impact REPORT

2020-2021

The *Future* Is What We Do.

IOWA STATE UNIVERSITY

Department of Electrical and Computer Engineering

Greetings from Coover Hall in Ames, Iowa!

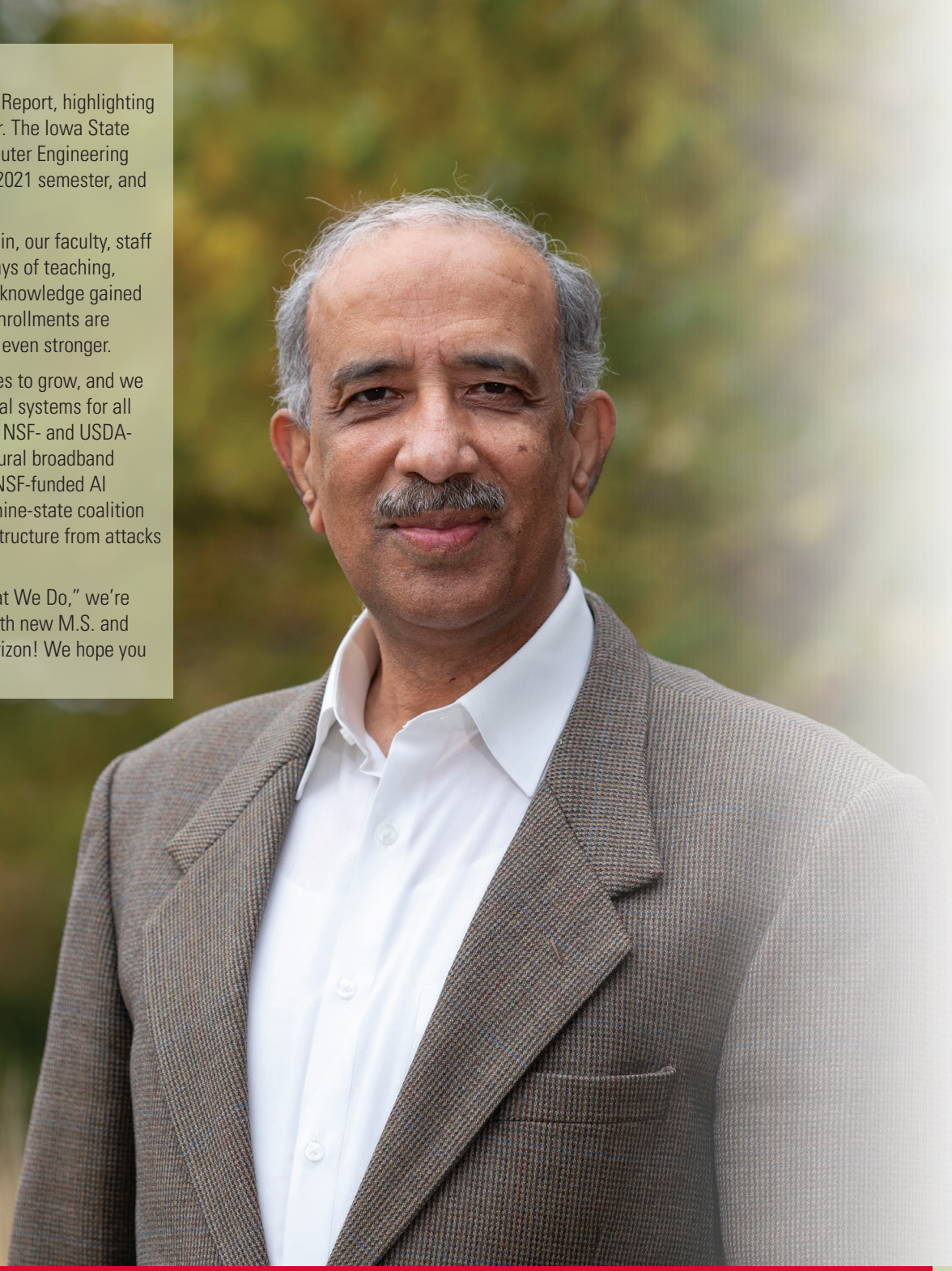
We are pleased to bring you our 2021 Impact Report, highlighting our challenges and successes in the past year. The Iowa State University Department of Electrical and Computer Engineering witnessed a full return to campus by the fall 2021 semester, and we have been busy ever since.

Now that we are together in person once again, our faculty, staff and students are implementing innovative ways of teaching, advising, researching and learning, using the knowledge gained through challenges from the pandemic. Our enrollments are bumping back, and our sponsored research is even stronger.

Our cyber security engineering major continues to grow, and we recently debuted a new minor in cyber-physical systems for all engineering majors. We also launched a new NSF- and USDA-funded PAWR wireless research testbed for rural broadband connectivity. Our faculty are part of multiple NSF-funded AI institutes. And finally, we are leading a new nine-state coalition designed to improve defense of critical infrastructure from attacks by computer hackers.

Being true to our motto of "The Future Is What We Do," we're already looking ahead to 2022 and beyond with new M.S. and Ph.D. degrees and research centers in the horizon! We hope you have a happy and successful new year.

Ashfaq Khokhar
Professor and Palmer Department Chair
Electrical and Computer Engineering
Iowa State University



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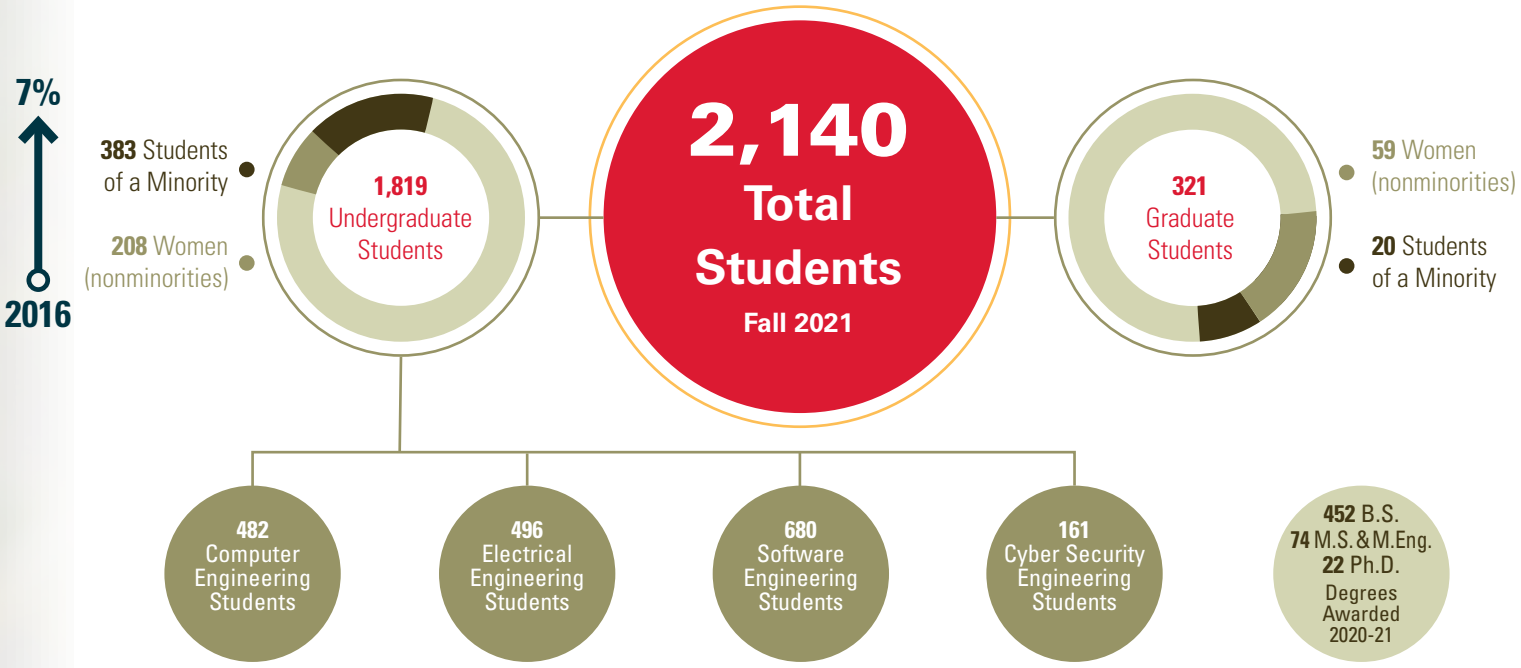
NEW ISU ECE FACULTY

Ashraf Gaffar
teaching professor
artificial intelligence

Amarsagar Reddy Ramapuram Matavalam
research assistant professor
power systems

Rachel Shannon
assistant teaching professor
engineering education

BY THE NUMBERS: **STUDENTS**



BY THE NUMBERS: **DEPARTMENT**

17 Patents submitted

16 Patents awarded CY2020

161 Journal articles

168 Conference papers

13 Books

3,456 Average number of citations CY2020

67 Faculty members

Teaching: **10**
Tenured/Tenure-Track: **47**
Adjunct: **6**
Research: **4**

21 NSF CAREER awards (15 on staff)

19 IEEE Fellows

20 Endowed professorships

2021 RESEARCH PORTFOLIO

Strategic Areas

- Bioengineering
- Cyber Infrastructure
- Data, Decisions, Network & Autonomy
- Energy Infrastructure
- Materials, Devices & Circuits

New Awards (CY2020)

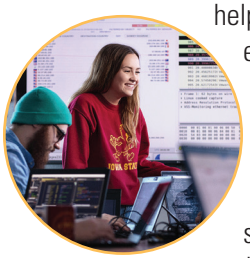
$23.3 Million

Expenditures (FY2021)

$15.6 Million

New cyber-physical systems minor leverages industry ties to enhance student futures

A first-of-its-kind curriculum in Iowa debuted this fall for students in Iowa State University's College of Engineering, helping to prepare students for a cutting-edge area of technology that's part of what has been deemed "the fourth industrial revolution."



The new undergraduate minor in cyber-physical systems (CPS) provides students with a foundation in the techniques of CPS – engineered systems that are built from, and depend upon, the seamless integration of computation and physical components. Many safety-, time- and life-critical systems now rely on CPS to become more efficient, robust, resilient, flexible, scalable, and secure.

Arun Somani, senior associate dean and distinguished professor of electrical and computer engineering (ECE), cited responsiveness to an opportunity to extend the college's strong cooperation with industry.

"This program is an excellent example of how Iowa State is responding to an emerging need. Multiple industries brought the needs to our attention. Our departments quickly came together to develop a solid program, based on ongoing research in the college, and which was vetted by our industrial partners. The final program is designed to serve common multiple industry needs and will create a CPS-aware workforce that will make our graduates more marketable."■

Pushing the future of nanoprinting, including improving accessibility

ECE Professor **Jaeyoun Kim** received a $525,000 NSF award to develop single-step, rapidly reconfigurable grayscale nanoprinting by light-controlled nanocapillary effect.

Kim's research explores using light to control certain polymers' height of capillary rise, and, in turn, enabling ultrahigh-resolution grayscale nanoprinting. The data will allow him to train machine-learning models to seek the optimal design of meta-surfaces and manufacturing.

Jaeyoun Kim, professor

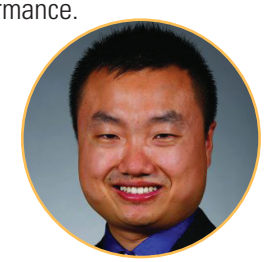
Kim will integrate nanomanufacturing technology, data science and machine learning to enrich nanomanufacturing and advance fundamental nanotechnology and computational sciences.

The team's work pushes nanoprinting and meta-surfaces to the next step, including making the relevant science more accessible to women and underrepresented groups in STEM.■

Zhaoyu Wang's CAREER award: Tapping smart meters' potential for much-needed grid resilience

Zhaoyu Wang, assistant professor in ECE, received a NSF CAREER award to unlock the potential of smart meters with new optimization and probabilistic graph learning methods to enable data-driven, real-time electric network monitoring.

Enhanced electric grid monitoring is needed to promote renewable integration while ensuring reliability, but current approaches rely on expensive sensors. Smart meters that electric utilities are already using for billing have potential, but without new computing innovations, smart meters only can provide limited insights into grid performance.

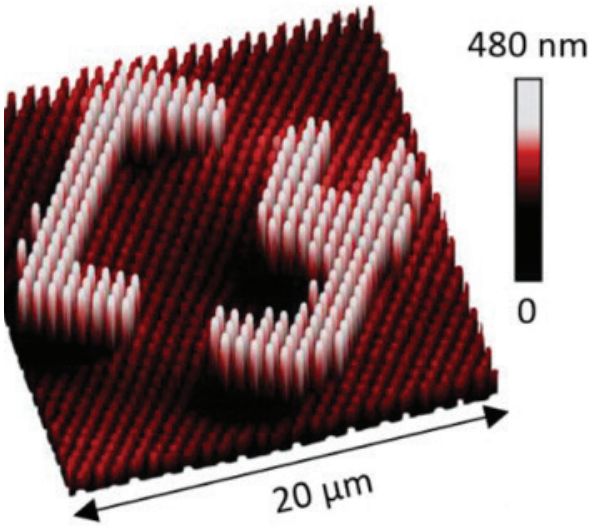


Zhaoyu Wang, assistant professor

Wang's team has three goals. They will create new grid topology and parameter identification algorithms that will leverage available but low-resolution smart meter data, discover data connections, and make possible real-time power distribution grid modeling. The team will also use new graph learning approaches that connect smart meters and other information sources to make fast and accurate outage detection possible. And, third, Wang's team will design robust data-recovery techniques to take on challenges in smart meter data asynchrony.

Wang's innovations will add up to real-time modeling and fast detection of large-scale outages, using smart meters that are already widely in use.

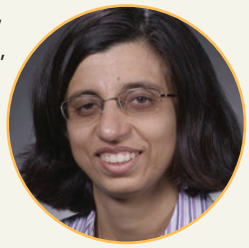
"By harnessing the data collected by existing smart meters, millions of dollars in potential sensor investments are saved. Our work will bring U.S. utilities much needed data-driven grid monitoring that helps minimize outages. Plus, our advances help promote the seamless integration of renewable energy into grids," said Wang.■



An example of nanoprinting, described in the article at left.

Secure and efficient algorithm design for signal recovery from "messy" data

Huge amounts of data are collected by a variety of electronic devices. A lot of this is distributed data, such as data from surveillance cameras, IoT devices and smartphones. All of this data needs to be stored somewhere, but the size and amount of data is too much to keep as is.



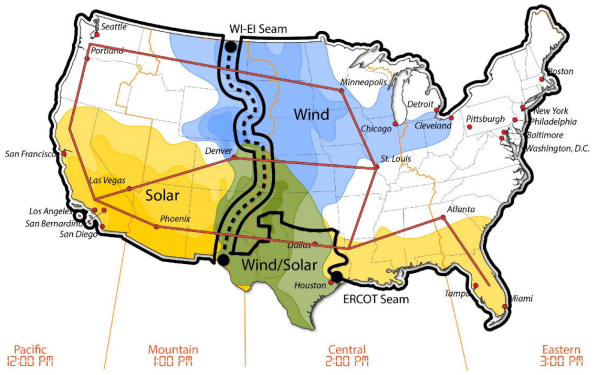
Namrata Vaswani, professor

Data needs to be compressed (sketched) before it can be stored at a smaller size – however, when the data is distributed and needs to be compressed in a privacy-preserving and secure fashion while also keeping the sketching algorithm simple, the design of the overall system is not straightforward. ECE Professors **Namrata Vaswani** and **Aditya Ramamoorthy** received a $564,500 NSF grant to solve this problem.

The idea of performing federated sketching is for different nodes to compute random "linear projections" of their own signal/image. In a different class of applications – projection imaging settings like MRI, CT or Fourier ptychography – linear or quadratic projections of the image are the only quantities that can be measured. Moreover, these are measured one projection at a time, making data acquisition very slow. For both federated sketching and projection imaging, there is a need to be able to reconstruct the image sequence using as few projections as possible.

According to Vaswani: "Our work designs efficient, secure and federated algorithms for accurate recovery and provides the first set of conditions under which a certain computational and sample budget is guaranteed to be sufficient with high probability. To achieve this, our work exploits what is called the low-rank assumption – the set of images, each arranged as a 1D vector, form a matrix that has a rank much lower than its dimensions."■

Aditya Ramamoorthy, professor



This map shows how a macrogrid (the red lines) could cross the seam separating the Eastern and Western connections, allowing most of the country to share electricity, including wind and solar energy.

Macrogrid study: Big value in connecting America's power grids

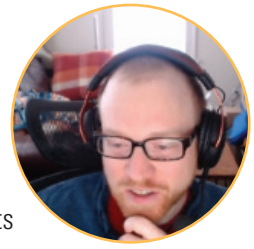
According to the Interconnections Seam Study, a two-year, $1.5 million study launched as part of a $220 million Grid Modernization Initiative announced by the U.S. DOE, a "macrogrid" that increases the electricity moving between America's Eastern and Western interconnections would more than pay for itself and boost grid reliability and resilience.

Iowa State engineers, including ECE Distinguished Professor **Jim McCalley**, contributed computer modeling expertise to the project, building a capacity expansion model that simulates 15 years of improvements to power generation and transmission. The ISU models took the grid-improvement process up to the year 2038. The results show benefit-to-cost ratios that indicate significant value to increasing the transmission capacity between the interconnections under the cases considered. Another benefit is increased adaptability.■

Twitch: An innovative way to deliver coding content to students

ECE Assistant Teaching Professor **Mat Wymore** is using the popular video livestreaming platform Twitch to stream coding demonstrations to students enrolled in his courses. Wymore livestreams his screen to his students and explains his coding demonstration on video while students have the ability to ask questions in the chat to the right of the screen. Twitch offers a more hands-on experience, where students can watch and ask questions about the demonstration in real-time and Wymore can personally engage with his students.

Wymore has used Twitch to stream in EE285, a class that discusses methods for systematically reducing problems into sequential steps compatible with computer-based tools, structuring computer programs for efficiency and maintainability. He also gives traditional lectures as well for students who may prefer to not use the platform.



Mat Wymore (on Twitch), assistant teaching professor

"Feedback has been mostly positive," Wymore said. "Some students enjoy it because they already use Twitch and watch streams and are familiar with the platform and find it fun."

Twitch is good for formatting coding demonstrations because it does not require in-person instruction, and formatting on Twitch is simple. It also gives students the ability to drop in and watch live, according to Wymore. "My motivation is partially to engage students on their own platforms versus on some other platform that we think is good for them," he said.■

Cyclone Engineer Benazir Fateh solves cutting-edge tech challenges at Google

Benazir Fateh, who received her Ph.D. in computer engineering in 2013, is a rising star in machine learning and artificial intelligence. In her current position as a machine learning specialist at Google, she helps some of the most recognizable companies in the world to transform their businesses by developing creative and scalable end-to-end machine learning solutions using Google Cloud Platform.

Benazir Fateh, ECE alumna

Fateh gets to work, learn and play with the newest technologies when they first emerge at Google. In her role, she sees the problems big technology companies face within the ML/AI world and helps figure out scalable solutions. She especially enjoys designing ML solutions.

Her favorite type of problem is large-scale end-to-end machine learning systems that have many moving pieces. "Complex challenges require understanding the nuances and limitations of existing products and solutions and creating a scalable solution – and that's exciting," Fateh said.

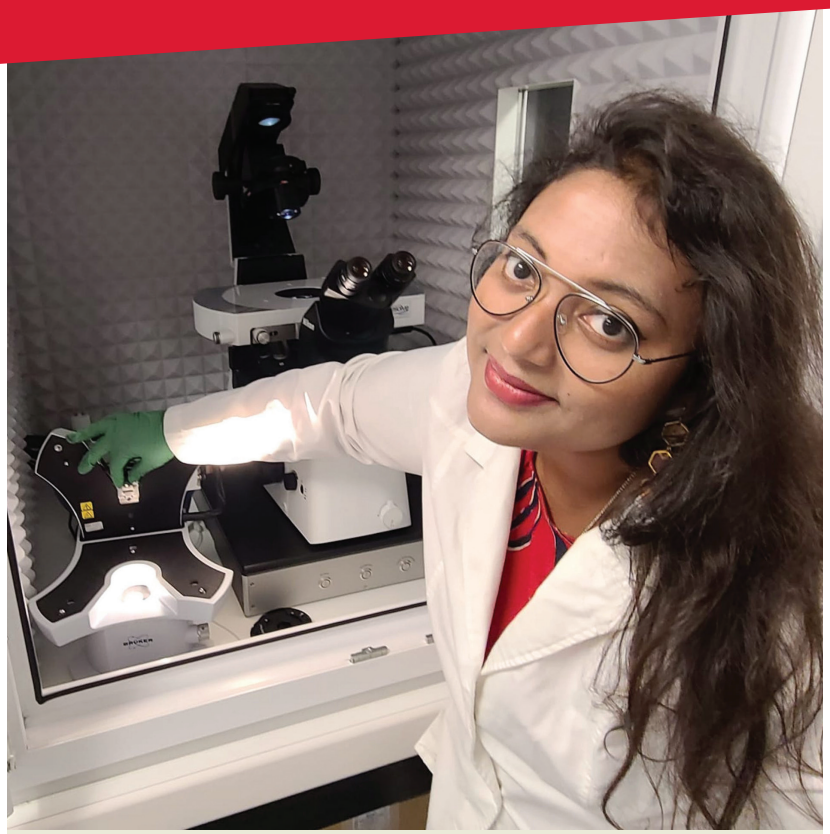
Prior to joining Google, Fateh quickly climbed the ranks in machine learning, data modeling and software architecture at John Deere and AIEnterprise, a leading digital commerce solutions provider.

During her time at Iowa State, Fateh made a difference to the community and culture of graduate students. She was instrumental in crafting a vacation and sick leave policy for graduate students and organized events promoting networking and community building. Fateh's contributions led to a Department of Electrical and Computer Engineering Recognition of Service Award in 2012. This year she received the ISU College of Engineering Young Alumni Award.

Fateh is a committed advocate of women in STEM and women's leadership. In 2021, Fateh was invited to give an address in the Iowa State Women in Data Science (WiDS) lecture series.

Fateh said, "I want to take every opportunity I can to share with young women professionals the lessons that have helped me being a woman in STEM and in data science in particular. Women in Data Science provides an excellent forum to do that."

She is also an ambassador for WiDS, mentors high schoolers interested in STEM careers, and has advised Cyclone Engineering senior design teams. Fateh also serves on the board of SpeakHire, an organization that develops the social and cultural capital of individuals from immigrant families to become leaders in the workforce.■



Inspiring future women engineers: Anwesha Sarkar

Anwesha Sarkar, ECE adjunct assistant professor, also works in the Iowa State University Nanovaccine Institute. She has been with the university since fall 2020 as faculty, specializing in bioengineering.

Anwesha Sarkar, adjunct assistant professor

Her engineering hero: Professor Jennifer A. Doudna, and her mother. Her mom was a high school STEM teacher in India for 35 years and has "always been my hero from my childhood and has inspired and supported me to pursue my dreams."

Her engineering superpower and innovative research: Atomic Force Microscopy (AFM). AFM has become a powerful tool to analyze biomolecules, biosensors, proteins, DNA and live cells. It provides high-resolution imaging and helps scientists figure out the topographical and nanomechanical properties of nanoparticles – which could find better agents for targeted drug delivery to reduce side effects.

How she inspires future women engineers: "I want to inspire current and future engineering students to understand different biophysical discoveries and learn their practical applications in bioengineering."■

Innovation in rural broadband connectivity: Hongwei Zhang and team receive $16m NSF PAWR award to establish wireless living lab

The Platforms for Advanced Wireless Research (PAWR) program announced Iowa State University and its partners as the fourth testbed in a diverse portfolio of large-scale research platforms located throughout the United States. Designated as ARA: Wireless Living Lab for Smart and Connected Rural Communities, the new platform in central Iowa complements the technical specialties of earlier PAWR platforms, adding a focus on technologies for rural broadband connectivity.

ARA will establish its wireless living lab across Iowa State University, the city of Ames and surrounding farms and rural communities in central Iowa. Creating a deeply programmable infrastructure, ARA will feature a wide range of wireless technologies as well as an application focus on precision agriculture in both crop and livestock farms. The NSF grant includes $8 million in federal funding and a matching investment in the form of cash and in-kind contributions from PAWR industry consortium partners. In addition to $7 million from NSF, the ARA platform has received another $1 million in financial support from the United States Department of Agriculture's (USDA's) National Institute of Food and Agriculture (NIFA).

Leading the ARA project for Iowa State is ECE Professor **Hongwei Zhang**. "ARA enables research in end-to-end broadband infrastructures for rural and remote areas, and it features high-performance, programmable platforms in wireless access, wireless backhaul and edge and cloud," Zhang said. "By supporting fundamental communication services such as ultra-reliable, low-latency communications, ARA enables field research studies such as tele-operations of vehicles or drones, that are of interest to rural and urban regions but are difficult to conduct in urban settings in early stages of the exploration."

The PAWR program is designed to accelerate the development and commercialization of promising technologies and applications, ensuring continued U.S. leadership in wireless communications while also preparing the emerging workforce for new job opportunities in the digital economy.

The ARA testbed will produce a heterogeneous network environment featuring a wide range of wireless technologies. For backhaul connectivity, ARA will create a multi-modal, high-capacity wireless mesh network, including low Earth orbit (LEO) satellite links, a free-space optical (FSOC) platform and long-distance millimeter wave (mmWave) and microwave point-to-point communications. In the radio access network (RAN), ARA will employ low-UHF massive MIMO (mMIMO) and other platforms to enable research across multiple frequencies, including the TV white space (TVWS) band and CBRS band.

The ARA platform will feature software-defined radios (SDRs) and programmable off-the-shelf equipment. This virtualized and programmable network will support research in areas such as bandwidth aggregation, channel bonding, dynamic and spectrum sharing, as well as resilient, high-throughput and long-distance wireless backhaul and access – which are expected to lay the foundation for more affordable rural broadband service.

To learn more about ARA, visit www.arawireless.org. For more information on PAWR, visit www.advancedwireless.org.■

Hongwei Zhang and others installed hardware for CyNet, an advanced wireless networking system that's a predecessor to the new ARA rural broadband project.

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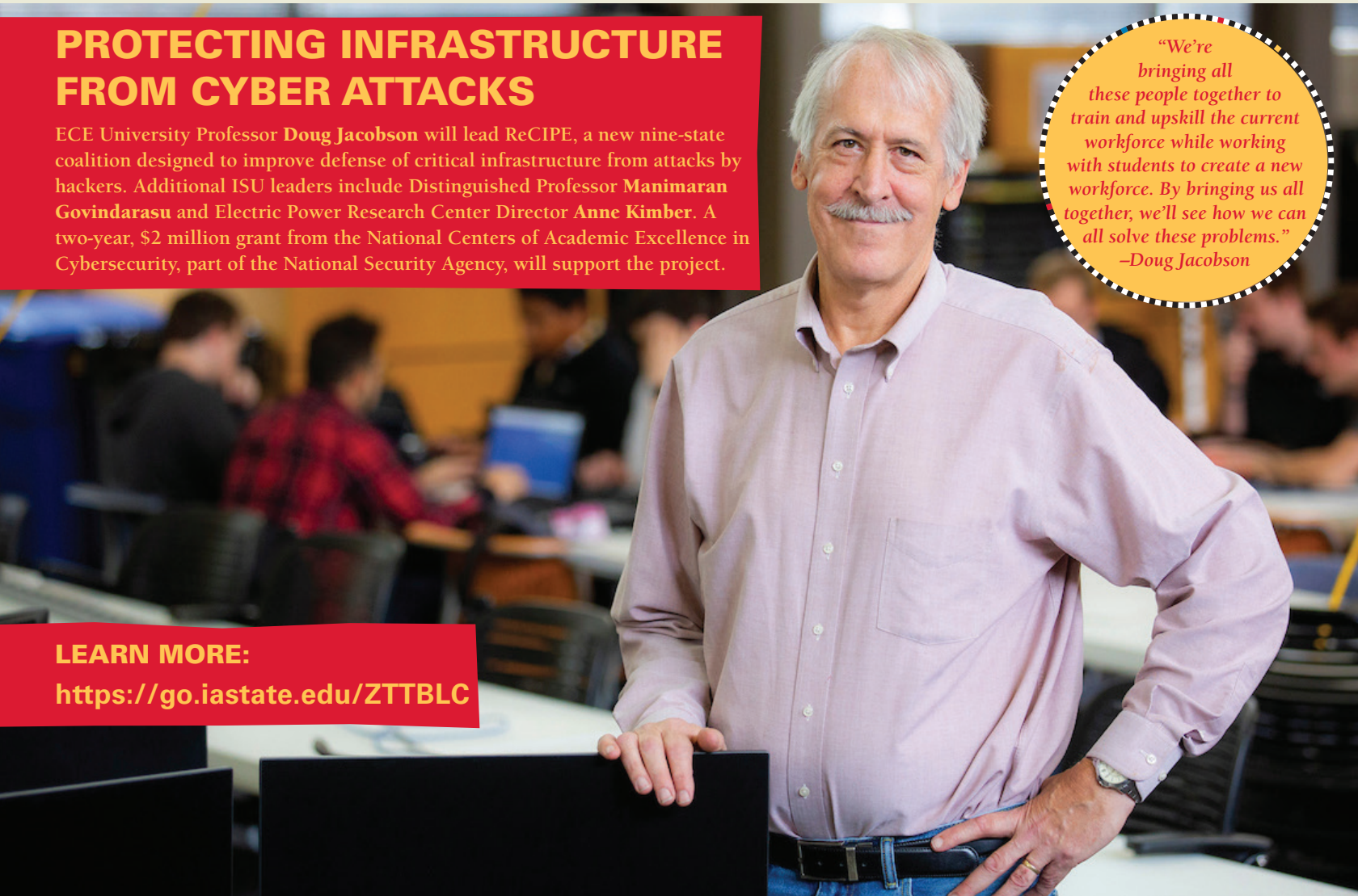
PROTECTING INFRASTRUCTURE FROM CYBER ATTACKS

ECE University Professor **Doug Jacobson** will lead ReCIPE, a new nine-state coalition designed to improve defense of critical infrastructure from attacks by hackers. Additional ISU leaders include Distinguished Professor **Manimaran Govindarasu** and Electric Power Research Center Director **Anne Kimber**. A two-year, $2 million grant from the National Centers of Academic Excellence in Cybersecurity, part of the National Security Agency, will support the project.



"We're bringing all these people together to train and upskill the current workforce while working with students to create a new workforce. By bringing us all together, we'll see how we can all solve these problems."
–Doug Jacobson

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