IOWA STATE UNIVERSITY
College of Engineering

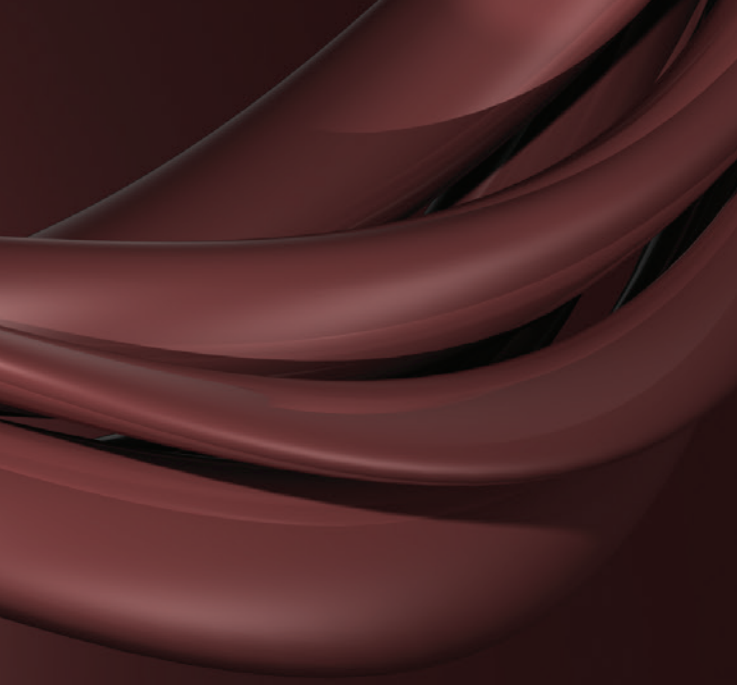
CYCLONE ENGINEERING RESEARCH

FALL 2019

Machine learning speeds up heart-valve simulations

Improving disinfection, protecting public health

Prebiotics for health from the inside



On the cover:
Cyclone Engineers combine strengths in multiscale biomaterials, biosensors and medical devices, functional imaging, bioinformatics, biomechanics, drug delivery and nanovaccines, cellular engineering and human factors engineering to improve health and quality of life worldwide. Just one example: We're harnessing machine learning to take on the challenge of creating personalized medical implants (read more on page 4).

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James L. and Katherine S. Melsa Dean of Engineering

Arun K. Somani
Associate Dean for Research
Anson Marston Distinguished Professor
Philip and Virginia Sproul Professor

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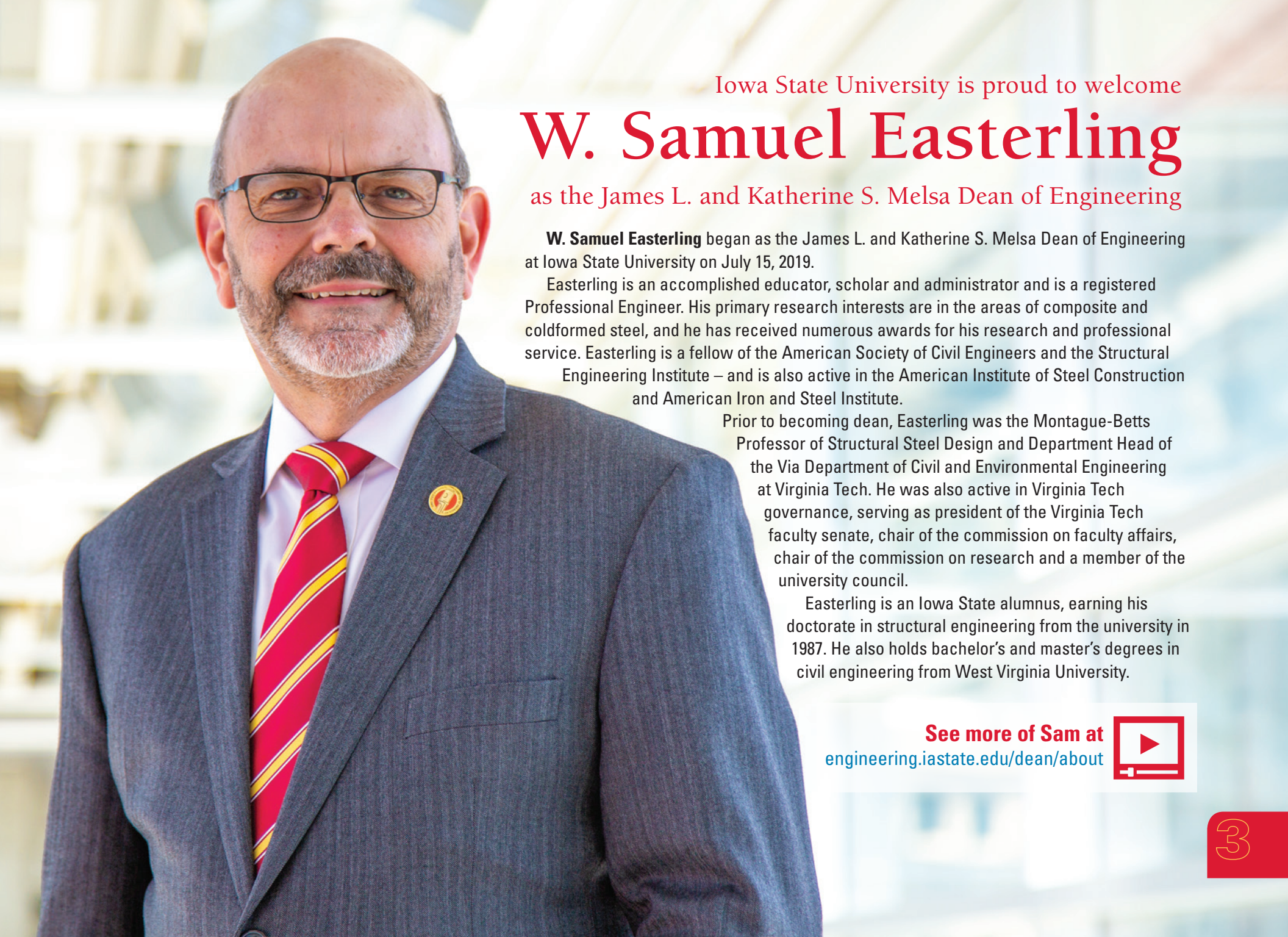


Iowa State University is proud to welcome

W. Samuel Easterling

as the James L. and Katherine S. Melsa Dean of Engineering

W. Samuel Easterling began as the James L. and Katherine S. Melsa Dean of Engineering at Iowa State University on July 15, 2019.

Easterling is an accomplished educator, scholar and administrator and is a registered Professional Engineer. His primary research interests are in the areas of composite and coldformed steel, and he has received numerous awards for his research and professional service. Easterling is a fellow of the American Society of Civil Engineers and the Structural Engineering Institute – and is also active in the American Institute of Steel Construction and American Iron and Steel Institute.

Prior to becoming dean, Easterling was the Montague-Betts Professor of Structural Steel Design and Department Head of the Via Department of Civil and Environmental Engineering at Virginia Tech. He was also active in Virginia Tech governance, serving as president of the Virginia Tech faculty senate, chair of the commission on faculty affairs, chair of the commission on research and a member of the university council.

Easterling is an Iowa State alumnus, earning his doctorate in structural engineering from the university in 1987. He also holds bachelor's and master's degrees in civil engineering from West Virginia University.

See more of Sam at
engineering.iastate.edu/dean/about

IN A HEARTBEAT:

Machine learning speeds up heart-valve simulations

Adarsh Krishnamurthy (pictured, left) and **Ming-Chen Hsu** (center) got to talking about their research interests – Krishnamurthy works in simulating cardiac mechanics and Hsu in simulating valve dynamics – when they had an idea.

"He had the heart without the valve, and I had the valve without the heart," Hsu said. "We thought 'why don't we just put them together?'"

Modeling heart-valve replacements

Modeling heart valves and the mechanics of the fluid moving through the heart chambers can be used to predict deformations and diseases that affect the valves. Simulations can also add a virtual prosthetic replacement valve to examine its effectiveness.

Replacing valves can be a very risky procedure for patients with valvular heart disease, so knowing as much as possible ahead of time about how a prosthetic valve will help a specific patient with specific circumstances will save money and lives.

But one simulation of heart-valve movement (dynamic closure and opening) takes about four-and-a-half hours to complete, and one simulation of fluid movement (with fluid-structure interaction) through a valve takes about one week. In addition, development of a coupled fluid-structure interaction model with accurate movement of the ventricles is complicated, and this can take years.

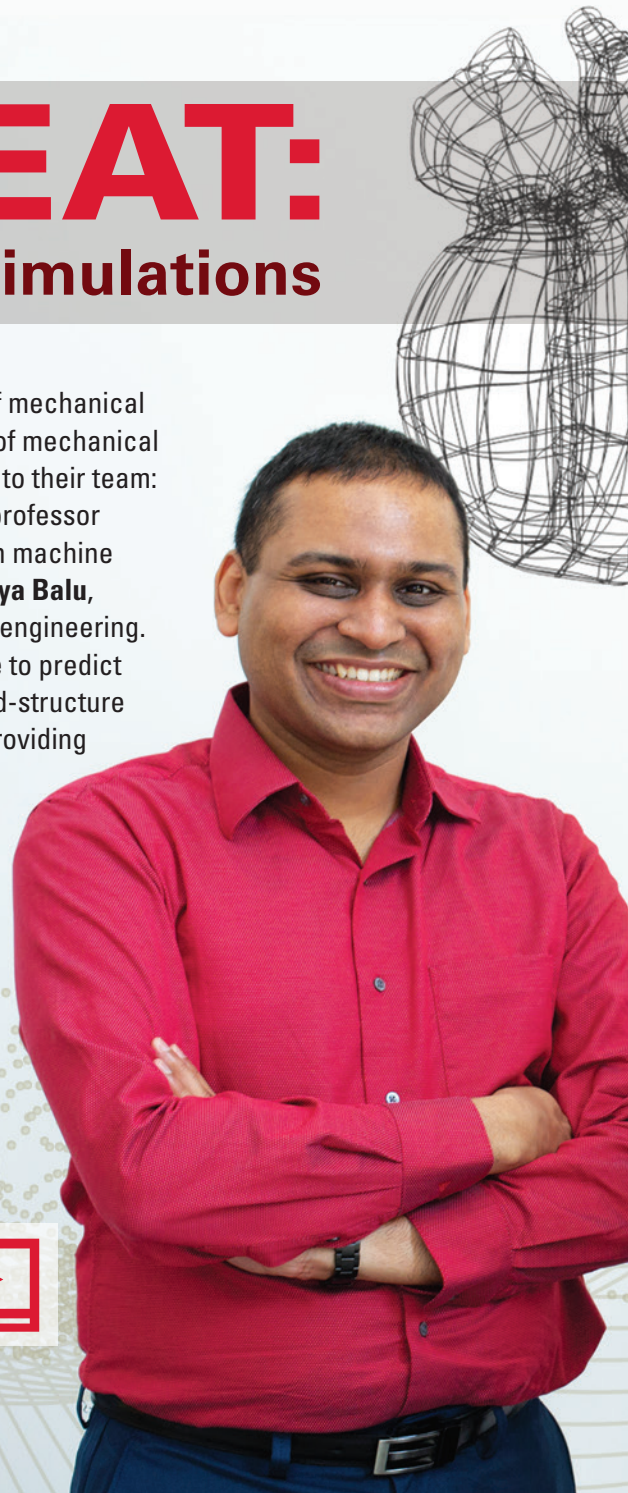
From years to minutes

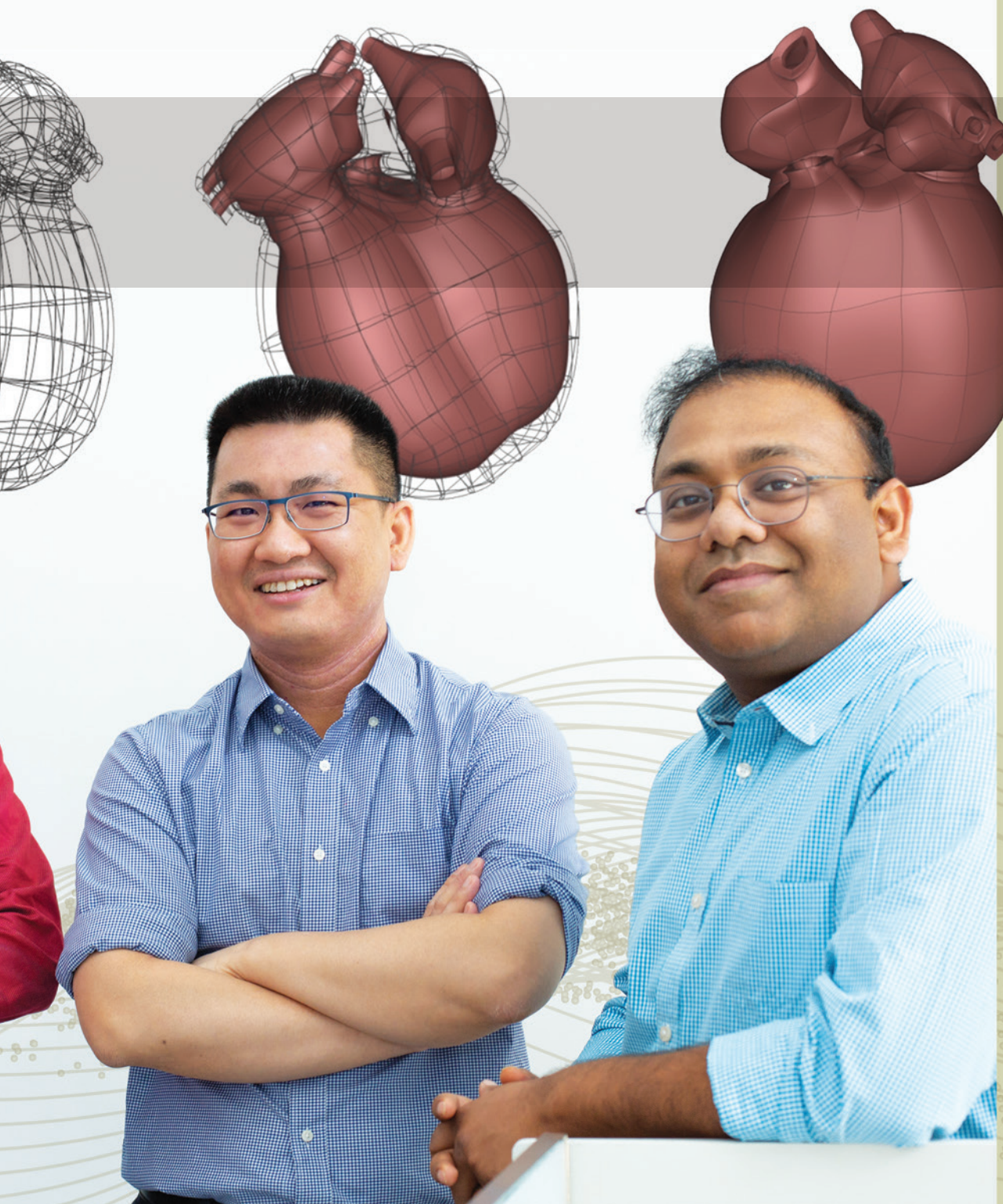
So Krishnamurthy, assistant professor of mechanical engineering, and Hsu, associate professor of mechanical engineering, knew who they needed to add to their team: **Soumik Sarkar** (pictured, right), associate professor of mechanical engineering, and an expert in machine learning. They also enlisted the help of **Aditya Balu**, graduate research assistant in mechanical engineering.

The team now hopes to teach a machine to predict heart valve simulations and, eventually, fluid-structure interaction simulations of heart valves by providing enough data and simulations to learn from. Their initial tests of machine learning have produced predictions that are 95% accurate according to the actual physics simulations that are run.

The potential with machine learning is simulations that normally take hours or days could be predicted by a machine within a matter of seconds. The long-term goal is to design custom-created heart valves unique to a patient's anatomy and health problems.

See more of the simulations at
engineering.iastate.edu/heartbeat





New **Center for Multiphase Flow Research and Education**

Iowa State's College of Engineering has launched the Center for Multiphase Flow Research and Education (CoMFRE).

The mission of CoMFRE is to integrate the activities and expertise of multiphase research leaders, broaden the impact of multiphase flow research, conduct unique and high-risk research, become an intellectual resource for government and industry, serve the needs of stakeholders and develop a skilled workforce.

Iowa State has a critical mass of CoMFRE-affiliated faculty working in this area using a variety of theoretical, computational and experimental resources.

"Multiphase flows are ubiquitous. They are found in our bodies, in our homes and in our environment. Having several disciplines represented in CoMFRE just shows the breadth of multiphase flow applications and activity at Iowa State," said **Ted Heindel**, CoMFRE director and Bergles Professor of Thermal Science in the mechanical engineering department.

CoMFRE

Center for Multiphase Flow Research and Education

SOMETHING IN THE WATER:

Improving disinfection to protect public health

Kaoru Ikuma (pictured, right), assistant professor in civil, construction and environmental engineering, is bringing clarity – clear, clean drinking water and clear answers – to environmental microbiology questions about water quality. She and her team are researching drinking water and waterbodies to improve public health protection.

Drinking water disinfection

Ikuma and her team are studying how pathogens in drinking water respond to chemical treatments. Conventional disinfection methods have for many years relied on chemical processes, and while methods typically work well, less is understood about cases when disinfection falters.

Ikuma is examining the biological reactions that chemical treatments cause.

"We understand the chemistry a lot better than the biology," Ikuma said. "We are relying on the chemistry to work for every biological scenario. That's where that gap exists, and I'm trying to fill that in."

By using transcriptomics, Ikuma examines transcription of DNA to RNA to figure out whether the bacteria would be killed by chemicals – or just knocked down but capable of fighting back.

Add to the challenge that some bacteria are already resistant to chemicals or can become resistant. For example, E. coli can become resistant to chlorine in very controlled environments.

"We are coming to a point where we have to change disinfection," Ikuma said. "The time is now to understand the biological reactions of pathogens better, so with the next generation of chemicals, we can make the best choices to ensure healthy drinking water."

Antibiotic resistance in waterways

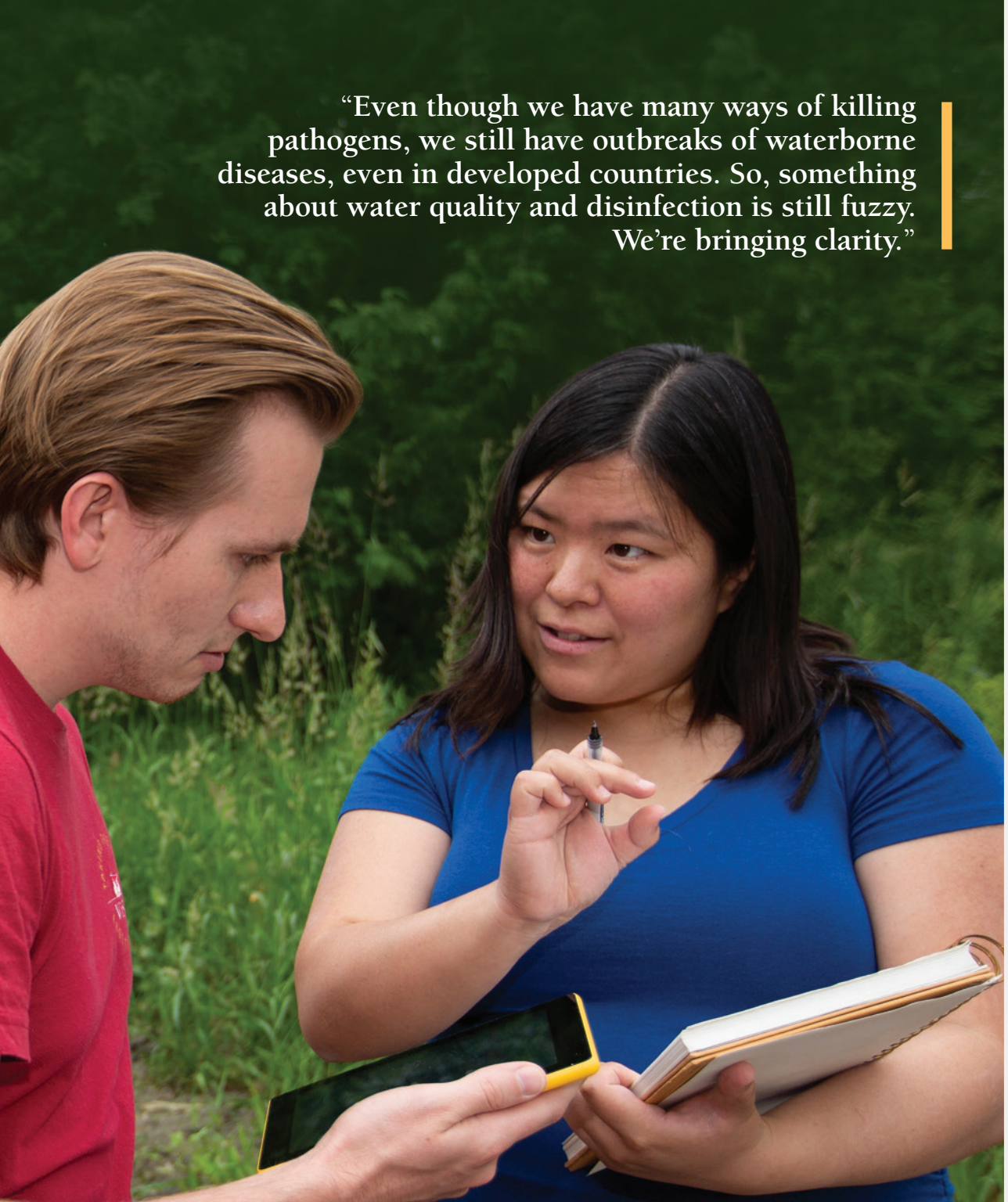
How concerned should we be about the spread of antimicrobial resistance from wastewater discharge? Ikuma's team is following the stream of AMR into our waterways.

AMR starts in the gut of humans and animals, so the natural next stop is wastewater treatment plants. At treatment plants, wastewater is cleaned, disinfected and then released into rivers and lakes.

Ikuma's team is investigating the behavior of AMR pathogens when they enter bodies of water. Disinfecting water kills bacteria, but AMR-coded DNA is capable of traveling on beyond host bacteria. AMR DNA could be transferring to other bacteria by horizontal gene transfer or being transported in water by simple absorption on particles.

Ikuma has been taking samples from the Skunk River outside Ames, Iowa, and examining studies of the Mississippi River to help shed light on AMR transfer in the environment.

"My main thing here is to say, does that extracellular DNA floating around matter? Because if it does, we need to really rethink disinfection of wastewater," Ikuma said.



Leading the fight against antimicrobial resistance

Iowa State University leads a national center taking on the global public health concern of antimicrobial resistance.

The National Institute for Antimicrobial Resistance Research and Education (NIAMRRE) brings together expertise in nearly every college at Iowa State with AMR researchers, educators, clinicians and extension personnel from across the nation. NIAMRRE will help build strong, collaborative research and educational programs that improve health for people, animals and the environment.

NIAMRRE’s goals include cultivating networks and resources to drive the national AMR research priorities, building effective teams, enhancing competitiveness of research teams seeking AMR grants and advocating for continued funding for AMR research.

Paul Plummer, Iowa State associate professor of veterinary diagnostic and production animal medicine, serves as executive director of NIAMRRE.

“Antimicrobial resistance touches each of us in our daily lives. This new institute provides a great resource for the entire country as we work to build strong, collaborative research and educational programs to mitigate this risk,” Plummer said.

NIAMRRE

2019 NSF CAREER

Three Iowa State University Cyclone Engineers have been selected for the 2019 National Science Foundation's Faculty Early Career Development Program (CAREER).

CAREER awards are the NSF's most prestigious awards given to early-career faculty. The program aims to build a firm foundation for leadership in integrating research and education.

"Our 2019 CAREER projects well represent Cyclone Engineers' innovative research – and commitment to excellent engineering education – that will help address society's grand challenges," said **Arun Somani**, associate dean for research. "The 2019 CAREER awards join 11 other active CAREER awards at the College of Engineering."

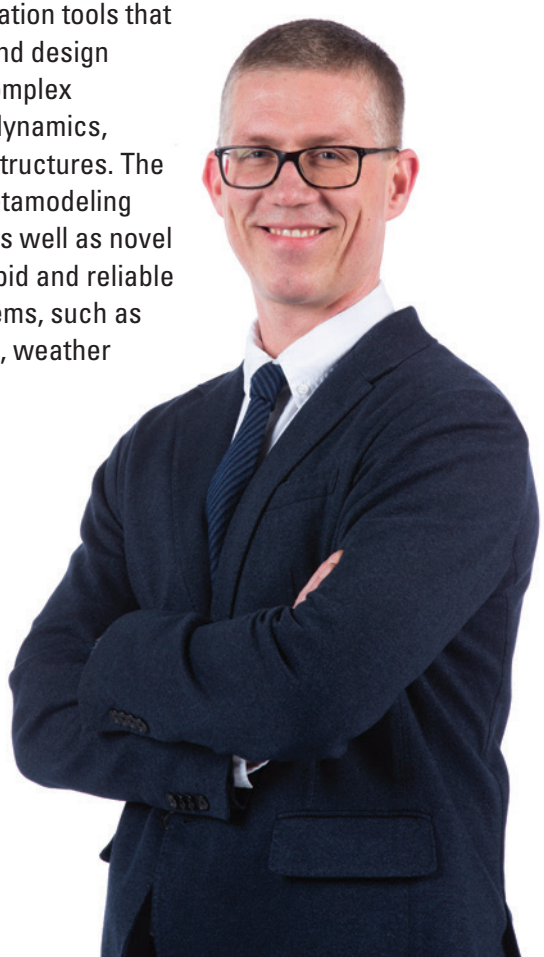
Leifur Leifsson

assistant professor of aerospace engineering

Multifidelity Modeling and Search Using Adaptive Field Prediction

Leifsson will create new computation tools that will enhance uncertainty analysis and design optimization under uncertainty in complex engineering systems, such as aerodynamics, electromagnetics and mechanical structures. The advanced methods will combine metamodeling techniques and machine learning, as well as novel adaptation techniques – offering rapid and reliable design of complex engineered systems, such as in transportation, energy harvesting, weather forecasting and communication.

Leifsson will also create a new undergraduate short course and organize a symposium on computational design – and will launch an online hub to make his advanced simulation-based design techniques available to other engineers across the country.



Award Winners

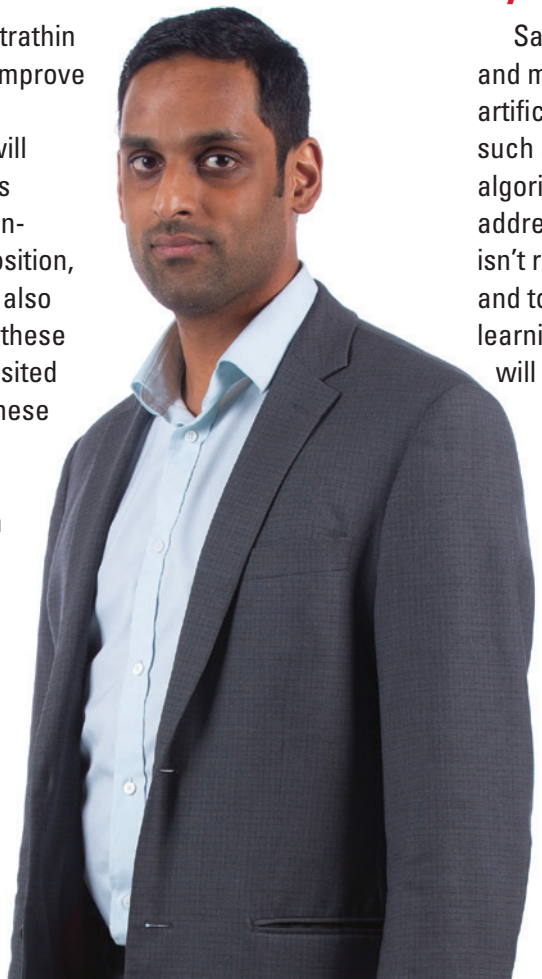
Matthew Panthani

assistant professor of chemical and biological engineering

Synthesis and Properties of Group IV Colloidal Quantum Wells

Panthani will develop new types of ultrathin semiconductor materials that may help improve the capabilities, efficiency and costs of computing and telecommunication. He will use novel materials synthesis techniques to create single- to few-atom thick silicon-germanium alloys with controlled composition, structure and surface chemistry. He will also coordinate molecules to the surfaces of these 2-D semiconductors, which can be deposited onto substrates to improve processing these materials into electronic devices.

Panthani will also partner with high school teachers to incorporate research lab experiences into their curricula and implement a workshop designed to encourage underrepresented groups to pursue STEM careers.



Soumik Sarkar

associate professor of mechanical engineering

Robustifying Machine Learning for Cyber-Physical Systems

Sarkar will build computational techniques to detect and mitigate risk in using machine learning and artificial intelligence for cyber-physical systems, such as self-driving cars. His framework and algorithms will help deep-learning models better address "edge cases" where the real-life situation isn't represented well in the training data set – and to fend off adversarial attacks on machine-learning-based decision systems. Algorithms will be validated on experimental self-driving cars and robotics test beds.

Sarkar will also develop new curricula, research experiences and other outreach activities for high school students and teachers in the critical interdisciplinary areas of system theory and data science.

Engineering health at the breakfast table

When mom said "breakfast is the most important meal of the day," she couldn't have imagined what Cyclone Engineer **Tom Mansell** has cooking.

Mansell is creating new probiotics and prebiotics that will treat disease as you eat your morning cup of yogurt.

Recent research has revealed that the complex ecosystem of our gut bacteria has a big impact on human health, playing a role in diseases ranging from cancer to depression.

"We know what a 'bad' microbiome can do to us. I'm working on how we can tip the scale with good bacteria to improve health," said Mansell, assistant professor of chemical and biological engineering.

Mansell's approach is inspired by carbohydrates found in human milk that have a single function: feeding bacteria in a baby's gut. If these natural prebiotics evolved just to feed a specific probiotic, perhaps more unique prebiotic-probiotic pairings can be engineered in the lab.

But processing these complex carbohydrates is an equally complex challenge. Basic building-block and synthetic chemistry aren't efficient options. Instead, Mansell's team uses enzymes, encoding them with DNA that tune metabolic pathways to generate specific prebiotics of interest.

"To keep costs down, we build on inexpensive ingredients of glycerol and lactose, but that makes for a lot of knobs to turn to refine the enzyme processing technique."

So Mansell's team created a biosensor to quickly and precisely gauge the results of specific processing conditions, speeding up process optimization.

Now the eye is on scale-up, studying how well prebiotic-fed probiotics thrive in organoid "mini guts" with fellow Cyclone Engineering researcher **Qun Wang**, and in animal models with **Mike Wannemuehler**, professor and chair of veterinary microbiology and preventative medicine in the College of Veterinary Medicine.

When probiotics grow strong on a steady diet of custom-paired prebiotics, they can be engineered to add disease-fighting capabilities.

"Probiotics may someday be able to make the drugs right in the gut, providing a pain-free way to deliver protein-based drugs that now require injections, to deliver anti-inflammatory agents or to secrete antimicrobial peptides to cure infection," said Mansell.

Raj Raman, Morrill Professor of agricultural and biosystems engineering, sees the purpose of any university as creating new knowledge and building human capital. In his research to improve engineering education, Raman does both.

Open doors, engaging instruction

"Iowa State opens our doors to a wide array of students, and most first-year students are taking a big step up, learning a new way to understand and work. We know that a significant fraction of our students will struggle to make this shift. So, if we are to fulfill our role, we can't just open the doors, we need to help first-year students succeed with specialized support.

"Some people will say 'well, you can't make everyone stay.' And I agree. If students find a better fit, that's a good thing. But when students leave because they don't feel welcomed or instructors aren't explaining why they need to learn concepts, that's something instructors can do something about. We need to do the work to make first-year classes more accessible and motivating.

"I've studied why students leave engineering programs. Turns out when you have non-engaging teaching going on, you lose students – and these aren't necessarily students who lack the academic background to succeed. "

Technology to humanize

"I use what I call hybrid-flipped classrooms. We talk through the last homework assignment at the beginning of class. I hold in-class office hours and schedule one-on-one meetings with students to answer questions and check in personally on their progress. I use self-paced video lectures to give more opportunity for one-on-one support. I want to leverage technology to humanize the learning process."

Mentoring science with practice

"Hands-on research experiences are really only as good as the mentoring students get in the lab. Working with colleagues in the School of Education, I examined REU participants' perceptions of mentoring. Students value mentors that are present, proactive and prepared. We now have evidence-backed training for graduate student mentors."

Prepared professionals

"P.E. licensure is important, and we wanted more of our students to take the Fundamentals of Engineering exam. So, my colleague, agricultural and biosystems engineering professor **Steve Hoff**, and I co-developed and co-teach a formal F.E. review class. This year, we've already seen 44 out of 50 students pass the exam."

AUTONOMOUS FLIGHT:
BUILDING TOMORROW'S AIR TRAFFIC CONTROL

From taxicabs of yesterday to rideshares of today to…autonomous personal aircraft of tomorrow? To see the future of getting around congested urban areas, look up in the air.

Peng Wei, assistant professor of aerospace engineering, is developing air traffic management systems to make Urban Air Mobility (UAM) a safe, efficient and scalable reality.

"UAM will make large cities feel small, with quick rides across town in autonomous, electric vertical-takeoff-and-landing aircraft," said Wei. "The potential of UAM comes with big operational challenges, though, that can only be solved using sophisticated methods from control, optimization, artificial intelligence and machine learning."

Peng Wei, assistant professor of aerospace engineering

Wei's team is creating algorithms and models for UAM operations from takeoff to touchdown:

- Arrival management models schedule landings based on both promised arrival times and how much battery power each UAM aircraft has left – and will help design the most energy-efficient arrival trajectories.
- Collision avoidance seeks to mimic the human intelligence of people walking in a crowded room without bumping into each other. Algorithms will provide flight-path-prediction capability to avoid crashes.
- Autonomous air traffic control combines centralized intelligence on the ground with distributed intelligence in the air for maximum UAM capacity and safety.
- Airspace management balances demand with available airspace and flightpaths to answer key questions about how many UAM aircraft can take off at a time, from where and for how long, given the variable conditions of weather and available electric battery on each aircraft.
- Fleet dispatch tools will optimize UAM dispatch, so companies can do precise and efficient scheduling of their fleet. Models will also integrate passenger and cargo uses for UAM.

Wei's UAM operations models are built using industry-provided data sets and tested in both open-source computer simulations and controlled experimental simulations in an unmanned aerial vehicle lab on campus.

"UAM models are incredibly complex. Proving to people that something as never-done-before as UAM is safe and reliable will take a lot of careful, incremental validation and working closely with government officials to write operations policy," said Wei.

UNDER PRESSURE:

Adaptive earth-bound training for zero-gravity emergencies

As spaceflight reaches farther and farther from a call to Mission Control, astronauts will need to be ready to independently take on emergency situations.

Michael Dorneich, associate professor of industrial and manufacturing engineering, is developing adaptive virtual training that prepares astronauts for both situation response – and the stress that goes along with the emergencies.

The training offers virtual practice handling in-flight scenarios, for instance putting out a fire, while monitoring the astronaut's individual stress responses, based on physiological measures such as heart rate and galvanic skin response.

Then, based on the astronaut's individual response levels, the system automatically adapts the training conditions to ensure training happens at increasingly higher target levels of stress. Not enough stress: Add in some flashing lights and smoke. Too much stress: Dial down the noise level.

"Each person's response to stressors is different – and may even vary in the same person depending on the day," said Dorneich. "We are using human factors engineering to customize stress training to most effectively inoculate astronauts from their unique stress responses. It's adaptive, dynamic training to prepare astronauts to think clearly and act quickly during in-space emergencies."

AGRICULTURAL AND BIOSYSTEMS ENGINEERING BACK TO NO. 1

The graduate program in agricultural and biosystems engineering at Iowa State is again ranked No. 1 in U.S. News and World Report magazine's latest rankings of graduate programs.

"I give a lot of the credit to our new facilities and also to the new research facilities we're developing at the BioCentury Research Farm, the Agricultural Engineering/Agronomy Research Farm and the new Feed Mill and Grain Science Complex that will be going up," said **Steven Mickelson**, department chair and the Charles R. and Jane F. Olsen Professor in Engineering.

LEADING RESEARCH

Eliot Winer, professor of mechanical engineering, has been named director of the Virtual Reality Applications Center. VRAC's world-class research infrastructure supports interdisciplinary research in virtual, augmented and mixed reality – as well as mobile computing, development robotics, haptics interaction and user experience.

Namrata Vaswani, professor of electrical and computer engineering, **Paul Durbin**, professor of aerospace engineering, and **Baskar Ganapathysubramanian**, professor of mechanical engineering, have been appointed to Joseph and Elizabeth Anderlik Professorships in Engineering. The Anderlik professorship will make possible new areas of research and teaching in emerging fields of study.

WINNING WITH WIND

Iowa State's CyWind team took home the top project development award and placed fifth overall at the 2019 U.S. Department of Energy's Collegiate Wind Competition.

The team, led by **Sri Sritharan**, interim associate dean for strategic initiatives, professor of civil, construction and environmental engineering and the Wilkinson Chair in the College of Engineering, received real-world experience to prepare them for wind energy egineering.

PROTECTING OUR LIFELINES

Flooding is a when, not an if, in the Midwest, so **Alice Alipour**, assistant professor of civil, construction and environmental engineering, is working with the Iowa Department of Transportation to better protect the "lifelines" of our roads and bridges.

Alipour's research team seeks to understand the adverse effects of floods on built infrastructure, propose mitigation strategies and create plans for possible failures so that the disruption to the transportation system is minimized.

STRENGTH IN NUMBERS

Jocelyn Jackson, a graduate student in mechanical engineering, is the new national chair for the National Society of Black Engineers. Jackson's goal as national chair is accomplishing NSBE's current strategic plan: graduating 10,000 black engineers annually in the U.S. by 2025.

"I wouldn't be an engineer if it weren't for NSBE because I was ready to give up. So I want to give back to the organization and pay it forward," Jackson said.

NEW MAJOR, LONGSTANDING LEADERSHIP IN CYBER SECURITY

Iowa State launches a new cyber security engineering major this fall, the first offered in the state.

While the major is new, Iowa State has been teaching and researching cyber security since 1995, making it one of the oldest programs in the country. Iowa State was one of just seven universities initially designated as part of the National Security Agency's Centers of Academic Excellence in 1999.

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Cyclone Engineer **Shan Jiang** is making pioneering discoveries about the self-assembly of Janus particles, which have a unique two-surface structure that enables two different interactions to happen on one particle. Jiang's work lays the groundwork for using Janus particles in biomedication, disease diagnosis, coatings and sensors.