Iowa State University
College of Engineering

CYCLONE ENGINEERING RESEARCH

FALL 2016

Cyclone Engineering Research

The College of Engineering at Iowa State continues to grow and evolve. We welcome Gül Kremer, who has joined the college as the C.G. "Turk" & Joyce A. Therkildsen Department Chair in Industrial and Manufacturing Systems Engineering, and will help the department continue its success in research and education. And students majoring in electrical and computer engineering will benefit from a new grant to that will transform their education.

The laboratories and research spaces in the college come in many shapes and sizes, all doing unique work that results in technological advancements across campus. Within these environments, you'll see cross-disciplinary collaborations that encourage diversity in ideas to develop the best solutions possible.

Groups of researchers come together to modify asphalt with more sustainable materials, while others are advancing materials through controlling microstructures. Teams are working to create a platform technology to develop nanovaccines. There's now a meta-skin that can cloak objects with great success, and a new place to study how to best augment human capabilities.

We celebrate that the partnerships we have with academia, industry and government agencies have created opportunities to explore these topics and more, as these connections are the key to progress.

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On the cover: *Researchers in the ATHENA Lab look for ways to use engineering to augment human performance and understand human capabilities. In this photo, the team is improving suturing techniques and tools.*

Developing telerobotics control systems, applying biomechanics for improved sports performance, creating visualization tools that improve battle space awareness. These projects and more are going on within the Augmentation and Training of Humans with Engineering in North America Lab.

The lab, known as ATHENA Lab for short, is one of four labs of its kind in the world. And the only one the Augmented Human International Conference Series recognizes in North America.

“We want to make humans more capable and safer, and we’re using a mix of ergonomics, augmented reality and cutting-edge technologies to accomplish our goals,” says **Richard Stone**, an associate professor of industrial and manufacturing systems engineering, co-director and co-founder of the lab.

ATHENA LAB AUGMENTS HUMAN CAPABILITIES

Engineering ideas and technologies enhance human performance, preserve safety and quality of life

The ATHENA Lab evolved from the Human Performance and Cognitive Engineering Lab that Stone started when he came to Iowa State in fall 2008. Fast forward to 2015 and bring in **Thomas Schnieders**, a Ph.D. student in industrial engineering and the other co-director and co-founder of the lab, who talked with Stone about the potential of having a recognized human augmentation lab on campus.

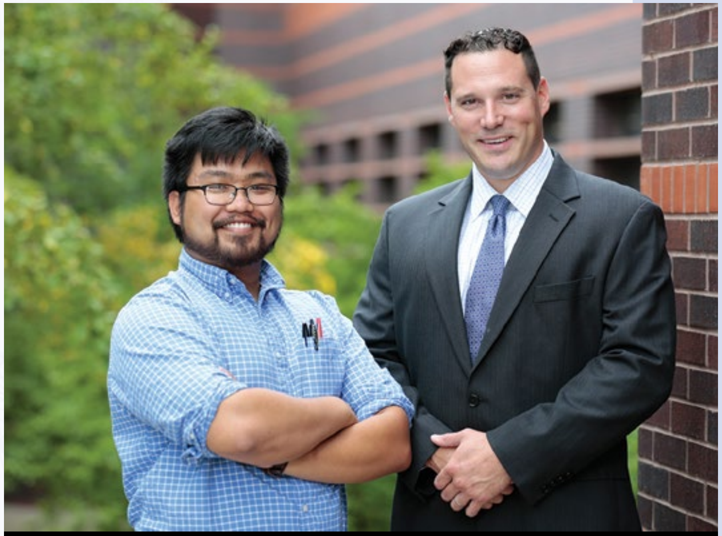
"The ATHENA Lab takes what we were already doing and gives us more focus. It also shows us other areas where we could be adding value with our work," explains Schnieders. "A lot of labs do great work individually in biomechanical, biomedical and cognitive science, but our lab tries to merge all these aspects to see how they work together."

No two days at the ATHENA Lab are similar. The researchers are constantly running new experiments, testing body armor one day and the next they might be focused on figuring out what technologies could make wound suturing more consistent.

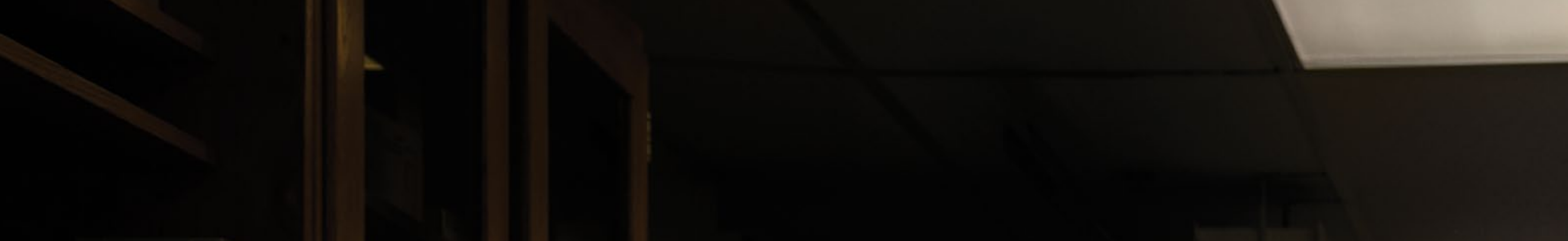
"Our setup is always changing, and we're moving equipment around all the time," Stone adds. "At any time you might see boxes of basketball shoes stacked to the ceiling or maybe robots tucked away on a shelf. It just depends on what problem we are working to solve."

The ATHENA Lab is also equipped with a large variety of sensors, cameras, hardware and software the researchers use to gather data.

Stone says the students who work in the lab bring a lot of energy and excitement to the projects. "The work we are doing is very focused. They get to work on projects they can apply to their everyday life, and they get to see the end results of their time and effort," he explains. "It's fun to see young students come in and show them a different side of engineering."



Richard Stone, *associate professor of industrial and manufacturing systems engineering (right) and* ***Thomas Schnieders****, Ph.D. student*



ENGINEERING BETTER HEALTH

Polymeric biomaterials combined with nanoscale delivery devices can improve preventative medicine

Surya Mallapragada knows the value an engineering perspective can add to advancing the biomedical field.

For years, Mallapragada, the Carol Vohs Johnson Chair in Chemical and Biological Engineering, has been researching the best ways to synthesize copolymers and nanoscale delivery devices to treat illnesses. Now, she's looking at ways to prevent disease.

"When we were focused on treatment technologies, we wanted to minimize the immune response to the drugs that were being delivered to a patient, creating an environment that would allow the medicine to be effective in fighting against a disease," she explains.

Shifting her focus to preventative medicine like vaccines, Mallapragada says her team wants to maximize immune responses to different drugs so the patient is protected against a variety of diseases and stays healthy. "We have a good understanding of which chemistries will elicit the right response given the different applications," she adds.

That information is being put to use within nanoscale drug-delivery devices Mallapragada's team is designing. Her group is focusing on vaccines that carry just the proteins or DNA from pathogens, a change from traditional vaccines that have been created using live, or attenuated, pathogens.

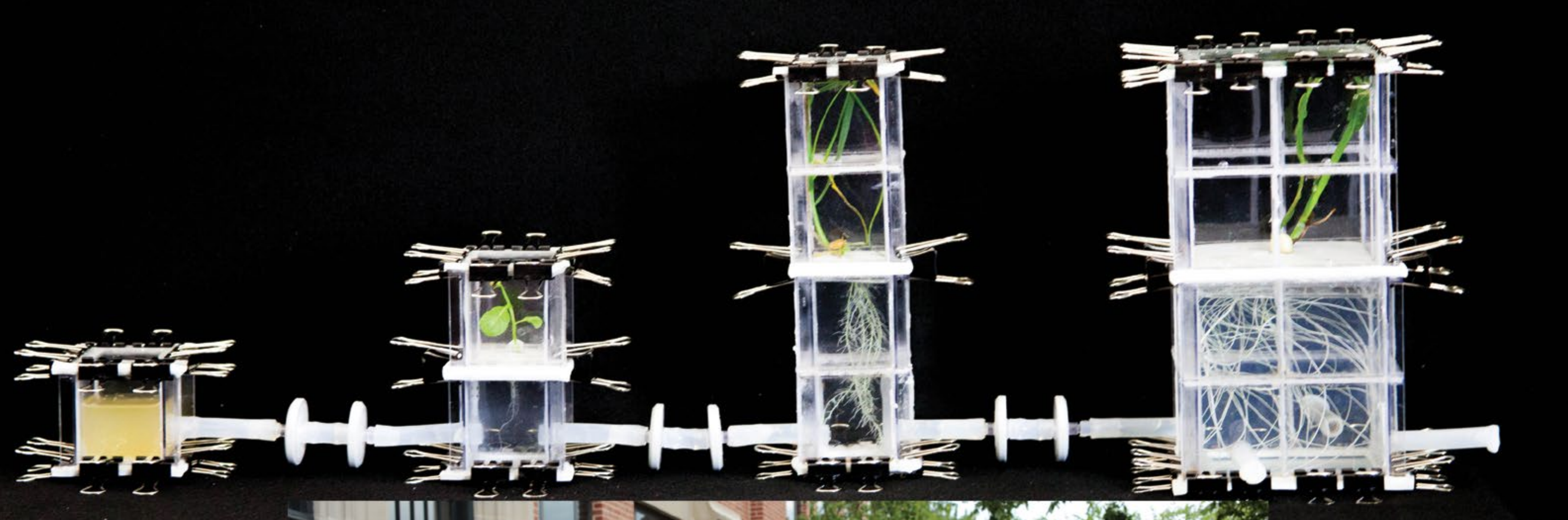
"When we use attenuated pathogens, we have to consider a number of factors, including growing a virus somewhere like chicken eggs and transporting and storing the virus," she says. "Since our work is using only part of a pathogen in a nanoscale delivery device made of a polymer, we can design materials that are more robust without having to worry about the disadvantages of working with live viruses."

Mallapragada's work is part of the polymers and materials research going on within the Nanovaccine Initiative at Iowa State. The initiative includes several researchers who are developing nanoparticle platforms that can be used in disease prevention.

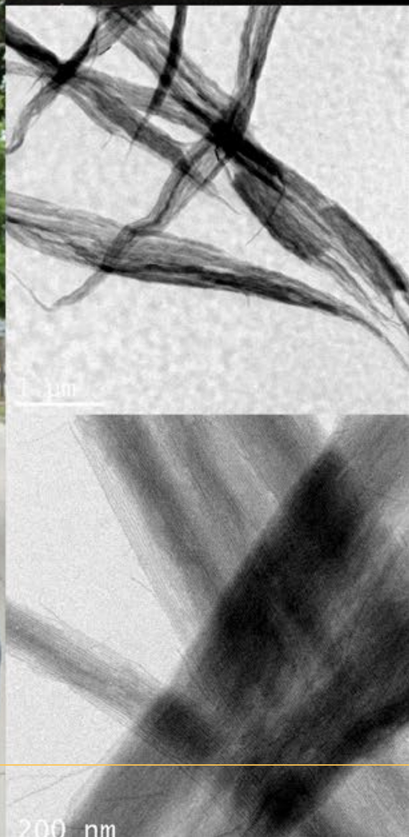
"The platform technologies we are creating aren't necessarily disease specific. It's a bigger picture plan to improve both the effectiveness and accessibility of vaccines," Mallapragada adds. One example would be having a team look at using proteins or pieces of pathogens to create a combination vaccine that fights both influenza and pneumonia since those diseases can often occur together.

The projects involve interdisciplinary teams that include researchers and medical professionals both on and off campus. "Immunologists are learning about materials science, and students and post docs in engineering are learning about cell cultures and animal models," Mallapragada says. "The collaborative environment has allowed us to thrive, and we're looking forward to seeing these projects eventually head to human clinical trials."

Surya Mallapragada*, Carol Vohs Johnson Chair in Chemical and Biological Engineering*



__Ludovico Cademartiri__ (right foreground), assistant professor of materials science and engineering, and his research team use an interdisciplinary approach to tackle a wide range of challenges in materials science



NANOSTRUCTURES AND LEGO® BRICKS

Advancing technology through practical and radical materials science

Materials science, chemistry, physics and life. These are the driving forces behind the research in **Ludovico Cademartiri**'s laboratory at Iowa State.

Cademartiri, assistant professor of materials science and engineering and associate scientist with the U.S. Department of Energy Ames Laboratory, says he and his graduate students work to go beyond understanding materials to exploring what's happening at the edge of the discipline.

"The general approach of our lab is that we try to use our skills at making materials to answer fundamental questions, whether they are related to materials science, another discipline, or some space between," Cademartiri explains.

The result is a good mix of interesting scientific problems, each with its own potential.

One project involves a big breakthrough but is also facing significant experimental challenges. The group wants to create a ceramic that behaves like a plastic. Combining the properties of these two classes of materials typically requires mixing them together in composites, which are difficult to process. No single material combines the properties of ceramics and plastics. Cademartiri says that while it's considered fundamentally impossible, the group has evidence to the contrary.

"We've seen similarities between plastics and crystals when crystals are very thin, 50 thousand times thinner than a human hair. Plastics are composed of an entangled mess of thin strands, molecules specifically. These strands are very flexible in plastics, which allows them to behave the way they do. We have clear evidence that some extremely thin crystal strands are similarly flexible. Determining exactly how similar they are is important to apply these materials but is also extremely challenging."

In another research program, the group has made significant headway in controlling microstructures in ceramics. The team has helped resolve an issue that had previously prevented making materials by selecting their individual components and then assembling and processing those components to create a material.

Cademartiri says in the past building a material from the bottom up has resulted in the material disintegrating during processing, making it hard to apply in devices. His team has found a new approach to avoid this issue entirely, thereby enabling an entirely new way of manufacturing materials with nearly complete control over their composition and structure. The findings will be published soon in two back-to-back articles in the journal *Advanced Materials*.

In a less traditional project, Cademartiri's team has been working to use LEGO® bricks to simulate an ecosystem in the lab to study how plants interact with their environment. "We can control and understand pretty well a plant in isolation, but there's so much more involved when you include the ecosystem wherein the plant exists," he says. "If we can simulate this environment, and understand and predict how plants will respond to it, we should be able to improve the reliability of our food supply."

While the group's overall focus is to provide solutions for global problems (like improving food supply) and to resolve issues at the foundation of modern materials engineering (such as programming material properties, replacing extremely rare elements in materials, translating materials and processes from the lab to the outside world, and understanding what happens at the interface of two materials), Cademartiri says he encourages his team to think outside the box.

"Materials are, in most cases, the bottleneck in the development of new technology and new solutions," he says. "Therefore, controlling materials or, in other words, knowing how to build things atom-by-atom, is one of the safest ways to have an impact on the world."

MAKING PROGRESS TOWARD INVISIBILITY CLOAKS

Meta-skin suppresses scattering microwaves, hides objects from radar detection

Two professors in electrical and computer engineering have made significant headway in an innovative stealth technology.

Liang Dong, an associate professor who researches micro-nanofabrication, liquids and polymers, and **Jiming Song**, a professor who studies electromagnetics, have combined their areas of expertise to create a flexible, stretchable meta-skin material that can render an object virtually undetectable by radar.

The meta-skin is made of metamaterials, or man-made materials that have properties not found in nature. These materials include an array of split ring resonators (SRRs) embedded in layers of silicone sheets. The resonators are filled with the liquid metal alloy galinstan and create small, curved segments of liquid wire that can absorb radar waves.

The researchers stretched multiple layers of the meta-skins along the surface of an object in a planar direction while also changing the spacing between the meta-skin layers in a vertical direction to trap microwaves and reduce the reflected portion of the waves.

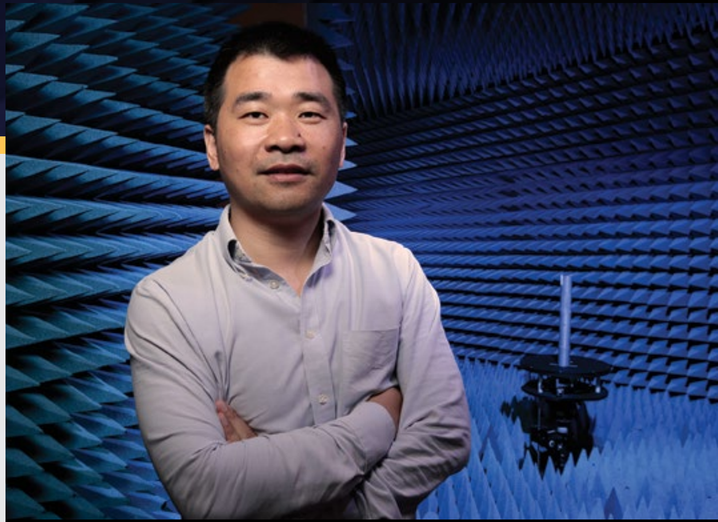
"Within our microwave testing chamber, we have successfully demonstrated a cloaking effect when we wrapped the meta-skin around a dielectric cylindrical rod," says Dong. "We saw a suppressed scattered field, which is an improvement from the more traditional technologies in place that only reduce backscattering."

These tests showed radar suppression was about 75 percent in the frequency range of 8–10 gigahertz.

While these advancements have fairly obviously applications for the military, the researchers also want to look at how to put this technology to use within different fields such as biomedical devices. They say they may be able to improve implanted medical devices that should not be exposed to microwaves or other electromagnetic waves.

Not to mention the possibility of creating a true invisibility cloak.

"We've seen that we can suppress microwaves, so we are now focusing on how to apply that same understanding to manipulate shorter wavelengths such as terahertz electromagnetic waves," Dong said.



***Liang Dong**, associate professor in electrical and computer engineering, in the electromagnetic anechoic chamber*

The current resonators can be tuned to absorbed different frequencies up to 9.15–12.38 GHz. Setting sights on shorter wavelengths could bring about more exciting cloak applications. "While this sort of technology would require new structures and design elements, we realize the potential is there to create it," Dong says.

"This project started as a conversation about doing something interesting with wearable films, and we are excited about the results we've seen so far. We are looking forward to taking this concept to the next level."

A NEW MODEL OF ENGINEERING EDUCATION

Collaborative course design will transform education and develop the next generation of engineers

Electrical and computer engineering technologies have evolved from simple electronics and computing devices to complex systems that profoundly change the world in which we live.

Designing these complex systems requires a new way of thinking, including developing social, professional and ethical responsibility.

As these advancements continue, faculty members at Iowa State are transforming the way they educate and prepare the field's future workforce.

A team from the Colleges of Engineering, Human Sciences, Design, and Liberal Arts and Sciences are working together to create a new instructional model for course design in electrical and computer engineering.

The project, "Reinventing the Instructional and Departmental Enterprise (RIDE)," received a $2 million National Science Foundation grant to transform approaches to teaching and learning in electrical and computer engineering, especially in relation to design and systems thinking, professional skills such as leadership and inclusion, contextual concepts, and creative technologies.

The changes in educational approaches will be driven by RIDE's cross-functional, collaborative instructional model for course design and will lead to different department structures and a more agile environment able to respond quickly to industry and social needs–and ultimately serve as a model for electrical and computer engineering departments across the country.

Another impact of the RIDE project will be broadening the participation of underrepresented students, especially undergraduate women, in the field of electrical and computer engineering. Project activities will emphasize inclusive teaching practices and learning experiences.

The RIDE project began this summer by developing strategies for managing change processes. During the first year, the project strategies will get underway, and by the second year, new versions of selected courses will be piloted. The electrical and computer engineering department will continually develop and refine department and curricular practices.

The College of Engineering is currently in the process of hiring a new chair for the Department of Electrical and Computer Engineering. This individual will serve as the principal investigator for the RIDE project, joining 14 current members of the team that includes the College of Engineering's Dean **Sarah Rajala**.

The project was awarded under an NSF activity known as "RED," which was created to help universities transform department structures, policies, practices and curricula to enable groundbreaking changes in undergraduate engineering education.

Diane Rover, *professor of electrical and computer engineering, promotes new educational approaches in the classroom through a new interdisciplinary project*

GÜL KREMER TO LEAD IOWA STATE'S DEPARTMENT OF INDUSTRIAL AND MANUFACTURING SYSTEMS ENGINEERING

Gül Kremer has been named the C.G. "Turk" & Joyce A. Therkildsen Department Chair in Industrial and Manufacturing Systems Engineering at Iowa State University. Her appointment officially began Aug. 16.

Since 2013, Kremer has held the position of professor of engineering design and industrial engineering at The Pennsylvania State University. She also served as program officer in the Division of Undergraduate Education at the National Science Foundation.

Kremer was a Fulbright Scholar at the Dublin Institute of Technology in Ireland from 2010–11 and held other professor positions at Penn State beginning in 2000.

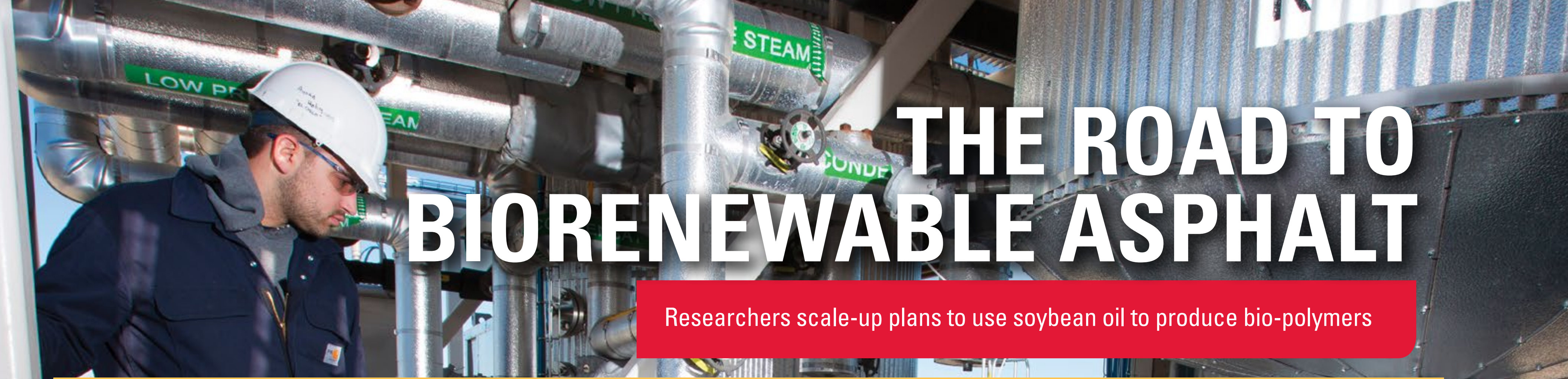
Gül Kremer, C.G. "Turk" & Joyce A. Therkildsen Department Chair in Industrial and Manufacturing Systems Engineering

She is a Fellow of the American Society for Mechanical Engineers and a senior member of the Institute of Industrial & Systems Engineers, and she has received several best paper and teaching awards.

"Gül is passionate about providing students the highest quality education, and we look forward to her contributions in this leadership role," said **Sarah Rajala**, dean of the College of Engineering. "She will continue the positive and collaborative atmosphere in the department and has strong support from the faculty and staff."

Kremer says she is excited about this new opportunity. "I will be surrounded by great people in this department, and I am looking forward to sharing my vision to further advance the department and contribute to the excellent reputation of the college," Kremer said. "I look forward to calling the beautiful Ames community home and becoming a Cyclone!"

Kremer holds bachelor and master degrees from the Yildiz Technical University in Istanbul, Turkey, an MBA from Istanbul University, and a Ph.D. from the Missouri University of Science and Technology.



THE ROAD TO BIORENEWABLE ASPHALT

Researchers scale-up plans to use soybean oil to produce bio-polymers

A new Bio-Polymer Processing Facility located at Iowa State University's BioCentury Research Farm gives researchers a broader understanding of what it would take to commercialize bio-polymers so they can be added to materials like asphalt.

Eric Cochran, associate professor of chemical and biological engineering, and **Chris Williams**, the Gerald and Audrey Olson Professor of civil, construction and environmental engineering, have been working together since 2010 to develop bio-polymers with soybean oil.

The professors originally set out to create a soybean based styrene-butadiene rubber. Early in their research, a member of Cochran's team figured out how to polymerize soybean oil into a thermoplastic. "A thermoplastic can be solid at room temperature, but if you heat it up you can make new shapes or dissolve it into another material such as asphalt. This is something that has not been feasible until now," Cochran says.

Eric Cochran, associate professor of chemical and biological engineering

Using the fundamental Flory-Stockmayer theory, the team can predict when a polymer system will gel. "The gelation is the point in which the individual polymer chains connect and form a giant molecule," explains Cochran. "The goal is to stop the process right before the gelation point to achieve a thermoplastic."

Discovering thermoplastics has fueled several projects over the years, including working with Argo Genesis Chemical LLC, a sister company to Seneca Petroleum Co. Inc., of Crestwood, Illinois. Williams, who manages the Institute for Transportation's Asphalt Materials and Pavements Program, has partnered with Seneca for more than 20 years. He says the shared knowledge and resource has led to significant advancements.

The partnership also made the Bio-Polymer Processing Facility at Iowa State a reality. Argo Genesis Chemical built the pilot plant and turned it over to Iowa State last summer.

The plant, which was designed specifically to produce bio-polymers from soybean oil, contains several industrial tanks all connected through a series of tubes, pipes, wires and hoses. The sensors on the equipment must be extremely precise due to the sensitivity of the polymer and chemicals involved.

Cochran and Williams are working to get enough of the polymer into asphalt so it can be viable as an asphalt modifier, resulting in a more sustainable approach to paving roadways.

Chris Williams, Gerald and Audrey Olson Professor of civil, construction and environmental engineering

NEWS BITES

ADVANCING AIRFLOW MEASUREMENTS IN BARNS

Katlyn DeVoe, a graduate student in agricultural and biosystems engineering, is developing a light-weight, portable device to analyze the airflow of fans in barns that contain cattle or hogs.

The mapping tool is called SWEAP (Segmented Wand for Evaluating Airflow Performance) and is meant to be a supplemental tool to FANS, the traditional and most accurate airflow mapping system on the agricultural fans market. DeVoe says FANS can be cumbersome to use, making it difficult to measure multiple fans across multiple rooms and barns. That's where SWEAP can help.

Katlyn DeVoe, graduate student

"Personnel can map multiple fans in quick succession using SWEAP, which is calibrated to be within 3–4% accuracy of the FANS unit," she explains. "If a fan's airflow measurement is questionable, they can then use the FANS unit to double check and then locate the problem to allow the fan to run at its maximum rated airflow capacity."

DeVoe presented a paper on the research during the Annual International Meeting for ASABE this summer.

INNOVATIVE COOLING TECHNOLOGIES

The U.S. Department of Energy's Ames Laboratory will be home to a new research consortium for more environmentally friendly refrigeration technologies. The consortium, named CaloriCool™, will develop caloric cooling technologies in partnership with other national laboratories, the private sector and universities. The work is sponsored by DOE's Advanced Manufacturing Office (AMO).

Refrigeration today uses age-old technology of vapor-compression, which consumes excessive amounts of electricity and generates unnecessary heat. CaloriCool will develop new cooling technologies based on compounds called caloric materials, which can generate cooling when acted upon by magnetic, electric or mechanical forces. Compared to the traditional vapor-compression, caloric cooling could reduce the need for energy for cooling by 20–30% in the United States alone. Implementing this technology will allow refrigeration to become safer, quieter, and more compact, efficient and environmentally friendly.

CaloriCool is one of four consortia that make up DOE's Energy Materials Network (EMN). The EMN will facilitate industry access to the unique scientific and technical resources available at the national laboratories, enabling manufacturers to bring advanced materials to market more quickly.

CaloriCool™
CALORIC MATERIALS CONSORTIUM

HEINDEL TO CONTRIBUTE EXPERIMENTAL DATA TO STUDY OF SPRAY BEHAVIOR

A group of researchers from across the nation are combining expertise in theoretical, computational and experimental studies to better predict and control sprays. The engineers say the research could improve combustion systems, liquid cooling and 3D printing and even help mitigate the wakes of ships.

Ted Heindel, Bergles Professor of Thermal Science

The U.S. Department of Defense is supporting the research with a grant of up to $7.5 million over five years that is part of the Defense Department's Multidisciplinary University Research Initiative. Of the grant, up to $1.6 million will support studies that **Ted Heindel**, Iowa State's Bergles Professor in Thermal Science in the Department of Mechanical Engineering, will conduct in his Experimental Multiphase Flow Laboratory.

Heindel will use his lab's X-ray tools to visualize dense spray flow near the nozzle, measure spray paths and create 3D spray images. The experimental data will help validate computer models and their predictions of spray behavior and control.

ENGINEERING WELCOMES 76 NEW FACULTY MEMBERS IN TWO YEARS

During FY15–FY17, the College of Engineering has added 40 assistant professors, 9 associate professors, 2 professors and chairs, 20 lecturers, and 5 senior lecturers to its ranks.

The significant increase supports the college's growing undergraduate enrollment, which increased by 22% from fall 12 to fall 15, and graduate enrollment, which increased by 35% from the same time.

"Our hires have hit the ground running, contributing to innovative education and research programs and also serving our state and nation," said **Arun Somani**, the college's associate dean for research.

The new faculty members were hired across all eight academic departments and their work impacts the college's eight strategic research areas:

- Advanced design and manufacturing
- Advanced materials
- Biorenewable processes
- Biosciences and bioengineering
- Computation, cybersecurity and decision sciences
- Dynamic systems and control
- Energy sciences and engineering
- Infrastructures and environment

The Departments of Mechanical Engineering and Civil, Construction and Environmental Engineering saw the most growth.

METAL ADDITIVE PRINTING AT ISU

A new metal laser sintering machine at Iowa State could be one of the first steps toward a new way of making things.

The Center for Industrial Research and Service (CIRAS) purchased the machine last fall. It uses a laser to melt powdered metal into the shapes described by a complicated design–a form of what's commonly known as 3D printing.

While plastic additive manufacturing machines, or 3D printers, are more common than metal ones, additive manufacturing technology in general may soon allow manufacturers to produce parts and products with less material in days instead of weeks.

Additive manufacturing machines follow computerized designs to build items one layer at a time–as opposed to traditional methods, which involve cutting metal or liquefying it and pouring it into a shape. The difference means manufacturers can start from scratch and create parts that before were impossible.

Researchers at CIRAS and engineering faculty and students are exploring the printer to help companies understand how they can best use metal additive manufacturing.

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IOWA STATE'S BAJA SAE TEAM HAS RECORD-BREAKING YEAR

The Baja SAE team at Iowa State recorded top-10 overall finishes in every event of the season for the first time in the group's history. The team placed sixth at Tennessee Tech, ninth at California and sixth at Rochester, New York.

Consistency in performance and some fine-tuning paid off for the Baja SAE team's mini off-road racer. The group designed the car to be lighter than previous years and installed a good suspension to handle all the rough terrain, accidents and breakdowns that occur during events.

Photo courtesy of Brad Cottrell.