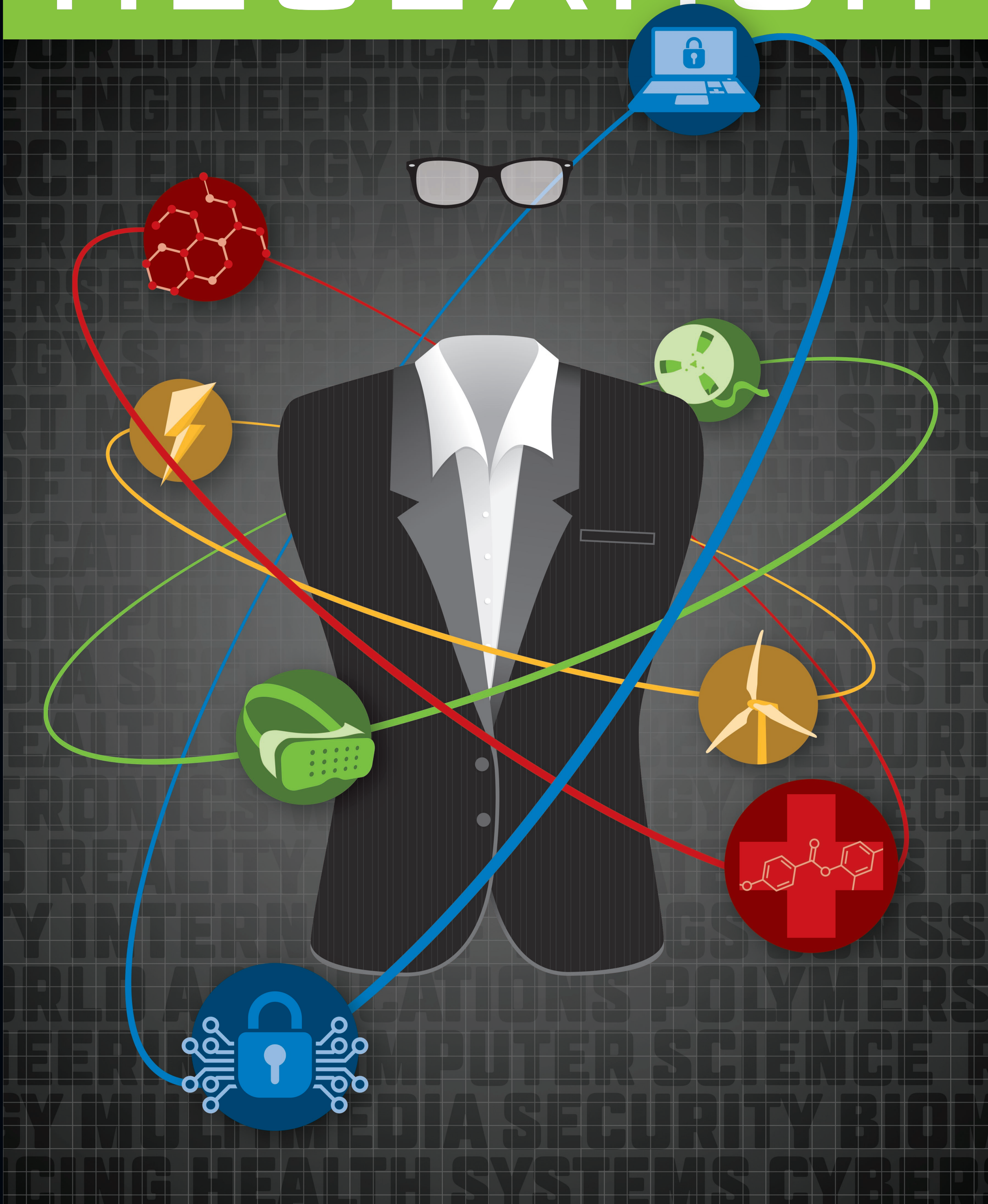
2018 – 2019

THE UNIVERSITY OF TEXAS AT DALLAS

THE JONSSON SCHOOL

RESEARCH



The Powerpuff Girls team launched their mousetrap car the farthest — 24 feet — at a UTDesign® Makerspace community outreach event. True to its name, a mousetrap car's sole source of power is the spring in a mousetrap, so participants devised clever ways to reduce friction and maximize force. About 50 students from two Dallas-area high schools competed.

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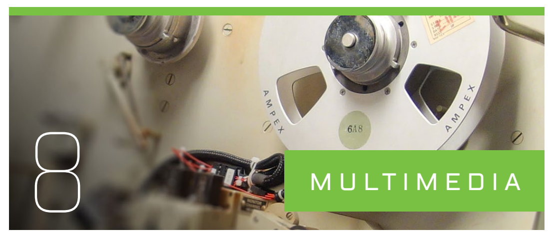
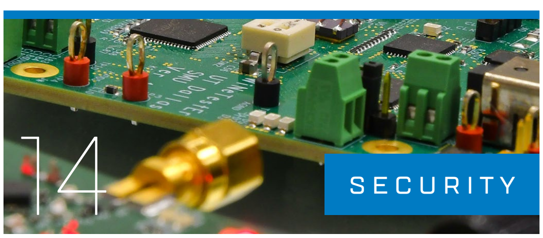
This issue highlights multidisciplinary research leading to real-world applications in four specific areas.





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ENERGY

FROM BENCH TO BLAST

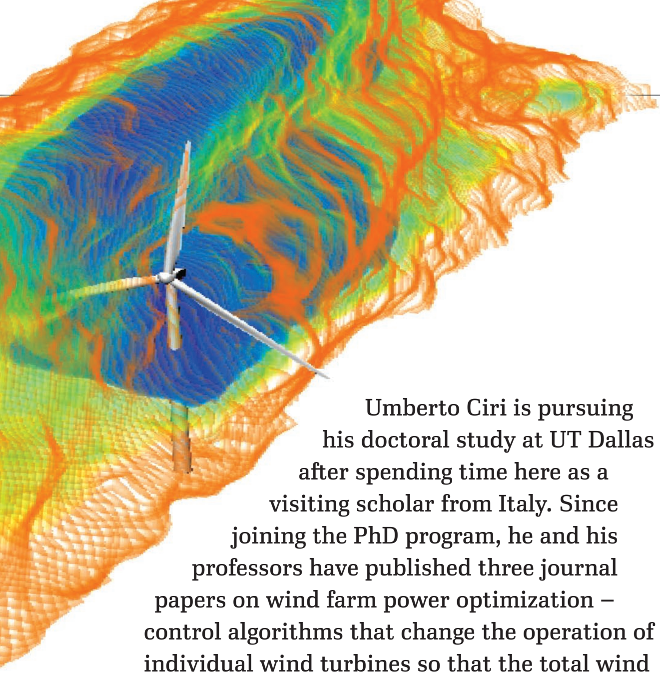
UT Dallas Wind Energy Working at Gale Force

This Jonsson School visualization of a wind turbine wake shows decreasing wind velocity.

ALL THE CURRENTS NECESSARY TO REACH the promises of renewable wind energy have now converged at UT Dallas. Internationally elite researchers from academia, government labs and industry have joined corporate partners in the form of a National Science Foundation (NSF) Industry/University Cooperative Research Center (IUCRC). A new wind tunnel unlike any other and a four story, 200,000-square-foot facility of labs, classrooms and office space have just opened. Highly motivated students are drawn to solving difficult problems with the potential for global impact.

"Wind energy is extremely relevant and good for the planet, and at UT Dallas, the world is open to you in terms of opportunities," said Jeanie Aird, a senior whose wind energy research experiences helped her earn recognition from the Barry M. Goldwater Scholarship and Excellence in Education Program in 2017, and who was first author of a study in *Wind Engineering Journal* published in December.

Aird is currently conducting wind research in two different areas. One project is a fluid mechanics-based model of ocean climate interaction with offshore wind farms under the direction of Dr. Stefano Leonardi, associate professor of mechanical engineering, and the other is an aerodynamic flow control model of different wind turbine blades to mitigate aeromechanical fatigue loads under the direction of Dr. Mario Rotea, head of the Department of Mechanical Engineering and holder of the Erik Jonsson Chair.



Umberto Ciri is pursuing his doctoral study at UT Dallas after spending time here as a visiting scholar from Italy. Since joining the PhD program, he and his professors have published three journal papers on wind farm power optimization – control algorithms that change the operation of individual wind turbines so that the total wind farm production is maximized. The articles were published in *Wind Energy* and *Renewable Energy*.

"Wind energy is a very important topic in terms of theoretical aspects and basic engineering practice, so it is personally gratifying," Ciri said. "But since wind is a renewable source of energy with several environmental benefits, our work is also of great practical importance."

The wind energy group at UT Dallas is primarily housed in the Department of Mechanical Engineering. In addition to Drs. Leonardi and Rotea, the group includes Dr. Todd Griffith, an associate professor who was recruited from Sandia National Laboratories and was a technical lead for Sandia's Offshore Wind Energy Program; Dr. Valerio Iungo, an assistant professor who was recruited from Switzerland; Dr. Yaoyu Li, a professor who has extensive industrial partnerships; and Dr. Jie Zhang, an assistant professor who was recruited from the National Renewable Energy Laboratory.

Organizations including the Department of Energy, Pacific Northwest National Laboratory, the NSF, Gulf of Mexico Research Initiative, and the Advanced Research Projects Agency-Energy (ARPA-E) have funded their research.

Iungo, Leonardi, Li and Rotea all currently have or have had projects in WindSTAR, the NSF IUCRC for Wind-energy Science, Technology and Research with the University of Massachusetts, Lowell. Since its creation in 2014, WindSTAR activities in the Jonsson School have included two dozen industry-driven research projects such as advanced control systems for wind turbines and wind farms, and diagnostic tools for wind farms using high-fidelity simulations of power production and LiDAR (Light Detection and Ranging) measurements.

Dr. Hongbing Lu, holder of the Louis A. Beecherl Jr. Chair, and Dr. Dong Qian, both professors of mechanical engineering, have recently joined the WindSTAR team with projects that seek to evaluate durability and new materials for wind turbine blades and towers.

During the summer of 2018, the University opened a $5 million wind tunnel known as BLAST: Boundary Layer and Subsonic Wind Tunnel. BLAST, designed by Iungo, has two test sections: a boundary layer section in which winds can reach up to 70 mph and a subsonic section in which winds can reach up to 100 mph, similar to mid-size hurricane winds. The new Engineering and Computer Science West Building that houses the Department of Mechanical Engineering opened shortly after. It has a high bay area to test and evaluate very large structures such as wind turbine blades.

"Our program covers a wide range of topics of direct impact to the wind power industry," Rotea said. "From wind resource characterization to turbine technology to wind farm performance to grid integration.

"Our tailwinds have picked up, and Texas in particular leads the country with installed wind power capacity and number of turbines."

Top: From left to right senior Jeanie Aird, Dr. Stefano Leonardi, doctoral student Umberto Ciri and Dr. Mario Rotea study a wind model.

Bottom: Dr. Valerio Iungo teaches an audience about the Boundary Layer and Subsonic Wind Tunnel that he designed. Winds can reach up to 70 mph and up to 100 mph in the two test sections.

CONTROLLING OUR COOL

IoT Solutions for Power Systems Applications

IN THE MIDST OF A SCORCHING NORTH TEXAS summer, losing air conditioning even briefly presents a crisis. With extreme temperatures or natural disasters leading to power outages, researchers at UT Dallas are devising novel ways to manage power and heating, ventilation and air conditioning (HVAC) applications.

"Millions of A/C units run at once," said Dr. Babak Fahimi, professor of electrical and computer engineering in the Jonsson School. "They work at a fixed speed, regardless of humidity, temperature, ambient conditions and health of the motor. And our traditional power grid can't always keep up."

Fahimi and researchers at the Renewable Energy and Vehicular Technology (REVT) Lab previously created a multi-port power electronic interface (MPEI) to allow efficient use of multiple renewable sources of energy. Today, he and PhD student Lizon Maharjan are adding two innovations — IoT-based microgrids and IoT-based HVAC monitoring.

Though the microgrid concept dates back to Thomas Edison, microgrids have recently received increased attention as a means for local energy control. A microgrid refers to everything from a separate grid for a critical facility, like a hospital, to a grid linking a village, or even a single home powered by alternative energy sources.

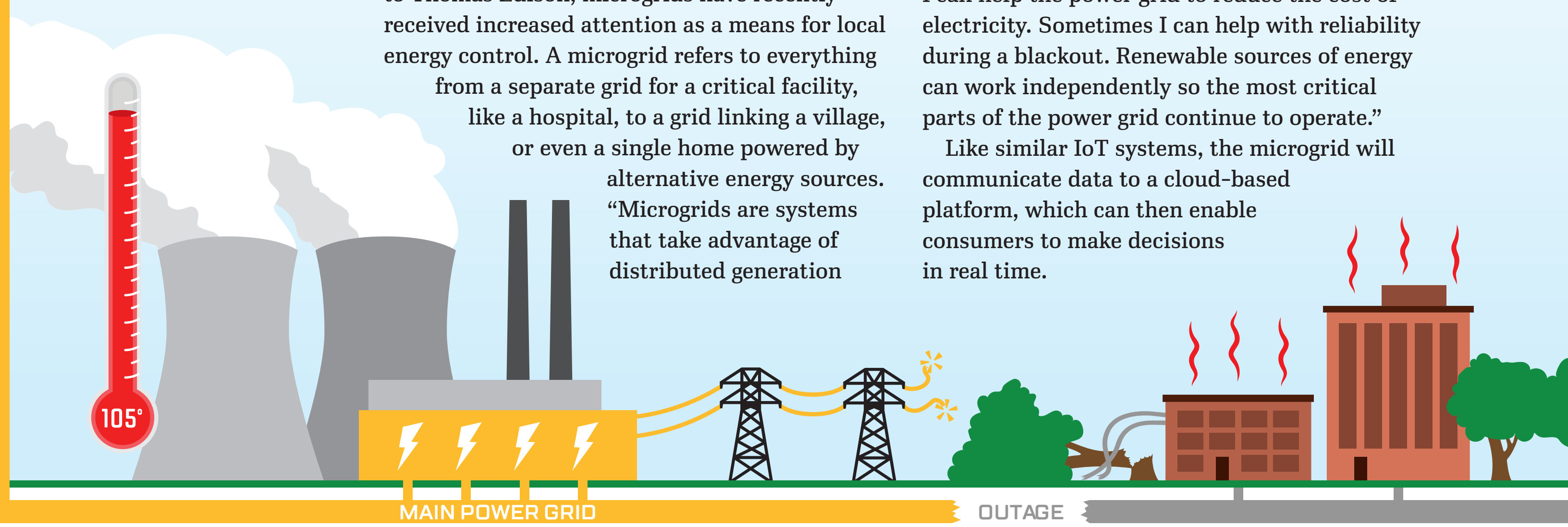
"Microgrids are systems that take advantage of distributed generation from a variety of renewable energy sources — solar, green and fuel cells," Fahimi said. "I believe the microgrid is the future of power systems. You don't have to transmit large amounts of power across hundreds of miles. You can even exchange power with neighboring microgrids to enhance the stability and reliability of electric power systems."

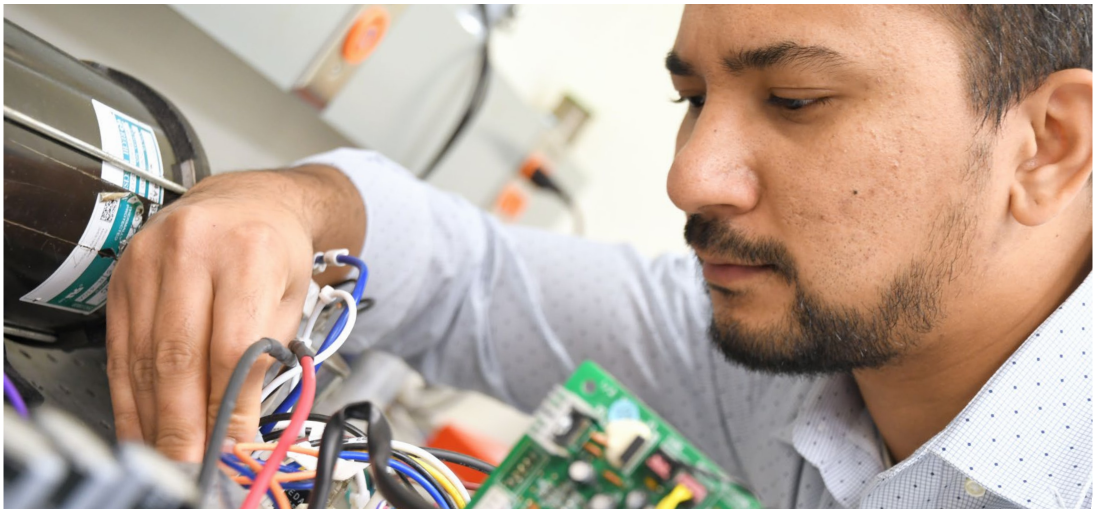
While the benefits are significant, managing numerous microgrids in concert with a major power grid presents many challenges. Currently, a homeowner who has installed solar panels will not necessarily benefit from the investment during a blackout unless the system can effectively store power and disconnect easily from the main grid.

"Multiple energy sources pose interesting engineering challenges," Fahimi said. "How do I monitor the harvest, how much energy is stored? What is the grid's condition? How do I process information from thousands of agents in my microgrid village, then create commands for harvest, billing and power storage? Sometimes I can help the power grid to reduce the cost of electricity. Sometimes I can help with reliability during a blackout. Renewable sources of energy can work independently so the most critical parts of the power grid continue to operate."

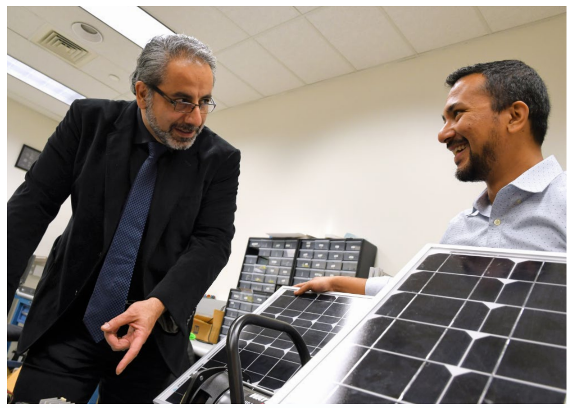
Like similar IoT systems, the microgrid will communicate data to a cloud-based platform, which can then enable consumers to make decisions in real time.

Bottom: Microgrids can disconnect from the main power grid during a power outage, using local, renewable sources of energy. IoT technology will enable more efficient management of multiple energy sources.





Top: Student Lizon Maharjan created both a prototype for a microgrid and a miniature air conditioning unit linked to an IoT monitoring system.



Bottom: Dr. Babak Fahimi and Maharjan link solar panels to their microgrid prototype in the Renewable Energy and Vehicular Technology (REVT) Lab.

"You have to run models in a cloud platform, then develop the best operational commands," Fahimi said. "That's a massive problem at the intersection of power electronics, data science, communication and artificial intelligence. I envision a point where a consumer can schedule when to switch on and off from a renewable energy resource through an app.

"We're making these technologies intelligent enough so they can prepare themselves," Maharjan said. "This is the biggest project of my life."

Their research on grid disaster mitigation is currently in press at *Institution of Engineering and Technology (IET) Smart Grid*. In addition to microgrids, Fahimi, an IEEE (Institute of Electrical and Electronics Engineers) Fellow is developing IoT solutions to enable air conditioners to respond to environmental conditions and notify consumers about needed repairs.

"We will communicate this information into a cloud, then issue commands according to local conditions," Fahimi said. "Consumers will have warnings so they're not surprised when the A/C unit stops working."

Similar to developing IoT solutions for microgrids, the air conditioner project requires interdisciplinary expertise.

"This project combines electrical engineering, signal processing, computer science and artificial intelligence to improve efficiency, reduce losses and ultimately create a better customer experience," said Fahimi, holder of the Distinguished Chair in Engineering.

For anyone who has scrambled to fix the air conditioner during peak times, the ability to schedule a repair in advance as well as the option to switch off the main grid during a blackout will make all the difference.

"I think using IoT solutions for power systems is like taking a highway with multiple off-ramps," Fahimi said. "If you want to stop, you don't have to travel back 200 miles, you just take the next exit. You can address the problem before you have gone too far."

Student researchers and Dr. Balakrishnan Prabhakaran (center) use multimedia equipment for a range of medical applications.

Mixed Reality for Managing PHANTOM PAIN in the Multimedia Lab

A PERSON WANDERS INTO A MIXED REALITY environment. A 3D mirror image avatar of the person appears, surrounded by a series of 3D games to choose from. Smashing brightly colored bubbles as they emerge from the floor is entertaining enough, but this immersive game has another purpose — physical therapy.

"Mirror box therapy is not engaging," said Dr. Balakrishnan Prabhakaran, professor of computer science in the Erik Jonsson School of Engineering and Computer Science at UT Dallas. "It's boring. But we have a series of games. We hope the patient will focus on playing the game rather than solving the pain problem."

Prabhakaran, a Distinguished Scientist of the Association for Computing Machinery (ACM), is working with the Dallas VA Medical Center to develop mixed reality therapies to treat phantom limb pain (PLP), severe pain occurring after an amputation. Even after adjusting to a prosthetic limb, the patient may feel chronic pain where the limb was located. Nearly 85 percent of amputees experience PLP, leading to ongoing distress.

Prabhakaran's student research assistant Kanchan Bahirat PhD'18 consulted Dr. Thiru Annaswamy, section chief of electrodiagnostic and spine sections, and Dr. Gargi Raval, staff physician, both at the Dallas VA Medical Center. Bahirat is the first author of an article on the subject of mixed reality therapies published in *MM '17 – Proceedings of the 2017 ACM on Multimedia Conference.*

"When we move, that action is visualized by our eyes and connects to our brain," Bahirat said. "But for the patient with limb loss, there is no visual feedback. That is the main reason for the ongoing pain."

MULTIMEDIA

BEYOND THE BOX

Previous research indicates that PLP is related to neuroplasticity in the somatosensory cortex — brain changes caused by experiences in the part of the brain that processes tactile information. Because the brain causes a pain sensation from past experience, the body requires new experiences for new neural pathways to develop and the pain to subside.

Mirror box therapy is currently used to treat PLP, during which a mirror reflection of the intact limb is projected to the place of the amputated limb, allowing the brain to complete its circuit. However, this therapy requires the participant to stare at the reflection without moving. Other digital therapies use preconstructed 3D models, which require using sensors to capture movement and do not always create a complete visual illusion.

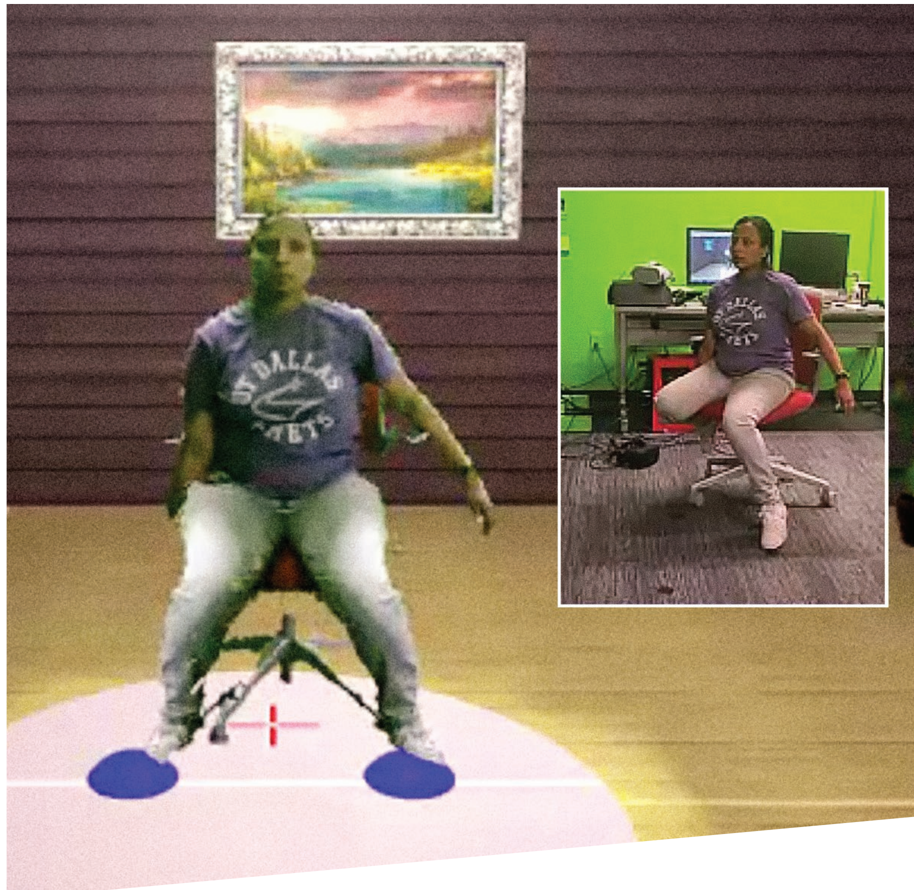
Prabhakaran and his team proposed a novel solution — using commercial virtual reality devices and cameras to create a mixed reality therapy session. A camera captures the patient's image, then a live 3D model of the phantom limb is generated using a mirror image of the intact limb. The model displays in real time, allowing the patient to move freely.

GAMING AS THERAPY

Prabhakaran's team intentionally made the therapy interactive, with games embedded in a mixed reality environment. Bahirat consulted the physicians to select exercises for both upper- and lower-limb amputations.

"The first lower-limb game for knee flexion and extension is called 'Bubble Burst,'" Bahirat said. "The second one has a stomping action simulating a piano game, and the third is a pedal game where you make a ball go up as you're making a pedal motion."

Patient trials are currently underway at the Dallas VA Medical Center. The therapy is completed daily at home for four weeks, so the team used readily available equipment. Each patient receives a Microsoft Kinect camera, an Oculus Rift headset and a gaming laptop.



Above: Kanchan Bahirat PhD'18 demonstrates how a mixed reality game generates a lower limb in real time.

Left and below: The therapy kit uses off-the-shelf virtual reality equipment including an Oculus Rift and a gaming laptop.

VIDEO AND THE PATIENT EXPERIENCE

The benefits of mixed reality therapy extend beyond entertainment and distraction. Because each session is recorded, insights from the video can improve interventions.

"No doctor can sit and watch 10 hours of video," Prabhakaran said. "An automated analysis can point out potential problems. 'Did you do your exercises?' Typically, a patient would say yes. I would say yes. But now, there is a recording. If there is no improvement, the physician can see what is going wrong."

Video data may also improve each patient's enjoyment and level of comfort with the process.

"The real feedback is from the patients," Prabhakaran said. "We have to consider the non-computer science challenges to make the games as effective as possible."

The research project was funded by the U.S. Army Research Office and the National Science Foundation.

HEROES behind the HEROES

Recovering Audio from the Apollo Moon Missions

THE APOLLO PROGRAM WAS PIVOTAL IN THE history of space exploration and scientific and engineering accomplishments, but until recently, most people have heard only sound bites from the missions. Thanks to the work of Dr. John Hansen, professor of electrical and computer engineering, and voice recognition researchers at UT Dallas, the general public now can listen to the conversation between the engineers, astronauts and backroom support staff that made up the Apollo missions.

"Almost all logistics support during missions were done through audio," Hansen said. "That's a real challenge when hundreds of NASA personnel all needed to work together while not necessarily seeing each other."

The audio archives, including much of Neil Armstrong's famous moon landing remarks, were stored on outdated analog tapes until Hansen and his team made them accessible.

Hansen's team at the Center for Robust Speech Systems (CRSS) in the Jonsson School received a National Science Foundation grant in 2012 to convert the extensive tape archive into exploreapollo.org, a public education and research website. The project, in collaboration with researchers at the University of Maryland, included audio from all of Apollo 11 and most of the Apollo 13, Apollo 1 and Gemini missions.

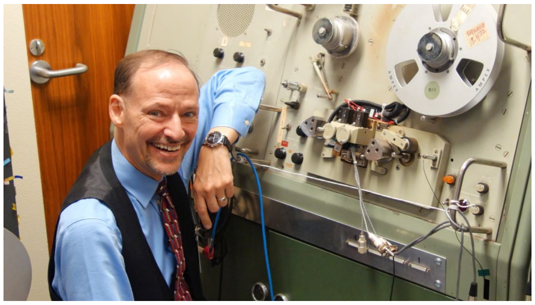
Hansen also currently serves as associate dean for research in the Jonsson School, a professor in the School of Behavioral and Brain Sciences and Distinguished Chair in Telecommunications. He is also president of the International Speech Communication Association (ISCA).

A GIANT LEAP FOR SPEECH TECHNOLOGY

The communications for Apollo missions comprised more than 200, 14-hour analog tapes, each with 30 tracks of audio. The tracks capture all communications between mission control specialists, astronauts and backroom support teams, but reflect challenges due to garbled speech, technical interference and overlapping air-to-ground loops. Imagine Apple's Siri trying to transcribe discussions with as many as 35 different people simultaneously using NASA's unique lexicon, and some speaking with Texas accents. Transcribing and reconstructing the audio archive required specialized advances in speech processing and language technology.

Hansen and his research scientist Dr. Abhijeet Sangwan recruited a team of doctoral students who digitized the archives, then developed algorithms to reorganize and analyze the audio. The algorithms are described in the November 2017 issue of *IEEE/ACM Transactions on Audio, Speech and Language Processing*.

Supervised by CRSS members, seven undergraduate UTDesign® teams helped create exploreapollo.org. The University's Science and Engineering Education Center (SEEC) also evaluated the website.



Dr. John Hansen shows the SoundScriber, the original equipment used to play the NASA Apollo mission audio.

REFINING RETRO EQUIPMENT

For decades, NASA played such tape reels using a 1960s device called SoundScriber, located at the NASA Johnson Space Center in Houston.

The device could read one track at a time, and the user had to manually rotate a handle to move the tape read head from one track to another. Hansen estimated it would take at least 170 years to digitize just the Apollo 11 mission audio.

"We couldn't use that system, so we had to develop a new solution," Hansen said. "We designed our own 30-track read head and built a parallel solution to capture all 30 tracks at once. This is the only solution that exists worldwide."

The new read head cut the digitization process to four months. Tuan Nguyen, a biomedical engineering senior with CRSS, spent a semester in Houston working on the project.

From left: CRSS members Dr. John Hansen, Chengzhu Yu PhD'17, Dr. Abhijeet Sangwan and Lakshmish Kaushik pose with a model of an astronaut at the NASA Johnson Space Center in Houston.

REVEALING THE HEROES BEHIND THE HEROES

After digitizing the files, researchers created software that could detect speech activity, including tracking what each person said and when, a process called diarization. Researchers also tracked speaker characteristics to analyze how individuals reacted in tense situations, and they uncovered how backroom support teams worked at NASA during the missions.

"This is not something you learn in a class," said Chengzhu Yu PhD'17. Yu began his doctoral program at the start of the project and now works as a research scientist focusing on speech recognition at Tencent Holdings Ltd.'s artificial intelligence research center in Seattle.

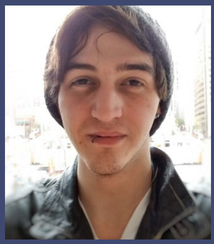
The team has demonstrated the interactive website at the Perot Museum of Nature and Science in Dallas. For Hansen, the project has highlighted the work of many people involved in the lunar missions.

"When we think of Apollo, we often think about the astronauts who deserve our admiration. However, the heroes behind the heroes represent the countless engineers, computer scientists and specialists who ensured the success of the Apollo program," Hansen said. "I hope our students today might be inspired from such Apollo team efforts to collaborate and commit their experiences in diverse STEM fields to address tomorrow's complex challenges."

ALUMNI PROFILE

VerNeil "CUBIE" Mesecher (BS'16)

VERNEIL "CUBIE" MESECHER BS'16 is an alumnus of the Jonsson School and the McDermott Scholars Program at UT Dallas. After completing a degree in computer science, he trekked to Seattle to work at Amazon Web Services (AWS). His role as a systems development engineer is a blend of a traditional software engineer and systems engineer. In other words, he develops software that improves the operational excellence of existing services



while reducing the time and investment needed to build new services. For AWS, this is an essential function, due to the large number of services and regions that it supports.

Q+A

How did UT Dallas prepare you to become a systems development engineer?

UT Dallas has a great focus on preparation for a career in computer science. In my experience so far, the strongest engineers can communicate effectively, discuss solutions and step back to look at the larger picture. The Jonsson School does an unusually good job of teaching the soft-skills part of engineering careers.

Can you tell me what a typical day at Amazon looks like for you?

A normal day at Amazon is hard to pin down. The culture is fast-paced in a good way, and I often switch gears between writing and reviewing code; engaging in design or technical discussions with other teams; working on proposals for my own ideas and initiatives; and helping mentor other engineers.

What sort of projects do you work on?

Currently, my team consults other internal teams about automation. With automation, an enormous amount of time and effort is saved, which allows engineers to focus on adding value to their products. When I engage with a team, I have to dive in to their code and learn as much as I can about the architecture and operations of their service as quickly as possible. Then I help highlight problem areas before contributing design and development to help fix those problems. Overall, I really enjoy the opportunity to work with a variety of experienced engineers and see how they solve problems.

You also worked with the robotics club, led by Dr. Nicholas Gans, clinical associate professor of electrical and computer engineering. Can you tell us a bit about that experience?

I worked with Dr. Gans for the first year and half I was at UT Dallas. Initially, I worked on a project with his Sensing, Robotics, Vision, Controls and Estimation (SeRViCE) Lab that involved building a set of 32 robots to act as chess pieces for a large chessboard that players could operate remotely. With Dr. Gans' sponsorship, I also won an Undergraduate Research Scholar Award that allowed me to conduct independent research. I examined the efficiency of an unusual holonomic drive base, which allows robots to move in all directions and rotate independently. I am extremely grateful to Dr. Gans for his support and guidance.

You worked on a National Science Foundation-sponsored project at Auburn University one summer. Can you tell me a bit about that experience?

I worked with Dr. Chase Murray on obstacle detection and avoidance for unmanned aerial vehicles in GPS-denied environments. That's just a fancy way of saying, "Strap some sensors on this drone and try to make it not run into walls in the lab." We used ultrasonic rangefinders attached to a Parrot AR drone to detect the locations of nearby objects and avoid them. We ran into many issues with this approach. However, I ultimately gained insight into the day-to-day work of researchers.

As a sophomore in 2013, you started a yo-yo club: Can you tell us about that club?

I started the Yo-Yo Club to share my passion for yo-yoing with other hobbyists. It was a relaxed club, rather than another club with added responsibilities and pressures. We taught each other tricks, performed at events around campus and volunteered by giving performances or lessons for kids at festivals and charity events. We also had one member, Phillip Wang, who won the South Central Regional Yo-Yo Championships a couple of years ago and competed at nationals! I think the members really enjoyed their time, which was the intent.

Do you still yo-yo?

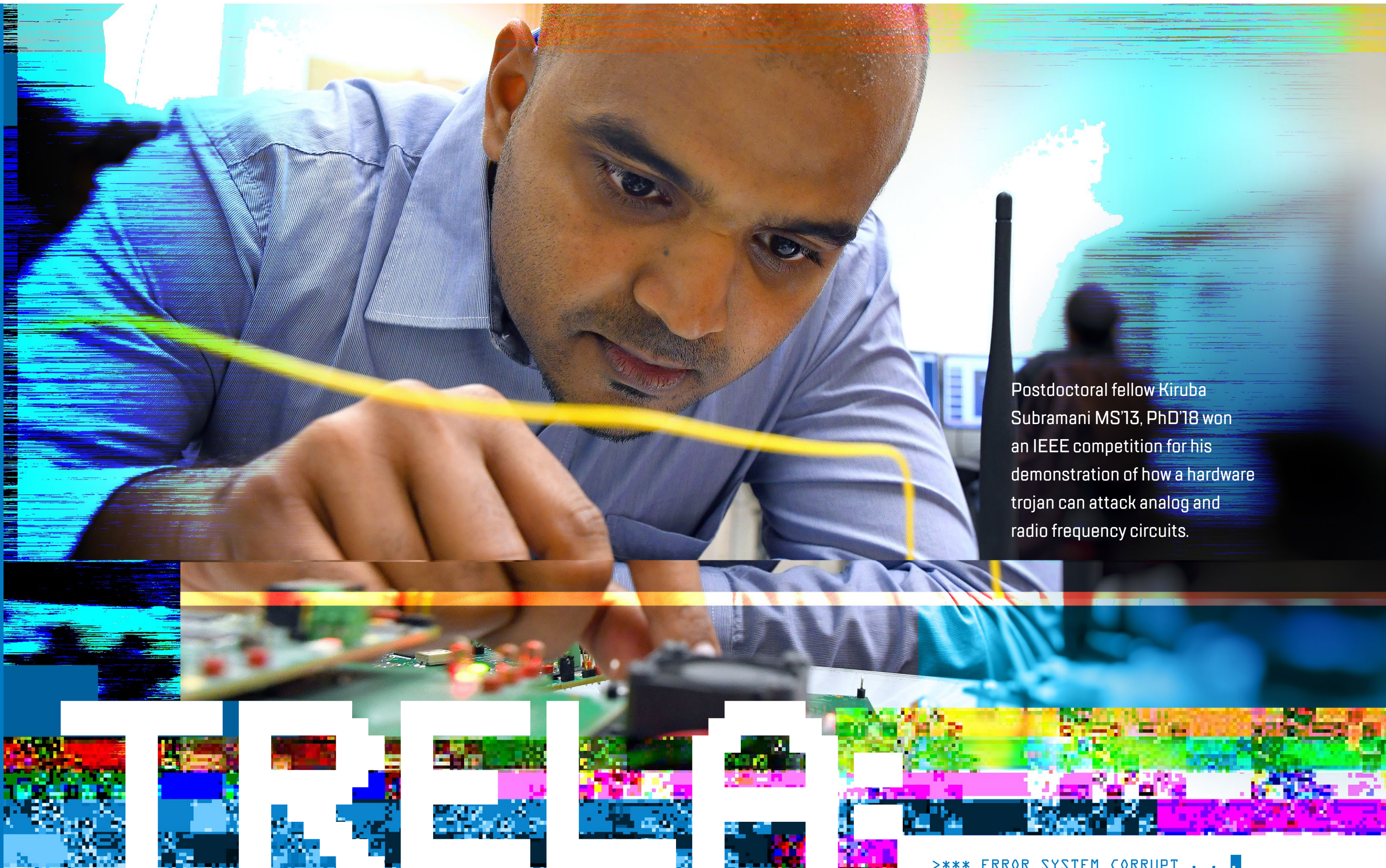
I do! I don't have as much time as I wish I did, but I still make it a point to pick one up on a regular basis so that I don't get too rusty. It's a very relaxing and engaging activity for me.

Do you have a favorite memory of your time here at UT Dallas?

One favorite memory is hard to pick. Honestly, the students and staff at UT Dallas made the experience amazing. However, if I had to choose, some of my favorite memories were of giving yo-yo performances at different talent shows and events around campus. Those always ended up being a lot of fun and led to some great friendships.

What advice do you have for other students?

Don't let failure stop you. Even with my successes in college, I also had my fair share of failures. I was rejected from every program I applied to my freshman summer. I ended up dropping my entire spring semester junior year due to mental health issues. I also initially struggled to find a job after graduation. I feel like most graduates feel pressure to end up at big-name, résumé-building companies right away, or else they are not doing well. Being successful has much more to do with getting past failure than it does with succeeding on the first try.



Postdoctoral fellow Kiruba Subramani MS'13, PhD'18 won an IEEE competition for his demonstration of how a hardware trojan can attack analog and radio frequency circuits.

TRELA

>*** ERROR_SYSTEM_CORRUPT . .

Ensuring Hardware Root of Trust for Emerging Technologies

FOR MONTHS, DR. KIRUBA SUBRAMANI MS'13, PhD'18, a Jonsson School postdoctoral fellow, had been researching a specific hardware security vulnerability. But on the first day of competition in the IEEE (Institute of Electrical and Electronics Engineers) International Symposium on Hardware-Oriented Security and Trust (HOST) demonstration challenge, his solution wasn't working.

"It was all hardware — something messed up," he said.

Subramani persevered and demonstrated how the hardware trojan — a malicious chip modification the legitimate designer or user is unaware of — can attack analog and radio frequency circuits. Then, to top it off, he also demonstrated how to detect the trojan attack. His project worked so well that he won first place for the 2018 HOST symposium's best hardware demonstration.

"Very few people can demonstrate these types of attacks in hardware and then propose defenses to solve the problem, but my advisor gave me the freedom and time to push my research forward," Subramani said. "With technology such as self-driving cars and internet of things becoming reality, these types of solutions are a big deal."

Subramani is a member of the Trusted and RELiable Architectures Research Laboratory (TRELA) led by his advisor, Dr. Yiorgos Makris, professor of electrical and computer engineering in the Jonsson School.

Makris is a pioneer in hardware security, a nascent field that is becoming more significant for the security of electronics and circuits and systems that are used in military, infrastructure, health, automotive and telecommunication applications. He is also a leader in how these devices communicate with one another.

"The core root of trust has always been the hardware," Makris said. "Implicitly when we build security protocols we assume the chips and other hardware are safe, secure and trusted, and we build the software on top.

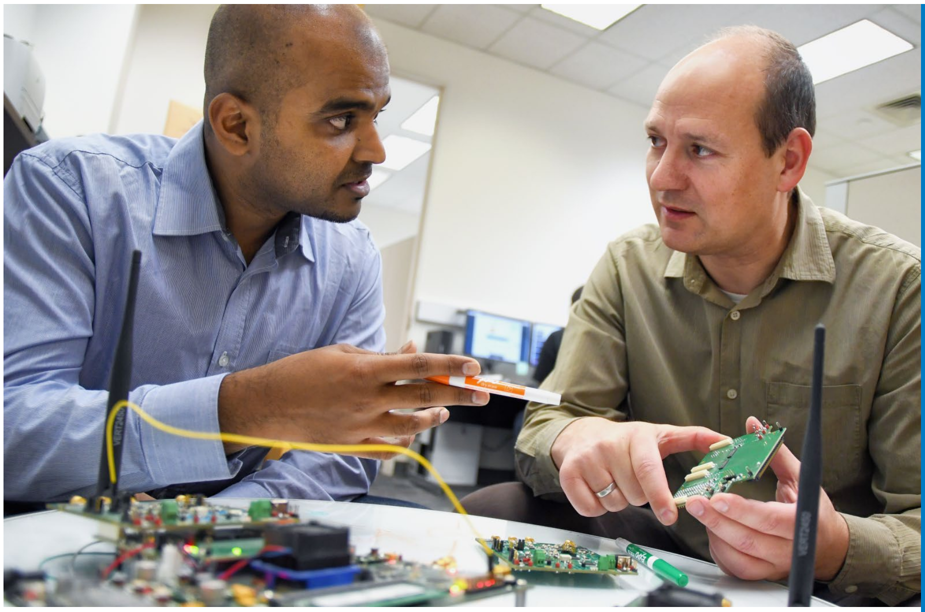
"However, about a dozen years ago, evidence began to show that that assumption is not necessarily valid: the hardware itself can be the entry point through which an attack can be staged to an electronics system."

To defend effectively against hardware insecurity, members of TRELA must have expertise in both digital and analog technology. Makris leads the Safety, Security and Healthcare thrust of UT Dallas' Texas Analog Center of Excellence, or TxACE, the largest university-based analog center in the world. He is also a member of UT Dallas' Cyber Security Research and Education Institute (CSI).

Makris' teams have developed several formal methods for ensuring the trustworthiness of chips. One of their key contributions is the statistical side channel fingerprint method. Statistical channel fingerprinting involves learning the distribution of secure chip parameters and then determining whether the pertinent measurements of a chip under evaluation fall outside this distribution.

Instead of relying on a small set of trusted chips to set the original parameters, in a paper published in the 2015 ACM (Association for Computing Machinery)/IEEE Design Automation Conference, among others, Makris' team demonstrates that side channels can be determined through advanced simulations and statistical analysis without the need for the original set of trusted chips. In a paper published in ACM/IEEE International Conference on Computer-Aided Design, his group has also used statistical side channel fingerprints to correctly identify provenance of chips from different fabrication facilities, possibly located in different countries.

In addition, an entire ecosystem of methods and tools has been developed around his Proof-Carrying Hardware Intellectual Property (PCHIP) solution for ensuring chip integrity.



Published in two parts in the 2018 *IEEE Transactions on Information Forensics and Security,* the PCHIP method provides the mathematical foundation to prove automatically that a piece of code included in hardware design is safe and secure.

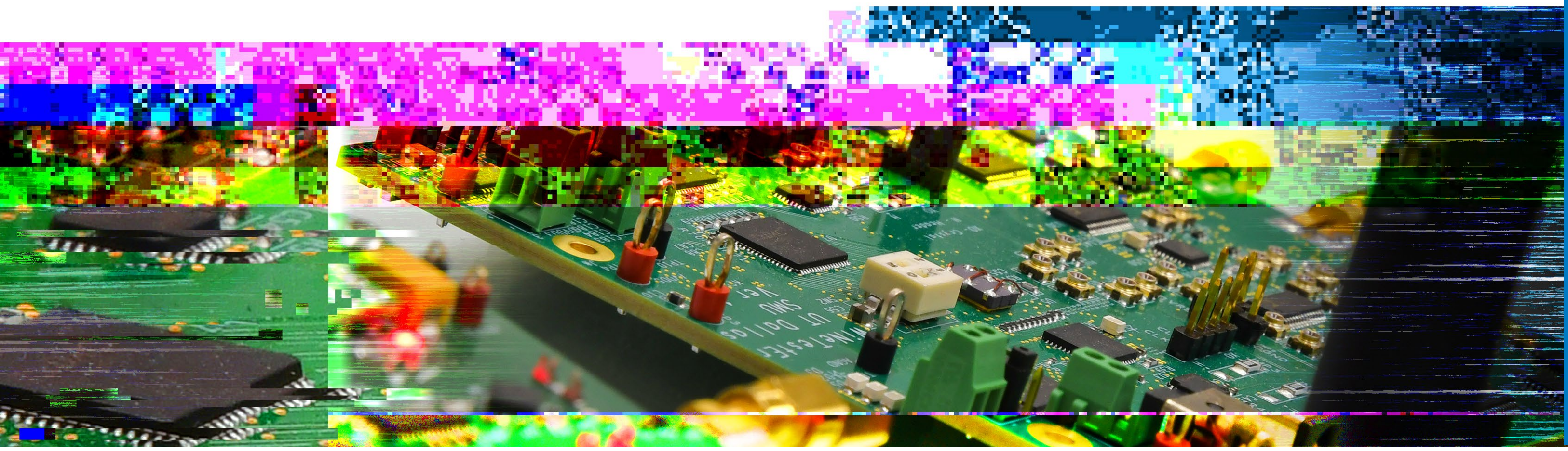
The work that won the HOST award is among the most recent innovations from TRELA.

The rest of the team involved in that demonstration included Dr. Angelos Antonopoulos, postdoctoral researcher in TRELA, and Dr. Aria Nosratinia, Erik Jonsson Distinguished Professor of electrical and computer engineering at UT Dallas. In 2016, Dr. Yu Liu PhD '16, a different member of TRELA who is now with Samsung Research America, won the same international HOST competition.

"What gets people excited about TRELA research is that we take ideas all the way from theory to demonstration," Makris said. "Now the attack is real — you can see it, you can feel it, and TRELA can help mitigate the damage."

Top: Subramani said the freedom given by his advisor, Dr. Yiorgos Makris (right), enabled his innovation.

Bottom: Makris and other TRELA members are pioneers in methods for ensuring the trustworthiness of chips, which, until recently, were always assumed to be secure.



COLLECT AND PROTECT

Data Security and Cyber-Physical Systems

FROM SMART THERMOSTATS TO PERSONAL fitness trackers, consumers are embracing IoT technology. While consumers have an array of IoT devices to choose from, the technology poses new risks.

"Many devices have sensitive data," said Dr. Murat Kantarcioglu, associate professor of computer science and director of the Data Security and Privacy Lab at UT Dallas. "A motion detector records when someone is home. Some track medical data you wouldn't want everyone to know."

Kantarcioglu and his collaborator Dr. Alvaro Cárdenas, associate professor of computer science and Fellow, Eugene McDermott Professor, recently received funding from the National Science Foundation to create an instrument that can gather and secure data from multiple cyber-physical systems (CPS).

CPS HACKS, GREAT AND SMALL

CPS devices range in size and scope from household IoT devices to large-scale industrial and government systems with both computer and physical components.

CPS hacks can cause significant physical damage. For example, the recent Stuxnet attack successfully subverted Iran's nuclear system. This system was not connected to the internet, yet was vulnerable to a covert attack that involved spinning and stopping centrifuges producing enriched uranium. While no state has claimed responsibility, the hack has raised concerns about CPS security in general.

Above left: Postdoctoral researcher Jairo Giraldo (left) and Dr. Murat Kantarcioglu are combining their expertise in cyber-physical systems, control theory and cybersecurity to develop an IoT security instrument.

Right: Kantarcioglu (right) and Dr. Alvaro Cárdenas will secure and compile data from multiple IoT devices using both hardware and open-source software.

"A lone hacker did not do this," Kantarcioglu said. "This was a sophisticated actor — probably $2 million invested and a large team, because someone needed to know how the centrifuges were programmed as well as how to control the device drivers."

Smaller systems critical to infrastructure could also be vulnerable.

"A CPS operating a dam could be hacked by an individual," Kantarcioglu said. "Someone could stop and start the flow of the dam remotely."

Additionally, consumers may have reason to be concerned about home IoT security.

"Imagine a situation like divorce proceedings," Kantarcioglu said. "How do you maintain privacy when your daily activity is tracked? As more people use these devices, I think we'll see more related court cases."

DATA MINIMIZATION AND SECURITY

One major concern about CPS devices is excess data collection. From a household system to health care or manufacturing control systems, risk increases.

"If a utility company only intends to collect data for billing purposes, then it shouldn't collect more fine-granular data than what is necessary," Cárdenas said. "Data minimization is a key principle in the new European Union's General Data Protection Regulation (GDPR) and the Fair Information Practices from Canada. My research goal has been to use the minimal amount of data necessary to achieve the CPS's objective."

Kantarcioglu and Cárdenas are both members of the Cyber Security Research and Education Institute (CSI) at UT Dallas. For this project, they will collaborate with Dr. Bhavani Thuraisingham, Louis A. Beecherl Jr. Distinguished Professor of computer science and the executive director of CSI, as well as other researchers to develop a system that can consolidate data from multiple devices. The key, then, is regulating what is shared.

"Privacy is a major concern," Kantarcioglu said. "While we are combining data, we also need to secure it using encryption and hardware. The vulnerability to attack depends upon the device."

OPEN-SOURCE SOLUTIONS

The team will work with graduate student developers to create open-source software that will secure multiple data streams while adjusting the frequency and granularity of data collection.

Dr. Jairo Giraldo, a postdoctoral research associate at UT Dallas, met Cárdenas while studying electrical engineering in Colombia. While Giraldo initially focused on control theory and power systems applications, he became increasingly interested in CPS cybersecurity.

"Many people can take advantage of broad, open-source instruments for security and privacy, even people from other research areas like control systems," Giraldo said.

Cárdenas said: "Our collaboration exemplifies the importance of interdisciplinary dialogue. We are adapting cybersecurity to the unique characteristics of CPS applications."

Researchers from other universities and institutions as well as industry and government are expected to continue the effort.

The average person will likely not have the skills to implement the software at home just yet. However, Kantarcioglu foresees the instrument becoming widely accessible.

"Our software will require some technical background," Kantarcioglu said. "Soon, however, I imagine a company will take this concept and market a product for the end user."

A CAD rendering shows how a device constructed with soft shape-memory polymer is implanted for spinal stimulation therapy.

APRL

An Ethos of Excitement for Polymer Science Applications

FOR RESEARCHERS AND STUDENTS STUDYING polymer science, the Advanced Polymer Research Lab (APRL) has an irresistible energy.

"It's definitely exciting keeping up with the research," said Sydney Sherman, bioengineering senior, Eugene McDermott Scholar and recent Goldwater Scholarship recipient. "There are plenty of ways to get involved in the lab and try new things. I've had the opportunity to do more than a typical undergraduate would in terms of being directly involved in research and grant writing. The lab is really moving forward."

Led by Dr. Walter Voit BS'05, MS'06, the APRL caught Sherman's attention at an undergraduate Honors Program presentation. Currently, she assists Aldo Garcia-Sandoval, a bioengineering PhD student who realized his own interest in biomedical applications research after learning more about APRL's range of activities.

"I met Dr. Voit when I was an undergraduate from Mexico," said Garcia-Sandoval. "I participated in an international summer research program, and I found a whole new world of opportunities. After that, I knew I wanted to earn my PhD and pursue research."

Voit, a professor in the Department of Materials Science and Engineering and Mechanical Engineering, directs the APRL at the Jonsson School. The interdisciplinary lab explores problems in polymer science and engineering, including shape-memory polymers.

Shape-memory polymers are self-adjusting, smart materials in which shape changes can be accurately controlled at specific temperatures. They are well-suited for biomedical applications because they can adapt to the human body's environment.

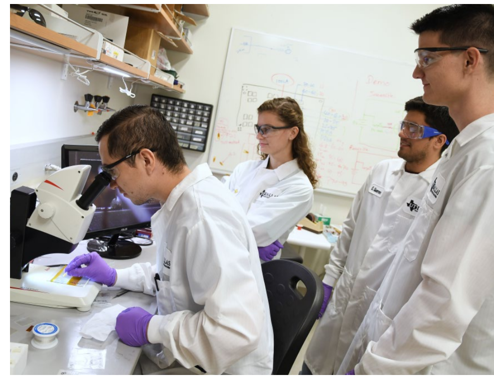
Lab researchers have successfully developed innovations such as an ultra-comfortable earpiece and smart prosthetic. While the lab explores myriad projects, there's one common goal: to impact society.

"These big, complex projects require a talented team with multiple, diverse skill sets," Voit said. "Our collaborative, high-powered ecosystem of discussion and innovation is what breeds excellence."

IMPLANTED DEVICES AND PROSTHETICS

Voit, himself one of the inaugural class of Eugene McDermott Scholars at UT Dallas, has worked with researchers throughout his tenure on devices designed to work within the human body.

The research team initially built a series of electronic devices that become soft and can grip surfaces such as large tissues, nerves and blood vessels. The research, featured in *Advanced Materials*, demonstrates implanted transistors that change shape while maintaining their electronic properties.



"In our device design, we are approaching the size and stiffness of precision biologic structures, but have a long way to go to match nature's amazing complexity," said Voit, who is also a member of the Texas Biomedical Device Center, which is housed at UT Dallas.

Garcia-Sandoval and Sherman are currently working on newer devices for spinal cord stimulation. The stimulation is used to treat trauma of the spinal cord and is focused on motor recovery. Previous devices constructed with more rigid materials tended to separate and cause long-term problems, but the shape-memory polymer is able to soften and better attach to the spine, causing a reduced immune system response. The stimulation devices are currently being tested at Cornell University. Garcia-Sandoval and his team published an article on the research last year in the *Journal of Neural Engineering*.

E-WHISKERS AND ELECTRONIC SKIN

More recently, lab researchers have developed shape-memory polymers to create electronic e-whiskers, devices that mimic the properties of natural animal whiskers. Voit and his team also described this project in *Advanced Materials*.

"We've created some of the highest density e-whiskers to date," Voit said. "If you drag many sensors together, they can measure properties including force, pressure, proximity, temperature and topography. As they brush up against surfaces, they mimic the sensing capabilities of human skin."

Robotics and prosthetics could be two of the biggest applications for the e-whiskers.

PHOTOPOLYMERS FOR 3D PRINTED DEVICES

In addition to his University role, Voit is now founder and CEO of Adaptive3D Technologies Inc., which aims to identify niche markets for new development. In particular, the company has created a high-strain, 3D-printable photopolymer resin with properties similar to rubber.

With generous funding from Defense Advanced Research Projects Agency, the National Science Foundation, and the National Institutes of Health, as well as longtime partnerships such as Texas Instruments Inc., Voit has led Adaptive3D to develop photopolymers specifically for additive manufacturing, a process of constructing three-dimensional, layered materials.

Voit takes pride in bucking the stereotype of the researcher as a solitary lab rat. He relishes collaboration, from the Jonsson School to the private sector.

"We want to make a difference," Voit said. "We don't want our intellectual property to just sit there. Larger companies rely on small companies for new enthusiasm, new materials and new technology. That's what we provide."

Clockwise from top left:

Dr. Walter Voit (center) works with Aldo Garcia-Sandoval (right) and others in the Advanced Polymer Research Lab.

Garcia-Sandoval, a PhD student, and other researchers use a microscope to manipulate the miniature, transparent medical devices.

Sydney Sherman conducts research as an undergraduate student in the Advanced Polymer Research Lab.

Dr. Taylor Ware PhD'13 (left) and doctoral student Cedric Paul Ambulo examine a shape-morphing 3D structure.

RESEARCH ON SMART MATERIALS GETS A BIG BOOST

Dr. Taylor Ware PhD'13, assistant professor of bioengineering in the Jonsson School, is taking ingenious approaches to examining smart materials.

His research has received a big boost with funding from both the National Science Foundation (NSF) and the U.S. Air Force.

The NSF Faculty Early Career Development (CAREER) Award is highly selective and supports early career researchers who exemplify the role of teacher-scholars while offering a unique opportunity for junior faculty to jump-start independent research.

Ware's CAREER project, titled "Designing Microscale, Shape-Morphing Liquid Crystal Elastomers as Tissue Adhesives," will receive nearly $500,000 over the next five years.

Ware aims to design smart materials that can stick to the soft, wet and moving tissues of the human body. While traditional glues rely on chemical bonds, these new adhesives will rely on mechanical bonding, similar to how Velcro works. Whereas Velcro always sticks to fabric, these materials will use shape changing structures about the size of a human hair to switch on and off the adhesion to soft tissue. The adhesives could be used in devices that are intended to heal wounds and deliver drugs. To achieve this goal, Ware will investigate the use of liquid crystal elastomers, which are like rubbery materials that undergo controlled shape change on heating and cooling. Currently, the use of these materials is limited in biomedical applications.

"The challenges in using liquid crystal elastomers are not small: the transition temperature of these materials is currently too high for use in biomedical applications; shape change is difficult to program in 3D microscale structures; and the biodegradability of these materials is uncontrolled," Ware said.

Ware and his research lab, which is concerned principally with creating smart materials, will tackle these issues one by one.

First, they must synthesize liquid crystal elastomers with other materials that offer controlled biodegradability. These smart materials must then be modified so that they change shape at more suitable temperatures and in such a way that they better adhere to model tissues.

"If successful, this work will engender broader impact in society by enabling a novel class of soft tissue adhesives," Ware said. "Soft tissue adhesives are needed for a wide variety of medical devices from wound healing aides to internal drug delivery patches, where intimate and persistent contact with soft tissues is critical."

For example, a common cause of postoperative pain and recurrence in hernia prolapse repair surgeries can be attributed to poor adhesion between soft tissues and supporting devices.

"Nearly 1 million of these interventions are performed in the U.S. each year. As such, improved tissue adhesives are a critical missing component to reducing health care-related costs and improving quality of life," he said.

Ware's research also is supported by a Young Investigator Research Program (YIP) grant that he received in 2017 from the Air Force Office of Scientific Research. The grant provides $360,000 over three years.

Ware's YIP project, "Designing Microstructure in Ordered Polymer Actuators," also seeks to improve the efficacy of liquid crystal elastomers. In this work, Ware hopes to synthesize liquid crystal polymers that are capable of both changing shape and carrying a heavy load.

One of Ware's PhD students was lead author on a paper that emerged from the YIP-funded research. Cedric Paul Ambulo and a team of authors — Ware included — penned the article "Four-Dimensional Printing of Liquid Crystal Elastomers" in the journal *ACS Applied Materials and Interfaces*.

"In this paper, we demonstrated the ability to fabricate shape-morphing 3D structures using liquid crystal elastomers," Ambulo said.

"Improved tissue adhesives are a critical missing component to reducing health care-related costs and improving quality of life."

Dr. Taylor Ware

"We employed the use of shear forces associated with direct write extrusion to program the liquid crystal molecules within the structure which influences shape-change."

Ambulo also won the Soft Matter poster prize at the International Liquid Crystal Elastomer Conference in Houston, Texas, in 2017.

Left to right: Ambulo, Ware and Patrick Ondrusek, a biomedical engineering junior, discuss a liquid crystal elastomer polymerization reaction.

"We are working hard in our research lab," Ware said. "This support from both the NSF and Air Force has allowed us to investigate projects that, if successful, will develop a fundamental understanding on how to manipulate these materials for better performance in both health care and defense."

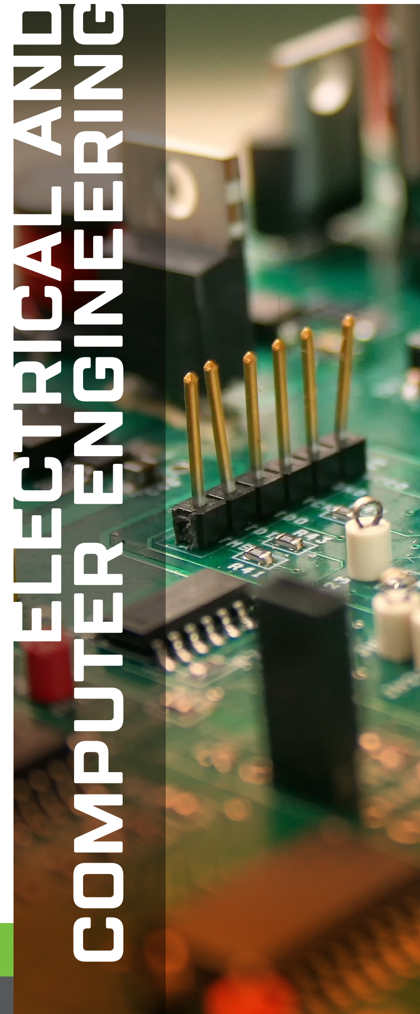
BIOENGINEERING

Within the Department of Bioengineering at UT Dallas, research is focused in six areas: bioimaging; biomaterials; biomechanics; biosensors and bioelectronics; neural engineering; and systems biology. Faculty include 21 tenured and tenure-track faculty as well as nine senior lecturers. In 2017, bioengineering faculty published 94 peer-reviewed journal publications, and research expenditures exceeded $8.6 million. Student enrollment has grown to more than 600 undergraduates and 130 graduate students. The department features both research and graduate education collaborations with members of UT Southwestern Medical Center.

COMPUTER SCIENCE

With 2,800 undergraduate, 1,000 master's and 180 PhD students, as well as more than 90 faculty members, the Department of Computer Science is home to leading programs in computer science and software engineering in the United States. The department is internationally recognized for its research contribution with nearly $7.6 million in research expenditures in 2017 and nearly $10 million in new grants each year during the past three years. Faculty and PhD students publish their research in major journals and present at key conferences. The department features a range of student organizations, and the UTDesign® program provides a unique opportunity for students to undertake industry-sponsored capstone projects.

ELECTRICAL AND COMPUTER ENGINEERING



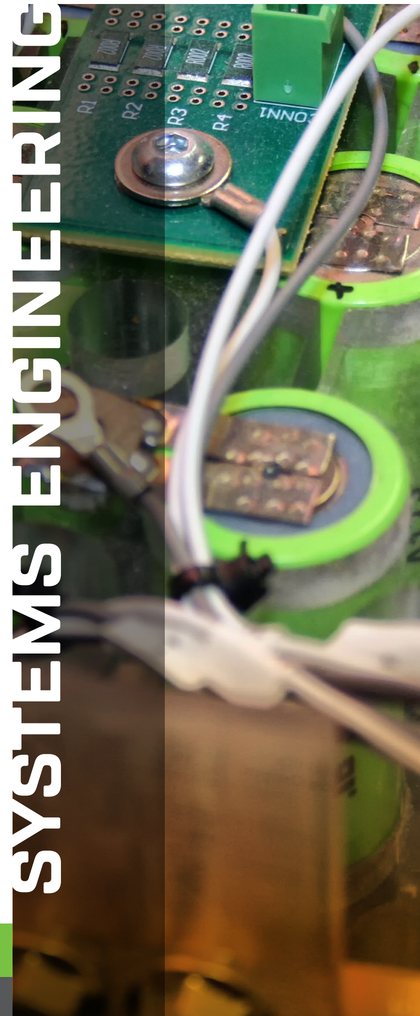
The Department of Electrical and Computer Engineering (ECE) prepares students for exciting careers in industry, academia, government and the military. The Jonsson School is located within the North Texas Telecom Corridor, home of the second-largest tech economy in the U.S. The School's robust internship programs place more than 1,200 undergraduate and graduate students annually, and the ECE department serves approximately 1,800 undergraduate and graduate students. ECE makes significant research contributions due to its expert faculty (including a member of the National Academy of Engineering and 16 IEEE Fellows) and its world-renowned research centers including the Texas Analog Center of Excellence and the Center for Robust Speech Systems.

MATERIALS SCIENCE AND ENGINEERING

The Department of Materials Science and Engineering at the Jonsson School mentors students in the research of advanced materials, including metals, semiconductors, composites, polymers, nanomaterials and biomaterials. Materials science is an interdisciplinary field that develops innovative applications of new materials in all areas of science. Most core faculty members are fellows in professional societies, and the department averages $6 million in annual research expenditures. Students apply their knowledge and analytical skills to create effective and novel solutions to practical problems using state-of-the-art instruments and cleanroom facilities.

MECHANICAL ENGINEERING

Mechanical engineering is consistently one of the top choices for undergraduate and graduate students at UT Dallas. In 10 years, enrollment in the department has now grown to more than 1,200 students. Core disciplines are dynamic systems and control; manufacturing and design innovation; mechanics and materials; and thermal and fluid sciences. Research is focused on problems of global significance in energy, robotics and nano/bio technologies. Led by faculty members with industry experience, teams of mechanical engineering undergraduates have won the top spot for the fourth consecutive time in the ASME (American Society of Mechanical Engineers') Manufacturing Science and Engineering Conference.



SYSTEMS ENGINEERING

Systems engineering is an interdisciplinary field that focuses on the design, modeling and control of complex systems. Faculty conduct world-class research in several areas: high-precision mechatronic systems; modeling and control of microcantilever-based devices and atomically precise manufacturing systems; energy storage systems, including algorithm development for state of health prediction; robotic systems, including nonlinear control of robots, teleoperators and multi-agent networks; network systems and control, including attack detection and mitigation; and data-driven optimal control methods for applications in neuroscience. The department's master's degree program includes courses at both the Jonsson School and the Naveen Jindal School of Management at UT Dallas.

UT DALLAS

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The Engineering and Computer Science West building will be dedicated soon. The $110 million, 200,000-square-foot facility houses about 50 faculty members, their research labs and students. Meeting spaces of varying sizes are designed for promoting collaboration, active research and project-based experimentation. Building walls are made of glass — turning even elevator, piping and heating systems into educational opportunities.