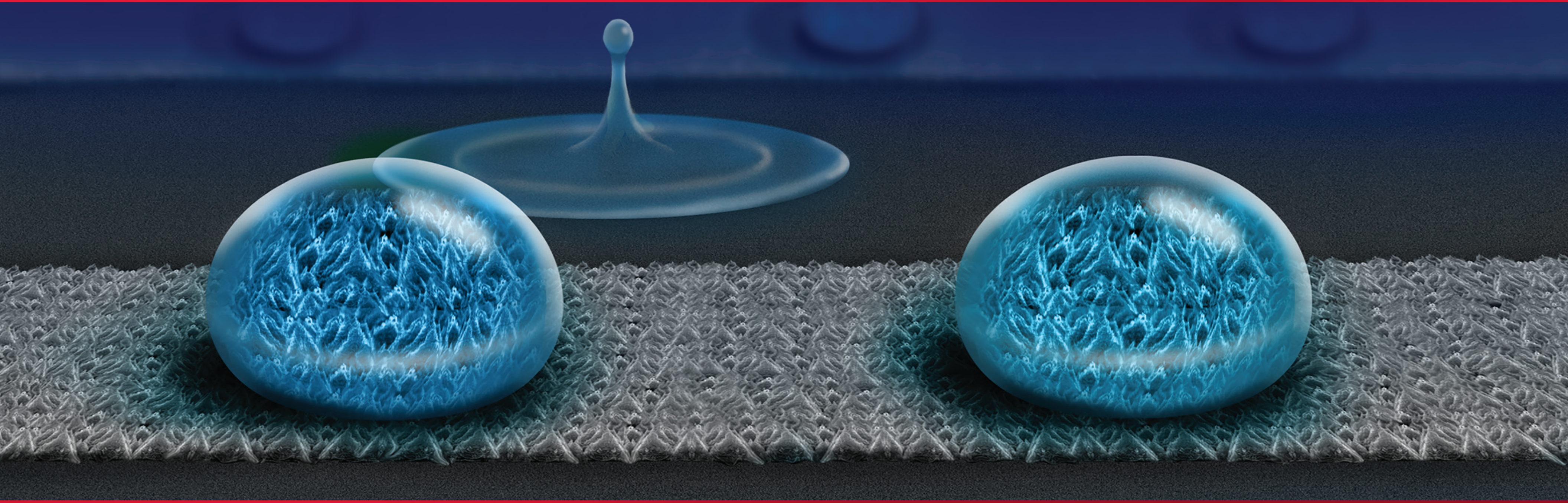
IOWA STATE UNIVERSITY
College of Engineering

CYCLONE ENGINEERING RESEARCH

SPRING 2018



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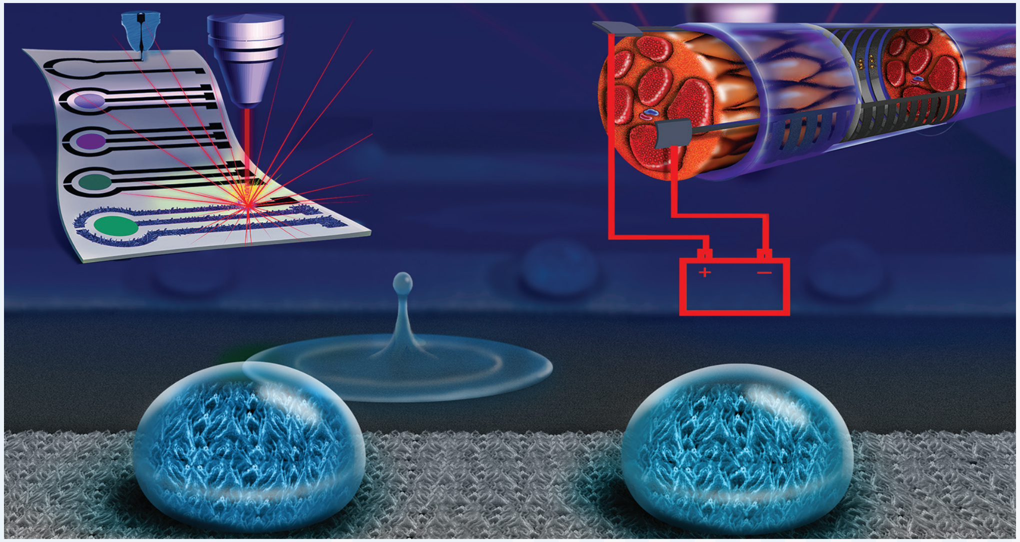

On the cover: *Jonathan Claussen, assistant professor of mechanical engineering, is treating printed graphene with lasers to create electronic circuits that repel water.*

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CYCLONE ENGINEERING
REACHING RECORD HIGHS*

- 17% — 9669 — Total Engineering Enrollment
- 17% — 54 — Women/URM Tenure-Eligible Faculty
- 22% — 1414 — Graduate Student Enrollment
- 25% — $99.3M — External Research Expenditures
- 42% — 1779 — Total Degrees Conferred

* Increases since 2013

FLEXIBLE, WATER-REPELLENT GRAPHENE CIRCUITS FOR WASHABLE ELECTRONICS

Cyclone Engineer **Jonathan Claussen** is creating new graphene printing technology and using it to produce low-cost, flexible, highly conductive and water-repellant electronic circuits.

"We're taking low-cost, inkjet-printed graphene and tuning it with a laser to make functional materials," said Claussen, an assistant professor of mechanical engineering and an associate scientist at the U.S. Department of Energy's Ames Laboratory.

Jonathan Claussen, assistant professor of mechanical engineering

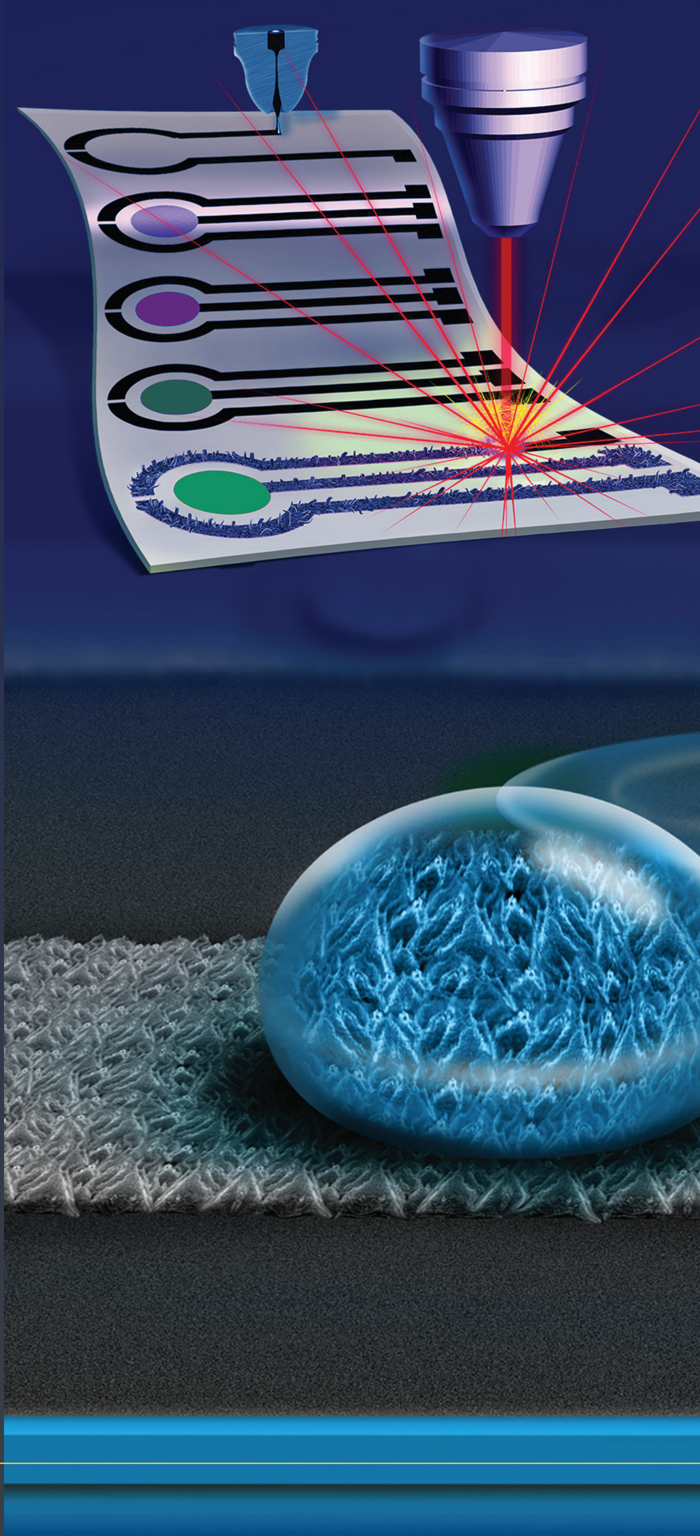
Claussen and his research team used flakes of graphene produced by inkjet printing technology to manufacture electric circuits on flexible materials. This graphene serves as not only a great conductor of electricity and heat but is also strong, stable, and biocompatible. However, the printed flakes alone are not highly conductive, so Claussen developed a rapid-pulse process that can treat the graphene without damaging printed surfaces as delicate as paper.

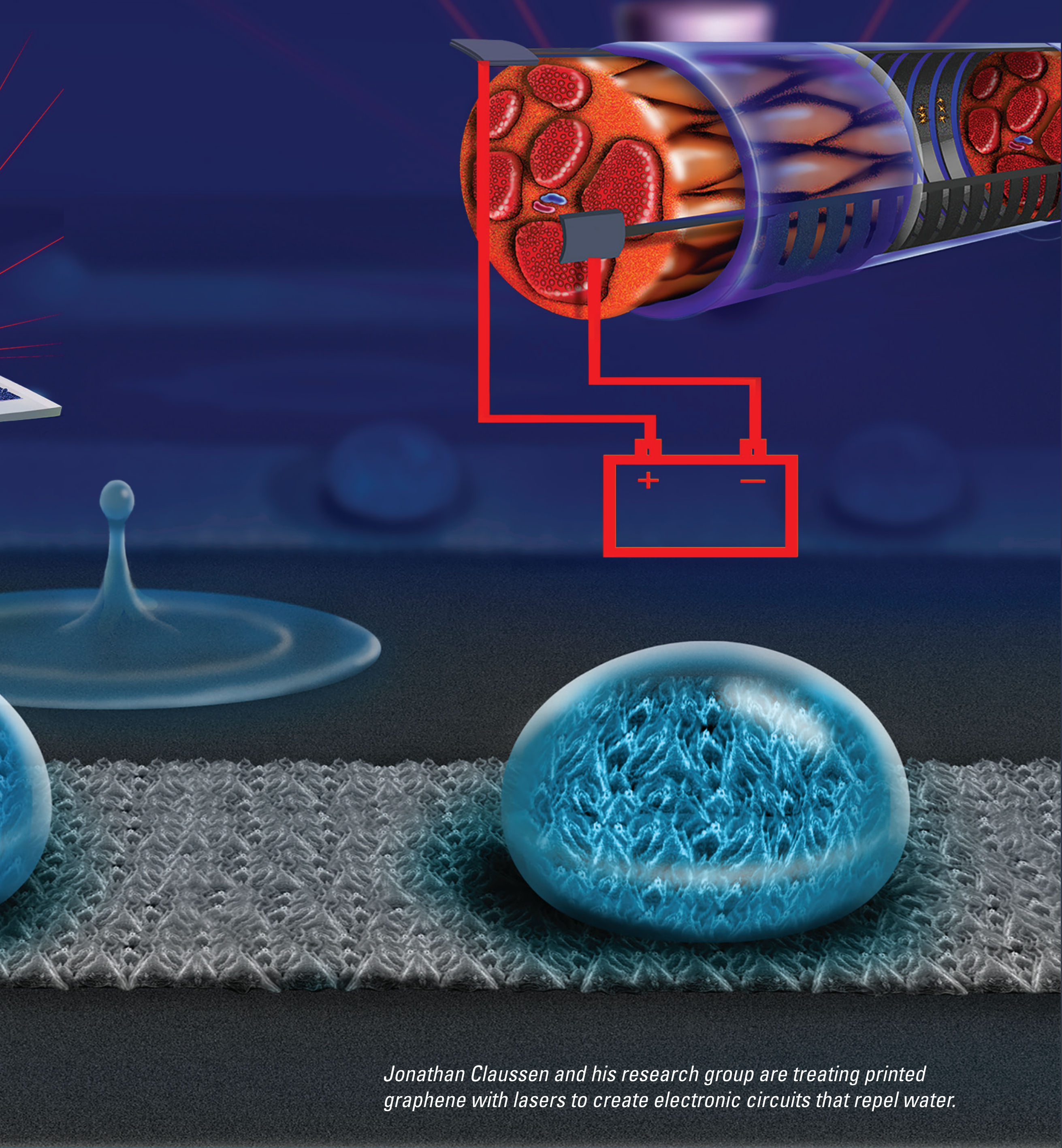
Additionally, the researchers have discovered how to take graphene-printed circuits that can hold water droplets and turn them into circuits that instead repels water.

The nanotechnology "would lend enormous value to self-clearing wearable/washable electronics that are resistant to stains, or ice and biofilm formation."

"One of the things we'd be interested in developing is anti-biofouling materials," said **Loreen Stromberg**, a postdoctoral research associate in mechanical engineering and for the Virtual Reality Applications Center. "This could eliminate the buildup of biological materials on the surface that would inhibit the optimal performance of devices such as chemical or biological sensors."

The research team included faculty, students, and other researchers from across the fields of mechanical engineering, agricultural and biosystems engineering, materials science, and chemistry from four different universities. The team is now working with the Ames-based startup NanoSpy Inc. to commercialize the technology.





Jonathan Claussen and his research group are treating printed graphene with lasers to create electronic circuits that repel water.

Virtual Reality Applications Center at the Intersection of Humans and Technology

Iowa State's Virtual Reality Applications Center is an interdisciplinary research center that includes a wide spectrum of experts with particular strengths in state-of-the-art interaction technologies, including virtual, augmented and mixed reality (VR/AR/MR), mobile computing, developmental robotics, and haptics interaction. VRAC researchers are also skilled at human-centered design and user experience (UX) evaluation as well as assessing the effectiveness of new interaction modalities via formal user studies.

VRAC is home to C6, a high-resolution immersive display environment, the Multimodal Experience Testbed (METaL) and Laboratory and the User Experience Lab (UX Lab).

VRAC established and now leads Iowa State's interdepartmental graduate major in Human Computer Interaction (HCI). With more than 200 students currently enrolled, the HCI program is now the largest interdepartmental graduate major at Iowa State and offers Ph.D. and master's degrees and professional certificates both on campus and online.

SAFETY SYSTEMS FOR AUTONOMOUS FLIGHT

Looking to the sky of the future, **Kristin Yvonne Rozier** sees Unmanned Aerial Systems (UAS) criss-crossing the horizon – and many new challenges for UAS safety and air traffic control. Rozier, an assistant professor of aerospace engineering, is developing new tools to help pilot-less aircraft safely fly themselves.

"Our goal is to create on-board systems that can analyze many different kinds of UAS data in real time. Is something broken, off-line, not responsive? We want to build in enough reasoning that the UAS can have self-awareness to make quick adjustments in air," said Rozier.

To get to an autonomous onboard system, first up is better techniques to accurately analyze the complex behaviors of UAS. Rozier and her team are creating new algorithms to enable formal methods evaluation specific to the needs and challenges of UAS.

"Our new approach will tie together data about UAS' design, flight and the air traffic control system. That will make it possible to take a step-by-step look at how UAS behave in a wide-ranging variety of scenarios. We really do need to answer the question 'How do you know this will be safe?' before UAS take flight," said Rozier.

Rozier plans the new tools to be scalable and efficient – and to integrate with the planned automated U.S. air traffic control system.

"UAS also prompt many questions about how we best regulate their use, and we hope that our research can help provide some answers and help create on-board technology to help show UAS are complying with regulations."

Rozier's work is funded by a NASA Early Career Faculty Award and a National Science Foundation CAREER award. Her team is also developing an open-source fixed-wing UAS kit so that other research groups and student organizations can more easily build and study UAS.

"We are creating a reconfigurable research test bed that is truly widely accessible. We are writing clear instructions for how to build it from inexpensive parts using common tools found in most labs," said Rozier.

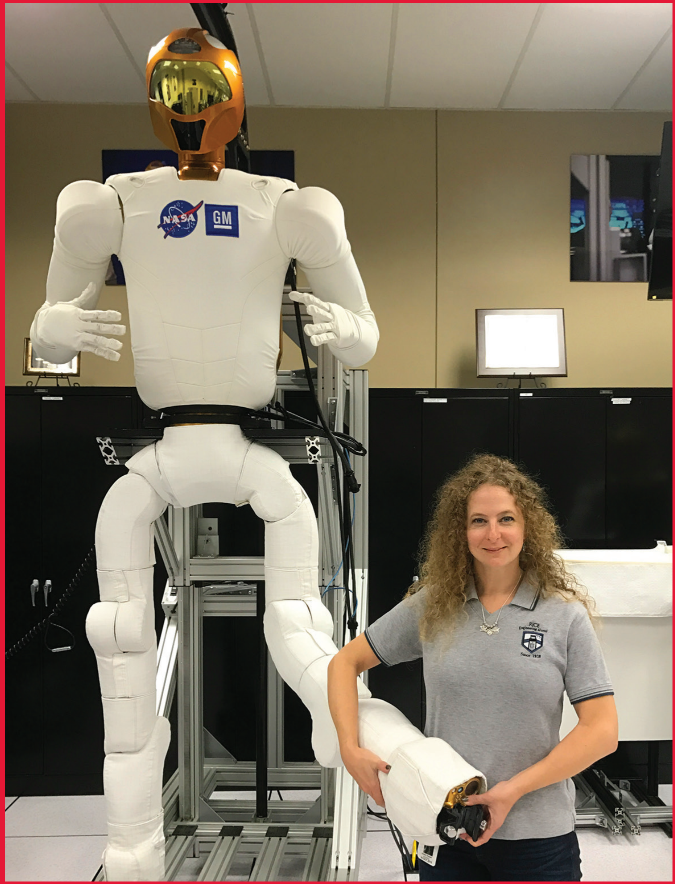
Putting UAS within reach of more engineers will increase the amount and breadth of fixed-wing safety research at a time when research is critically needed.

"Future technologies like UAS will make our lives better, but only if we make them as safe as possible," said Rozier.

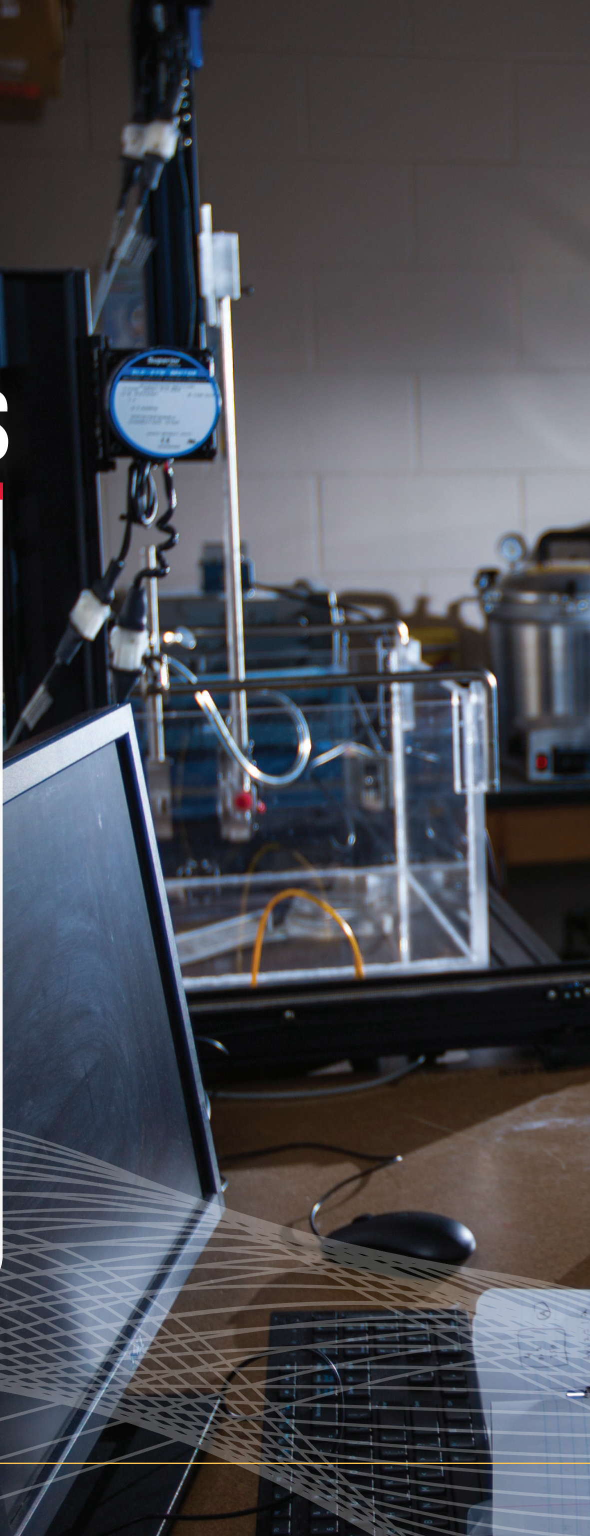
Autonomous space systems

In a NASA-funded project, **Kristin Yvonne Rozier** is optimizing the self-governance of autonomous systems for space missions. Rozier's research team is studying a joint from a NASA robot to develop an onboard system that monitors and diagnoses problems during autonomous system missions.

The framework, called R2U2, will continuously monitor sensors, software and hardware to detect trouble while meeting the challenges of working in real time, being flexible across many types of platforms, and strict requirements for size, weight and power.



NONINVASIVE TREATMENT OF MEDICAL IMPLANT INFECTIONS



Timothy Bigelow, an associate professor of mechanical engineering and electrical and computer engineering, is using high-intensity ultrasounds as a noninvasive way to treat infections that can grow on medical implants.

"Medical implant infections are uncommon, but when they do occur you have to have a second operation to remove the implant and replace it," Bigelow said.

Bigelow and his research team use high-intensity ultrasounds to destroy bacteria biofilm, which is a protective matrix that prevents antibiotics from being effective and can lead to the development of antibiotic-resistant strains of bacteria. The ultrasounds break down the bacteria and fragment the cells, all through the body wall, eliminating the need for an invasive surgery.

In a project funded by the National Institutes of Health, Bigelow is currently focused on hernia mesh repair. He plans to eventually work on more intensive procedures involving artificial heart valves and heart assist devices, which can be much more serious if an infection does occur. In addition to ultrasound therapy, Bigelow is also working to improve the diagnosis of medical conditions such as early-stage ovarian cancer.

Bigelow said that his research combines elements of both electrical and mechanical engineering.

"Ultrasound therapy is at the boundary of both electrical engineering and mechanical engineering," said Bigelow. "It requires an understanding of wave propagation, a critical part of electrical engineering, as well as an understanding of stress/strain and thermodynamics in order to understand how the waves are really interacting with the biological structures. Without both, designing safe and effective therapies would not be possible."

Timothy Bigelow, associate professor of mechanical engineering and electrical and computer engineering

Center for Nondestructive Evaluation Research to Ensure Safe Engineering Systems

Iowa State's Center for Nondestructive Evaluation is a national research leader in the development and application of inspection and sensing technologies. Over the Center for NDE's 30-year history, more than 100 companies have partnered on projects that help ensure the safe use of engineering systems ranging from offshore oil facilities, to bridges and roadways, to civilian and military planes.

Center for NDE engineers and scientists pioneered and commercialized simulation models for three major inspection methods – eddy current (ECSIM), ultrasonics (UTSIM) and radiography (XRSIM) – all of which are used widely in inspection optimization, detectability studies and training. Researchers have also made key discoveries in materials characterization of metals, ceramics and composites.

Center for NDE faculty are training the next generation of NDE experts through Iowa State's undergraduate NDE minor and an on-campus or online graduate NDE certificate.

IOWA STATE UNIVERSITY

Center for Nondestructive Evaluation

MAPPING PATHS TO PRODUCTIVE PLANTS

A computer network and a plant don't seem to have much in common at first glance. But when **Julie Dickerson** looks, she sees many similarities – and sees how her expertise in computing network science can help unravel complex biological systems.

"Mapping networks of how genes influence plant growth and development is key to increasing crop productivity to help feed a growing world population," says Dickerson, Northrop Grumman Professor in honor of Fred W. O'Green in electrical and computer engineering. "Bringing what we know about computing networks provides some methods to really examine the complicated genetic relationships."

However, using the data science we know works in human-built systems becomes more challenging when mother nature gets involved.

"Computer systems were designed for simplicity and efficiency, but nature comes up with things humans could have never thought of," says Dickerson. "Biological systems are really robust with a lot of redundancies, parallel pathways and even alternative pathways that lie dormant until just the right conditions are switched on."

The combination of increasingly large amounts of available genetic data and the simple "we don't know what we don't yet know" about biological systems makes network modeling challenging.

Dickerson is focusing on alternative genetic splicing in plants, or the process of gene expression where one gene code can yield multiple proteins. First observed several decades ago, alternative splicing was thought to be the exception to the gene expression rule, but new genome sequencing technologies have revealed alternative splicing is very common. And very complex.

"We keep developing better tests and sensors that gather detailed data about gene expression, and all of a sudden we can see things going on with the genome that we didn't know about before," said Dickerson. "We now have so much more information to build network models with – that's a challenge on its own. But we also know much mystery still remains, and we must model with that uncertainty – that's the really interesting challenge."

Dickerson and her team use machine learning to analyze huge genetic system data sets to make hypotheses about the flow of connections in gene expression. She also works closely with biologists who are experts in plant systems to help integrate their expertise into network models.

The ultimate goal is revealing the overarching governing principles of plants' genetic expression.

"Data and computing capability are both increasing, and as time resolution improves, we will be able to really see what's going on with genes and regulation" said Dickerson. "Understanding the network of gene expression is the first step to developing precise predictive breeding to improve plants' health and productivity."

Julie Dickerson, Northrop Grumman Professor in honor of Fred W. O'Green in electrical and computer engineering

Biologists + Engineers = New Approaches, New Solutions

Julie Dickerson is the principal investigator on a National Science Foundation Research Traineeship grant that brings together plant sciences, statistics and engineering to provide innovative training in a program called Predictive Plant Phenomics (P3).

"At Iowa State, we've done an excellent job marrying two of our longtime strengths: engineering and life sciences," said Dickerson. "This work in data-driven plant science is only possible because of the unique combination of expertise."

Co-principal investigators on the P3 NRT are **Ted Heindel**, Bergles Professor in Thermal Science in the Department of Mechanical Engineering; **Carolyn Lawrence-Dill**, associate professor of genetics, development and cell biology; and **Pat Schnable**, C.F. Curtiss Distinguished Professor in the Department of Agronomy and director of Iowa State's Plant Sciences Institute.

The program will train 28 graduate students to effectively integrate diverse data streams and approaches, including plant data collection and analysis, sensor development, high-throughput robot technology, and plant image analysis.

"Leading faculty from departments collaborate on our NRT," said Dickerson. "Our students are getting a one-of-a-kind education that will allow them to develop data-driven plant breeding and management improvements."

Predictive Plant Phenomics

CYBER EVERYWHERE:

NEW TOOLS TO OPTIMIZE AND SECURE THE INTERNET OF THINGS

Cyclone Engineers are developing new tools to optimize networking and secure information in our new world of mobile devices in every pocket, "smart homes," and remote sensors on everything from bridges to plants.

"Cyber is no longer just in our computers. It's now 'cyber everywhere,'" said **Daji Qiao**, associate professor of electrical and computer engineering. "That opens the door for these devices to make our lives easier – but it also presents never-seen-before problems for security."

Qiao is leading a National Science Foundation project to create a new type of test bed to better understand the behavior of the Internet of Things and advance IoT networking, performance and security.

The research team, which also includes **Doug Jacobson**, University Professor of electrical and computer engineering and director of Iowa State's Information Assurance Center; **Yong Guan**, associate professor of electrical and computer engineering; and **George Amariucai**, associate professor of computer science at Kansas State University, plans a scalable, hybrid research "sandbox" so researchers can try out new IoT strategies.

First, the team will build a small, lab-based physical IoT network of devices ranging from simple to sophisticated and capture devices' and network behavior. Next, they will build a larger, more complex IoT network on campus. Last, they'll work to integrate the physical IoT networks with a virtual network, built on Jacobson's ISEAGE environment.

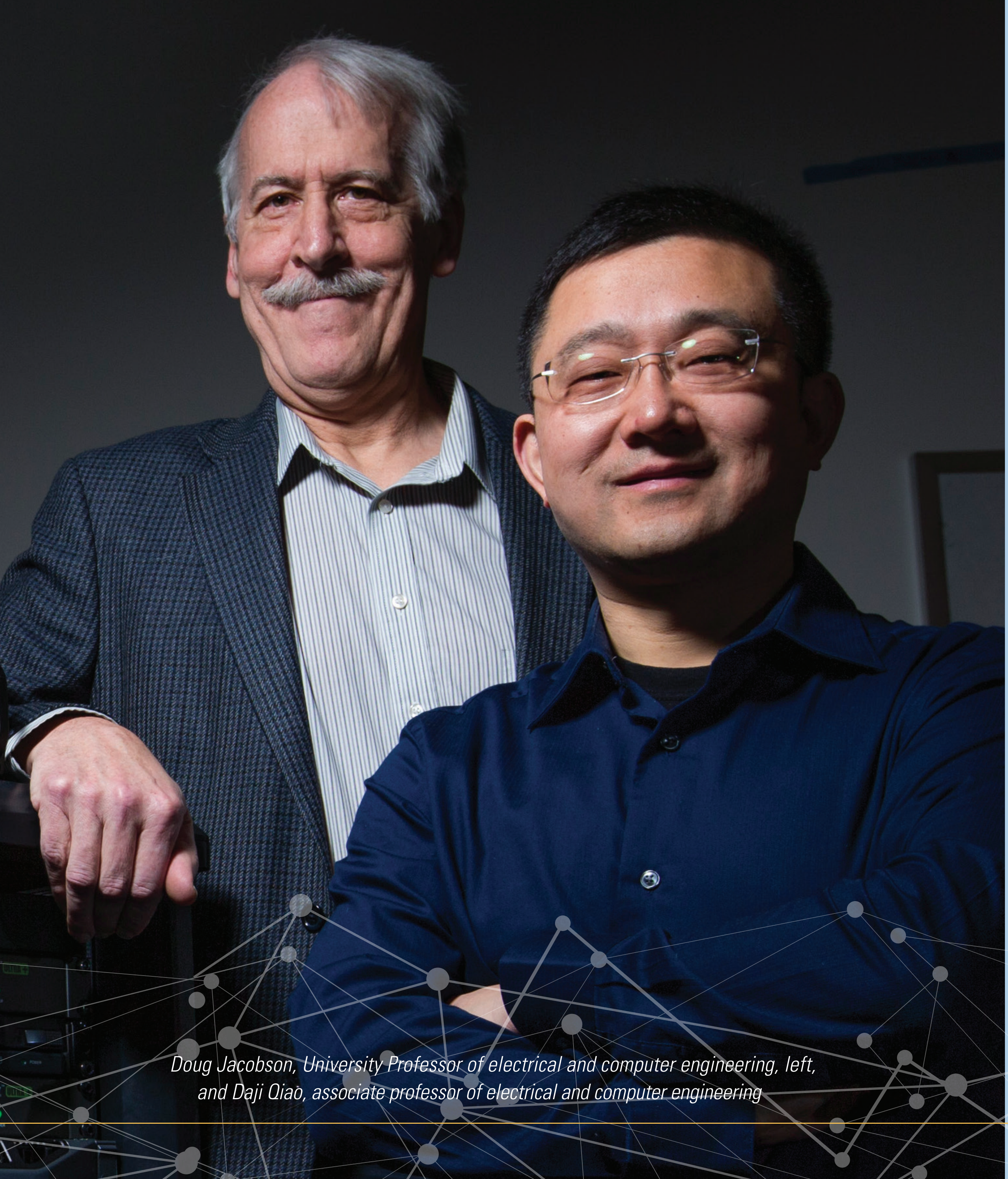
ISEAGE is a unique, open-source internet emulator that was created so researchers could run and study controlled cyberattacks without actually causing any cyber damage.

"Just like in experimenting with internet attacks, we simply cannot build a physical replica of the IoT network large enough to give us an accurate picture," said Jacobson. "ISEAGE offers a platform to add large-scale virtualization – and it's a great fit for extending to the IoT."

The hybrid virtualized test bed, called IoT Event Emulation Environment or $IoTE^3$, will be made available to researchers across the nation to run their own experiments. And as more and more new physical IoT devices are added to the system, the size and the realism of $IoTE^3$ will grow and grow.

"The virtualization network will be the bridge between all the physical networks. It will continue to monitor what happens and feed that into its virtual simulator," said Qiao. "As we see changes in the IoT, we will continually update and upgrade to better reflect real life."

ISEAGE
Internet-Scale Event and Attack Generation Environment



Doug Jacobson, University Professor of electrical and computer engineering, left, and Daji Qiao, associate professor of electrical and computer engineering

Information Assurance Center: Research, Teaching, Outreach

Iowa State's Information Assurance Center is a nationally recognized leader in information assurance research, teaching and outreach.

The IAC is one of the oldest and largest information assurance groups in the country, earning a charter designation as a Center of Excellence by the National Security Agency. Interdisciplinary research efforts range from network modeling to data mining to identity theft.

"More than 40 faculty from diverse areas of expertise come together in the IAC to work on the big challenges to securing computers, network, things and people," said **Doug Jacobson**, IAC director and University Professor of electrical and computer engineering. "Our research is world class, but we couple that with education and outreach to increase our impact."

Since the mid-90s, IAC faculty have trained new generations of information assurance researchers in their laboratories. And more recently, the IAC launched Iowa Cyber Alliance, the nation's first statewide program to provide cyber security outreach and education to government agencies, businesses and all Iowa citizens.

INFORMATION ASSURANCE CENTER

NEWS BITES

SEVEN 2018 NSF CAREER AWARDS

So far in 2018, seven Cyclone Engineers have been selected for National Science Foundation Faculty Early Career Development (CAREER) awards:

Alice Alipour, civil, construction and environmental engineering: Resiliency of Electric Power Networks under Wind Loads and Aging Effects through Risk-Informed Design and Assessment Strategies

Chinmay Hegde, electrical and computer engineering: Advances in Graph Learning and Inference

Shan Hu, mechanical engineering: Advances in Graph Learning and Inference

Juan Ren, mechanical engineering: Dynamics and Control-Based Approaches to Cellular Mechanotransduction Manipulation

Adarsh Krishnamurthy, mechanical engineering: GPU-Accelerated Framework for Integrated Modeling and Biomechanics Simulations of Cardiac Systems

Neil Gong, electrical and computer engineering: Graph-based Security Analytics: New Algorithms, Robustness under Adversarial Settings, and Robustness Enhancements

Zengyi Shao, chemical and biological engineering: Exploring Nucleosome-Depleted Sequences for Novel Applications in Synthetic Biology

VIRTUAL GLIMPSE OF NEW MISSISSIPPI RIVER BRIDGE

Nir Keren, associate professor of agricultural and biosystems engineering, designed a virtual reality simulation of the new I-74 Mississippi River Bridge under construction between Davenport, Iowa, and Moline, Illinois.

The simulation, which will be made available to the public, will show drivers what it will be like to drive across the new bridge, alongside the current bridge. Users can compare the scale and usability of the two structures, drive as motorists from one end of the bridge to the other, and switch through various modes, viewing the new bridge from many vantage points.

"Every time you think of construction on this scale, it's easy to lose sight of what it's going to look like at the end," Keren said. "But if you can actually see the end product, that keeps people excited."

The project was a partnership between the Iowa Department of Transportation, Iowa State's Virtual Reality Applications Center and Iowa State's Institute for Transportation.

SIMULATOR HELPS MARINES MAKE HURRICANE DECISIONS

Cameron MacKenzie, assistant professor of industrial and manufacturing systems engineering, developed a web-based Hurricane Decision Simulator to enable U.S. Marine Forces Reserve commanders to make informed and timely decisions in the face of hurricane warnings.

The Hurricane Decision Simulator gives Marine Forces Reserve personnel practice in making shelter and evacuation decisions in the context of many different types of realistic simulated storms and forecasts. The simulator gives decision-makers a chance to better understand relationships between forecasts and decisions, so that when a real hurricane threatens, commanders will make better decisions based on their practice with the simulator.

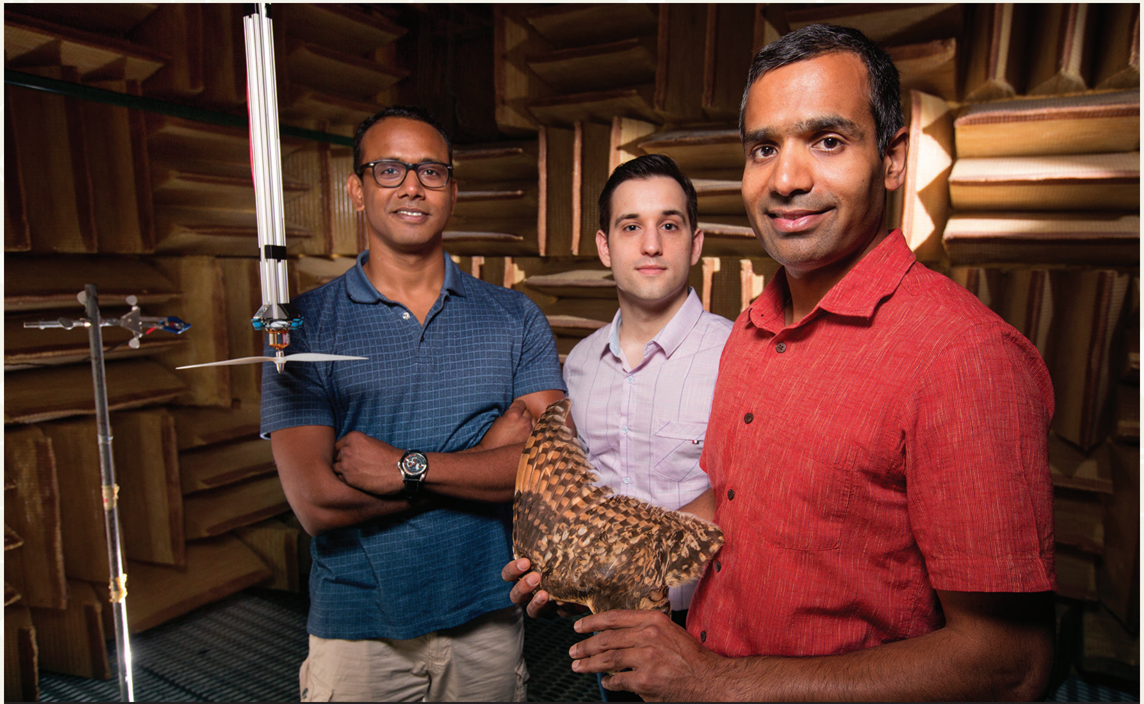
MacKenzie worked with **Eva D. Regnier**, associate professor at the Naval Postgraduate School, on the simulator. MacKenzie and Regnier's paper on their work was a finalist for the 2017 Manufacturing & Service Operations Management Practice-Based Competition and a finalist for the 2017 Public Sector and Operations Research Paper Competition for the Institute for Operations Research and the Management Sciences.

See more of Cameron MacKenzie's Hurricane Decision Simulator at
www.engineering.iastate.edu/video-extras

QUIETER AIRCRAFT INSPIRED BY OWL WINGS

Anupam Sharma, assistant professor of aerospace engineering and Walter W. Wilson Faculty Fellow, is running high-powered computer simulations to learn exactly how owl wings manipulate air flow, pressure and turbulence to create silent flight. He and his research team aim to produce practical ideas for making ultraquiet aircraft and wind turbines.

"Our approach is bio-inspired as opposed to bio-mimicry. Our designs won't look like owl wings. We're studying the physical mechanisms behind the owl's silent flight. Then we're taking simplified geometries inspired by the owl wings and applying those to aircraft wings, rotor blades of jet engines and wind turbines," said Sharma.



***Anupam Sharma**, right, and aerospace engineering graduate students **Andrew Bodling** and **Bharat Raj Agrawal** are studying how owl wings produce silent flight.*

DRIVING BUS SYSTEMS TO GO ELECTRIC

Mechanical engineering student **Ryan Saunders** spent a semester studying the feasibility of electrifying CyRide, Iowa State's and the City of Ames' shared bus system.

He worked closely with mechanical engineering lecturer **Howard Shapiro** and the electric bus manufacturer Proterra to examine potential emissions reductions and cost benefits of switching to electric buses. Saunders' proposal led CyRide to begin analyzing the feasibility of converting some bus routes in Ames to electric buses.

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SOLAR UTILITY VEHICLE

Iowa State's solar car racing team, PrISUm, created a new kind of electric-solar car: one with room for the family, trunk space for groceries, and a deluxe infotainment system.

PrISUm raced its "solar utility vehicle" across Australia in the Bridgestone World Solar Challenge, showing the world that a vehicle of the future can be both super-efficient and a super-comfortable ride.

Photo courtesy of Team PrISUm.