IMPACT REPORT

2019 - 2020

IOWA STATE UNIVERSITY

Department of Electrical and Computer Engineering

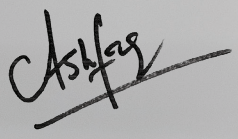
The Future Is What We Do

Greetings from Coover Hall in Ames, Iowa!

2020 was a challenging year for us all. Students, faculty and staff all faced a variety of stresses, but the collective strength prevailed. We graduated, innovated and succeeded on many fronts.

In 2020, the Iowa State University ECE department received funding from DoE, NSF, DoD, NIH and numerous industry sponsors for new research projects. The department was the recipient of an unprecedented number of college, university and professional awards, including the NSF CAREER award, teaching excellence awards, outstanding staff and alumni awards, professional society fellowships and best paper awards.

We are looking ahead to a brighter 2021, and here in ECE at Iowa State, the future is what we do! Hoping you all have a happy, healthy and successful new year.



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

NEW ELECTRICAL AND COMPUTER ENGINEERING FACULTY

Nick Fila
research assistant professor
engineering education

Houqiang Fu
assistant professor
wide bandgap semi-conductors

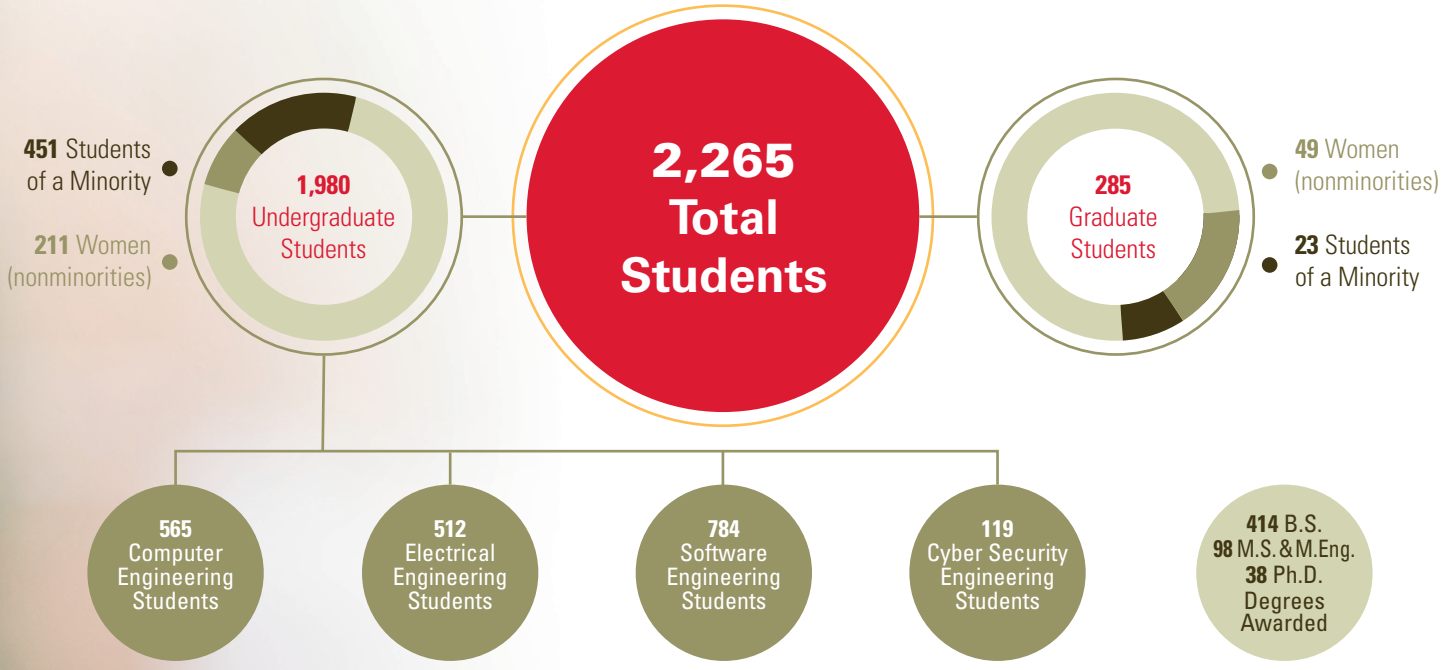
Ravikumar Gelli
research assistant professor
cyber-physical systems

Berk Gulmezoglu
assistant professor
hardware security

Shana Moothedath
assistant professor
control systems

Anwesha Sarkar
adjunct assistant professor
biosensors

2019-20 BY THE NUMBERS: STUDENTS



2019-20 BY THE NUMBERS: DEPARTMENT

11
Patents submitted

10
Patents awarded

150 Journal articles
176 Conference papers
7 Books
3,508 Average number of citations

60
Faculty members
Teaching: **6**
Tenured/Tenure-Track: **48**
Adjunct: **1**
Research: **5**

22 NSF CAREER awards
20 IEEE Fellows
17 Endowed professorships
32+ Total fellowships

2020 RESEARCH PORTFOLIO

Strategic Areas

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

Expenditures

$15.4 Million

New Awards

$10.25 Million

RESEARCH **HIGHLIGHTS**

Sustainable agriculture in the cloud

Ratnesh Kumar, professor

Ratnesh Kumar, Murray J. and Ruth M. Harpole Professor with ECE at ISU, recently received $600,000 from NSF for a project helping farmers monitor their crops, optimizing the farming experience with cloud-based technology.

By knowing the most optimal level of nutrients and irrigation a crop needs, farmers won't have to use excess resources and further harm the environment. Since Kumar will be using MyGeoHub, a cloud-based data service, this information and decision making will be accessible through web browsers and other infrastructures (e.g, AgMIP) — leading to a more technically-savvy and environmentally-friendly farming industry. "This also helps our environment, as otherwise, the unused resources are lost to waterways causing contamination and eutrophication, and to the atmosphere contributing greenhouse gases," Kumar said.

Early successes

Cheng Huang, assistant professor

Cheng Huang, ECE assistant professor since 2018, received his first National Science Foundation (NSF) award, of nearly $500,000, as the principal investigator of the project "Next-Generation Fully Integrated Power Management Circuits: Enabling Faster and More Efficient Computing and Communication in Smaller and Lower-Cost Mobile Electronics." Huang's research focus is on wireless power and power management issues in integrated circuits.

Hugo Villegas Pico, assistant professor

Since joining ISU ECE in 2019, Assistant Professor **Hugo Villegas Pico's** research is aimed at improving the reliability of the power grid in order to prevent untimely disconnections in times of crisis or natural disaster. Recently, Villegas Pico received his first grant of $250,000 from NSF toward research to ensure that future power grids integrate smoothly with renewable energy sources, as well as maintain optimal performance during high stress periods, including natural disasters such as tornadoes and hurricanes. He also leads a team that received a $700,000+ grant from the U.S. Department of Energy to research how to orchestrate the restoration of wind-dominant grids after storms or attacks.

Mai Zheng's CAREER award: Tomorrow's advances in storage systems

Mai Zheng, assistant professor

Mai Zheng, assistant professor in ECE, received a NSF CAREER award of $500,000 to improve computer storage systems' ability to protect data during crashes and other disruptions.

Storage systems are the fundamental computing building block of our modern lives – and their "robustness is crucial to systems ranging from financial institutions, where downtime can result in millions of dollars lost, to scientific computing, where the generated data advances any number of challenges facing humanity," said Zheng. As he builds his professional career, Zheng's work will enable the creation of a new flexible, scalable framework for thoroughly testing the crash consistency of many different storage systems. His work will also engage an inclusive next generation of engineers by developing new courses around storage systems to give students in-depth knowledge and techniques in storage hardware, software and optimization. Zheng will work with Science Bound and IINSPIRE-LSAMP programs at ISU to increase diversity in STEM disciplines.

ISU selected as finalist for major NSF PAWR research grant focused on rural broadband

Hongwei Zhang, professor

The Platforms for Advanced Wireless Research (PAWR) program, jointly funded by NSF and a consortium of 35 leading wireless companies and associations, has selected Iowa State University and its partners as one of two finalists in a national competition for a large-scale wireless research testbed aimed at studying novel ways to reduce the cost of broadband delivery to rural communities.

The ISU-led project, headed by ECE Professor **Hongwei Zhang**, is titled "ARA: Wireless Living Lab for Smart and Connected Rural Communities." If awarded, it will be the fourth city-scale testbed in the United States. The PAWR Project Office manages a $100 million public-private partnership and oversees these research platforms.

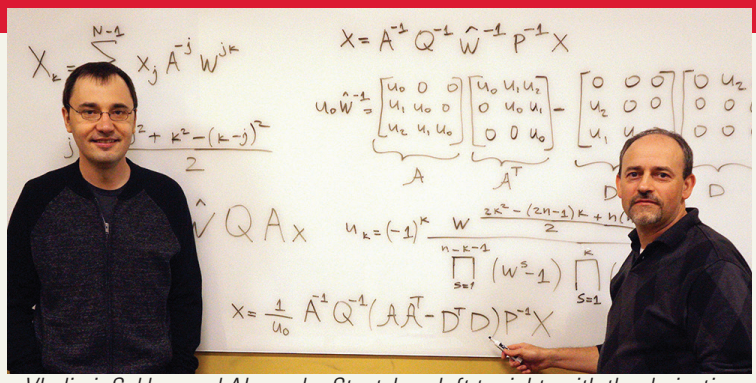
"Iowa State and our partners are excited about this project developing better technologies to connect rural communities and accelerating broadband availability," said **W. Samuel Easterling**, James L. and Katherine S. Melsa Dean of Engineering. "This will have a big impact and make available more opportunities to connect families, schools, farms, municipalities and others across rural America."

Engineers explore algorithm's capabilities in special cases "on the unit circle"

If you've used a cell phone, browsed the internet or needed a medical image, you've benefitted from the fast Fourier transform (FFT). The transform and its inverse (known as the IFFT) have been in use since 1965. For example, in your cell phone the FFT is used to analyze the signal received from the base station (or cell tower). The IFFT solves the inverse problem: it synthesizes the signal that your phone sends to the base station.

In 1969, researchers developed a more useful, generalized version of the FFT known as the chirp z-transform (CZT). But nobody had come up with a generalized version of the IFFT. It was a 50-year-old puzzle in signal processing.

That is, until last fall, when ECE Associate Professor **Alexander Stoytchev** and ECE Lecturer **Vladimir Sukhoy** announced in a research paper they had come up with a closed-form solution for the inverse chirp z-transform (ICZT) and a fast algorithm for computing it.



Vladimir Sukhoy and Alexander Stoytchev, left to right, with the derivation for the ICZT algorithm in structured matrix notation. Photo by Paul Easker.

Now Stoytchev and Sukhoy report new research results about their algorithm.

In a paper published by Scientific Reports, the two show how their algorithm functions "on the unit circle," which refers to a special case of its parameters. The paper demonstrates that, on the unit circle, the ICZT algorithm achieves high accuracy has the O(n log n) time complexity. "This algorithm is more general than the IFFT, but maintains the same speed," Stoytchev said.

Two Cyclone engineers receive NSF grant to create smarter aircraft and spacecraft

Phillip Jones, associate professor

ISU ECE Associate Professor **Phillip Jones** and Assistant Professor of Aerospace Engineering **Kristin Rozier** have been awarded $1.2 million from NSF for their research on computer and network systems in air- and spacecraft, entitled "Resource-Aware Hierarchical Runtime Verification for Mixed-Abstraction-Level Systems of Systems."

Air- and spacecraft are made of complex systems that must seamlessly work together, switching control through a carefully orchestrated hierarchy.

"The end goal of the project is to make these complicated systems safe. When these systems interact with society, we want to have confidence that people won't get hurt and property won't get damaged," Jones said.

This project aims to combine concepts from formal methods, control theory, hardware-software integration and software engineering to design runtime monitors that inspect cyber-physical systems without interfering with their normal operation.

"This project is a true representation of outstanding quality multidisciplinary research work in the College of Engineering and underscores the importance of hardware-software co-design in real-time systems," said ECE Professor and Palmer Department Chair **Ashfaq Khokhar**.

Cyber-physical system will monitor crops, drive decisions, boost yields

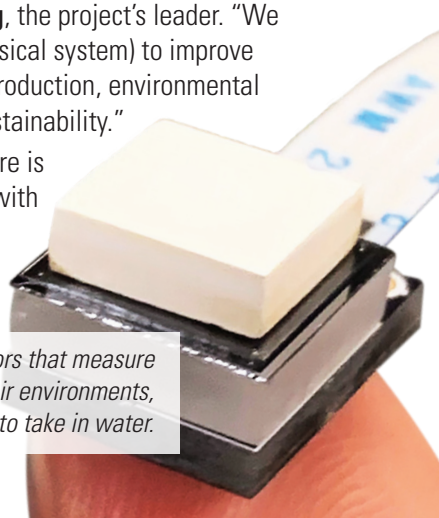
Liang Dong, professor

After decades of growing corn and soybean yields across the Midwest's Corn Belt, per-acre yields are approaching their theoretical limits. But there's still a need for more grain to feed people and livestock. Where can that grain come from? How can farmers and fields produce even more? Is there a new, sustainable way to boost productivity?

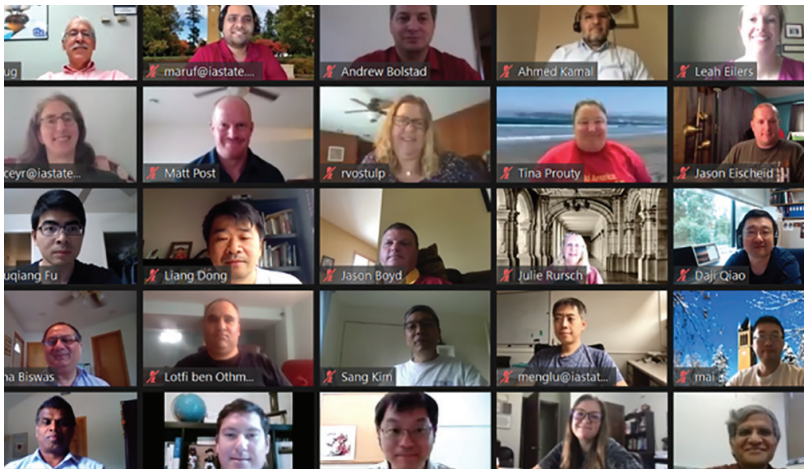
Engineers, geneticists, agronomists, system modelers and machine-learning experts at Iowa State University and the University of Nebraska-Lincoln think they might have a way. They're combining their electronics, computing and crop expertise to develop a system that will constantly monitor fields at near single-plant resolution, predict productivity and help farmers manage their water and fertilizer use.

"The idea is to combine and interact two subsystems – a cyber system and a physical system – to solve problems," said ISU ECE Professor **Liang Dong**, the project's leader. "We want to build a new CPS (cyber-physical system) to improve agricultural management for crop production, environmental quality and agricultural systems sustainability."

The U.S. Department of Agriculture is supporting the collaborative effort with a three-year, $1.05 million grant to Iowa State and Nebraska-Lincoln.



Liang Dong's research uses small sensors that measure internal sensations of plants and their environments, such as the ability of a plant to take in water.



Top: ECE graduates celebrated virtually this year, by submitting photos such as this one to our commencement video events. Middle two: The Digital Women student organization painted pumpkins in the Coover Hall courtyard while masked. Bottom two: ECE faculty and staff held their annual retreat on Zoom.

ECE alum joins forces making protective gear

During this time of uncertainty, Cyclone Engineers across the country are putting their engineering skills to good use, doing their part in fighting COVID-19. Over 1,000 miles from Ames, 1980 electrical engineering alum and ECE inaugural Hall of Fame member **Kathy Engholm** sewed masks for frontline workers in New Mexico.

Engholm recently retired after spending over 33 years working at Tektronix. When she received an email from a local fabric shop looking for volunteers to help make thousands of masks for healthcare providers, the National Guard, Navajo Nation and other at-risk groups, she eagerly accepted the challenge.

"We were continually working to increase the efficiency of our production line so we could finish more masks per day. I got to help brainstorm and test many ideas for changing the order of the steps, combining or dividing processes at the various stations, modifying the pattern and adjusting how work was done at each stage. My job experiences in manufacturing, program management and design for manufacturing were really helpful," Engholm said.

Visiting Mars with a virtual CyBot: Innovation in hands-on learning during COVID-19

In a normal semester, ISU ECE's Introduction to Embedded Systems course features a popular project simulating exploration of the surface of the planet Mars, using iRobot Roomba-based mobile robots fitted with microcontrollers, nicknamed CyBots, after Iowa State's mascot Cy.

The CyBot platform is an embedded systems platform – a programmable mobile system composed of various sensors for solving embedded systems problems. In this course, the platform is used to develop a prototype of a Mars Rover that can avoid obstacles, collect data about the Martian terrain, stay within a radiation safe zone and navigate to a communication relay station to send findings back to Earth.

As part of the course, students learn basic computer concepts and interact with the "real world" using CyBots. Students control the movement of CyBots and gather information using various sensors, including sonar and infrared, mounted on a servomotor (also part of the CyBot), to sweep from 0-180 degrees in a room.

In mid-March 2020, Iowa State announced that classes would be moving online after spring break. Converting a hands-on course and lab with 220 students and 10 lab sections to an online format in such a short amount of time was not easy.

"We came up with the idea for each TA to take a CyBot home and modify the lab deliverables, so even though students weren't getting the hands-on experience of seeing it and working with the CyBot in the lab, they were still able to learn the material and get some of the same team experiences and development practices as they would have from the lab," said former TA and recent graduate **Lindsey Sleeth**.

"In the spring, the labs continued to use the physical CyBots, since they were halfway through the semester when courses went virtual. With support from ECE's Electronics Technology Group (ETG), the TAs took the CyBots home at spring break, and students worked with TAs the rest of the semester to run code on the robots," said ECE University Professor **Diane Rover**, the spring course instructor. "It was not ideal, but it provided a path to support labs to finish the semester."

In the summer and fall 2020 semesters, ECE Associate Professor **Phillip Jones** was the instructor for the course, which transitioned to be entirely online, and students and TAs interacted through synchronous, scheduled lab periods. ETG replaced the physical CyBots with a simulated robot and emulated I/O interfaces – actual hardware was remotely accessed by students through a virtual desktop, and students were able to program and navigate virtual robots from home.

The simulated CyBot hardware was designed and implemented by a senior design team of then-students

Lindsey Sleeth, *recent graduate and former TA, at home with a CyBot.*

Sam Rai, **Jacob Aspinall**, **Isaac Klein**, **Nathan Nordling**, **Geonhee Cho** and **Jisoo Han**. Aspinall, working under Jones' supervision, developed the graphical user interface for the CyBot simulation, which is a key component for running the labs remotely. The combined work of the team and Aspinall's interface resulted in a product that ETG could take from a prototype into instructional lab use.

"The results of this summer were way better than Dr. Jones and I expected," said ECE Engineer **Matthew Post**, who led ETG on the project. "During our validation testing, we only discovered a few minor bugs and no major issues. The feedback from the students was that things went better than normal due to the lack of real-world challenges that come with interfacing with hardware and software. We have a lot of hope for the future of this project, such as remote access to the labs and the ability to simulate code on the hardware, which can prevent programming errors that might cause damage to our physical platform."

Both Rover and Jones were honored with the Spring 2020 Teaching Innovation Award from the Iowa State University Office of the Senior Vice President and Provost in recognition of their work and innovation with this course.

"The award reflects that we successfully focused our efforts on student needs and learning," Rover said. "Our TAs did double duty as both students and teachers with virtual instruction. They were sometimes the glue keeping students engaged. We used the power of our team approach to innovate."

The embedded systems course is part of a National Science Foundation project entitled "Reinventing the Instructional and Departmental Enterprise (RIDE)." The goal of the program is to reshape core technical ECE curricula through pedagogical approaches that promote design thinking, systems thinking and professional skills, such as leadership and inclusion. The program also aims to contextualize course concepts, as well as stimulate creative, socio-technical minded development of ECE technologies for future smart systems.

ISU ECE Professor and Palmer Department Chair **Ashfaq Khokhar** said, "This award truly recognizes the team effort that Diane and Phillip have put together, along with support from ETG. Thank you all for your leadership and efforts, and heartiest congrats to Phillip and Diane on this truly deserving recognition!"

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SOLAR POWER CRATE

In times of natural disaster or emergency, the Iowa Army National Guard strives to maintain a rapid response time. In such times, access to flexible, mobile power sources is crucial. In order to provide this power, the Electric Power Research Center (EPRC) at Iowa State University has received a grant from the Iowa Economic Development Authority to develop a solar power crate to be installed at Camp Dodge in Johnston, Iowa.

LEARN MORE:
ece.iastate.edu/solar-power-crate

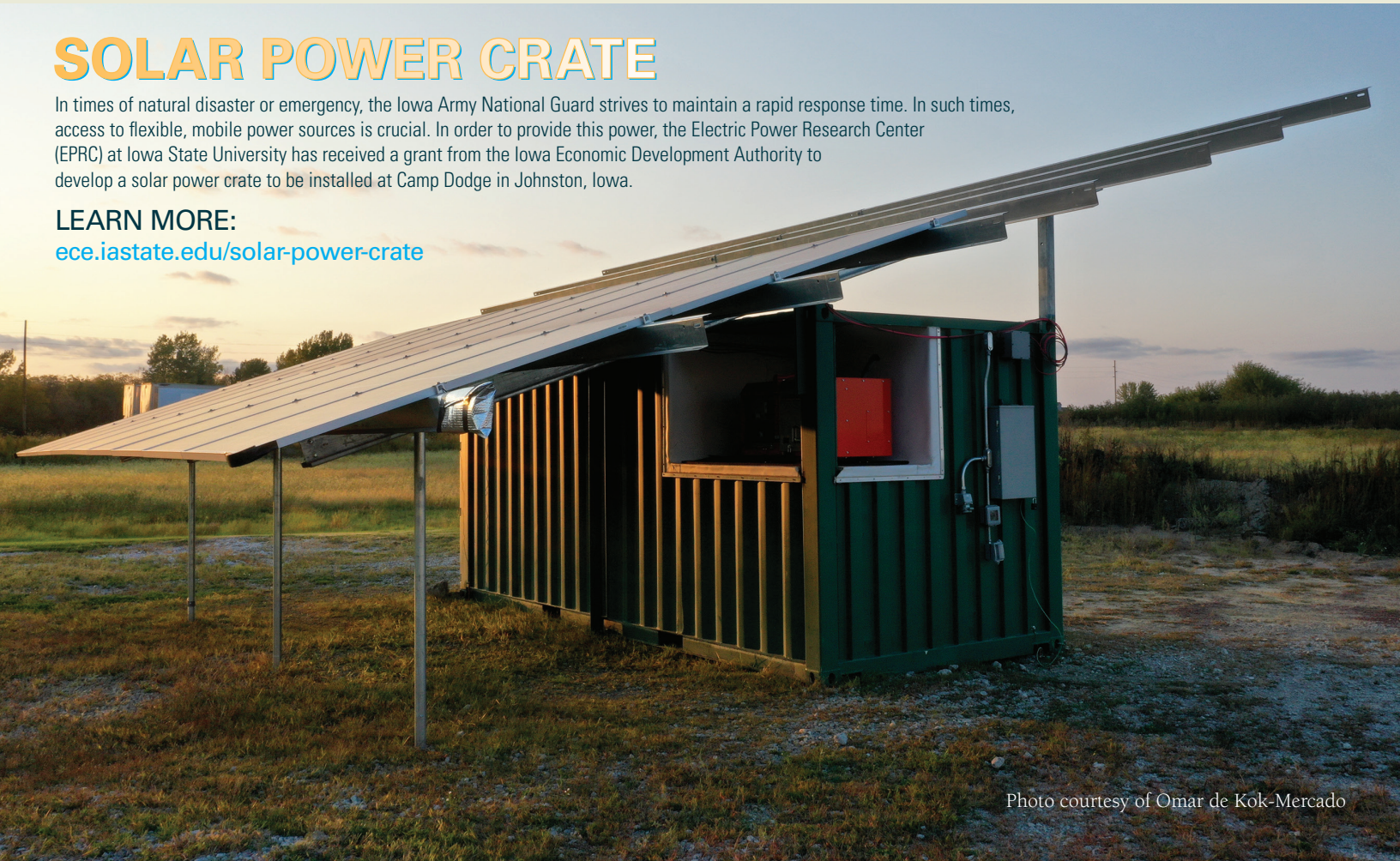

Photo courtesy of Omar de Kok-Mercado