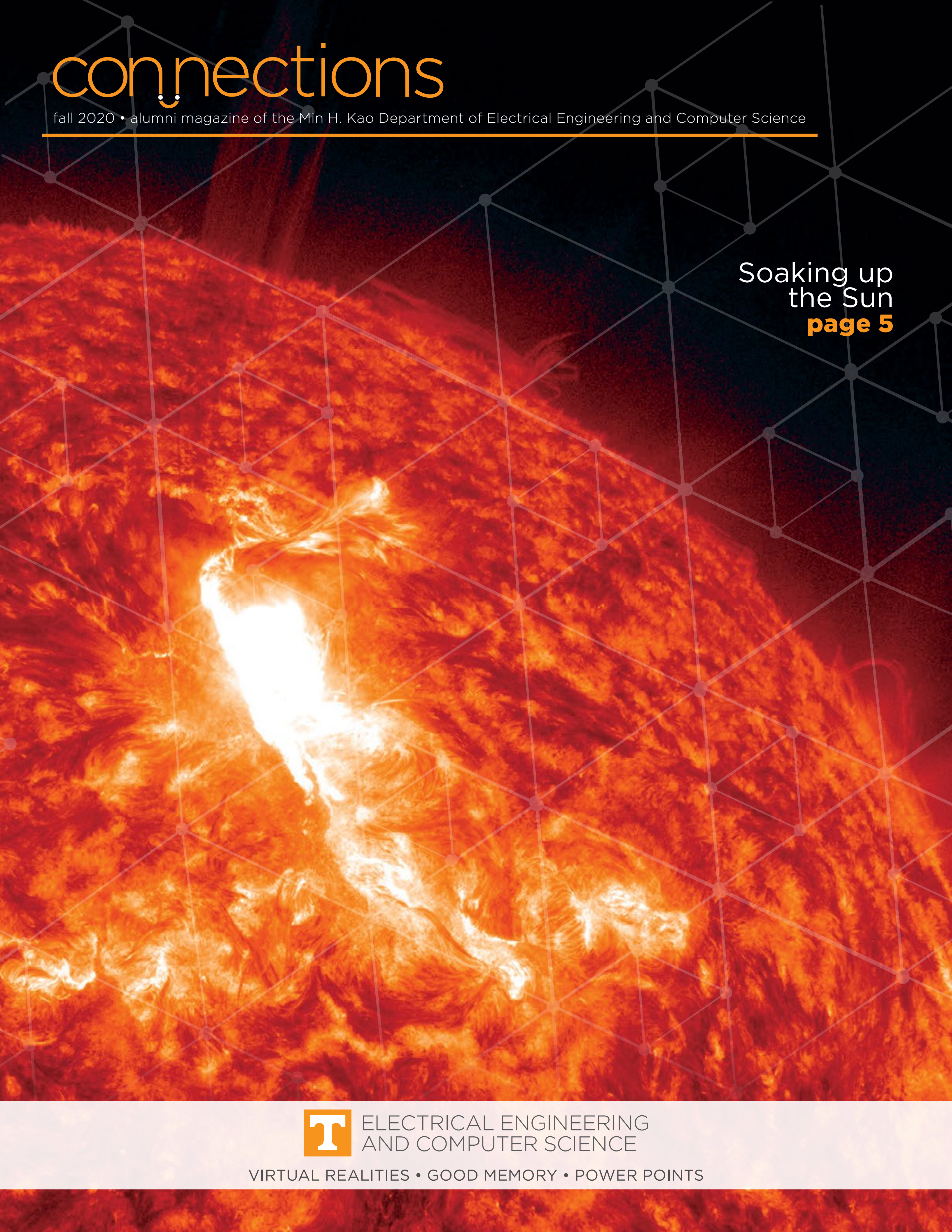
connections

fall 2020 • alumni magazine of the Min H. Kao Department of Electrical Engineering and Computer Science



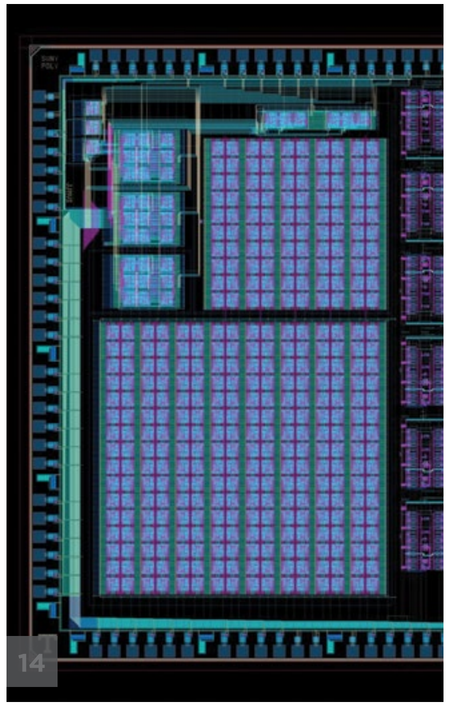
Soaking up the Sun

page 5

ELECTRICAL ENGINEERING
AND COMPUTER SCIENCE

VIRTUAL REALITIES • GOOD MEMORY • POWER POINTS

Table of **Contents**



DEPARTMENTS

On the Cover: Photo of sun during solar flare eruption on January 22, 2012. Photo courtersy of NASA's Goddard Space Flight Center.

Connections is published annually by the Min H. Kao Department of Electrical Engineering and Computer Science at the University of Tennessee, Knoxville. **eecs.utk.edu**

Department Head
Gregory Peterson

Director of Communications
Christie Kennedy

Project Manager
Melissa Callahan

Designer
Andy Gallaher

Writers
Kevin Bogle
David Goddard
Laura Tenpenny

Photography
Randall Brown
Shawn Poynter
Jessica Tezak

Printer
University Printing and Mail

From the **Department Head**

Greetings from the Min H. Kao Department of Electrical Engineering and Computer Science. The past year has been unique and challenging in so many ways, with exciting new developments for the department against a backdrop of events including an election season, social justice awareness, and a pandemic that has transformed our daily existence. This magazine addresses a few of the myriad activities and events from the past year; we hope you find it informative, entertaining, and inspiring.

Our department boasts an outstanding group of faculty members who are exploring and inventing the technologies of the future, teaching the next generation of students, and volunteering to lead on campus, in professional groups, and to benefit society. We include stories about some our faculty's fascinating work ranging from novel applications of microwave signals (pg.2), the impact of new memory technologies and structures on next-generation computing systems (pg. 10), library development targeting the world's largest and fastest supercomputers (pg.7), applying semiconductor technologies to build scalable electronic (neuromorphic) "brain" systems (pg.14), and societal and technical issues related to the power grid (pg.12).

The reason we exist as a university, our raison d'etre, is to educate the students who will invent and lead our future economy and society. Our student body boasts outstanding individuals seeking to fulfill this promise. We include stories about the experience of one undergraduate student graduating during the pandemic (pg.20) and another learning hands-on via the co-op program (pg.18). Given the prevalence of social media, one of our graduate students explores the evolution of emojis and their use (pg.15). A perennial challenge for our students comes with balancing athletics and academics, and we share the inspiring story of EECS graduating a professional athlete and computer scientist (pg.22).

The technologies built upon electrical engineering, computer engineering, and computer science are foundational to our modern life and promise to further transform our lives. The disruptions from the COVID-19 pandemic have necessitated wholesale changes to many aspects of how we work, interact, play, and relax, in large part using the tools built by our field. Our community faced these challenges this year and we share some stories about how faculty and students have adapted to continue meeting our goals (pg.8). Despite the difficulties of 2020, the impact of our faculty, students, and alumni shines as a beacon of hope and opportunity.

Looking ahead, we will strive to maintain the Volunteer spirit of excellence in education, research, and service. We thank you for your continued support and encouragement!

Sincerely,

Greg Peterson
Professor and Department Head,
Min H. Kao Department of Electrical Engineering and Computer Science

Vital Technology

By Kevin Bogle. Photography by Jessica Tezak.

Despite many advances in technology, the only reliable way to monitor the vital signs of a particular person is through physical contact. There are many scenarios—like during the COVID-19 pandemic or in tense military operations—where it would be advantageous to review such data remotely. Thanks to a team from EECS, that dream has now become reality.

"We started by thinking about saving lives by remotely detecting vital signs of buried bodies after earthquakes under debris, moving to within few meters, and up to 50 meters for non-contact measurement," said Professor Aly Fathy, who, along with Associate Dean for Academic and Student Affairs Ozlem Kilic, serves as faculty lead on the project. "Now, we are moving to monitoring people's vital signs in jail to prevent suicides, for example, or monitoring patients with infectious disease like in situations similar to the current coronavirus epidemic."

The system, known as VitalWave, uses optics and microwave radar-based technology to monitor things like heart rate, blood pressure, temperature, respiration, and even oxygen levels.

Fathy noted that microwave technology is important to the breakthrough, as it allows users to detect subjects behind walls, such as in a combat situation, or under debris during a search-and-rescue mission following a catastrophe.

The project has been sponsored by the Defense Advanced Research Projects Agency (DARPA), as well as the US Army and US Air Force.

The Department of Defense recently added its support through the Joint Warfighter Medical Research program, awarding $300,000 to UT for its role on the team. MaXentric Inc. also received funding for its work on the program.

"We at UT are leading the basic research, developing the new ideas, and implementing the prototypes for VitalWave, said Fathy. "MaXentric then takes it to the next level, including validation, user-friendly interfaces, contacts with the Department of Defense, and building engineering models."

Over the course of the three-year project, the team will work to miniaturize the radar and speed up the software. The latter will include machine learning to improve the accuracy of remotely measured vital signs.

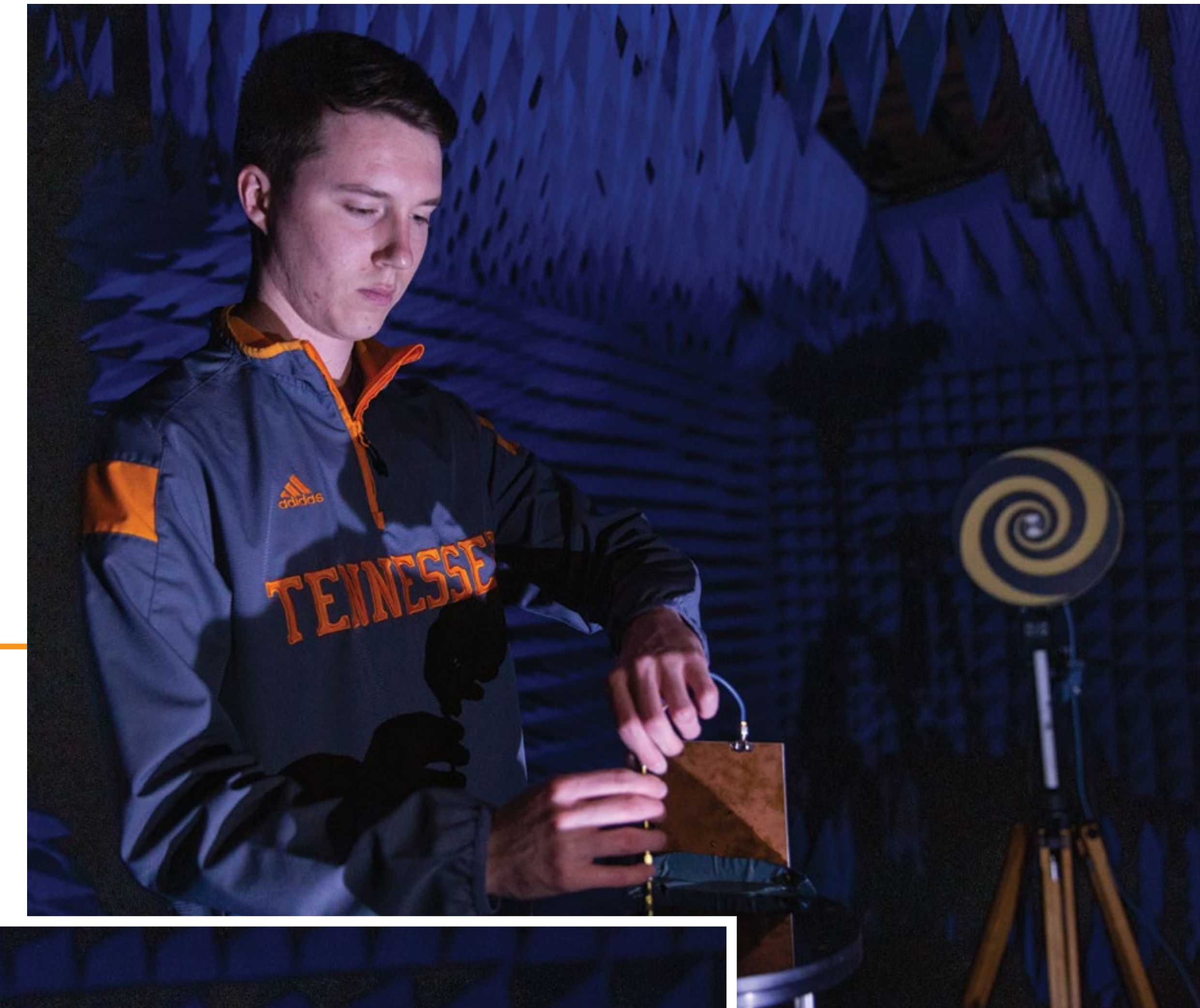
In the final year of the project, the team will demo the enhanced prototype and validate results, and then MaXentric will start the approval process with the US Food and Drug Administration.

In developing VitalWave, Fathy and the team have discovered other, less obvious ways the system could benefit society.

"Hospitals could use it to monitor sleep apnea in new born babies, giving instant warning if something is wrong, and that's just one of many potential medical implications," said Fathy. "It could also be used to provide gait analysis in real time, which will have great impact on those rehabilitating and learning to walk again as well as athletes who are looking to improve their performance."

And, in the long run, improve safety and security along the way.

> "We are moving to monitoring people's vital signs in jail to prevent suicides, for example, or monitoring patients with infectious disease like in situations similar to the current coronavirus epidemic."
> **—Aly Fathy**



An Echoless Chamber

Much of the research work that Fathy and Kilic do—including being leading researchers on the cutting-edge of 5G, or 5th generation technology—requires them to be able to take accurate measurements free from any outside electronic signals or interference.

Deep within the heart of the Min H. Kao Electrical Engineering and Computer Science Building lies a room, technically known as an anechoic chamber, or a chamber without echoes.

Inside the chamber is another, smaller room where faculty and students test sensitive equipment without disruption.

The room is lined with specialized foam building blocks—hundreds of individual "pyramids" that point in from all sides—that help absorb signals and prevent them from bouncing around inside the room.

In such an environment, researchers can set up transmission and monitoring devices to test various attributes of electronic signals, confident that their machines are picking up only those signals that the team itself is creating. This setup allows them to fully explore the properties of new devices and transmission methods, adjusting to process to be as accurate as possible.

Soaring Up The Sun

By Kevin Bogle.

As more solar power is being generated and used than ever before, managing its growth, and the policies governing its use, requires a better understanding of the factors driving that growth.

Now, an interdisciplinary team from UT is researching the residential adoption and use of solar panels at the intersection of socio-economics, politics, science, and engineering.

"This project is designed to investigate the characteristics of American residents who have installed solar panels on their homes and why they did so," said co-PI Chien-fei Chen, research associate professor of electrical engineering and computer science in CURENT.. "This could be enormously useful for managing the evolving US power grid and understanding barriers to greater use of renewable resources." Using satellite data from DeepSolar—provided by Stanford University—the team identified the number of solar installations per household and total area of installations across service areas of the Tennessee Valley Authority (TVA). An initial analysis by the team showed that low-income assistance programs contribute to residential solar adoption in all areas, especially in cities, and higher electricity prices in general are more closely associated with higher adoption rates, especially in rural and suburban areas.

An additional early finding revealed demographic factors such as income, education, and age to be important factors, but incentives programs aimed at homeowners, the physical suitability of climate and home (suitable rooftop) in the area, and the potential financial savings also play a strong role.

"The use of satellite data has been critical for identifying several hot spots of solar adoption that previous studies likely overlooked, said Professor of Industrial and Systems Engineering Xueping Li. "For instance, instead of focusing on counties with high levels of solar adoption, we are identifying the communities within those counties that are hot spots."

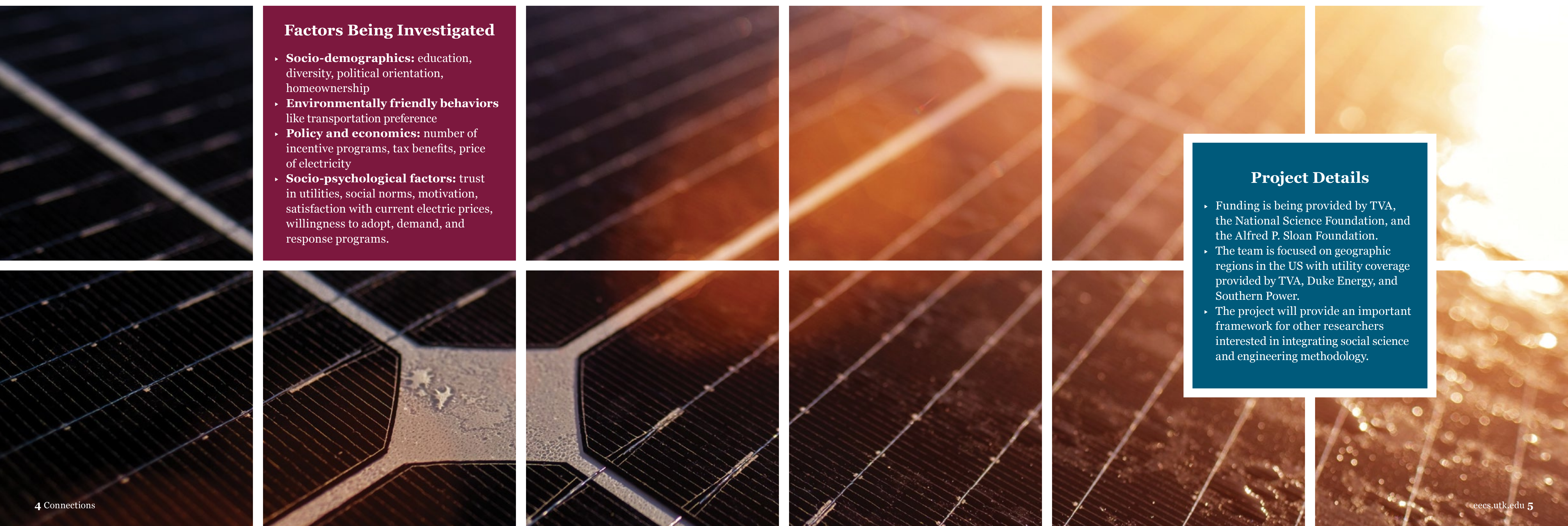
"Interestingly, census tracts with a higher level of racial diversity tend to have higher adoption rates, especially in rural areas," added Chen.

With these initial findings, the team then expanded their analysis to include all counties in the US and performed regionally specific spatial analysis using maps from the platform ArcGIS. They used a machine learning approach called Random Forest to help sift through thousands of possible drivers of solar adoption.

"There are a large number of diverse factors that are correlated with residential solar adoption, and these factors differ by geographic region and community characteristics," said computer science master's student Gerald Jones.

"Random Forest allowed us to let the data guide us to the factors that were most important in a particular area. The data set contains over 300 variables and the analysis allowed for a ranking of each variable's predictive importance which helped in selecting a set of variables to start with."

After refining the model, they compared the results to a statistical and sociological approach to explain the "whys" of solar adoption.



Factors Being Investigated

- **Socio-demographics:** education, diversity, political orientation, homeownership
- **Environmentally friendly behaviors** like transportation preference
- **Policy and economics:** number of incentive programs, tax benefits, price of electricity
- **Socio-psychological factors:** trust in utilities, social norms, motivation, satisfaction with current electric prices, willingness to adopt, demand, and response programs.

Project Details

- Funding is being provided by TVA, the National Science Foundation, and the Alfred P. Sloan Foundation.
- The team is focused on geographic regions in the US with utility coverage provided by TVA, Duke Energy, and Southern Power.
- The project will provide an important framework for other researchers interested in integrating social science and engineering methodology.

"Results of the regression models indicated that solar adoption is more common in suburban areas," said Chen.

Last December, the team surveyed 2,300 Tennessee residents serviced by TVA, asking whether they had any previous experiences with rooftop solar and identifying variables related to adoption (financial, environmental, physical, or a lack of considering the option), based on the discrete choice experiment in the survey. Trust in the utility, data privacy concerns, satisfaction with the price of electricity, and interest in other energy-saving programs were also measured.

"Households earning over $150,000 are around three times more likely to purchase rooftop solar as those earning between $50,000 to $75,000 after controlling for age, gender, and home ownership status," said Associate Professor of Economics and co-PI Scott Holladay. "These results illustrate distributional issues around rooftop solar where high-income households are more likely to take advantage of the benefits of rooftop solar."

> "Our ultimate goal is to determine how to efficiently and equitably integrate residential solar generation onto the electric grid."
> —**Charles Sims**

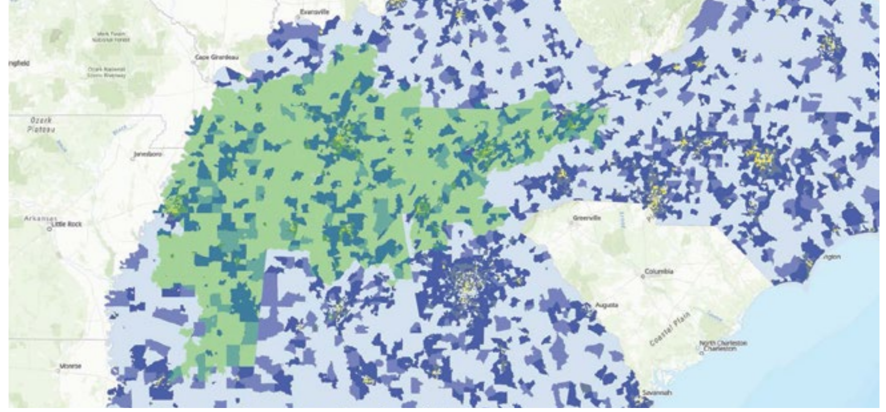
The team also used respondents' locations to estimate which parts of the grid are most likely to see increases in rooftop solar. One finding showed residents in Tupelo, Mississippi, for example, are around four percent more likely to purchase a system than those in Bowling Green, Kentucky, while holding system characteristics constant.

"It was interesting because few studies have looked at how the utility-customer relationship that was built elsewhere outside the solar projects could impact residents' intention to adopt rooftop solar," said post-doctoral researcher with CURENT, Xiaojing Xu.

Finally, participants were asked to choose from different combinations of financial savings and carbon-emission reductions. This information will be used to develop a decision-making curve from which the researchers could estimate the public's overall probability of adopting rooftop solar systems in given conditions.

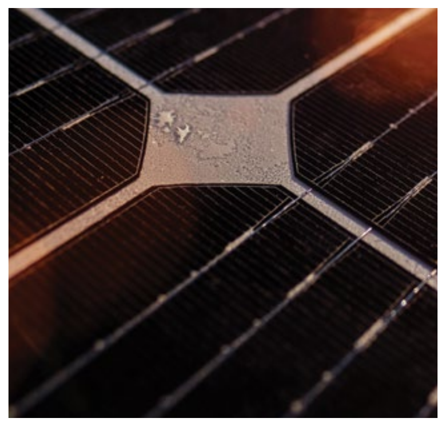
In the project's final phase, the team will combine the results of DeepSolar and the TVA survey to understand the dynamic interplay between customer incentives to invest in solar generation systems and utility incentives to invest in new resource and transmission assets.

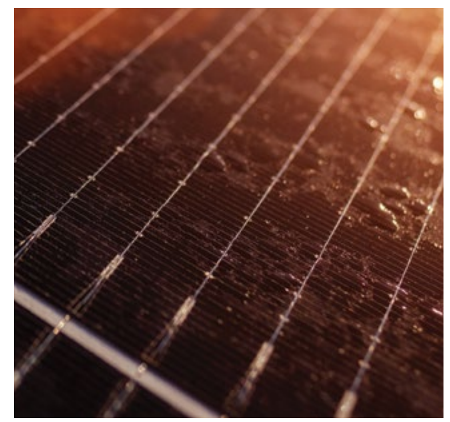
"Our ultimate goal is to determine how to efficiently and equitably integrate residential solar generation onto the electric grid," said Associate Professor of Economics Charles Sims, the project's PI. "Achieving these goals requires a clear understanding of what drives customers to adopt solar, and this project has moved us closer to this goal. The next step is to determine how utilities should respond to and adapt to the spread of this new emerging technology."

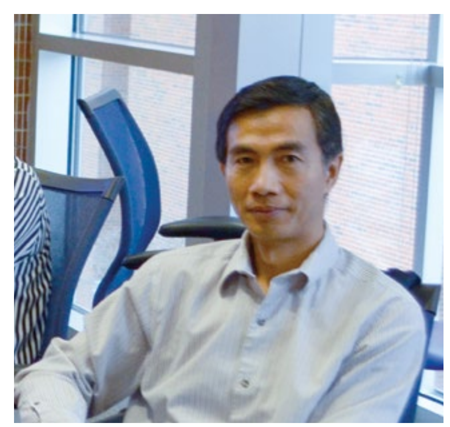


Residential Rooftop Solar Panel Area by Total Area

- Tennessee Valley Authority
- None
- Low (<= 50th Percentile)
- Medium (50th–75th Percentile)
- Medium (75th–95th Percentile)
- High (>95th Percentile)







Team members, clockwise from top left, Xiaojing Xu, Chien Fei-Chen, Xueping Li, Gerald Jones, Jr., and Charles Sims.

Full Speed **Ahead**

By David Goddard. Photograhy by Shawn Poynter.

Advancements in computing occur at a breakneck pace, with systems that once held the spot as world's fastest falling down the list just a few years later.

A major goal in the field of supercomputing is achieving exascale computing, which means a level of performance where the machine is conducting one quintillion operations per second.

Japan's Fugaku system recently ranked first in the world's annual Top500 list of fastest computers with a speed of 415.5 petaflops per second, almost three times faster than Oak Ridge National Laboratory's (ORNL) Summit, which was knocked from the top spot. Despite its speed, Fugaku is still not even halfway toward exascale.

One of the ways computer scientists hope to achieve such speeds is through the use of computational libraries, which group and share critical aspects of high-performance computing, allowing for ever-increasing processing speeds.

"Developing powerful new libraries will enable us to push back against current boundaries by the way we utilize and share the most optimal algorithms," said Distinguished Professor Jack Dongarra, director of the Innovative Computing Laboratory in the Min H. Kao Department of Electrical Engineering and Computer Science. "Like a lot of things related to computing, it's an ongoing process that builds upon itself, improving as we go."

Dongarra, who is also Distinguished Staff at ORNL and a Turing Fellow at the University of Manchester in England, is a key player in those efforts through his leadership of a major research thrust aimed at tackling the issue, known as Computational Libraries Optimized Via Exascale Research, or CLOVER.

CLOVER relates to several areas identified as mission critical by DoE, ranging from national, economic, and energy security to health care, science, and Earth itself.

For its part, Dongarra's group recently received additional funding of $14.7 million and will likely receive a total of $26 million during the project's lifespan from 2016 through 2023.

"It's a big project, with many implications," said Dongarra. "We're about halfway through the project, and we expect that the hardware side will probably be around $1.8 billion by the time we're done, with the applications and software side, which is what we are working on here, also drawing about another $1.8 billion."

The work being done at UT, ORNL, Argonne National Laboratory, and Lawrence Berkeley National Laboratory is considered public, while the parts being handled by Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories are classified.

Dongarra said that about 800 people are working on the project, with 23 groups working on applications and software alone, adding that he's helping coordinate some of those efforts. The team has certain milestones that have to be met, so they are driven more by those than the overall final product.

"From our standpoint, we can just focus on providing the best software that we can," Dongarra said. "Having said that, all the groups are in constant contact to make sure we're all on the same page and that we meet the needs of those developing the applications."

And helping the country solve its own critical needs in the process.

Sponsored by the US Department of Energy, **CLOVER** is bringing to bear the following four current projects, each with their own approaches and goals, and merging them into a larger effort:

- **SLATE**, which aims to boost the architecture of computing through the improvement of accelerators and multi-core units;
- **PEEKS**, with a focus on tackling issues such as complex memory structures, data flow, and system hierarchies, particularly through a product called GINGKO;
- **HEFFT**, a new highly efficient version of Fast Fourier Transform (FFT)—which itself has described as "one of the top 10 algorithms of the 20th century"—that can be used in exascale computing is being developed;
- **Kokkos Kernels**, a type of library that is already available that can handle advanced mathematics involved with high-performance computing.

Virtual**Realities**

EECS faculty talk about the realities of virtual learning

By Kevin Bogle.

In early 2020, COVID-19 began to spread around the world and eventually grew to pandemic proportions. In late March, in-person classes at UT transitioned to being fully online, and faculty, staff, and administration had just a few weeks to prepare.

Now, the department is in the midst of a fall semester like no other before it. As a significant amount of educational instruction continues online, some of our professors talk here about their experiences with various forms of distance learning technologies over the years.

Professor Michael Langston (CompSci) recalled the days of teaching television college courses.

"My experience with distance learning began when I was on the faculty at Washington State University in the early 1980s," said Langston. "I sometimes taught my graduate classes interactively at the main campus in Pullman and at satellite campuses in Spokane, Vancouver, Everett, and the Tri-Cities. I could see and talk to students at each remote site. They could see and talk to me."

However, Langston took things a step further and actually visited his distance education students personally, too.

"At least once each semester, I would leave Pullman and visit each remote site and deliver a lecture to the other campuses from there. I really enjoyed the opportunity to interact closely with everyone in this fashion."

By the early 1990s, distance learning over the internet was being utilized by what was then UT's Department of Computer Science.

"In the fall of 1993, a few of us in the department offered our core graduate courses as online synchronous courses that were taught in a studio room in the Circle Park building," said Professor Michael Berry (CompSci). "We lectured in that room while broadcasting to a satellite classroom in Oak Ridge for employees at ORNL and professionals in the Oak Ridge community."

With the COVID-19 pandemic unabated, the university's administration and faculty worked through the summer to plan and prepare for the possibility of more courses being taught online in the fall than ever before.

"As far as spring 2020 goes," Berry said, "part of the challenge was that faculty had to learn Zoom quickly and try to lecture synchronously or record lectures and use the class period for online office hours. The most immediate take-away lesson I had from the spring term that has shaped my approach for the fall has to do with having more empathy for students taking several online courses. The fatigue factor of having to stare at a screen for a large portion of the day is real and students were able to convey that to me in the spring. I have deliberately tried to keep my Zoom sessions to a maximum of 30 minutes, unless students have more questions, and I try to engage them with polls and clicker Q/questions to break up the monotony and gain feedback on their learning."

> "I'm teaching two classes in the fall, all online, and I'm working very hard to make the experience for the students non-boring and personal."
> **—James Plank**

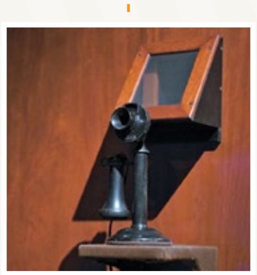
"I'm teaching two classes in the fall, all online, and I'm working very hard to make the experience for the students non-boring and personal," said Professor James Plank (CompSci), who said that distance learning will likely be woven into the fabric of the college experience from now on.

"I assume there will be a large learning curve," Plank said, "but I think that moving forward, all classes will have significant online components, so I have to adapt with the times."

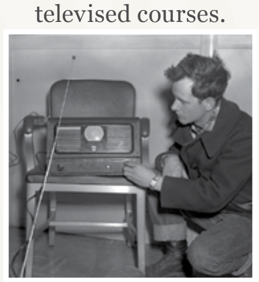
Telecommuting Timeline

Late 1800s: Adult correspondence education by mail became an accepted option for distance learning. Around the same time, the idea was first conceived of transmitting an image alongside audio over wire.

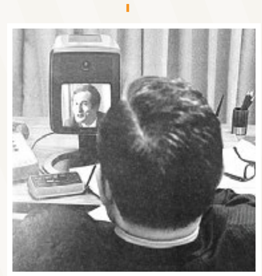
1919: WHA, the first federally licensed radio station dedicated to educational broadcasting, was started by University of Wisconsin professors.



1927: The first public demonstration of a one-way videophone.

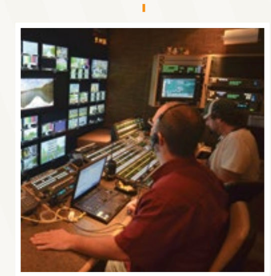


Mid-1930s: The University of Iowa was the first to experiment with televised courses.



1956: AT&T created a Picture-Phone prototype and made the first-ever video call.

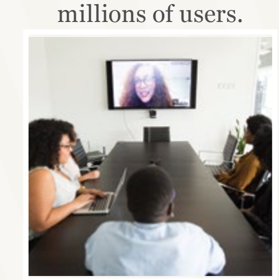
1964: Bell Systems introduced the Picturephone at the World's Fair in New York.



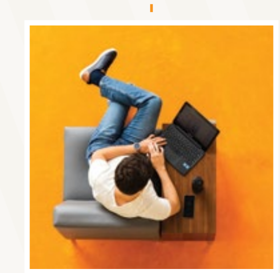
Early 1980s: Some universities began to offer remote classes via television.

1982: Compression Labs introduced the first commercial group video conferencing system for corporate customers.

1994: Connectix introduced the QuickCam, now considered the first webcam. UT's Innovative Technologies Collaborative assisted instructors with developing online classes as early as 1999.



2006: Skype, the first real, peer-to-peer videoconferencing system, was introduced and quickly adopted by millions of users.



2008: The number of UT students taking courses online increased to 2,613, up from 514 in 2001.

2013 Version 1.0 of the Zoom videoconferencing platform was released. UT soon adopted Zoom as its online class platform.

GOOD MEMORY

By David Goddard. Photography by Randall Brown.

Early CAREER Award Winners

The Tickle College of Engineering is proud to feature one of three Early CAREER Award winners that have been announced in 2020. That makes 19 total for the college since 2016 and speaks highly of the creative research activity for our young faculty members. Discover all our Early CAREER Award winners from 2019-2020 at **tiny.utk.edu/ECA**.

The need for ever-faster computing continues to grow, helping those machines play an important role in simulation, modelling, and artificial intelligence in ways that touch almost all aspects of modern life.

Keeping up with those demands has also required finding new, more efficient ways of accessing memory and storing data. EECS Assistant Professor Michael Jantz understands those needs well. Jantz has devised a concept that could further fuel computing performance by better managing how data and memory are used.

He explained that conventional memory storage requires constant voltage, using the example of someone losing files or projects when the computer crashes or suddenly restarts. Such memory is called "volatile," as it can be lost if power is interrupted, but offers low response times and good overall performance.

On the other hand, disk-based storage is typically non-volatile. Files and other application data can be stored permanently on hard drives, but these technologies have the disadvantage of being much slower.

Jantz's solution proposes taking advantage of select parts of both by better understanding how applications and software interact with and use data in memory.

"New storage-class memory systems allow you to have persistent data, but can also be used like traditional memory," Jantz said. "Because they don't draw as much power, you can manufacture them with much larger capacities. A modern volatile memory unit might hold up to 32 gigabytes of storage, but the newer storage class memory units can store up to 512 gigabytes or more in the same physical area."

To get a better idea of what works best for individual applications, the team is studying how performance is affected when applications use different types of memory storage.

"We first have to understand what portions of an application's data should go where, in terms of memory use, before we can design a program to better control how memory is utilized," he said. "Someone doing data analytics might only want a small amount of very fast memory, whereas an application that uses large tables or creates a database might prefer a persistent storage medium with more capacity, even if it's not quite as fast."

He pointed out that the way that software interacts with memory and its underlying hardware technologies are largely unchanged since the 1970's, although, obviously, the demands placed on machines and the expectations of what they can do has increased greatly.

Jantz will make the project's results, data, and coding public both during the project itself and at least five years after it is set to conclude in 2025.

> "Data movement and storage are still major bottlenecks for many computing applications, and conventional memory technologies have already been scaled to their physical limits."
> —**Michael Jantz**

CAREER Award Winner
Michael Jantz

Power Points

Liu's Research into Grid Keeps Electricity Flowing

By David Goddard. Photography by Jack Parker.

Breakthroughs in Technology

Liu has also been a part of several technological advances along the way, several of those being related to improving or augmenting GPS as it relates to grid monitoring:

- **Pulsars as guides**
  GPS has largely been used as a tool for timing signals on power grids, but it can fail through either accidental or malicious acts. Liu helped develop technology that uses pulsars in space as the basis for timing instrumentation, providing a key part of grid security and monitoring from an unstoppable source;
- **A chip-level atomic clock**
  Frequency disturbance recorders are a key part of monitoring the grid's health, giving feedback whenever there is an anomaly in the system. Traditionally, GPS had been used as part of the mechanism, but Liu helped develop the world's first atomic clock at chip scale for commercial use, greatly improving accuracy and providing a reliable backup should GPS be unavailable;
- **Using eLoran as an alternative measurement**
  Liu has worked to demonstrate the feasibility of using eLoran as a timing mechanism, as its system of broadcast and transmission offers more security than some satellite timing and measurement systems.

Turning on the lights, microwaving a meal, or setting the DVR to record your favorite show is as simple as flipping switches or pressing a couple of buttons…assuming the power is flowing.

That's where Yilu Liu comes into the picture.

Liu is an internationally-recognized expert in several areas related to power grids, including their performance and security. She's also both the UT-ORNL Governor's Chair for Power Grids within the Min H. Kao Department of Electrical Engineering and Computer Science and deputy director of the Center for Ultra-wide-area Resilient Electric Energy Transmission Networks (CURENT), positions that have helped bolster her role as a key player in this important field, both locally and internationally.

"We've made some pretty big improvements, even in just the last few years," said Liu. "We've had a lot of success within our department, and when you add in critical partners like ORNL, who has funded numerous projects, and the 35- plus institutions involved with CURENT, we're really making critical advancements."

Technological innovation is a key tool in helping keep the grid flowing normally, and an area where Liu continues to excel. For more than a decade, technology that she developed known as FNET/Grideye has helped monitor the nation's power grid, best seen via CURENT's star attraction: a movie-theater-sized screen that shows the nation's grid in real time and can send alerts to the appropriate agency when a problem arises.

Liu herself has received two patents related to grid monitoring in the past year alone. The Synchrophasor Measurement Method for Power Systems uses samples from the grid that have been taken at GPS-synchronized moments, allowing for better control and monitoring, while the Mobile Universal Grid Analyzer allows researchers to use their cell phones to get a real-time look at the grid.

The FNET/Grideye system has been made even better by the implementation and use of Frequency Disturbance Recorders, or FDRs, that sample the grid more than five million times per hour, roughly 1,400 times per second, sending the data back FNET/Grideye.

The FDRs in use by the system only require ethernet access, GPS connectivity and a power supply, making them extremely portable and versatile, all of which helps keep the grid up and running.

The system can also be used to help researchers learn what happened in past power-related incidents. For example, the team was able to study a 2008 case where a power plant in Florida failed, and what that meant for connected stations throughout the US.

"Keeping the nation's power supply secure and working is a vital task, one that I take very seriously," Liu said. "Many people might view storms and their related outages as the main threat, but the reality is that there are a lot of important operation considerations to be made and a number of things that could go wrong that need to be avoided."

Thanks to Liu, those problems could be a thing of the past.

> "Keeping the nation's power supply secure and working is a vital task, one that I take very seriously."
> **—Yilu Liu**

MindGames

By Kevin Bogle.

For decades, many scientists and engineers have dreamed of and worked toward the realization of computers that think, even robots that can move and interact with the world, all on their own. There is no doubt that artificial intelligence captures the imagination, but many aspects of brain-inspired computing have been primarily the subject of science fiction.

For instance, real-time learning, adaptability in an unpredictable environment, and reactive control remain as challenges for brain-inspired computers. At the same time, machine learning has shown a great deal of success in feature classification and related applications.

Led by Associate Professor Garrett Rose, Professor James Plank, and ORNL researcher Catherine Schuman (PhD/CompSci, '15), the Tennesseans Exploring Neural Networks Lab (TENNLab) has been developing new computer architectures and approaches that build on the success of machine learning while providing a platform for real-time learning and control applications.

"Robot-control systems are a great example application of the architectures explored by our TENNLab team," said Rose. "In recent years, our team has demonstrated several small robots controlled by neuromorphic systems, which are brain-inspired computer designs that reside entirely on the robot itself, a big step toward autonomy."

Such systems require little power to operate relative to their large machine learning counterparts and can perform tasks such as object avoidance without guidance from humans.

A recent small robot, the Ground Roaming Autonomous Neuromorphic Targeter (GRANT), can sometimes be seen roaming the halls of the Min H. Kao Building, demonstrating autonomous object avoidance and targeting.

GRANT is controlled using a recent iteration of a computer architecture dubbed the Dynamic Adaptive Neural Network Array (DANNA), pioneered by Professor Emeritus Mark Dean. DANNA is an example of what Rose and his students now refer to as a reconfigurable neuromorphic array (RNA)-based system.

"Being reconfigurable means that it allows for the implementation of any neuromorphic application in the form of a spiking neural network that can be mapped to the resulting hardware," said Rose. "Further, RNA style systems are adaptable in that they are built with hardware that enables the neural network to learn on-the-fly, adapting to and learning from real-world stimuli in real-time."

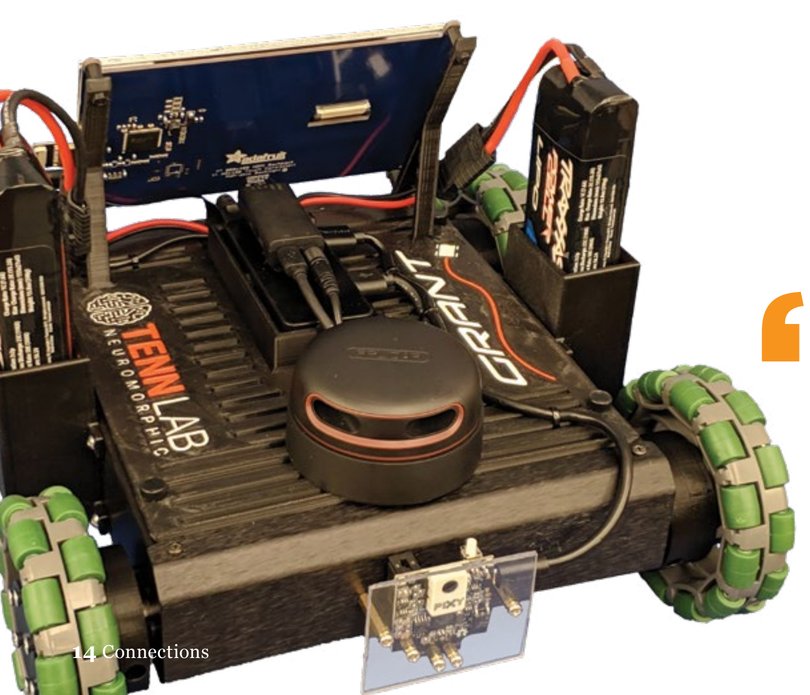
Spiking neural networks are a key element in the team's work, because they are designed in such a way that neurons only activate when certain criteria are met, in much the same way that neuron's in a person's brain activate for specific tasks, thoughts, or reactions.

The TENNLab team has received funding from the Air Force Research Laboratory (AFRL) and other agencies to explore the important role of nanoelectronics in the realization of brain-inspired or neuromorphic computer architectures. This work has led to an experimental RNA-style architecture known as Memristive DANNA (mrDANNA), which leverages nanoelectronic devices known as memristors in the realization of dense artificial synapses.

Memristors are resistors that "remember" and are known for their ability to change resistance with use, literally adapting or learning in a way similar to what has been observed for biological synapses. Being nanoscale devices, they are key to providing significant device density and low power operation, critical components for neuromorphic computing.

The many performance benefits of memristor-based neuromorphic systems have been demonstrated by many research groups, TENNLab included, through detailed modeling and simulation. Working with collaborators from the SUNY Polytechnic Institute in Albany, New York, Rose and his group have also been able to move beyond simulation and fabricate working mrDANNA integrated circuits that the team continues to test in the laboratory.

Through this work, the TENNLab team is moving ever closer to nanoelectronic enabled neuromorphic computers that could one day "think" all on their own.



> "In recent years, our team has demonstrated several small robots controlled by neuromorphic systems, which are brain-inspired computer designs that reside entirely on the robot itself, a big step toward autonomy."
>
> **—Garrett Rose**

Why Isn't There a *Sarcasm* Emoji?

By Scott McNutt.

Have you been longing for a specific emoji, say a sarcastic smile, but don't know how to get it? Have you been curious why some emojis are available and others aren't? Do you wonder how emojis become officially sanctioned and distributed in the first place?

Many Twitter users are asking such questions. It makes sense since emoji use is growing rapidly as our means of communication increasingly go digital. In fact, by 2018, more than 2,700 emojis had been added into the Unicode Standard, the single, universal character standard for all digital text, which is maintained by the Unicode Consortium. Every year, the consortium accepts "new emoji" proposals and approves a very limited number (usually less than 250) of them that demonstrate proof of demand, usually from search engine statistics, Google Trends, Wikipedia, and more.

Recently, a team of researchers, including analysts from the Haslam College of Business and the Tickle College of Engineering, published an article determining which emojis the public is looking for on social media.

The authors culled more than 30 million tweets mentioning the word "emoji" from a one-year period to distill requests for specific emojis. The team examined timing, locations, and context of new emoji requests and did a sentiment analysis to determine the strength of desire for various new emojis among the Twitter users who want them.

This work resulted in an algorithm that maintains a list of Twitter users' new emoji requests. With the team's online Real-Time Requested Emoji Tracking System, one can view Twitter users' emoji demand by month, week, or day, or by a selected time period, unique number of requests, or frequency of requests.

Yunhe Feng, co-author of the study and a PhD student in computer science, says not all demand for new emojis can be fulfilled quickly due to technical constraints and thus proposals need to be approved by balancing several factors. This tracker will give both petitioners and the Unicode Consortium a clear picture of new emoji demand on social media when requesting and approving a new emoji.

"Analyzing new emoji requests on social media is a way to crowdsource ideas. The real-time, interactive nature allows people from the Unicode Consortium to see what the demand is by just looking at the scores we developed in our ranking system," Feng said.

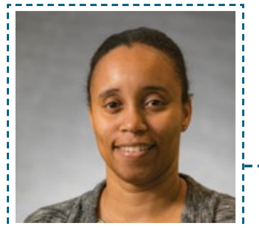
While the consortium has been responsive to popular demand for emojis over time, the research team's work shows it is possible that some emojis might be helpful to meet an urgent need or fulfill a good cause. COVID-19 could be an example of a suddenly needed emoji; Feng notes that it has appeared in their rankings.

Co-author Wenjun Zhou, associate professor of business analytics and statistics, cites two examples of emojis added to the Unicode Standard in part due to their contributions to social good: the hijab emoji, which helps promote inclusivity for the 550 million Muslim women on the planet, and a mosquito emoji, which allows medical professionals to better explain mosquito-borne illnesses like malaria, Zika, dengue, and yellow fever.

"It's a matter of trying to prioritize," Zhou says. "If something is requested for a long time, frequently, and has strong social benefits, the consortium puts it at the top of the list."

With their website, anyone can see the emojis Twitter users are clamoring to use. At the time of publication, "sarcasm" was the most eagerly desired emoji, but by the numbers, "dignity" is currently in first place, with more than 10,650 requests.

FACULTY NOTES

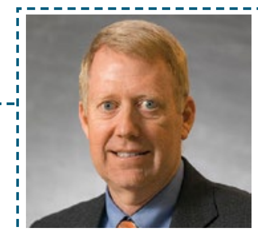


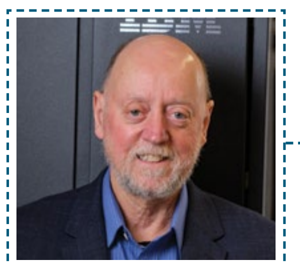
Nicole McFarlane was chosen as the first faculty member to hold the Tickle College of Engineering ADVANCE Professorship, which was created to allow faculty candidates to have personal interaction with someone during their application process to answer questions about the campus climate; leave policies and benefits; or issues surrounding inclusivity, religion, or family matters.

James W. McConnell Professor **Fran Li** was named the editor-in-chief of IEEE's *Open Access Journal of Power and Energy* (OAJPE) at the start of 2020. The journal focuses on the development, planning, design, construction, maintenance, installation, and operation of equipment, structures, materials, and power systems for the safe, sustainable, economic, and reliable conversion, generation, transmission, distribution, storage, and usage of electric energy, including its measurement and control.

Earlier this year, EECS Advisor **Joanna Rathbone** received the Innovative Advising Award from the Tennessee Academic Advising Association (TennACADA). Rathbone has been selected from among all the advisors at UT for this award, which highlights her involvement in our department academic advising program. The award is given to recognize advising efforts that document innovative and/or exemplary practices resulting in improvement of academic advising services.

Min K. Kao Professor **Leon Tolbert** was recently named among the 2020 class of Chancellor's Professors, one of the highest faculty honors bestowed by the university. Tolbert was also named winner of the 2020 SEC Faculty Achievement Award for UT. Faculty winners receive a $5,000 honorarium from the SEC and become their campus nominee for the SEC Professor of the Year Award. The holder of nine patents, Tolbert is an accomplished researcher and leader in the area of power electronics and electric machinery.





Distinguished Professor **Jack Dongarra** has been selected for the 2020 IEEE Computer Society Computer Pioneer Award for leadership in the area of high-performance mathematical software. The award is presented to outstanding individuals whose main contribution to the concepts and development of the computer field was made at least fifteen years earlier.

Faculty members across the college enjoyed well-earned promotions at the start of the 2020 fall semester: Tenured and promoted to full professor: **Garrett Rose**; tenured: **Audris Mockus**; tenured and promoted to associate professor: **Michael Jantz**.

Associate Dean **Ozlem Kilic** was one of two college faculty recently selected to participate in the IAspire Leadership Academy, part of the national Aspire Alliance. The academy aims to develop and train the next generation of underrepresented leaders in STEM higher education. Kilic looks to make an impact in providing students with an accessible, high-quality engineering education.

Five faculty members received One UT Collaboration and Innovation Grants this past May. The new program promotes UT's mission to educate, discover, and connect by supporting innovative ideas; creating collaborative opportunities; and advancing student success, research, and outreach and engagement. EECS recipients were Associate Dean **Ozlem Kilic** and Min H. Kao Professor **Leon Tolbert**.

Assistant Professor **Ahmedullah Aziz** has been selected for a 2019 EDAA Outstanding Dissertation Award by the European Design and Automation Association. His award is in the category of "New directions in logic, physical design, and CAD for analog/mixed-signal, nano-scale, and emerging technologies."

Professor **Mike Berry** was one of four college faculty members selected to join the inaugural cohort of UT's faculty fellows for technology-enhanced teaching. He will work through October 2020 in a mix of consultations, group sessions, and on the development of web-based and asynchronous resources.

New Faces

Assistant Professor Helen Cui

PhD in Electrical Engineering, Virginia Tech

Assistant Professor Helen Cui joined the department in January 2020. She received her PhD in electrical engineering from Virginia Tech in 2017. Following graduation, she was a postdoctoral fellow in the Department of Electrical and Computer Engineering at UCLA working on RF magnetics.

Cui's research interests span high-density magnetics design and optimization, multiphysics modeling, and magnetic material characterization. She was the recipient of the Best Presentation Award at the Applied Power Electronics Conference in 2013. She is an active member in IEEE Power Electronics Society and IEEE Women in Engineering.

"I feel humbled and grateful to be a member of CURENT at the EECS department of UT. This is the great place that many power electronics researchers have dreamed for," Cui said, "Being able to work with such amazing people makes this new journey full of possibilities."

Assistant Professor Doowon Kim

PhD in Computer Science, University of Maryland

Kim's research interests include computer security (data-driven security and usable security) and computer networks (Internet measurement). Particularly, he is interested in identifying the root causes of security threats by understanding actors (e.g., adversary and end-users) involved, with data-driven and human-centered perspectives (e.g., usability study). Kim was awarded the 5th Annual NSA Best Scientific Cybersecurity Paper (2017) and the Ann G. Wylie Dissertation Fellowship (2019). His works on the code-signing PKI have generated interest from media such as Ars Technica, the Register, Schneier on Security, and Threatpost.

"I am really thrilled to be joining such an amazing EECS team this fall," Kim said. "This department is vibrant and rapidly growing and has outstanding students, which led me to be drawn to UT."

Assistant Professor Alex Williams

PhD in Computer Science, University of Waterloo

Williams leads UT's Laboratory for Transformative Work where he introduces and evaluates new systems, algorithms, and techniques that seek to improve the modern workforce's productivity and well-being. His research is inherently interdisciplinary, often intersecting human-computer interaction, artificial intelligence, cognitive science, machine learning, and workplace studies. Before joining UT, Williams spent several months working as a postdoctoral researcher at the University of California. He has also worked in several additional teams across Microsoft Research, Mozilla Research, ORNL, and the University of Oxford—many of whom he continues to collaborate with today.

"I'm fortunate to complement the exceptional faculty at Tennessee's flagship institution with a new flavor of computing research," Williams said. "Further, I'm elated to have the opportunity to engage with UT's exceptional student body in the classroom, across departments, and within new research engagements. As a native Tennessean, I couldn't be more at home."

UT-ORNL Governor's Chair for Power Electronics **Yilu Liu** was awarded the 2020 IEEE Power & Energy Society Wanda Reder Pioneer in Power Award this past spring. The award was established to foster more diverse leadership by supporting career advancement, networking, and education of women in the electric power and energy industry. Liu was cited specifically for her innovative contributions and leadership in synchrophasor-based wide-area monitoring and control systems.

A paper featuring the work of Professor **Gong Gu** was selected by Chemical Science as "Pick of the Week." Chemical Science is the flagship journal for UK's Royal Society of Chemistry. Working with An-An Sun and Shang-Peng Gao of the Department of Materials Science at Fudan University in Shanghai, Gu's research is entitled "Peculiar bond characters of fivefold coordinated octet compound crystals."

A **Priceless** Opportunity

When I was given the offer to do a co-op for Bridgestone, a Japanese multinational tire manufacturer, my main concern was if this work would be worth delaying my education. After 14 months experiencing electrical engineering, and a real multidisciplinary workforce, I can confidently affirm that this was a priceless opportunity.

My co-op experience began in summer 2019 in McMinnville, Tennessee, in what is known as a "flagship" plant, always producing and innovating as fast as possible. The training was concise yet helpful enough to get me to work quickly. I started out with the senior electrical engineer in the powerhouse. There, I finished programming logic to replace and upgrade steam valve control devices and design a human-machine interface display for operator use. From then on, the work took me all over the plant with different engineers and interacting with all departments of the factory. Jobs covered everything from monitoring large power systems, writing manuals, HMI design, and changing AutoCAD Electrical Drawings for system modifications to ethernet or serial networking communication, programming machine upgrades, safety circuits, electrical panel installation, and lots of troubleshooting in the field.

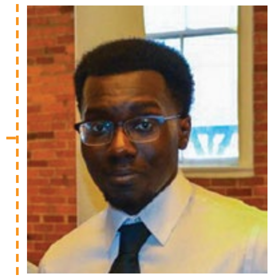
Only so much of the work could be done in the office. Half of my time was spent collaborating with production management, electricians, information technology, chemical, industrial, and mechanical engineers. Although, the most helpful information came from the maintenance and operator technicians for the machines. Talking with the people who keep the facility producing was invaluable and is necessary to engineer useful technology.

The major project that I served on was a complete overhaul of how the plant transported tires. A mechanical engineering co-op student and I were tasked with automating a step of the tire assembly machine process that previously needed operator manual labor. While they worked on the design, parts, and drawings, I worked on implementing the driving motors, sensors, and the drastic program changes needed to safely and efficiently get the modification operational. The engineer I was working for was a constant mentor through this project, but he left plenty of room for failure.

I am thankful for the opportunities this co-op has provided me with—the opportunities to fail and get back up to try again. I was taught how to tune out the pressure, remove assumptions, and problem-solve from the beginning through to the end. When that robot moves or that logic controller starts communicating, the sense of accomplishment enforces the reason I want to be an engineer. I do not doubt that this experience has laid the foundation for a strong work ethic and efficient habits. I started this co-op without even knowing what a controls engineer did and I end it as a more confident student and hopefully a promising engineer.

STUDENT NOTES

Graduate students **Yaw Mensah** and **Alec Yen** were among four TCE students selected for prestigious National Science Foundation Graduate Research Fellowship program awards. Each will receive a $34,000 annual stipend for three years, $12,000 toward tuition and fees at the graduate institution of their choosing, and increased chances to take part in international research



The 2020 Bodenheimer Fellowship recipients were **Daniel Burns**, **Ian Schomer**, and **Roy Tan**. The fellowships are awarded to superior EECS graduates from UT and can be valued at more than $43,000 per year. The award was established in honor of Robert E. Bodenheimer who taught ECE courses at UT for nearly forty years prior to his retirement.

Three EECS graduate students were recognized for Excellence in Graduate Research as part of the Graduate Student Senate's GSS Awards. Honorees included **Shaghayegh Aslanzadeh**, **Razieh Kaviani Baghbaderan**, and **Farshid Tamjid**. The award is presented to graduate and professional students who have received national and/or international recognition in their field and show promise in their area of research and/or creative achievement.

PhD student **Shahram Hatefi Hesari** was elected vice president of the UT Graduate Student Senate in April. In addition to being a research and teaching assistant in the department, Hesari has served as a teaching assistant at Tennessee Governor's School and mentored young scholars for CURENT. He will serve for the 2020-2021 school year.

Katelyn Bolinksy, **Gary Burns**, and **Alec Yen** were honored for Extraordinary Academic Achievement while **Sean Toll** joined Yen as being named a Top Collegiate Scholar.

Alec Yen was named Undergraduate Researcher of the Year, which honors excellence in undergraduate research through independent inquiry, classes, and student employment. Yen's current research investigates low-power circuits for monolithic integrated spectral analysis.

Several EECS students were among those recognized at the 2020 Chancellor's Honors virtual event. Twelve were honored with Extraordinary Professional Promise, given to students who demonstrate professional promise in teaching, research, or other contributions. Students included **Chandler Bauder**, **Xianda Deng**, **Yan Du**, **Wei Feng**, **Farnaz Foroughian**, **Handong Gui**, **Shahram Hesari**, **Chengcheng Li**, **Samaneh Morovati**, **Clara Nguyen**, **Kellen Oleksak**, and **Farshid Tamjid**.

Prosise Perspective

A Senior's Thoughts on Graduating Amid the COVID Crisis

The group of students includes Kendra Anderson (BS/EE, '19); Jeremiah "Jerry" Duncan (BS/CS,'19); Andrey Karnauch (BS/CS, '18; MS/CS, '20); Idan Kanter (BS/CE, '18); Ben Sergent (BS/CE, '20); Daniel Enciso Gonzalez (BS/CE, '18); and Abigail Prosise (BS/CS, '20).

By Laura Tenpenny.

Racing from field to study group, Abby Prosise arrived sweaty and grass-stained, but victorious. She and her co-ed team just won an intramural flag football championship.

"Absolutely nothing, not even homework, could ruin that night," Prosise recalled. "It was even sweeter that I got to win with my brother, who was a grad student at the time."

It's memories like this that she hoped to relive post-graduation with friends and family in a crowded living room.

For Prosise and fellow UT seniors, that moment is on hold and the living room is empty.

"I know it's the right thing to do, but it won't feel like I've really graduated until I've walked," Prosise said, discussing virtual commencement. "I lived in on-campus housing, so I had to move back home when the university closed due to COVID-19. I didn't have the chance to say goodbye to many of my friends. I feel like managing problems is the best anyone can do right now."

And Prosise believes the university is doing its best, given the circumstances.

"UT has put students first," she said. "I heard some public universities were not communicating with their students for weeks at a time, so I am thankful for the transparency from leadership."

Prosise also appreciated the pro-rated refund for campus housing, part of more than $30 million UT returned to students. She's also received regular support from faculty.

"My professors have been extraordinary," she said. "Within the first few days of going online, our senior design professor, Dave Icove, and his TAs laid out a clear plan for the rest of the semester. I can always rely on engineering to make sensible decisions."

Following graduation in May, Prosise, a computer science major, counted herself fortunate to have a job at Garmin awaiting her.

"I love their work and their work culture," she said. "They're well-rounded and that's no surprise with the variety of departments, including fitness. When my parents visited, my mom commented that the employees were the most 'fit nerds' she'd ever seen."

For outstanding academic merit, Prosise was named a Min H. Kao Electrical and Computer Engineering Scholar for the past three years. This honor got her a roundtrip ticket to visit Garmin, Kao's company.

"We toured headquarters and met Garmin-employed UT alumni, including Dr. Kao himself," she remembered. "I still can't believe it happened."

The following Engineering Expo, Abby made sure to stop at the Garmin booth for an interview. She was shortly rewarded with a summer internship that led to an offer of full-time employment upon graduating. She now works for the Aviation Displays team as a software engineer.

"Specifically, I'll work on modifying and developing the Garmin Display Unit, the screen pilots refer to while in the air," said Prosise.

A freshman class in coding set her on the path to Garmin and further solidified the foundation she would need to succeed.

"I fell in love with the logic of coding and chose to major in computer science," Prosise said. "Computer science focused on hardcore, traditional coding and because of that I feel completely prepared to work with the aviation hardware at Garmin."

Ready to stretch her wings, she also recognizes the priceless moments and friendships her degree made possible.

"Some of my favorite times were late nights studying in Min Kao with my classmates," said Prosise. "It was stressful at the time, but looking back, those people helped me through the hardest classes and became my best friends. It's an unbreakable bond."

coding like a pro
with Corey Vereen

By Laura Tenpenny.

When you hear recurring questions about your ability to start as defensive end for the Vols and also study computer science, doubt would seem natural...not so for Corey Vereen (BS/CS, '17).

Vereen became fascinated with engineering after repairing his home computer. Influence from his brother who also studied engineering encouraged that interest. Athletic programs from his native Florida and across the South courted Vereen, a celebrated high school football player.

"At UT, I sat down with an EECS professor and discussed the computer science program," said Vereen. "There was an interest in academic success that I didn't see elsewhere. With that academic support, UT's football history, crazy fans, and stadium, my choice was easy."

At his very first practice, Vereen's determination to do both football and computer science was questioned by another player.

"I said 'you don't know me, dude,'" recounted Vereen. "I was there to get my degree because it's what pays the bills when you can't play football anymore. I had that understanding going into it, and without my mom and dad, I wouldn't have had that mindset."

Of course, there was some validity to his fellow player's concern, despite Vereen's fervor.

"Doing football and engineering was the hardest time in my life," said Vereen. "There's nothing like having a CS 360 assignment due the same week you play Alabama. But thankfully, I don't think there's a professor or TA at UT that doesn't want students to succeed."

Professor Michael Berry was one such professor, whom Vereen looked to during his early years in computer science.

"We're very proud of Corey," Berry said. "He did well in a challenging program, and you would hardly have guessed that he maintained a starting position in a premier college football program. Corey's successful career in computing is due to determination and a passion for problem-solving that ranged from dissecting the spread offense on the field to designing robust web/mobile software for real-world applications."

After a couple years of professional play that included a stint with the Patriots and a couple injuries, Vereen chose to focus on his career in computer science and technology. He's a year into a job as a junior software developer with Onlife Health, which provides software for companies that allows employees to track their health, set goals, and better their everyday lives.

"People don't realize the toll playing takes, physically and also mentally with being away from family," said Vereen. "It came down to deciding what I really want. Ultimately, I want to be with family, especially my fiancée before we get married this fall. I also want to build a career in technology and one day start my own tech company."

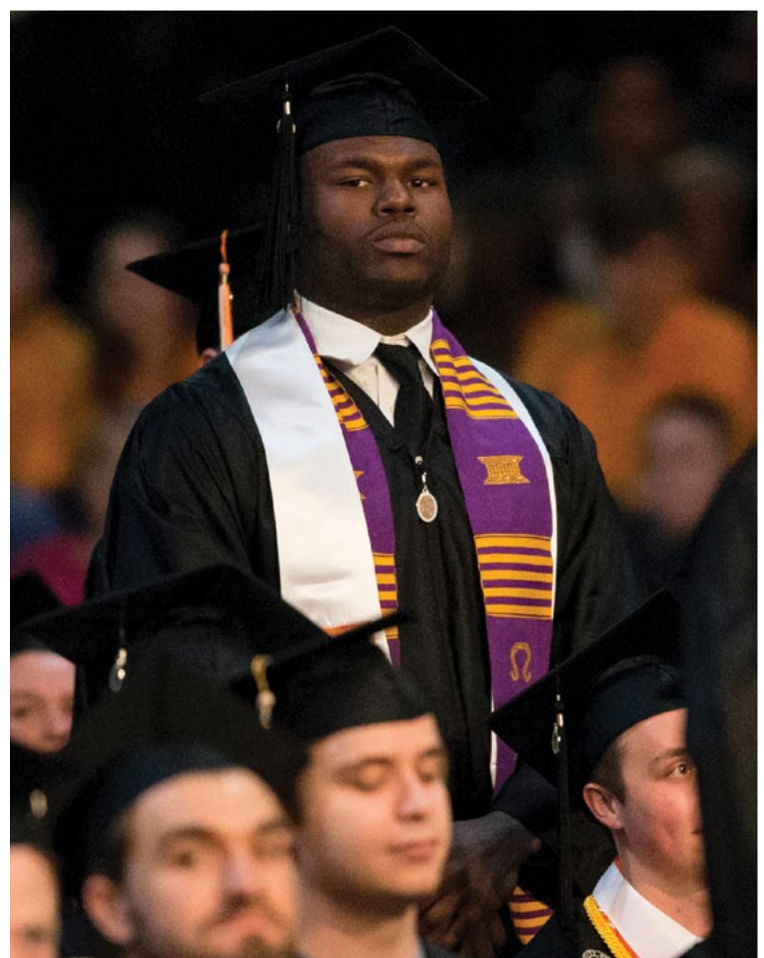
Vereen is gaining experience to do just that, thanks to his degree. Despite the doubters, Vereen walked across UT's commencement stage in 2017.

"It's hard to say which was better, graduating or beating Florida in Neyland," said Vereen with a smile.

With his drive, no doubt many sweeter victories await.

"At UT, I sat down with an EECS professor and discussed the computer science program. There was an interest in academic success that I didn't see elsewhere. With that academic support, UT's football history, crazy fans, and stadium, my choice was easy."

—Corey Vereen



"I am thankful for the opportunities this co-op has provided me with. I do not doubt that this experience has laid the foundation for a strong work ethic and efficient habits. I started this co-op without even knowing what a controls engineer did and I end it as a more confident student and hopefully a promising engineer."

—Issac Vaughn, Jr./EE

Your support helps improve educational experiences for students like Isaac within and beyond the classroom. We are Volunteers. Be Proud. Be Involved. Be Invested.

Call 865-974-8890 or visit **giving.utk.edu/eecs**.

Around the **Department**

1. Staff members Julia Elkins, Susan Cormia, Amanda Humphrey, and Kim Cox welcome new students to EECS during Welcome Week.
2. Systers: Women in EECS@UTK student organization members Lydia San George, Farnaz Foroughian, and Eva Hedayatipour participate in the Grace Hopper Celebration of Women in Computing in Orlando, Florida.
3. UL Professor of Practice David Icove and student members of the UT Amateur Radio Club.
4. UT-ORNL Governor's Chair Yilu Liu and CURENT faculty, research staff, and students were honored for issued patents, at the UT Research Foundation Awards.
5. EECS students strike a post for the selfie contest at the Min Kao Day celebration
6. Systers: Women in EECS@UTK student organization members host an Arduino workshop for fellow EECS students.

TICKLE COLLEGE OF ENGINEERING

MIN H. KAO DEPARTMENT OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE

401 Min H. Kao Building
1520 Middle Drive
Knoxville, Tennessee 37996-2250
Phone: 865-974-3461
Email: eecs-info@utk.edu
Web: eecs.utk.edu

eecs.utk eecs_utk eecs_utk

 A project of the Min H. Kao Department of Electrical Engineering and Computer Science with assistance from the Tickle College of Engineering Office of Communications. PAN E01-1340-001-21. Job 442792.

big orange. big ideas.