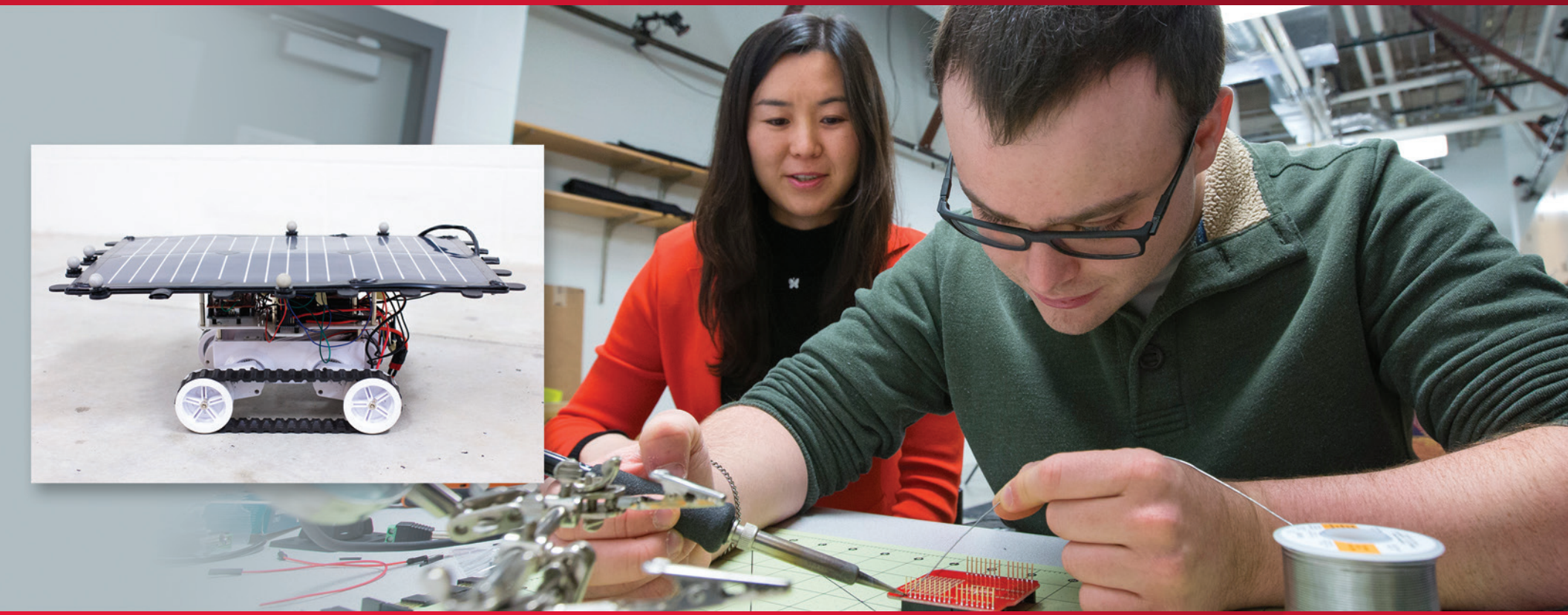

IOWA STATE UNIVERSITY

College of Engineering

CYCLONE ENGINEERING RESEARCH

SPRING 2016

Cyclone Engineering Research

The College of Engineering at Iowa State builds on the university's land-grant mission, addressing common, global challenges with practical solutions. Our faculty are dedicated to developing technologies and ideas that are applied in society and transferred into industry.

Solar-powered robots to improve environmental monitoring. Agricultural machinery equipped with sensors to provide knowledge that saves time and money. Additive manufacturing as a mainstream technology to reduce waste and enhance performance. Multiphase flow discoveries that make biofuel generation better. A large-scale initiative that emphasizes the value of engineering to young students. More security against cyber threats.

Iowa State is advancing research in emerging areas, collaborating across campus and the world, while also nurturing the next generation of engineers.

On the cover: Ran Dai (left) and Adam Kaplan work on solar-powered robotic vehicles in Dai's Automation and Optimization Laboratory at Iowa State.

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CONTENTS

POWER MANAGEMENT IN SMART ROBOTS

Designing solar-powered vehicles for long-duration, high-efficiency missions

Using renewable energy to power aerial and ground vehicles could change the way we handle aspects of environmental monitoring, search and rescue missions, surveillance, and agricultural practices.

To navigate these sorts of dynamic environments, **Ran Dai**, an assistant professor in aerospace engineering and Black and Veatch Faculty Fellow, says a solar-powered robotic system offers a lot of promise.

During her first year at Iowa State, she and undergraduate research assistants manufactured the first prototype of a solar-powered ground vehicle in her Automation and Optimization Laboratory.

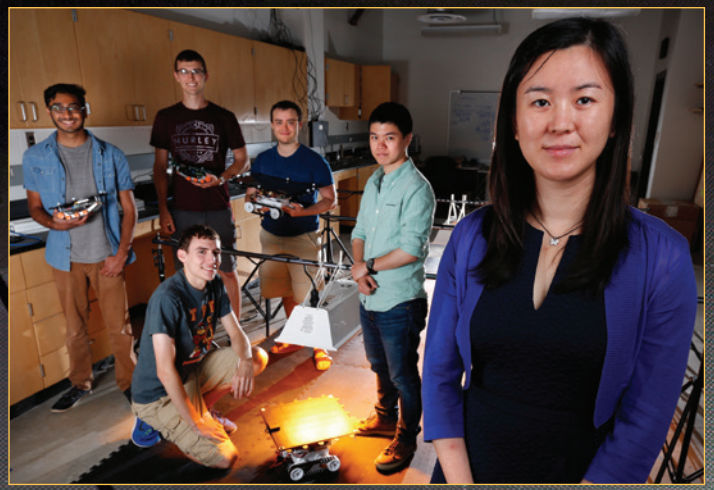
The vehicle was capable of designing an efficient path to harvest energy from the environment while simultaneously allocating its available power among electric components. The team also created an indoor solar simulator to have a static environment for evaluating the robot's performance.

Now, confident her ideas will work, Dai has moved forward with a second- and third-generation robot, adding real-time power tracking to record the vehicle's power intake and consumption, along with a solar-powered unmanned aerial vehicle.

The project is supported by a $500,000 grant provided by the National Science Foundation's CAREER program, which is designed to support the research and teaching of junior faculty, and will expand the usefulness of these unmanned vehicles even more with advancements that will improve their endurance and capability.

Dai says her biggest obstacle in this work is the weather. "Our algorithms can help the robot make decisions based on available solar energy, but if it's cloudy, the robot could go into sleep mode to conserve energy, resulting in a delay in completing a mission."

She says those sorts of delays could be offset with cooperative, back-up vehicles that harvest energy while the other robots are doing work. When the working



***Ran Dai**, foreground, an assistant professor in aerospace engineering and Black and Veatch Faculty Fellow is working to develop technologies that will help robots manage their energy use to improve efficiency and battery life*

robots need to recharge, the second group could step in to realize a persistent operation.

"The key to being able to make a system like this work is to find out how to make a robot energy-aware and autonomous," she says. "That way it could recognize changing solar conditions and make necessary adjustments."

Dai also plans to develop an open-source software program everyone can use. She hopes this will lead people who are interested in the technology to create their own solar-powered robots.

In the end, it's the big picture that drives Dai forward — she wants to contribute to the country's economic vitality, public health and security with these robots.

***Matthew Darr**, associate professor in agricultural and biosystems engineering*

MARKET-READY SOLUTIONS

Advanced ag machinery technology developed at ISU transfers to industry

Matthew Darr's research group strives to make an impact that extends knowledge and scientific development to the marketplace. "Seeing our results ported out to the public sector where we're able to help agricultural producers with intelligent technologies — that's our 'why,'" he says.

Darr, an associate professor in agricultural and biosystems engineering, runs an industry-focused research program at Iowa State, working on innovations in the agricultural equipment and agricultural automation sectors.

"We've developed strong relationships with industry partners, which helps us better understand their needs. We then focus our research on addressing applied research questions through targeted applications of advanced technology, science and innovation," he says.

Much of the group's work is data driven, with researchers working to both collect and analyze complex data from a range of agricultural systems. Darr says analysis of vehicle sensor networks has become a focal point for the group's research.

The team develops algorithms for sensors used within agricultural equipment for a range of purposes and then works with industry partners to get that intelligence integrated into a commercial product.

Because the agricultural field relies heavily on telematics to gather data, Darr's group creates hardware and software solutions that integrate the process. One such project involved assessing the logistics behind cellulosic ethanol supply chains in the Midwest. Industry partners used technology from Darr's team to gather data and then made informed changes to how the plants operate, saving time and money.

Another area Darr is exploring is unmanned aerial vehicles, which involves remote sensing with UAVs. "We are utilizing this technology to acquire plant health indicators for individual plants. This allows us to create a quality index that is used to adapt farming operations and make decisions related to crop production," he explains. "The data from these UAVs can help producers make decisions about everything from water management to fertilizer application."

While most of the group's work has a significant impact in the Midwest, Darr says there's an international component to the team. Test research of the group's technologies happens on four continents every year, something Darr says provides the group with a greater understanding of how technology could help in the less developed ag markets.

The team's successful approach in partnering with industry to create transferrable technology is an accomplishment in and of itself. Thanks to Iowa State's land-grant mission, the university has flexible options for industry partners that address intellectual property concerns and facilitate the process for all parties involved.

He adds that diversity in the research group, which includes computer scientists, researchers from a number of engineering disciplines, ag technologists and students, gives the team a broad perspective for approaching problems.

The team's work recently contributed to three innovation Silver Medal awards at AGRITECHNICA 2015, a global showcase of ag machinery in Hannover, Germany. The award-winning innovations, which were developed at Iowa State University and licensed to John Deere, involved the operation of harvesting equipment.

"When we see the value our work creates for producers, we know we're making contributions to the agricultural industry," Darr says. "Iowa State creates an environment where this is possible, and we are able to make a difference because of it."

ENGINEERS, ELEMENTARY EDUCATORS AND FUTURE TEACHERS PARTNER TO TEACH STEM

At Iowa State, integrating engineering into K-12 classrooms is a collaborative effort that spans across campus and into surrounding school districts. Trinect, a program funded by the National Science Foundation STEM-C Partnerships, brings together three groups to introduce engineering concepts to young students: engineering graduate students, preservice teacher students and cooperating elementary teachers from Des Moines Public Schools.

Adah Leshem, pre-college education program director at CBiRC

"Trinect is about sharing knowledge and helping elementary teachers gain confidence in teaching STEM subjects," says **Adah Leshem**, pre-college education program director at the NSF Engineering Research Center for Biorenewable Chemicals located on Iowa State's campus. Leshem is Trinect's project co-director and was a driving factor in establishing the program.

"We know there's a crucial timeframe for engaging young students in STEM fields and there's often a lack of opportunity for students to experience these subjects. We think Trinect can help fill those gaps."

Each semester, 10 Trinect Fellows, who are engineering graduate students, work with 3rd-5th grade students and their teachers. The fellows help teachers understand the concepts of the engineering design process as well as reaffirm common subjects such as math, science and technology.

"Instead of having graduate fellows teach the concepts, they act as a resource for teachers and students. The approach engages teachers as they develop innovative activities focused on STEM subjects," Leshem explains.

Iowa State's School of Education's preservice teachers represent the third partner of Trinect. These students are placed in cooperating teacher classrooms for 16 weeks and participate in teaching STEM concepts. At the end of the program, they are better prepared to independently integrate these types of lessons into their own classrooms once they are in the workforce.

Leshem says an external partner will measure the overall effectiveness of Trinect. The data will evaluate how the triad functions as a team and how the approach the program is using compares to traditional learning methods.

"We'll be continually improving our program as we receive feedback and looking for additional opportunities to expand collaborations," Leshem says.

trinect

MORE DATA, MORE VULNERABILITIES

Protecting and securing data takes on many forms at Iowa State, where researchers in electrical and computer engineering are tackling big threats in the digital world: detecting malware on apps, improving online privacy and eliminating insider threats.

Mathematical abstraction and software reasoning

Suraj Kothari, Richardson Professor of Electrical and Computer Engineering, mixes theoretical ideas and practical application together as he looks for ways to improve the quality and security of software. The tools he has developed utilize visual mathematical models to dissect and conquer larger problems.

Suraj Kothari, Richardson Professor of Electrical and Computer Engineering

Recently, his models have been applied to detecting malware attacks within mobile applications for a Defense Advanced Research Projects Agency project. Kothari's team designed a tool that gathered important information about an app as it scanned code for malware. This data is then presented in a compact form for a human analyst to review, allowing for more accurate assessments about an app's intentions than systems currently in place. The tool is flexible enough to be refined and extended to address future malware attacks.

Machine learning to secure information

Morris Chang, associate professor of electrical and computer engineering, wants to make sure data collected by third-parties (think: healthcare workers or employers performing background checks) stays private. He says individuals providing personal information are increasingly exposed to vulnerabilities that may exist within a third-party's data-collection system.

Through DARPA's "Brandeis" Program, Chang is creating technology that helps secure privacy over the Internet through distributed algorithms that protect user's data on mobile devices. Chang's approach focuses on securing data before it is transmitted via Internet to remote cloud services. These services then use machine learning techniques to process data, allowing the data to be transferred in an irreversible way before reaching the Internet.

Morris Chang, associate professor of electrical and computer engineering

The project brings together researchers from several universities and segments the work to propose a solution to addresses the efficiency, privacy, security and flexibility of Internet computation.

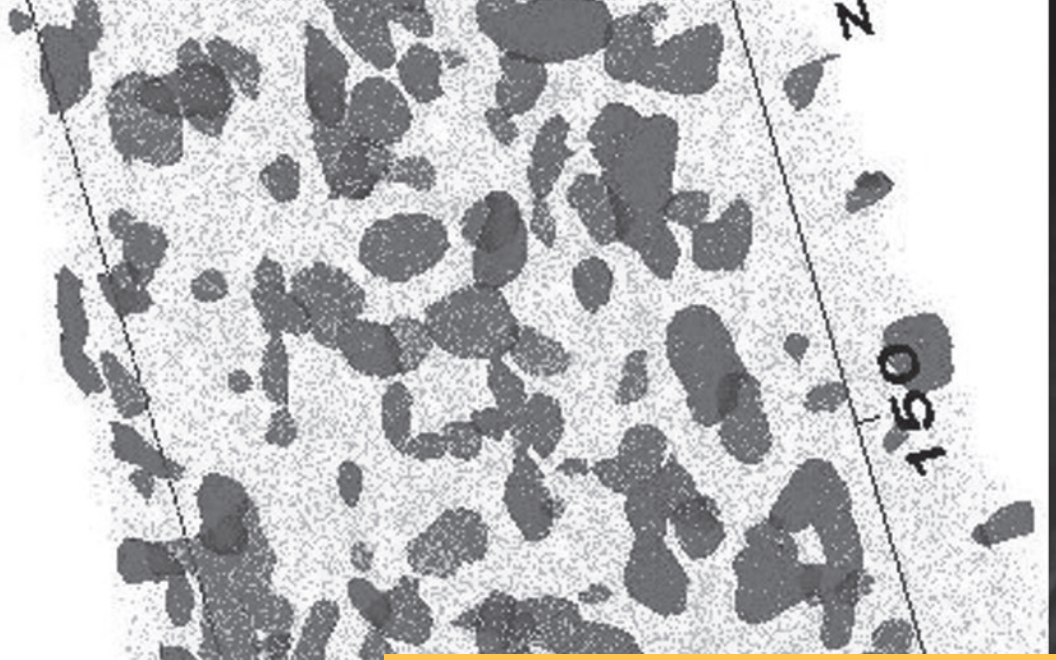
Parsing big data to identify threats

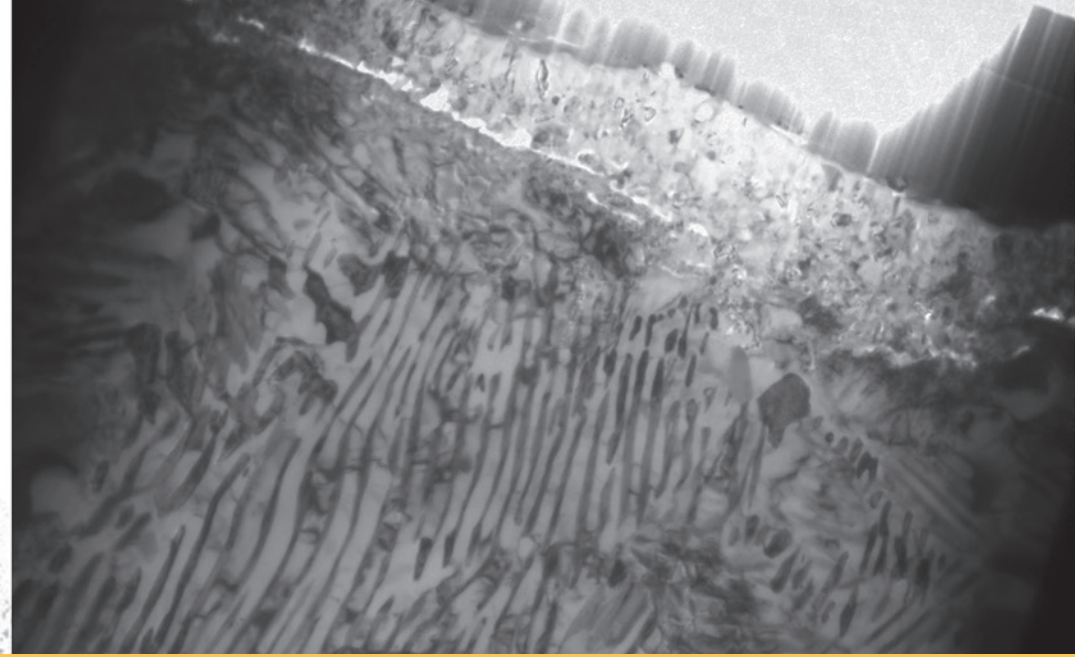
Srikanta Tirthapura, associate professor of computer engineering, makes big data more manageable with methods that analyze extremely large data sets, especially data that quickly changes, which are often referred to as data streams.

Part of Tirthapura's research is applied to cyber security, where he looks at how to convert, store and analyze information to find anomalous user behavior or unauthorized access. One example is insider threat detection, where someone within an organization who has authorized access to some parts of the system misuses his or her access.

Srikanta Tirthapura, associate professer of electrical and computer engineering

He says detecting insider threats adds an extra challenge because the user is familiar with the system. In this case, technology is essential to search through gigabytes of files to identify unusual behaviors. That's why Tirthapura has created tools that can be used across a variety of datasets and problems to efficiently retrieve and process information.





Peter Collins *works with a student on material characterization*

With his plans to develop an open-source manufacturing platform, **Peter Collins** is determined to make additive manufacturing a mainstream technology.

Collins, who is an associate professor in materials science and engineering, says the advantages of additive manufacturing—using fewer resources, improving material performance and creating one-of-a-kind products—can be a game changer for manufacturers of all sizes.

That's why he's working on a program that will reduce the amount of testing involved with the additive manufacturing process.

"When we look at creating a better material, additive manufacturing is a great place to start," he explains. "Rather than taking a huge piece of material and sizing it down to fit within the parameters we have, researchers add small amounts of powder to specific areas of a material to achieve desired

NEW HEIGHTS FOR MATERIALS SCIENCE

Integrating material characterization to strengthen additive manufacturing

characteristics and geometries. It's simply a more efficient and effective approach."

Collins wants to tailor materials to exact specifications, such as designing high strength on one side of the material and high stiffness on the opposite side. He says being able to change composition of a material is useful for many industries, including energy, aerospace and automobile markets.

But testing materials created through additive manufacturing is a significant investment and a big part of why the process isn't commercially available. "Manufacturers spend sizable amounts of money to create a large piece of material, then section it into smaller pieces to send off for mechanical, fatigue and composition tests," Collins says. "As you can imagine, it's expensive, and if something doesn't meet the desired performance, you have to create a new piece of material and do it all over again."

Material characterization, which involves looking at how the atoms and crystals in the material are arranged, can help researchers predict the composition of a material and reduce the expenses associated with testing. "Knowing how materials will respond after they go through specific processes will help us understand what elements we will lose and what characteristics the material we've developed will exhibit."

Peter Collins, associate professor in materials science and engineering

A large part of his research with groups such as the Defense Advanced Research Projects Agency, National Science Foundation and the Boeing Company focuses on bringing this materials science mindset into additive manufacturing.

He also wants to reduce costs associated with additive manufacturing, which accumulate thanks to the equipment, like lasers and electron beams, used in the process. So he's developing an open-source manufacturing platform with visions that every town could implement additive manufacturing. "Something like this would mean a farmer could go into town and repair or create a new piece of equipment instead of paying an exorbitant amount to have one made and shipped to them," he explains.

While he knows there's a lot of research that needs to be done before this vision becomes reality, he says his approach is definitely a step in the right direction.

"Adding material characterization to the process gives us the information necessary for exploring and creating superior materials for the manufacturing industry much quicker than has been done in the past."

LEADERSHIP IN MULTIPHASE FLOW EDUCATION AND PRACTICE

Taking multiphase flow research from fundamental theory to device-scale application

A cohesive group of researchers at Iowa State has joined together to accelerate discoveries in multiphase flow science and their transfer to industry.

The group known as CoMFRE initially started out in 2002 as an informal way for faculty to share insights about related research projects. Now, the team is more formally organized with a mission to bring ideas together to make computational and experimental multiphase flow research more cohesive and connected.

Shankar Subramaniam, professor of mechanical engineering

Shankar Subramaniam, professor of mechanical engineering, and **Rodney Fox**, distinguished professor in chemical and biological engineering, lead the group of 18 faculty members who make up CoMFRE. The group also collaborates with a number of experts in industry, academia and national laboratories.

Subramaniam says having a large number of faculty and experts involved has helped the group expand its impact. "We aren't working on just one problem. We're working on a set of techniques that can be rapidly realigned to various problems. I anticipate that over the next 20-25 years we can continuously reinvent ourselves to solve whatever the hard multiphase flow problem of the day happens to be."

One major initiative within CoMFRE is biofuels. As biomass, such as corn stover, is heated to create fuel, multiphase flow researchers can analyze how changes in the composition of biomass and flow impact the reaction.

The team develops simulations of biomass reactors, analyzes computational data gathered during the process, and evaluates the economics of the facilities used to generate biomass and biofuels, effectively performing an entire life-cycle analysis that focuses on efficiency and sustainability.

"From a computational perspective, all of our work involves a variety of statistical and mathematical methods and visualization," Subramaniam says. "While it's relatively easy to compute large amounts of data, we take our research beyond information. We provide insight into the processes occurring and look for answers to research questions."

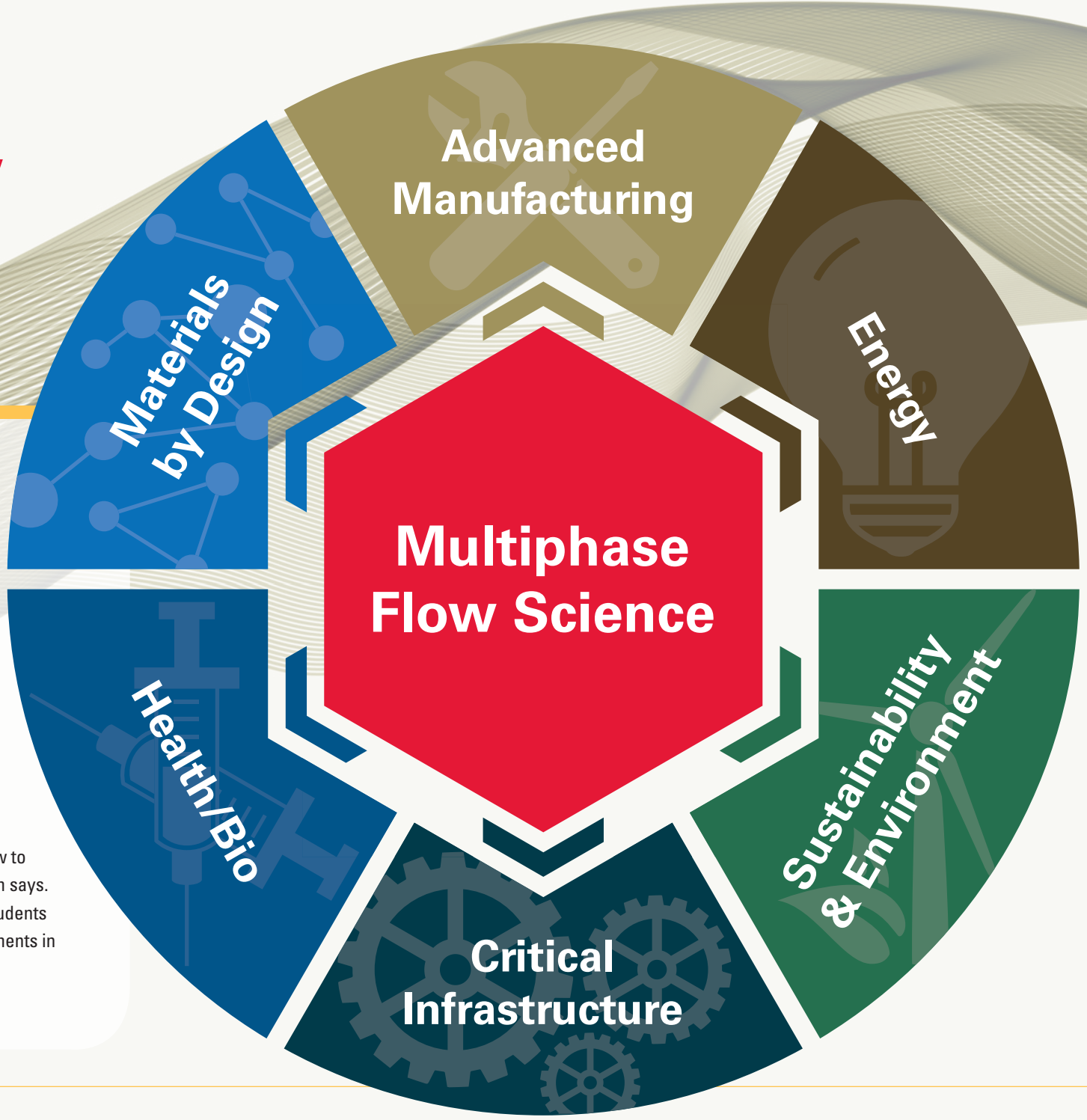
As the long-term applications and science research being developed under the umbrella of CoMFRE continues to grow, Subramaniam says the group's industry outreach will also expand. CoMFRE facilitates training, seminar and networking opportunities for industry collaborators, where the group shares rich knowledge and diverse expertise to advance research in the multiphase flow field.

Collaborators come from a variety of industries including energy, healthcare, materials design, advanced manufacturing, sustainability and infrastructure.

DISCOVERY,

The team also incorporates training and workforce development for graduate students, providing them with skills that can be applied across industries to investigate multiple challenges. CoMFRE is even proposing to break away from the traditional Ph.D. structure to act as more of a learning community, where graduate students work with peer groups and a whole group of faculty members acting as advisers. In addition to refining their technical skills, the students will be trained on entrepreneurship, which would prepare them to adapt to changes that can occur in the research landscape over time.

"We want our graduates to be cognizant of how to connect their work to societal issues," Subramaniam says. "We think we've set up CoMFRE to prepare these students to be industry leaders while we also make advancements in our research."



NEWS BITES

WIND ENERGY INITIATIVE CONTINUES BUILDING PROGRAMS

This fall, more than 80 researchers and industry practitioners in the wind energy field came to Iowa State's campus to share ideas and projects during the Wind Energy Industry Symposium.

The event, hosted by the College of Engineering's Wind Energy Initiative and organized by the Engineering Research Institute, showcased several engineering faculty members and offered a place for speakers to share local, state and national perspectives on how to grow and expand wind energy research.

WEI also emphasizes education in Wind Energy Science, Engineering and Policy through a National Science Foundation Research Experience for Undergraduates as well as the nation's first Ph.D. degree. A $3.1 million NSF Integrative Graduate Education and Research Traineeship award helped WEI establish the Ph.D. program.

BALANCING ROADWAY ACCESS WITH SAFETY

Iftin Thompson wants to improve how access points on roadways are managed, a focus she says can make roadways safer. The graduate student in civil engineering explains that studying how drivers handle areas like driveways can inform necessary changes to those points to reduce crash rates.

Iftin Thompson, civil engineering graduate student

Thompson found her niche in transportation engineering as an undergraduate at Morgan Sate University. She then came to Iowa State, where she's working with **Peter Savolainen**, associate professor of civil, construction and environmental engineering, at the Institute for Transportation.

Her work was recently recognized when she received the the L.L. Waters scholarship from the American Society of Transportation and Logistics. "It's a great honor to receive the scholarship," she says. "It definitely confirms for me that I'm headed in the right direction."

JILES NAMED AS JEFFERSON SCIENCE FELLOW

David C. Jiles, Palmer Endowed Chair of the Department of Electrical and Computer Engineering, has been selected as a 2016-2017 Jefferson Science Fellow. Jiles, an Anson Marston Distinguished Professor, will begin his one-year appointment as a scientific adviser in Washington, D.C., in August 2016.

David Jiles, Palmer Endowed Chair of electrical and computer engineering

The Jefferson Science Fellowship program was established in 2003 as an initiative of the Office of the Science and Technology Adviser to the U.S. Secretary of State, and is designed to further build capacity for science, technology, and engineering expertise within the U.S. Department of State and U.S. Agency for International Development.

Iowa State also had a Jefferson Science Fellow in 2014-2015. **Jim Alleman**, Cerwick Faculty Professor of Environmental Engineering at Iowa State University, served as a senior science adviser for civil, construction and environmental project focus elements within USAID's Bureau of Europe and Eurasia.

STRENGTHENING RESEARCH IN THE COLLEGE

Two programs at Iowa State and the College of Engineering are helping reinforce a strong research program while supporting a growing undergraduate enrollment.

Graduate Recruiting Initiative

Over the past several years, the College of Engineering has implemented the Graduate Recruiting Initiative. The program runs parallel to the Presidential Scholars Program at Iowa state, and both aim to recruit top doctoral students in strategic research areas.

Arun Somani, associate dean for research

Funding for the first year comes from dean's and president's offices for the respective programs. In three years, the initiatives have resulted in a 27 percent increase in Ph.D. students and 35 percent increase in total graduate students in the College of Engineering.

"We're seeing at least 40 additional Ph.D. students next year in the college," says **Arun Somani**, the college's associate dean for research. "We're proud of this increase and will continue to build the momentum of recruiting high-quality graduate students that will advance our research and innovation."

Presidential High Impact Faculty Hires Initiative

The Presidential High Impact Faculty Hires Initiative was implemented at Iowa State to support targeted faculty hiring in the strategically important areas of big data and of translational health.

Within big data, the college has hired faculty whose work enables big data (e.g. data mining; information management; data fusion; data visualization; etc.) as well as applies big data (e.g. bio- and materials-informatics; analysis, simulation, and design of large-scale complex engineered systems; sensor technologies; agricultural and environmental systems; multi-scale modeling; etc.).

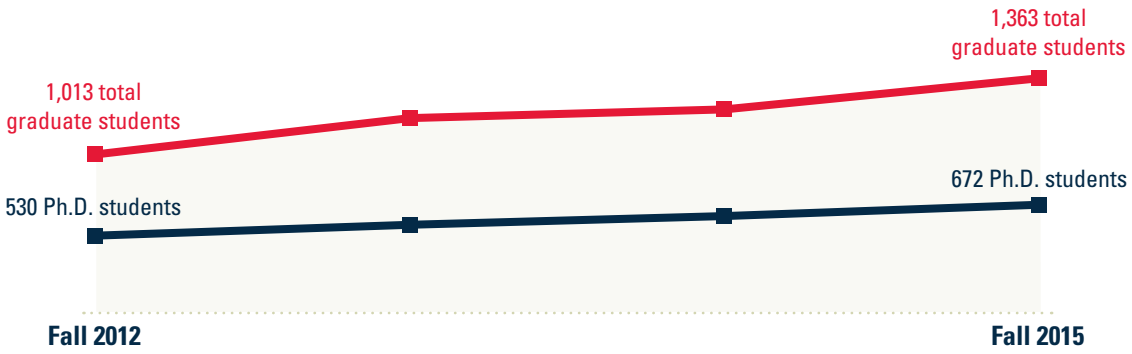
The translational health cluster relates to engineering through biomaterials and biomechanics; diagnostic, therapeutic and medical devices/systems; bioinformatics and applications; synthetic biology; and biophotonics and bioimaging.

"These positions emphasize interdisciplinary collaboration, which is a crucial component to expanding research and education in these emerging areas," Somani says.

In fiscal year 2015, the college hired 38 new faculty members, including 10 lecturers.

By the numbers:

Through recruitment initiatives, the College of Engineering has seen steady growth in its graduate programs.



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A VIRTUAL GAME-DAY EXPERIENCE

Iowa State University's Athletics Department and the Virtual Reality Applications Center have joined forces to give prospective football players a glimpse into what it's like to be a star at Jack Trice Stadium. The ISU Athletics department collaborated with **James Oliver**, a university professor, the Larry and Pam Pithan Professor in Mechanical Engineering and the director of VRAC, **Eliot Winer**, associate professor in mechanical engineering and associate director of VRAC, **Vijay Kalivarapu**, an assistant scientist for VRAC, and a team of students to leverage virtual reality technologies and create a game-day application for recruiting the best football players from across the country.

The research team utilized the C6, a 10-foot by 10-foot room that surrounds the user with computer-generated 3-D images, and an Oculus Rift, a portable head-mounted display that connects to a laptop, to recreate the game-day experience at Jack Trice Stadium and all the fun and excitement that come along with a football game. While working on the project, the researchers also developed a paper they presented at the SPIE/IS&T Electronic Imaging Conference comparing the user experience between the C6, Oculus Rift, and current ISU recruiting practices, along with the challenges they encountered in developing the application.

Kalivarapu says he continually makes tweaks to the application for improved interactivity. The game-day application is also used on the road to make recruits feel like they are a part of the team.