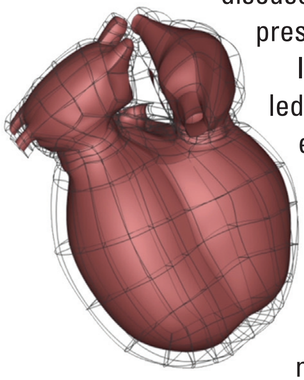
Iowa State University
College of Engineering

CYCLONE ENGINEERING RESEARCH

FALL 2021

Personalized sensors for one-of-a-kind health monitoring



New low-cost, personalized, and ultra-soft structured sensors will make possible unique tissue sensing modalities to help treat illnesses from cardiovascular disease to COVID complications to pressure wounds.

In a $2 million project, a team led by Iowa State mechanical engineering faculty **Baskar Ganapathysubramanian**, **Soumik Sarkar** and **Adarsh Krishnamurthy** are using computational and machine-learning models to develop novel biocompatible materials that are matched to human tissues for personalized sensing. They also plan to improve the 3D printing sensor manufacturing process to include real-time control – ensuring more effective materials and tailored sensors that are designed in convergence.

Read more about how Cyclone Engineers are harnessing AI to solve tough engineering challenges on page 4.

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W. Samuel Easterling
James L. and Katherine S. Melsa Dean of Engineering

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Connie Hargrave appointed associate dean for equity and engagement

Connie Hargrave has been named the first associate dean for equity and engagement in the Iowa State University College of Engineering.

"While this position is new, it will leverage our already strong commitment to equity in the college," said **W. Samuel Easterling**, James L. and Katherine S. Melsa Dean of Engineering. "As the college's chief diversity, equity and inclusion officer, Dr. Hargrave will have the opportunity to develop and lead a significant expansion of these efforts."

Hargrave has had a 20-year career at Iowa State, including serving as a faculty member in the Center for Technology in Learning and Teaching; director of Science Bound; director of graduate education in the Department of Curriculum Instruction; and coordinator of education programs at the U.S. Department of Energy's Ames Laboratory.

Hargrave holds a master's degree from the University of Northern Iowa and a doctorate in curriculum and instructional technology from Iowa State.

She has served in three fellowships during her career and received 80 grants and contracts to design, develop, execute and study research-based STEM education outreach impacting more than 47,000 students and 350 educators.

"Dr. Hargrave's combined academic and professional experience related to diversity, inclusion and recruiting students into STEM disciplines give her multiple unique skills to help us advance our mission of educating future engineering students and serving the communities where we live," Easterling said.

A.I. for Breakthrough

NSF AI Research Institute: Using digital twins to multiply crop production

A new $20 million National AI Research Institute led by Iowa State will use the latest artificial intelligence tools to develop digital twins of individual crop plants and entire farm fields. The discoveries will help plant breeders improve crop varieties and farmers boost production.

The Cyclone Engineers behind a new artificial intelligence research institute say their work can accelerate the productivity and sustainability of agriculture at a time when the world's population is increasing, cropland is decreasing and the climate is changing.

The National Science Foundation and the U.S. Department of Agriculture's National Institute of Food and Agriculture are supporting the five-year grant to establish an AI Institute for Resilient Agriculture (AIIRA).

Baskar Ganapathysubramanian
Joseph C. and Elizabeth A. Anderlik Professor in Engineering

Productive partnerships

Baskar Ganapathysubramanian, the Joseph C. and Elizabeth A. Anderlik Professor in Engineering, will lead AIIRA. It will include collaborators from across Iowa State, Carnegie Mellon University, the New York University Tandon School of Engineering, the University of Arizona, the University of Nebraska-Lincoln, George Mason University, the University of Missouri and the Iowa Soybean Association.

The institute also includes collaborators from the tech and agriculture industries, governments, commodity groups and other organizations.

"These are problems that can't be answered by any individual," Ganapathysubramanian said. "We need engineers, data scientists, plant scientists, social scientists, farmers, educators and entrepreneurs. AIIRA will bring all this expertise together."

Deploy the twin

AIIRA researchers will continuously feed real-time data from sensors from plants and fields – including weather data, soil measurements of water and nitrogen, soil and topography maps, ground and drone-based imaging and satellite information – to predictive digital twins.

In addition, the digital twins will be loaded with the latest understanding of plant growth and development.

The digital twin will be a functional, virtual representation of a real system, which can be used to run various what-if scenarios and make decisions in the virtual world. The results can then be applied to decisions in the real world.

Investments that grow

The AIIRA team aims to, like an investment portfolio, find the right mix of plant varieties and management practices to produce the best crop – all virtually.

And with an eye on the future, they say the approach could pay big dividends and make the power of AI available to many students, scientists, business leaders and farmers: More efficient plant breeding for changing environments, optimized planting and fertilization decision-making, research-based policy making, new ag management products, and even increased rural entrepreneurship in the area of AI.

Innovations

Ultra-precise agriculture, down to the single plant

Rather than tending fields by the hundreds of acres, farmers could one day tend each and every plant with the help of machine learning, robots and other technologies. A five-year, $7 million grant from the National Science Foundation and the U.S. Department of Agriculture's National Institute of Food and Agriculture will help a team led by Cyclone Engineers develop such a cyber-physical system.

Soumik Sarkar
Walter W. Wilson Faculty Fellow in Engineering

The research team, headed up by **Soumik Sarkar**, Walter W. Wilson Faculty Fellow in Engineering and an associate professor of mechanical engineering, is applying and integrating layers of technologies – including sensors, machine learning, artificial intelligence, high-throughput phenotyping platforms such as drones and small-scale rolling robots that can also fertilize, weed and cull single plants in a field – with the ultimate goal of replacing farmers' reliance on heavy machinery and broadcast spraying in operations of all sizes.

Sarkar says the project, called COntext Aware LEarning for Sustainable CybEr-agricultural systems or COALESCE, will go beyond precision agriculture to ultra-precision agriculture, where ag producers can, for instance, localize crop problems early on and make decisions and start controls before troubles spread.

COALESCE project members come from Iowa State, University of Illinois Urbana-Champaign, George Mason University, the Iowa Soybean Association, Ohio State University and University of Arizona.

Photo by Ashlyn Rairdin and courtesy of Soumik Sarkar/Iowa State University.

WIRELESS LIVING LAB

At-scale, real-world broadband testbed for connected rural communities

Iowa State is building a wireless "living lab" in central Iowa, laying the foundation for more affordable rural broadband service.

The project will create a research testbed for a wide range of wireless technologies across Iowa State's campus, the city of Ames and surrounding farms and rural communities in central Iowa – with an application focus on precision agriculture as well as on rural education.

"This is what Iowa State University's land-grant mission is all about – bringing to bear our research and innovation to meet the needs of Iowans," said Iowa State University President **Wendy Wintersteen**. "Rural broadband has become an essential need. Iowa State is very excited to work with our partners to develop affordable wireless technologies that will help connect and create opportunities for families, schools, farms and communities across the state."

Hongwei Zhang, professor of electrical and computer engineering, and other researchers installed hardware at the Iowa State University Research Park for an advanced wireless networking system that's a predecessor to the new ARA rural broadband project.

With a coverage area of hundreds of square miles of rural communities, the ARA Wireless Living Lab serves as an at-scale, real-world infrastructure for rural wireless research.

Hongwei Zhang, a professor of electrical and computer engineering, leads the project.

"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," Hongwei 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 ARA Living Lab includes unique wireless platforms such as low-UHF massive MIMO and mmWave wireless access, as well as long-distance free-space optical backhaul and low-earth-orbit (LEO) satellite communications. ARA employs both software-defined-radio (SDR) and programmable commercial-off-the-shelf (COTS) platforms, effectively leveraging open-source wireless software platforms such as OpenAirInterface, srsRAN and SD-RAN.

Funding includes $7 million from the National Science Foundation and $1 million from United States Department of Agriculture's National Institute of Food and Agriculture. The funding will be augmented by in-kind contributions from the Platforms for Advanced Wireless Research (PAWR) Industry Consortium to match the federal investment.

State, community and industry partners

Iowa Communications Network (ICN), Iowa Department of Transportation (IDOT), Iowa Statewide Interoperable Communications System (ISICS), Iowa Regional Utilities Association (IRUA), Iowa Communications Alliance, the City of Ames, Story County, local school districts, the Meskwaki Nation, Woodland Farms, U.S. Cellular, Collins Aerospace, and John Deere. Researchers from the University of California – Irvine, Ohio State University and International Computer Science Institute are also key members of the project team.

Extending rural STEM workforce with extended-reality education

Eliot Winer, professor of mechanical engineering and director of Iowa State's Virtual Reality Applications Center, leads an interdisciplinary team developing extended-reality STEM education to strengthen the rural workforce.

The team will pilot XR-enabled activities and simulations not easily accessible in the physical world, particularly in rural areas. Approaches will be co-designed with citizens of Storm Lake, Iowa – all with a long-term vision of sparking interest in STEM careers ranging from welding certificates to advanced degrees in engineering.

"It's not just about putting the technology itself in rural areas, but it's also about using that technology in a strategic and effective way to deliver educational content in these communities that are critical to the well-being of the country," said Winer.

The pilot study team, supported by the NSF, includes researchers from engineering, educational technology, industrial design, architecture, 4-H Youth Development, among others.

More than the sum of its parts

***Pete Collins**, Al and Julie Renken Professor in Materials Science and Engineering, explains how Iowa State leads interdisciplinary additive manufacturing research*

Additive manufacturing (AM) holds the promise of transforming nearly every way that materials and components are conceived, designed, produced and used in service.

The possibilities and expected innovations are numerous, and their realization requires a truly multidisciplinary cadre of researchers.

Here at Iowa State, researchers are at the forefront of additive manufacturing, conducting leading research on: the design of new materials and additive manufacturing precursors; the manufacturing processes themselves; and the tools necessary to realize a vision where the materials state itself is known for every part produced – and its performance guaranteed.

New Materials

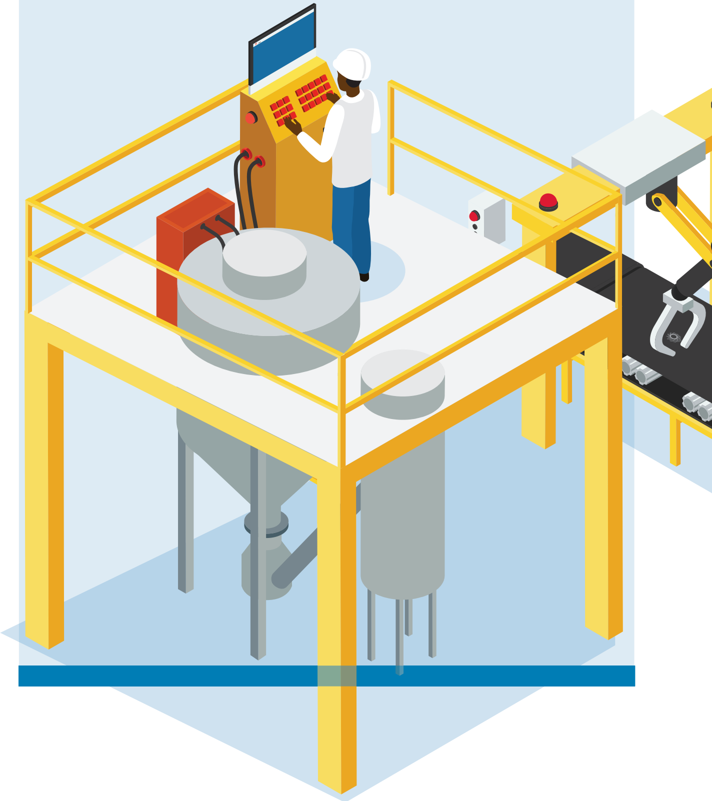
The microstructure of advanced materials "remembers" the localized thermal and mechanical histories. Additive manufacturing provides exciting new ways to radically change these histories, entering into process spaces that are not possible using any existing manufacturing techniques, making new materials possible.

Iowa State materials engineers are developing new ways of modeling and simulating the interplay between alloy composition, processing parameters – and the resulting predictions of microstructure, properties and performance are changing the way we design advanced materials.

Advanced Alloy Powders

The U.S. Department of Energy's Ames Laboratory, located on the Iowa State campus, has a long tradition of excellence in processing important AM precursors, most commonly powder.

We have experts in modeling and simulation of the atomization process to help drive our process efficiency improvements (triple current industry yields) and in creating powder of the highest quality – including understanding the basic science associated with designing powder surface chemistries – to control the consolidated microstructure and properties that delivers high performance in final additively manufactured components.



Manufacturing Process

State-of-the-art AM goes hand-in-hand with hybrid manufacturing, which involves multiple manufacturing processes integrated with AM, along with multiple material components.

Both hybrid manufacturing and the manufacture of hybrid materials requires a very sophisticated understanding of the science of the manufacturing process itself. At Iowa State, we are developing the next generation of digital and physical tools to plan, predict and control the manufacturing process in order to achieve complex-shaped, high-performance components.

Nondestructive Evaluation

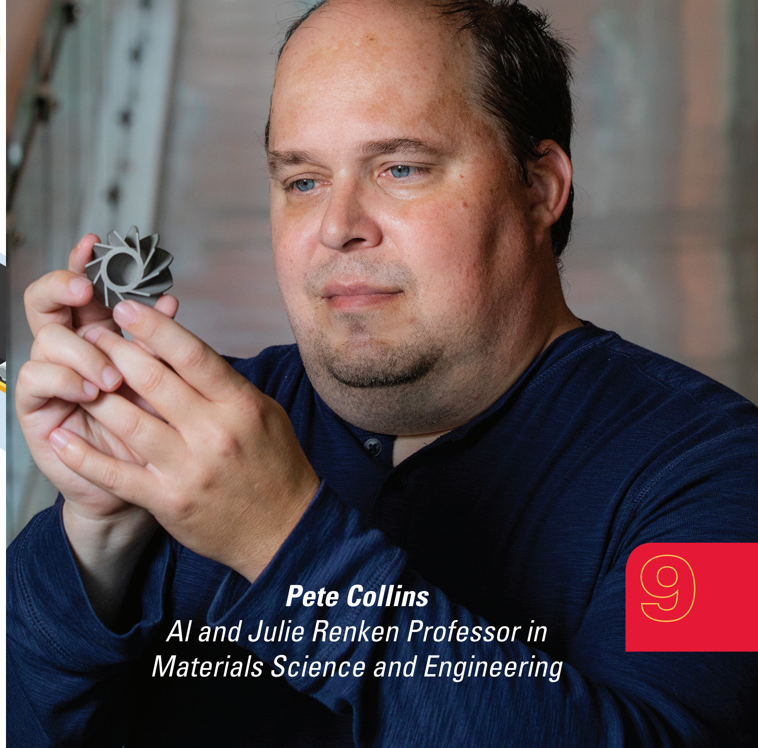
Application of nondestructive evaluation techniques is what provides the confidence to not only place additive manufactured parts into service but also remove parts from service.

Additive manufacturing enables increasingly sophisticated shapes and increasingly novel hybrid materials to be designed for extreme environments. So, researchers at Iowa State's Center for Nondestructive Evaluation are developing new physical, measurement and data analysis tools to determine the materials state of additively manufactured materials, both post- and, even better, during their manufacture.

What's Next

These Iowa State specialties are part of a larger, interdisciplinary team that has a vision to realize the multiple promises of additive manufacturing.

Better materials for more demanding applications. Generatively designed structures with spatially engineered hybrid materials. Ensuring that the quality of every part manufactured is unparalleled by engineering, controlling, and verifying the materials state. Redefining cyber security and enabling the digital thread. These possibilities, along with the training that we are providing to our students and engagement with various partners, are making for an stimulating time at Iowa State.



Pete Collins
Al and Julie Renken Professor in Materials Science and Engineering

Powerhouse of the cell, key to new treatments

Mitochondrial DNA manipulation offers insights into related diseases

If you remember just one thing from high-school biology, it's that the mitochondria are the powerhouses of the cell. But could mitochondria also hold the key to gene therapy and new tailored drug development for diseases and disorders?

Zengyi Shao, Vernon Guse Faculty Fellow and associate professor of chemical and biological engineering, and her team are developing a comprehensive mitochondrial genetic toolkit in a new project funded by the National Institutes of Health.

The toolkit will be used to untangle the complex nature of mitochondrial genetics and the impact mitochondrial DNA (mtDNA) mutations have on health disorders like type 2 diabetes, cancers and neurological disorders.

Model yeast mirrors human energy generation

Drawing on previous research on tailoring microbial platforms for specific purposes, Shao and **Deon Ploessl**, a Ph.D. student and National Science Foundation fellow in chemical and biological engineering, first plan to develop a new model yeast system to gain insights on mtDNA dysfunctions and how those connect to diseases.

"The previously well-studied model yeast is too dissimilar to human physiology, so we need a new option. We aim to establish a simple testbed that more closely mirrors human energy generation and offers practicality in terms of cost and timescale of genetic manipulations," said Shao.

Bringing CRISPR to mtDNA

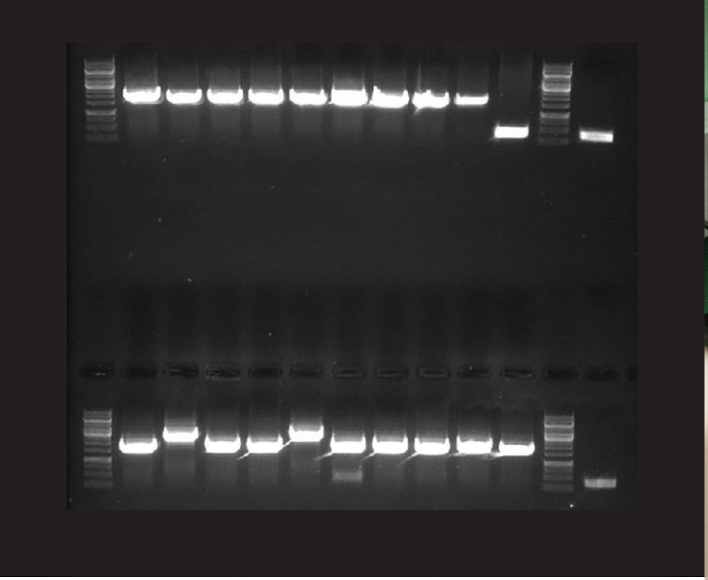
The lack of an extensive mtDNA manipulation toolkit represents a major challenge in investigating the role of mtDNA and its mutations in eukaryotes, including humans.

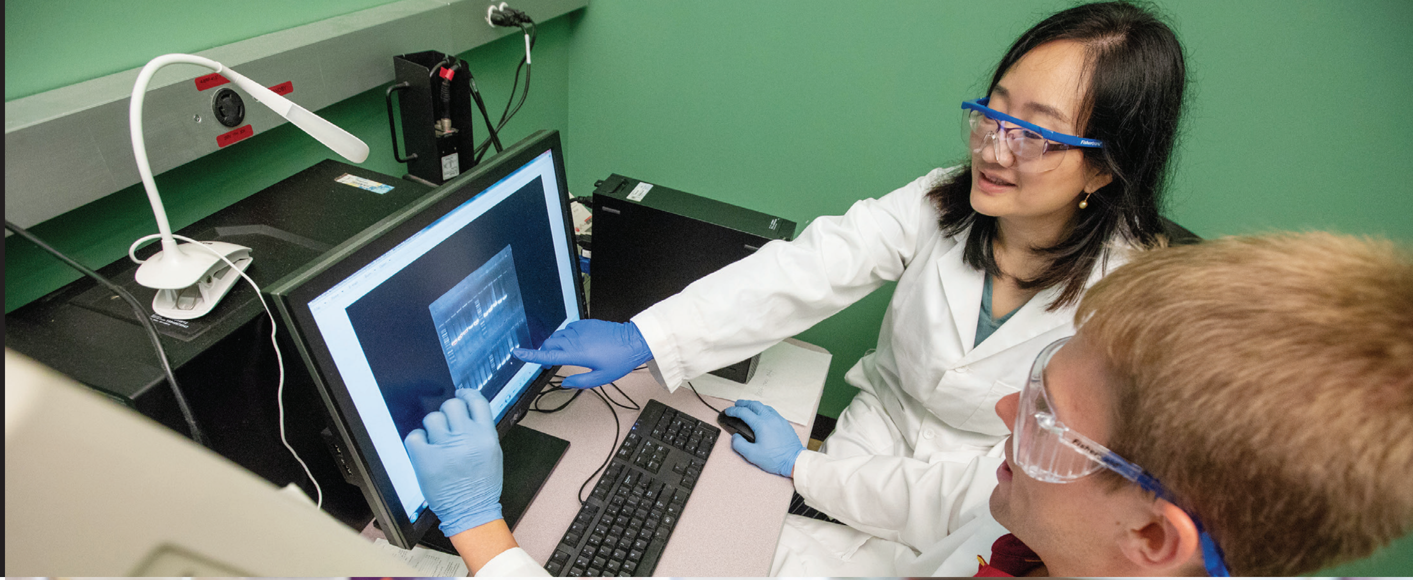
"Our work aims to follow the development path of the CRISPR technology, which is currently capable of effectively editing nuclear DNA. We hope that labs can easily edit mtDNA in the same manner they edit nuclear DNA. This ability holds exciting potential across many disciplines," said Ploessl.

Tailored treatments, broad applications

Shao's team will use the genetic mtDNA toolkit to study specific mtDNA-associated diseases, such as obesity-related human illnesses. They plan to zero in on how modulating fluidity of inner mitochondrial membranes might change mitochondrial physiology, offering new customized drug development possibilities.

And the potential for mtDNA editing reaches far beyond biomedical applications to many other areas, such as agriculture.

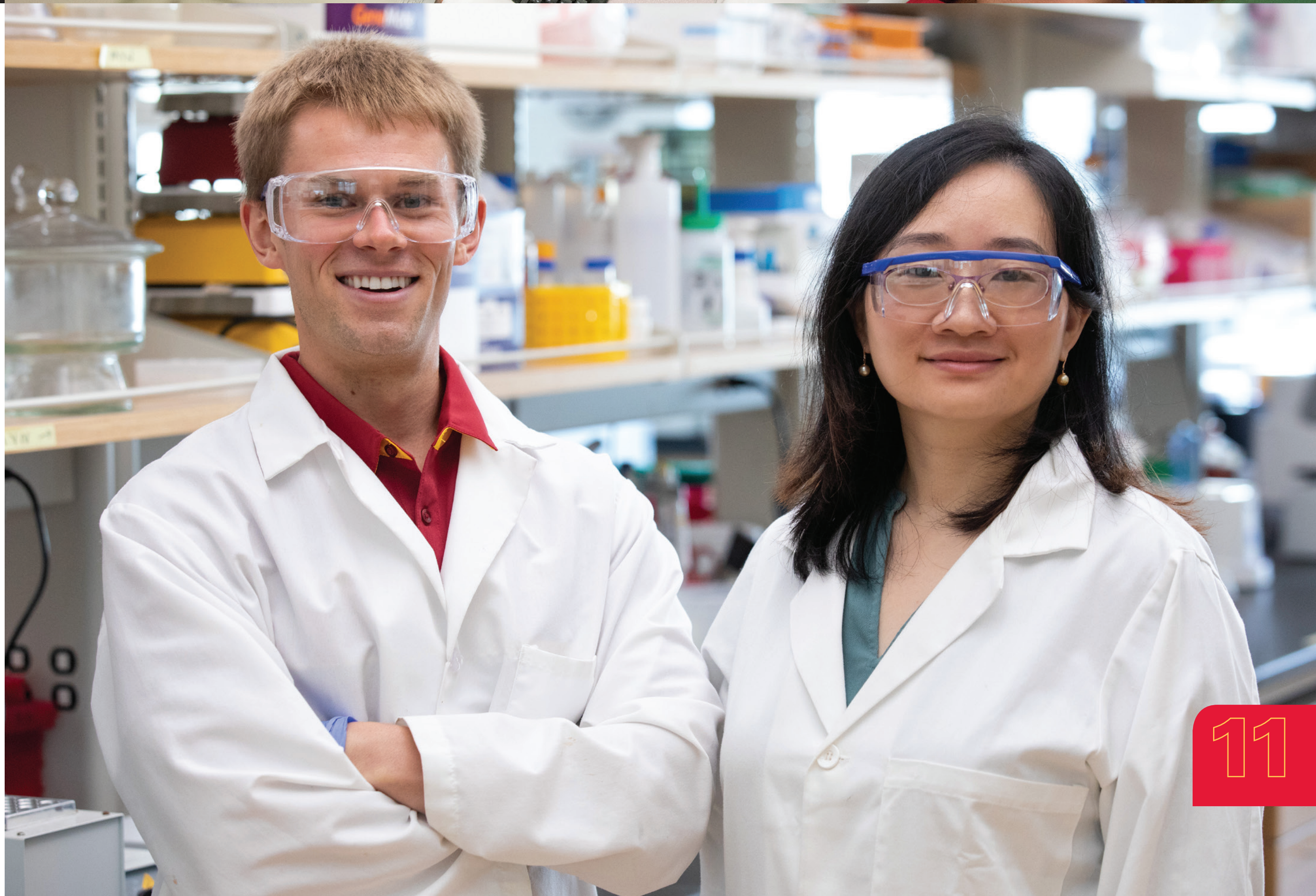




“The possible avenues made accessible by an extensive mitochondrial manipulation toolkit seem limited only by one’s ingenuity. For example, producing livestock with increased body weights using the same amounts of feed. The strategies developed for mitochondrial manipulation could also mediate similar issues faced in chloroplast DNA engineering, potentially enhancing plant photosynthesis and biomass yields,” said Shao.

TOP LEFT & TOP RIGHT: DNA electrophoresis for confirming correct genome editing. The research team looks to bring CRISPR-like editing to mitochondrial DNA.

RIGHT: **Zengyi Shao**, Vernon Guse Faculty Fellow and associate professor, pictured right, with **Deon Ploessl**, Ph.D. student and National Science Foundation fellow.



NIGEL REUEL

associate professor of chemical and biological engineering

Biomanufacturing better treatments

PROBLEM:

Therapeutic cells show promise as a new treatment option for chronic illness, but advances must be made in manufacturing reproducibility to get therapeutic cells out of clinical trials and into widespread use.

PROJECT:

Reuel will develop novel, real-time sensors and reinforcement learned (RL), dynamic control policies to improve reproducibility in large-scale manufacturing of differentiated, cell therapies.

The research team will build the reinforcement learning agent and test it using simulations with the latest RL algorithms. In parallel, the team will develop real training environments for differentiated cell culture with multiple sensors and control elements. The training environments will then be used to train the RL agent.

Reuel will benchmark this new, dynamic control approach against static differentiation "recipes" using a range of model cells with Iowa State and external collaborators.

POTENTIAL IMPACT:

Reuel's work will make possible practical manufacture of regenerative medicines to treat many diseases such as cancers, autoimmune disease, infectious disease, repairing tissue damage and neurological disorders. The new modular framework will be easily tailored to different types of sensors, stimulation cues and cell targets, setting it up to take on emerging biomanufacturing challenges.

"Cell therapies are the next wave of therapeutic innovation, demonstrating incredible outcomes and ability to tailor specifically to each patient. In order to realize their full impact, they need to be made more efficiently and safely. Our work will be a part of this effort," said Reuel.

POSSIBILITIES:

Part of the project includes new course modules, a tool development workshop and even an interactive art exhibit to educate students and the public about machine learning.

"Both graduate students and undergrads will get training and experience in tool design, cell culture and reinforcement learning, further strengthening the nation's biomanufacturing capabilities," said Reuel.

2021 NSF CAREER AWARD WINNER

Tapping smart meters' potential for grid resilience

PROBLEM:

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.

PROJECT:

Wang will unlock the potential of smart meters with new optimization and probabilistic graph learning methods to enable data-driven, real-time electric network monitoring.

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.

POTENTIAL IMPACT:

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.

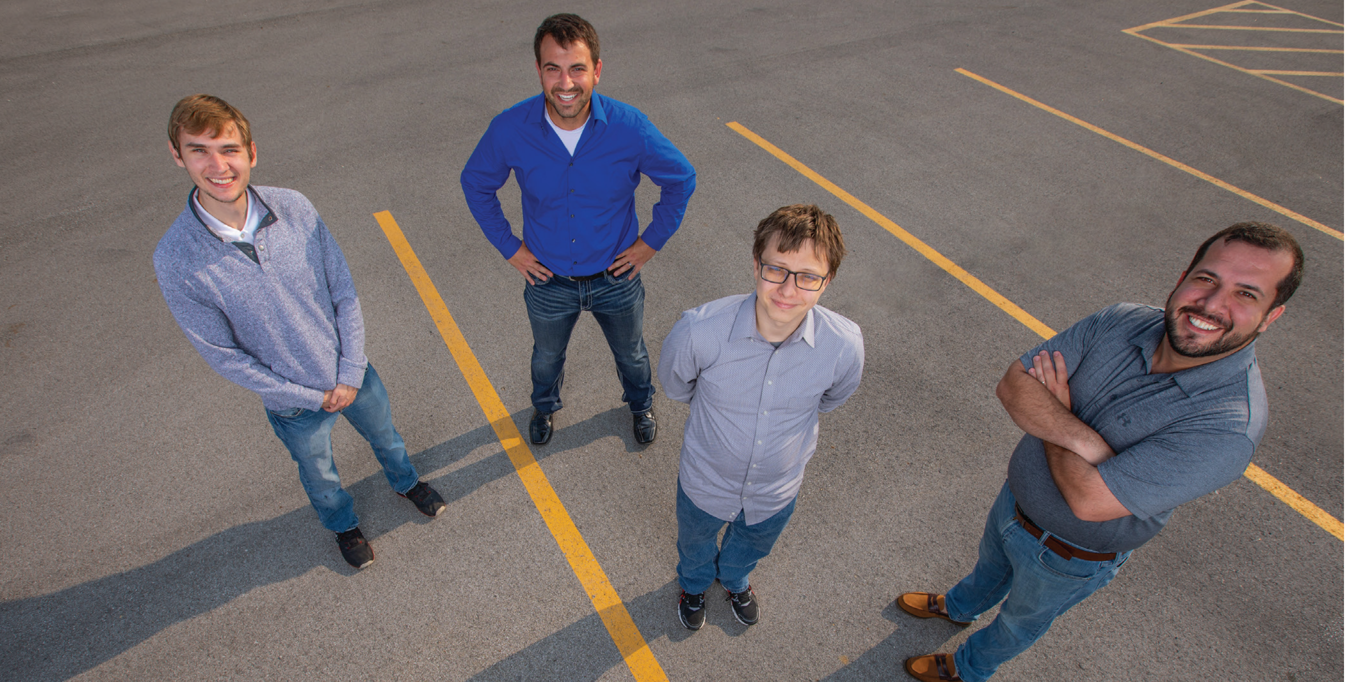
POSSIBILITIES:

Broader impacts of Wang's project include integrating power engineering education with data science. He'll make available open-source data sets, create training for energy professionals and develop interactive smart grid educational activities for high school students.

ZHAOYU WANG

associate professor of electrical and computer engineering

2021 NSF CAREER AWARD WINNER



Where the soybean oil meets the road

At Iowa State, innovation is all around us, even under our car tires in the asphalt pavements we drive and park on.

Take for example, **Nacu Hernandez** ('12 Ph.D. chem engr), who along of a group of fellow Cyclone Engineers, created Invigosoy. Hernandez is joined in the business, SoyLei Innovations™, by current chemical engineering graduate students **Austin Hohmann** and **Baker Kuehl** and research scientist **Michael Forrester** ('18 Ph.D. chem engr). Their mission is to improve the asphalt pavements – not by promoting the expensive process of laying new asphalt, but by prolonging the life of existing asphalt.

"Our technology is about applying chemically modified soybean oil to old asphalt," says Hernandez. "It's done through polymer science, and how soy-based product impacts the old asphalt molecules found in recycled asphalt pavements. It's not just a short-term change that is found in many other products."

After starting with small batches produced in Iowa State labs, the group is now working with a company in Indiana to produce commercial quantities of their material. Testing has been carried out at 15 different sites around the U.S. and sales are taking off.

Building the future… for 150 years

Iowa State's Department of **Civil, Construction and Environmental Engineering** celebrates its 150th anniversary in 2021.

Read the latest on Cyclone Engineers' groundbreaking research in advanced materials and manufacturing, engineered medicine, engineering education, energy systems, resilient infrastructures, secure cybersecurity and autonomy, and more at **news.engineering.iastate.edu**

Sritharan named assistant dean for research

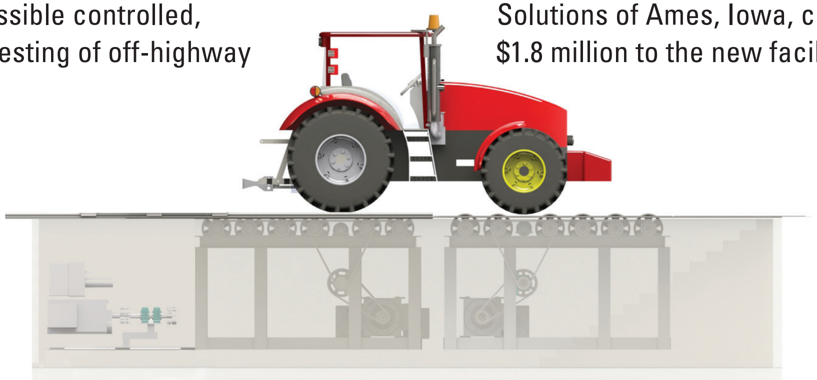
In the newly created assistant dean for research role, **Sri Sritharan** the Wilkinson Chair in the College of Engineering and a professor of civil, construction and environmental engineering, will provide visionary leadership to help expand the scope of research endeavors in the college, assist with achieving strategic research goals and enhance research productivity.

Scan this QR code to go directly to our news website.

On track: Chassis dynamometer for testing tractors

Installation is rolling along on Iowa State's dynamometer, which will be one of only a few publicly available chassis dynamometers in the world capable of testing large farm and construction machinery.

The state-of-the-art dynamometer makes possible controlled, dynamic testing of off-highway vehicles with advanced traction control systems. The facility is designed to test vehicles up to 450 kW (600 Hp), with speeds of up to 80 km/h (50 mph), and offers independent monitoring and loading of each wheel. Danfoss Power Solutions of Ames, Iowa, contributed $1.8 million to the new facility.



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Building for the future

Thanks to a $42 million gift commitment from **C.G. "Turk"** and **Joyce A. McEwen Therkildsen**, Iowa State's Department of Industrial and Manufacturing Systems Engineering will have a new facility to serve as its home and provide technically enhanced research laboratory and learning spaces where industrial engineering students can gain the knowledge to design tomorrow's innovative, nimble and intelligent processes needed now more than ever across all industrial sectors.