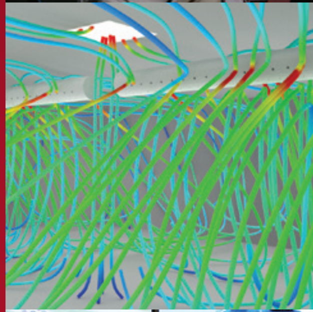
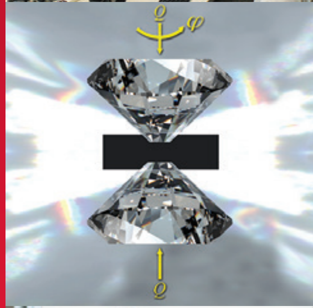
Iowa State University
College of Engineering

CYCLONE ENGINEERING RESEARCH





Cyclone Engineering Research

The College of Engineering at Iowa State delves into diverse interdisciplinary research initiatives aligned with its signature research areas that bring together exceptional capabilities and expertise.

Within the materials area, a novel multiscale theory explains new phases of materials under high pressure, paving the way for superior materials. Research in advanced manufacturing is leading to specialized technology that can be commercialized and change the landscape of American manufacturing. In addition to these projects, our researchers are using big data for faster discoveries in energy efficiency, transforming the transportation infrastructure and keeping water clean.

These projects are just a few of many that demonstrate the expanse of our research from fundamental science to progressive technologies for industry.

Sarah A. Rajala
Dean of Engineering
James and Katherine Melsa Professor in Engineering

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

Editor: **Jessi Strawn**
E-mail: engineeringinfo@iastate.edu
Website: www.engineering.iastate.edu/research

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Matt Frank, associate professor of industrial and manufacturing systems engineering, in the Rapid Manufacturing and Prototyping Laboratory

CUSTOMIZED PRODUCTS, PROCESSES

Delivering advanced manufacturing technology ready for commercialization

Researchers in Iowa State's industrial and manufacturing systems engineering (IMSE) department are major players in the country's goal to strengthen the resurgence of manufacturing in America.

With their projects to be supported by three of the recent federal manufacturing research centers – America Makes, the Institute for Advanced Composite Manufacturing Innovation and the Digital Manufacturing and Design Innovation Institute – they are working to solve unique manufacturing problems.

"Creating a product involves a great deal of reasoning and planning by individuals, which can lead to unwanted variation," explains **Matt Frank**, associate professor of IMSE. "We reduce that variation through automation solutions that generate high-quality products at a competitive cost all while using fewer resources."

But the group isn't working in the typical factory setting. Researchers explore complex, difficult-to-make components, like wind turbine blades and one-of-a-kind replacement products.

"It's tough to justify applying conventional automation technologies for products that aren't high volume," explains **Frank Peters**, associate professor of IMSE. "Instead, we like to partner with companies with interesting problems and create specific solutions that can be commercialized to improve the manufacturing system."

That's exactly what's happening at Iowa State's Wind Energy Manufacturing Laboratory (WEML). The lab is partnering with the National Renewable Energy Laboratory to incorporate advanced composites, specifically carbon fiber, into wind blade manufacturing. Using carbon fiber in place of fiberglass allows for lighter blades and may have the potential to lower the cost of wind energy.

Peters says WEML has been investigating composites for some time, and the connection with collaborators expedites getting the technology into industry.

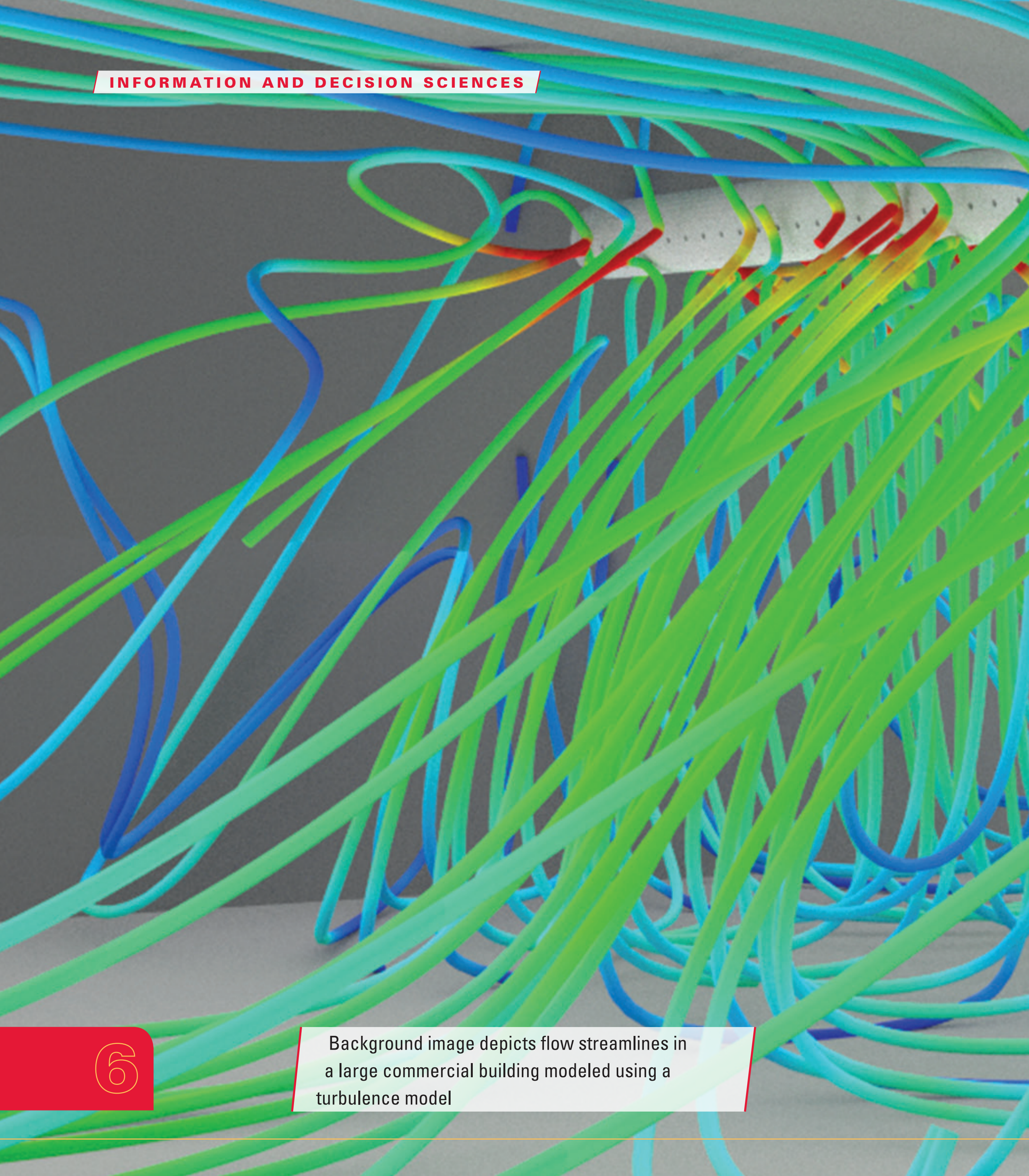
In another area, researchers generate customized replacement parts – whether it's a human bone or tractor part – with rapid manufacturing. Frank's lab features reconfigured traditional manufacturing technologies that act like 3D printers. From there, he's able to produce components using materials with preferred properties.

The group is also working on a project to connect metal 3D printers with a subtractive finishing process. "If we can implement this rapid manufacturing process in such a way that it will create extraordinarily customized products in an affordable way, it's going to make a big impact for consumers in the United States," Frank says.

Other projects include an automated system to produce patterns for large metal castings used in industry and military. The team has worked with the Defense Advanced Research Projects Agency to make manufacturability analysis software with the goal of reducing the design-to-build time frame. "The software analyzes proposed design ideas, giving feedback about everything from how difficult parts will be to machine, cast or weld, to what aspects within the design will drive up costs," Peters explains.

"As the country continues to look for ways to manufacture products within a variety of fields, our engagement with industry on relevant and applied solutions are an example of how that can happen," Frank says.

***Frank Peters**, interim department chair and associate professor of industrial and manufacturing systems engineering, in the Wind Energy Manufacturing Lab*



Background image depicts flow streamlines in a large commercial building modeled using a turbulence model

Insurmountable data is no match for **Baskar Ganapathysubramanian**. In fact, he says the more data, the better. That way he's sure to evaluate every possible scenario within the models he creates.

Ganapathysubramanian, associate professor of mechanical engineering, uses mathematical techniques and computational tools to solve a variety of real-world phenomena.

He's especially interested in applying this technology to energy and the environment, like he's doing with a project that studies how energy is utilized in buildings.

He says he was initially inspired to research the topic after reading the National Academy of Engineering's Grand Challenge to restore and improve urban infrastructure. "When I saw that approximately 45 percent of the national energy budget is used to heat and cool buildings, I knew that even the smallest

A FASTER WAY TO OPTIMAL SOLUTIONS

Using simulation and modeling to improve sustainable buildings

improvements in energy efficiency could have a substantial impact in terms of saving costs and use of nonrenewable resources."

Ganapathysubramanian uses modeling and simulations to investigate ways to improve design for new sustainable buildings as well as to augment existing building controls. His end goal is to improve the use of natural flows within these structures.

So far, his group has spent time understanding how beehive-shaped mud houses in Harran, Turkey, control internal temperature without any powered conditioning. Additionally, the team has looked at Iowa State University's solar-powered Interlock House to determine the best ways to allow for natural ventilation. Another project has researchers evaluating ideal locations for air quality sensors.

"Performing this work without a computational framework requires a great deal of time and painstaking measurements to explore a select few scenarios," he explains. "In our case, however, after we create a model of a building, we can make endless changes to our settings to determine how to make it more sustainable. The ideas we are generating, once implemented, are going to have a substantial impact on the building design and energy market."

Creating these models is no easy task. Modeling fluid flows, such as natural ventilation, is incredibly difficult, and it often results in various levels of approximations because of the complexity of the flows.

Ganapathysubramanian says an intersection of unique developments at Iowa State supports the mathematics behind his work and has led to even better results for his research. He is also thankful for the various collaborative activities that ISU enables and supports.

Most of the building research is in collaboration with **Ulrike Passe**, associate professor in architecture, who is interested in leveraging mathematical models to understand and design sustainable buildings.

Collaborating with **Ming-Chen Hsu**, assistant professor of mechanical engineering, Ganapathysubramanian has created a framework for modeling natural flows in complex geometries. Hsu is currently looking at incorporating his immersed-modeling method that takes a complex geometry and immerses it in a cube, thus allowing the team to explore a variety of complex geometries in a straightforward way.

Umesh Vaidya, associate professor of electrical and computer engineering, helps with understanding how to control and sense the flow physics. Together with Ganapathysubramanian, they have created a rigorous framework for rapid (real-time) contaminant analysis and sensor placement strategies.

These mathematical methods and tools also have utility in other areas of energy and sustainability. Ganapathysubramanian works with ISU agronomists (like **Pat Schnable** and **Asheesh Singh**) to apply similar tools to improving agricultural productivity.

Ganapathysubramanian adds that the tools and methods are the foundation to significant improvements in science. "As we use these technologies across disciplines, we'll see that having more time available to spend on analyzing a wide range of scenarios leads to superior end products."

EASING TRAFFIC HEADACHES

InTrans performs need-based research to improve transportation infrastructure

Since Iowa State's Institute for Transportation (InTrans) first began as the Local Transportation Information Center in 1983, researchers have transformed the surface transportation landscape through innovative methods, materials and technologies.

Now, with specialization in areas that range from work zone safety and traffic engineering to sustainable pavement and integrated earthworks operations, there are nearly 200 students, professional staff and faculty working within the 16 centers and programs that make up InTrans.

The research happening within the institute focuses on developing practical and applied solutions that can be quickly implemented to improve roadways, making the traveling experience better and safer for everyone.

Take for instance InTrans's Center for Transportation Research and Education, which is leading three of 11 research teams under the Federal Highway Administration's SHRP2 Implementation Assistance Program. Securing these projects involved working with three state department of transportation partners to identify priorities and pull proposals together.

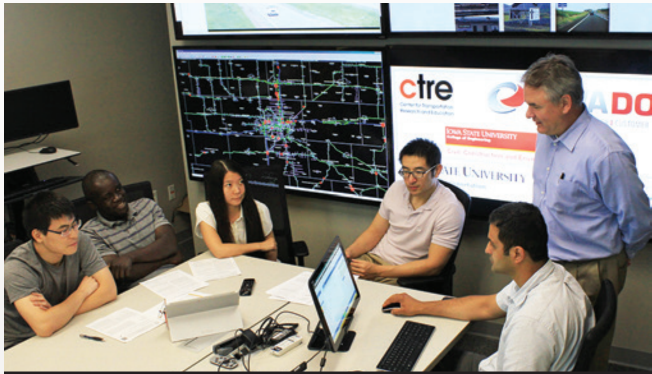
The teams are working on identifying driver characteristics and roadway features that play the most significant role in road departure crashes (Iowa DOT); evaluating the roles of speed and driver distraction in work zone crashes (Minnesota DOT); and determining the effects of distracted driver behavior and speed limit enforcement on crashes (Michigan DOT in partnership with Wayne State University).

Shauna Hallmark, director of InTrans and professor of civil, construction and environmental engineering, says the ability to work with transportation agencies locally and nationally, as well as private-sector and university affiliates, has been a large part of InTrans's success.

"We offer a unique range of expertise that is in high demand as the country addresses major issues within transportation infrastructure. These relationships help speed up improvements to roadways through knowledge sharing and thorough investigation," she adds.

As Iowa State University's primary resource for promoting transportation education, research and extension activities, InTrans is also improving the learning environment of students, faculty and staff.

A new Traffic Operations Lab features real-time connectivity to data and system performance directly from the field to researchers and students. "The lab extends traditional training for students and gives them an opportunity to be a part of using technology to improve systems performance and safety. The lab's big data provides opportunities to blend transportation and computer science techniques toward developing unique front- and back-end solutions for public agencies and the transportation research community," Hallmark adds.



Researchers analyze Iowa highway traffic data, in real time, at the Iowa State University Traffic Operations Laboratory

InTrans is also home to Iowa State's master of science in transportation, an interdisciplinary degree with supporting academic programs in the colleges of engineering, design and business.

Educating the next generation of transportation practitioners reaches beyond those enrolled at the university through InTrans's *GO!* magazine. The online publication combined with other outreach activities help K-12 students understand the variety of career needs in the transportation industry.

"The educational component of InTrans is crucial for our institute," Hallmark explains. "We've spent countless hours creating programs and activities that address everything from policy to maintenance to make the transportation system more durable, reliable, safe and sustainable. We have to prepare others to keep the momentum moving forward."

That momentum includes more than $13.6 million research dollars secured in 2014 from federal, state and private funding. "The increase we've seen in high-profile projects shows that we're a talented team of researchers dedicated to delivering results. We're excited to continue assembling and supporting world-class teams through new projects."

Shauna Hallmark, director, Institute for Transportation

MATERIALS UNDER EXTREME CONDITIONS

Search for new materials and phases under high pressure and large plastic shear

When you look at the properties and strength of a diamond, which is created under intense heating and pressure, it's clear there's value in understanding how it's synthesized. Phase transformations under high pressure, like when graphite is formed into a diamond, are at the heart of the theoretical work **Valery Levitas** has been conducting throughout his extensive international career.

Levitas, Iowa State's Schafer Professor and faculty member of aerospace engineering and of mechanical engineering, conducts fundamental research to predict and discover new phases of materials under high pressure. His work can be translated into engineering applications, including synthesizing superior materials for new technologies and products.

A significant part of his research investigates ways to retain high-pressure phases after pressure is released. To do this, he uses plastic shear, or an irreversible deformation that is applied with a rotational diamond anvil cell (DAC). He explains that plastic deformation not only changes the shape of a sample, it also changes the sample's microstructure and generates new defects and phase transformations.

More importantly, the shear drastically decreases the pressure necessary to create desired phase transformations. "Near the defects we create, there are regions with concentrations of large stresses, which can be considered as pressures in different directions," he says. "Instead of applying external high pressure, we apply a lower value of pressure coupled with large plastic shear to generate new defects."

Using a rotational DAC in place of a traditional DAC has required Levitas to develop a new multiscale theory to explain the interactions between phase transformations and plastic flow under pressure. He says this is because unlike traditional high-pressure physics, which operates with the single parameter of pressure, he has to understand the effect of six components of stresses and six components of plastic strains, as well as the effect of evolving defects.

The corresponding analytical and computational approaches he developed to support his theory explain mechanisms of strain-induced phase transformations at the nanoscale as well as the complex behavior of a sample in rotational DAC.

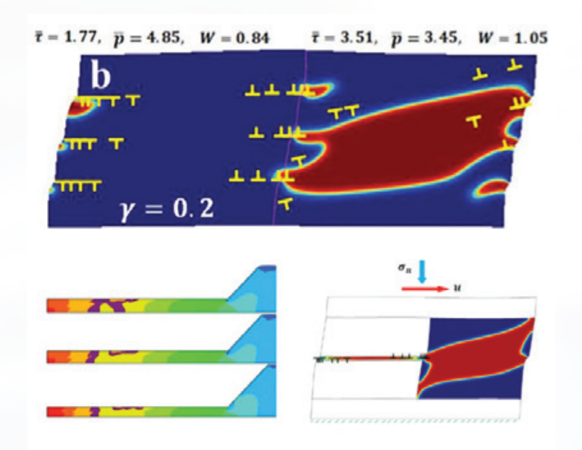
His research group has been able to predict and confirm new phenomena through experiments. Notably, the team has proven the possibility to reduce transformation pressure by an order of magnitude to transform boron nitride

Illustration of a sample being compressed and sheared in a rotational diamond anvil cell

from graphite-like to superhard, which may serve as a precursor of new technologies. Experiments have also revealed a new amorphous phase of silicon carbide that may shed a light on how armor ceramics are damaged under projectile penetration.

Levitas began his work in Kiev, Ukraine, and brought his high-pressure theories and technology to the U.S. in 1999. It took him eight years to obtain his first federal grant on this topic from the Defense Threat Reduction Agency, but now this work is supported by the Defense Advanced Research Projects Agency, National Science Foundation and Army Research Office.

"As the only team in the world working on this topic theoretically and the only one in the U.S. performing experiments with rotational DAC, I'm encouraged to see interest growing," Levitas says. "Having an understanding of materials, including how they behave in natural and technological processes like earthquakes, friction and wear, surface treatment, military applications, and mechanochemical processes like ball milling, will lead to ways of controlling these processes and creating even greater materials."



Examples of modeling of processes in a compressed and sheared sample from a rotational diamond anvil cell, and the interaction between dislocations and phase transformations at the nanoscale

Michelle Soupir, associate professor of agricultural and biosystems engineering

SOIL AND WATER SAMPLES ILLUMINATE ANTIBIOTIC RESISTANCE

Studies of manure application reveal antibiotic resistance movement

While using manure as an organic source of fertilizer has helped the agricultural industry maintain balance in integrated crop and livestock systems, there is some risk the manure contains bacteria that may contaminate water bodies if transported off the field by rain.

Michelle Soupir, an associate professor in the Department of Agricultural and Biosystems Engineering, and her team of researchers are examining the transport of two pathogen indicators: *E. coli* and enterococci. Both are identified by the EPA as indicators of potential fecal contamination of water resources. She also looks for relationships between the traditional pathogen indicators and antibiotic resistance.

Soupir says identifying the resistance is incredibly difficult. “When you monitor environmental systems, you can be on a fishing trip of sorts when determining what resistance might be out in the environment. In our study, we targeted tetracycline and tylosin.” Both are antibiotics. Tetracycline treats bacterial infections like acne and genital or urinary infections, whereas tylosin isn’t prescribed to humans but is in the same class as other common human antibiotics like erythromycin.

The fieldwork is conducted at the North East Iowa Research Farm (NERF), near Nashua, Iowa. A different land-use treatment is applied to one-acre plots of crops, separated from other plots by berms and curtain drains to reduce cross-contamination from either above or below the surface. Manure is injected into some of the plots in bands close to the root system before the first hard frost.

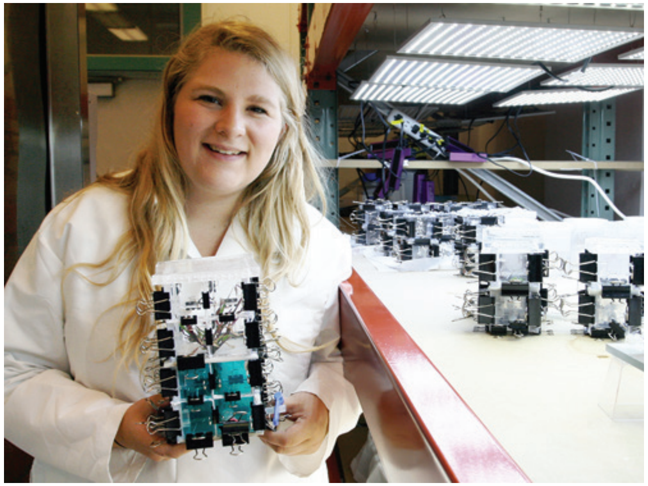
“It’s applied in the fall so ammonia doesn’t volatilize, and we don’t lose the nitrogen we’re applying,” says Soupir. “It’s always a gamble, because you want to do it right before the soil freezes.” The manure is then held in the soil all winter at cold temperatures, which is a benefit to water quality as the cold temperatures tend to kill off some of the pathogens and resistant bacteria.

The team is getting data from three points in the system. Samples of the manure that is applied to specific plots tells them how much antibiotic resistant bacteria and pathogen indicators are going onto the plots. Measurements of the soil show how long the organisms survive. This leads the research team to take samples of water, which tells them what organisms are moving off site and could potentially be moving into surface water.

But the results of this have not been as expected. “We rarely see statistically significant differences between the manure amended and control plots in the tile drainage water,” says Soupir. “It’s been surprising that there aren’t more statistical differences. For the most part, it’s been pretty good news for pork producers because the method of manure application (injection in the fall) seems to be a good management strategy for preventing pathogens and resistant bacteria from moving into the tile drains.”

The project is on its fourth year, and while most of the results are on swine manure, the researchers have begun to look at a poultry-amended site as well as a beef-amended site. Soupir says these research sites are novel because they have received manure application for long periods of time. “It’s really made me appreciate the need for long-term studies.”

NEWS B



Graduate student Kara Lind holds one of the plant environments made from LEGO bricks

MATERIALS SCIENCE GRAD STUDENT APPLIES ENGINEERING KNOWLEDGE TO PLANT BIOLOGY

After she finished her undergrad in chemical engineering at Iowa State University, **Kara Lind** was looking for a change of pace. She didn't stray too far from her roots. Lind is still at ISU, but now she's a graduate student in the field of materials science, where she has been working with different materials to study plant growth.

Lind is focusing on two research projects, the first of which involves growing plants on paper surfaces. "It hides the plant's response to gravity," she says. "Since it can't grow down, you end up growing the roots in two dimensions." This system is not only inexpensive, but allows Lind and her colleagues to control very specific conditions of the environment.

For her second project, Lind is growing plants in systems built from LEGO bricks. This unexpected building material has worked well for the research team, because it's commercially available, modular and made of transparent plastic with a high melting temperature, allowing the team to sterilize the plant's environment.

She says her interest in this work comes from a desire to benefit society by addressing global food security. "We're not looking directly at the field in an agricultural sense, but we're looking at understanding how plants respond to stressors." Knowing plant responses gives insight to better ways to grow them, ultimately providing more efficient ways to meet the growing food demand.

ITES

COMPUTER SECURITY IN THE CLASSROOM

Cyber-security experts at Iowa State have developed materials for the nation's first computer security literacy curriculum for primary education. The program teaches students to recognize and respond to security threats such as malicious software, unsecured wireless networks and online scams. "This project will enable teachers across the state to be able to help their students be safer online and will continue to position ISU and the state of Iowa as leaders in cyber security education," said **Doug Jacobson**, professor of electrical and computer engineering. The curriculum will include a variety of materials including lesson plans, video modules, presentation materials, current events topics, quizzes and in-class activities. It will be available for free to teachers for the 2015-16 year and is supported by Iowa State's Information Assurance Center, Iowa State Information Technology Services and the U.S. Department of Justice.

IOWA STATE ON TOP FOR PATENTS

Researchers at ISU were awarded an overall 31 U.S. patents during the 2014 year, placing the university at 70th in the world among universities granted U.S. utility patents. The ranking comes from a report by the National Academy of Inventors and the Intellectual Property Owners Association, and it is based on data from the U.S. Patent and Trademark Office. "Iowa State faculty and scientists are extremely productive in creating new knowledge that leads not only to patents, but also helps address global challenges such as sustainability, food security and human disease," said **ISU President Steven Leath**. "The same intellectual property that earns patents also leads to student and faculty startup companies that generate economic development and embody our land-grant mission." Some of the patents issued included wind turbine tower systems, computer encryption logic and technology for improved treatment of Parkinson's disease.

STRIPS BENEFIT CROP SOIL

Photo courtesy of Anna MacDonald

A new grant from the U.S. Department of Agriculture is allowing the promising STRIPS program at Iowa State to expand. The Science-based Trials of Rowcrops Integrated with Prairie Strips program involves planting thin bands (typically 30 feet wide) of native prairie plants throughout fields of crops. According to **Matt Helmers**, a professor of agricultural and biosystems engineering and one of the leaders of the STRIPS project, the prairie plants have stiff stems and deep roots, which helps to slow runoff on the fields. By slowing the water, sediment is not able to stay suspended, and thus much less is carried through the field. The program, which began in the fall of 2003, has seen a 95 percent reduction in sediment losses. The three-year grant will allow the project to widen its scope and test its methods in new geographic areas and agricultural practices.

IOWA STATE UNIVERSITY
College of Engineering
4565 Memorial Union
Ames, IA 50011

TEAM PRISUM WINS FORMULA SUN GRAND PRIX

Iowa State's solar car racing team achieved its first overall victory at this summer's Formula Sun Grand Prix in Austin, Texas. Team PrISUm says strategy played a big factor in its success.

For this competition, the student-engineers chose a battery that runs cool but doesn't store as much energy to beat the Texas heat. The team also closely tracked weather data and the car's power storage and efficiency to adjust speed and lap times.

Team PrISUm's approach resulted in consistent performance during triple-digit temperatures. Phaëton, the team's 12th solar car in 25 years of racing, completed 223 laps over 24 hours of racing around the Circuit of the Americas Formula 1 track.

Photo by the Formula Sun Grand Prix