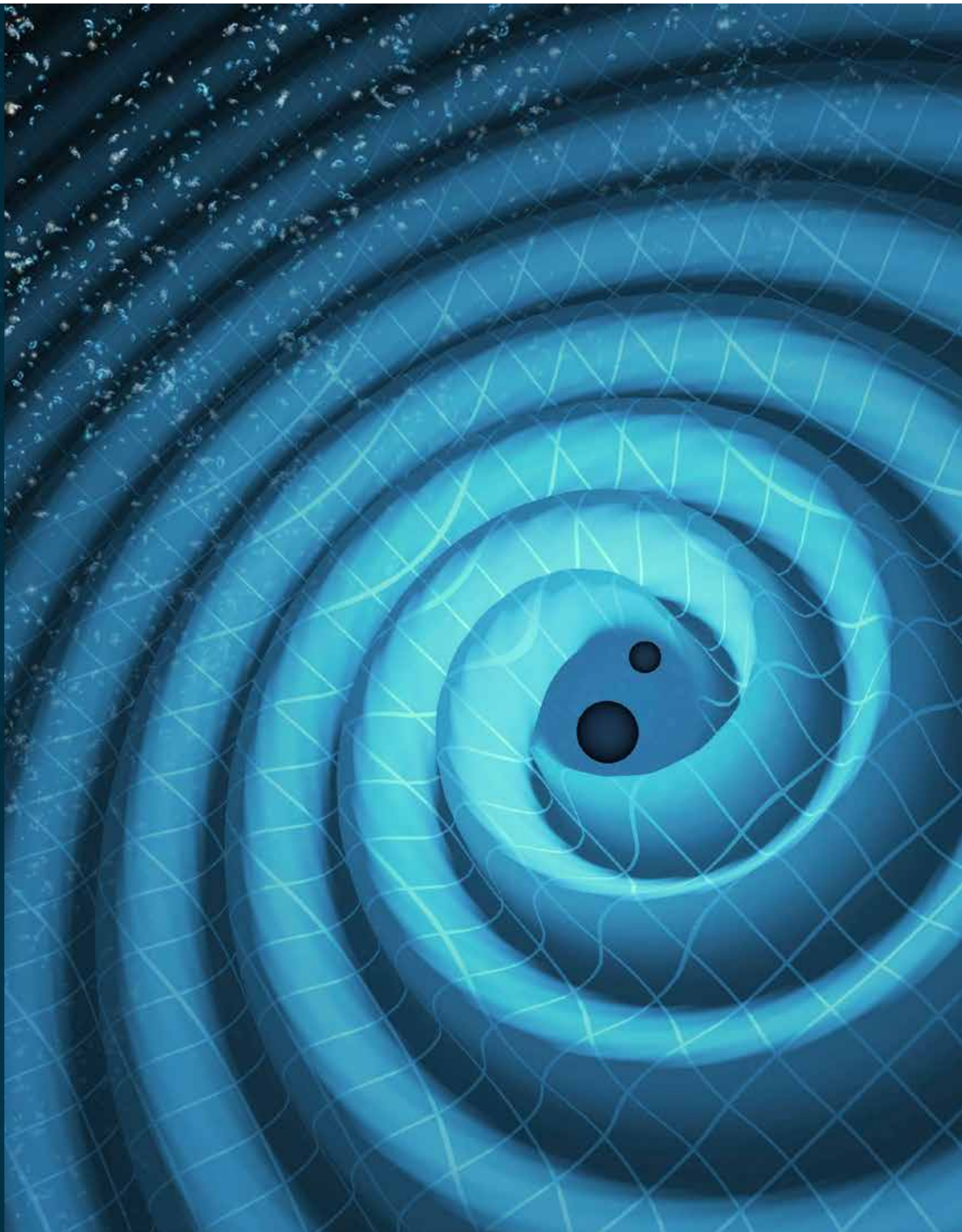
MISSOURI S&T JOINS LIGO SCIENTIFIC COLLABORATION AND WORLD-CLASS ASTROPHYSICS RESEARCH

Last spring, Missouri S&T became the state's only institution to join the worldwide LIGO (Laser Interferometer Gravitational-wave Observatory) Scientific Collaboration (LSC) of researchers committed to detecting cosmic gravitational waves. This research explores the fundamental physics of gravity using the emerging field of gravitational wave science as a tool for astronomical discovery.

Leading Missouri S&T's involvement with the LSC is **Marco Cavaglia**, professor of physics and an expert in gravitational physics and multimessenger astrophysics.

Multimessenger astrophysics began in 2017 with the first observation of the merger of two neutron stars. Gravitational waves, first detected in 2015, became a new "messenger" that can provide more information about the universe. Researchers now use data from gravitational waves along with established messengers such as electromagnetic waves and high-energy particles like neutrinos and cosmic rays to learn about the universe.



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