Iowa State University
College of Engineering

CYCLONE ENGINEERING RESEARCH

‘SENSING SKIN’ MAKES WIND ENERGY MORE COST-EFFECTIVE

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

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

Editor: Jessi Strawn
engineeringinfo@iastate.edu

BUILDING ON A RICH HISTORY OF INNOVATION

Dean Sarah Rajala and Associate Dean for Research Arun Somani are leading a growing research enterprise at Iowa State University's College of Engineering.

From a cyber-physical testbed for power grid research to a new, streamlined approach to vaccine design—the college's faculty is committed to developing creative solutions that make a worldwide impact.

Iowa State is conducting transformational engineering research that addresses today's greatest challenges. Learn more about these cutting-edge discoveries:

CONTENTS

SECURI

A SMARTER POWER GRID

Cyber-physical testbed gives realistic platform for power grid security research

With the nation's security and economic vitality in his sights, **Manimaran Govindarasu** is setting out to make the power grid infrastructure more resilient against evolving and continuous cyberattacks.

These attacks could result in anything from compromised data within utility companies to significant blackouts across the country.

"Our current power grid is designed to manage randomly occurring faults from things like devastating storms, but it doesn't have the same capacity when it comes to malicious cyberattacks," explains Govindarasu, Mehl Professor of Electrical and Computer Engineering.

Competing with these attacks and developing defensive and mitigative strategies requires a safe, realistic place to configure and simulate compromises to the grid. That environment is exactly what Govindarasu is creating with a cyber-physical security testbed.

The testbed, which integrates industry standard control software, communication protocols, and field devices combined with real-time power system simulators, provides an accurate representation of cyber-physical grid interdependencies.

Researchers, including faculty and graduate and undergraduate students, use the testbed to assess vulnerabilities and risks, analyze system impacts, and validate and evaluate countermeasures.

Govindarasu also incorporates the testbed into the coursework of a senior/graduate-level course on cybersecurity as well as in senior capstone design projects. Additionally, he offers the technology to outreach programs, giving people outside the university a chance for hands-on experience with power grid and cybersecurity.

"Not only are we studying the impact of these attacks, we are gaining insight into how to prevent them from happening in the first place," Govindarasu says. "It's a great opportunity for all those involved—the students get to learn technical skills, and their projects provide more data to incorporate into our research."

The system he has created is unique on a university campus, but Govindarasu feels it's the best place for such a technology.

"We are uniquely positioned at Iowa State because we have strong industry-university collaborative programs in information assurance and power engineering. Taken together, we can incorporate all these ideas in one place and really start doing something about the problem," he says.

While the testbed is operational, Govindarasu is working on enhancing it by scaling it up, federating it with complementary testbeds and adding remote access capability. These advancements require creative solutions, but they would also allow for more partnerships to form within the project.

TY

“Other universities and national labs want to be able to access the testbed to run different scenarios and collect results. We want to create a web interface that would allow for this work and also add to the functionality of the technology,” he says.

The testbed was first funded by a strategic research initiative within the electrical and computer engineering department. Later, the college added funds when the project showed promise. Now, it has support from the U.S. National Science Foundation and in-kind donations.

“It has taken some time to develop a full system that functions so well, and it has been a synergistic group effort with my colleagues Dr. Ajjarapu and Dr. Jacobson and our students,” Govindarasu says. “We definitely have more work and collaborating to do, but it’s exciting to be part of something that is so timely and can have such an important impact.”

Manimaran Govindarasu, Mehl Professor of Electrical and Computer Engineering

REDUCING THE COST OF WIND ENERGY

DIAGNO

Sensing skin monitors structural health of wind turbine blades, giving insight into needed repairs

An inexpensive polymer that can detect damage on large-scale surfaces could be pivotal in making wind energy a more affordable alternative energy option.

The material, which is made into 3-inch square pieces, is a nanocomposite elastomeric capacitor fabricated from a dielectric layer sandwiched between two painted conductive layers. When the skin is placed on a surface, engineers can measure its capacitance, or stored electrical charge, to make inferences about any changes in geometry taking place on that surface.

Simon Laflamme says using this material on large-scale structures, such as wind turbines, could mean making less expensive, condition-based repairs when small cracks and other deformities appear instead of incurring the high cost of maintenance on a fixed time interval or after a breakdown, which may necessitate the replacement of huge components, like an entire turbine blade.

Laflamme, assistant professor of civil, construction and environmental engineering, has been developing the sensing skin since he was a student at MIT. While he didn't originally plan on the skin being used on wind turbines, he says it's a great application.

That's because current structural health monitoring of wind turbine blades can't be done in real-time on a continuous basis. "The turbines have to be physically inspected, and this usually happens only once or twice a year. By the time inspectors get to a blade, it could have sustained too much significant damage to do minor repairs," Laflamme explains.

Once it's adhered to a surface, the sensing skin would act as an indicator, automatically telling engineers to inspect a blade if something unusual happens. Over time, a pattern of how blades deteriorate emerges, providing insight into better maintenance plans for wind turbines, which could extend the life of the blades, as well as provide new ideas for future blade designs.

All of these factors come together in what is called an automated condition assessment. "The sensing skin is integral in capturing the entire lifecycle of blades as changes happen rather than through the reverse inspection that is used today," Laflamme adds.

His research has become truly multidisciplinary. The skin itself is produced in collaboration with the materials science and engineering department, but it also has ties with electrical and computer engineering for designing cost-effective data acquisition systems. Additionally, various efforts have been undertaken with aerospace engineering and several centers on Iowa State's Campus, including the Center for Nondestructive Evaluation and the Bridge Engineering Center.

OSTICS

Laflamme says an approach that brings in different ideas is absolutely necessary. “It’s the way modern problems are going to have to be solved. We have to share insight to create the best solution,” he explains.

He adds that he appreciates being able to bring this perspective to the undergraduate and graduate students working on the research project. “We have at least 12 students who are getting a sense of how valuable multidisciplinary engineering is, and they are truly enjoying the experience,” Laflamme says. “Integrating the concept into their education means it becomes a natural way of thinking for the next wave of engineers in industry, and that’s going to mean big things for what’s to come.”

Simon Laflamme, Assistant Professor of Civil, Construction and Environmental Engineering

REVOLUTIONIZING DISEASE PREVENTION AND TREATMENT

NANOT

Using a systems approach coupled with nanoscale technology to develop next-generation vaccines

For more than a decade, **Balaji Narasimhan** has been determined to improve vaccine delivery and availability, a mission that's especially important for parts of the world where access to such life-saving, preventative medicine isn't always practical or even possible.

One project includes searching for ways to boost the effectiveness of vaccines through experiments with the chemical composition and size of polymer-based nanoparticle adjuvants used to deliver antigens that trigger the body's immune response, tailoring these to be released over an extended period of time. Another looks at using nanoparticles to load vaccine components and delivering them "needle free" to improve patient compliance.

Now, Narasimhan, Vlasta Klima Balloun Professor of Chemical and Biological Engineering, is leading a collaborative effort in vaccine development with 43 investigators from five universities, two national labs, three research institutes and five companies. The group will be seeking large-scale funding to launch a national center on nanoscale technologies to develop next-generation vaccines.

The project, entitled "Systems Design of Nanovaccines," will receive up to $1.5 million over three years as part of Iowa State's Presidential Initiative for Interdisciplinary Research, a program launched by President Steven Leath to support research efforts that could lead to major advances, discoveries and technologies.

The research group plans to use a systems approach for vaccine development. Different from the current step-by-step method, the systems perspective frames the development of new and improved vaccines as a supply chain and considers all the steps—ranging from conceptualization to testing to global distribution and everything in between—as early as possible with built-in feedback at each step.

"The result is a better product made in a shorter period of time because you don't have to wait for one step to be done to start the next. It could potentially shorten the time it takes to develop new vaccines from 10 years to about 5 years," Narasimhan says.

Building on his existing research in nanotechnology, Narasimhan adds that formulating the vaccines into nanosized particles is effective because the immune cells the vaccines are trying to activate typically do a good job of internalizing, or taking up, the smaller particles.

Many viruses, such as H1N1 influenza and SARS, are also nanosized. "We are trying to mimic some of those pathogens using synthetic, man-made degradable polymer particles containing proteins

ECH

specific to the pathogen to essentially trick the immune system into thinking it's dealing with those pathogens so it mounts a potent immune response," Narasimhan explains.

In the end, Narasimhan hopes the group's efforts make vaccines more accessible. That might mean single-dose vaccines that can be self-administered. Or it could be vaccines that don't have to be refrigerated, which would cut costs in half. Or maybe it's a combination of those things and more.

"For these sorts of advancements to be made, we really need to operate in a cross-disciplinary setting," Narasimhan says. "We need to be open to embracing ideas from other fields, as collaborating with experts gives us an advantage to develop better vaccines and with more efficiency."

Balaji Narasimhan, Vlasta Klima Balloun Professor of Chemical and Biological Engineering

ADVANCING PRODUCTION IN LARGE-SCALE INDUSTRIES

Calling for a multidisciplinary, value-driven philosophy for systems engineering

Energy. Transportation. Civil infrastructure. Aerospace. These and many other large-scale, complex industries are critical to the security and prosperity of our nation. And they are in need of some serious attention.

That's where **Christina Bloebaum** says she can make a difference. Bloebaum, the Dennis and Rebecca Muilenburg Professor of Aerospace Engineering at Iowa State, is investigating a new educational and technological framework to improve the way these systems and related products are developed.

The implication of her work is a more efficient use of valuable resources, like time and money, while making an end product better suited for specific purposes.

Her approach, which uses integrated research in social sciences and engineering, emphasizes a value-driven design process. This requires each decision to be tied back to a value function, such as maximizing profit or mission success, which is established at the beginning of a project.

"We also want to explore the use of serious games to enable research as well as educate the future workforce about how these complex products and systems are designed and delivered," she adds. "Gamification offers an immensely powerful yet largely unexplored approach to enable a paradigm shift in practice, as well as training, in systems engineering."

As the former NSF program director of both the engineering and systems design program and the system science program, Bloebaum has seen a need for this sort of research firsthand, noting the current approaches used aren't keeping pace with technological advancements.

Her own accounts are supported by the National Academies' *Rising Above the Gathering Storm, Revisited* report, which describes how America is falling behind on the technology front and suggests that drastic measures need to be taken.

Bloebaum knows a change in systems engineering at the highest of levels involves a lot of different ideas coming together. Her experience with informed decision support through work on multidisciplinary design optimization will prove useful. And she's gathering other ideas through interdisciplinary research teams coordinated to pursue grants related to her overarching idea.

"There are so many different components that need to be addressed in what we are proposing to do—from what type of widget to use to how communication flows through organizations—and we need to analyze a great deal of information

NTION

to determine what changes can have the biggest impact," she says.

Visualization technology will help support the process. She has used the technology to capture decisions made by end users of a complex product as well as to provide a representation of how the systems engineering process flows, identifying how changes in one area affect other areas.

Because her framework will mean altering long-standing processes, Bloebaum wants to provide demonstrations of success by partnering with larger agencies, such as NASA.

"Once we can prove we have a low-risk, incredibly high pay-off proposition, we can show others the benefits of our approach," she says. "Along the way, students will have learned this framework through our educational outreach, and the result is a self-sustaining solution to a serious problem."

Christina Bloebaum, Dennis and Rebecca Muilenburg Professor of Aerospace Engineering

ECONOM

A NEW KIND OF SOLAR CELL

Improving the performance of organic, thin-film materials with perovskites to make solar energy more affordable and accessible

With the sun providing most forms of energy, whether indirectly or directly, it's no wonder **Vikram Dalal** has spent more than 40 years working on better ways to access its energy.

But it's the potential to provide the developing world with a more reliable source of energy that most inspires him.

Dalal, Whitney Professor of Electrical and Computer Engineering, says cost-effective solar energy could be a consistent source of electricity for parts to the world that typically rely on diesel generators or kerosene for energy.

"If we could accomplish this, it would mean clean drinking water, refrigeration to keep vaccines cold and electricity at night. All positive things that could drastically improve people's way of life."

And so, Dalal is working on a new class of solar cell. His research, which is currently funded by the National Science Foundation as well as the Iowa Energy Center, joins organic and perovskite solar cells with thin films of silicon.

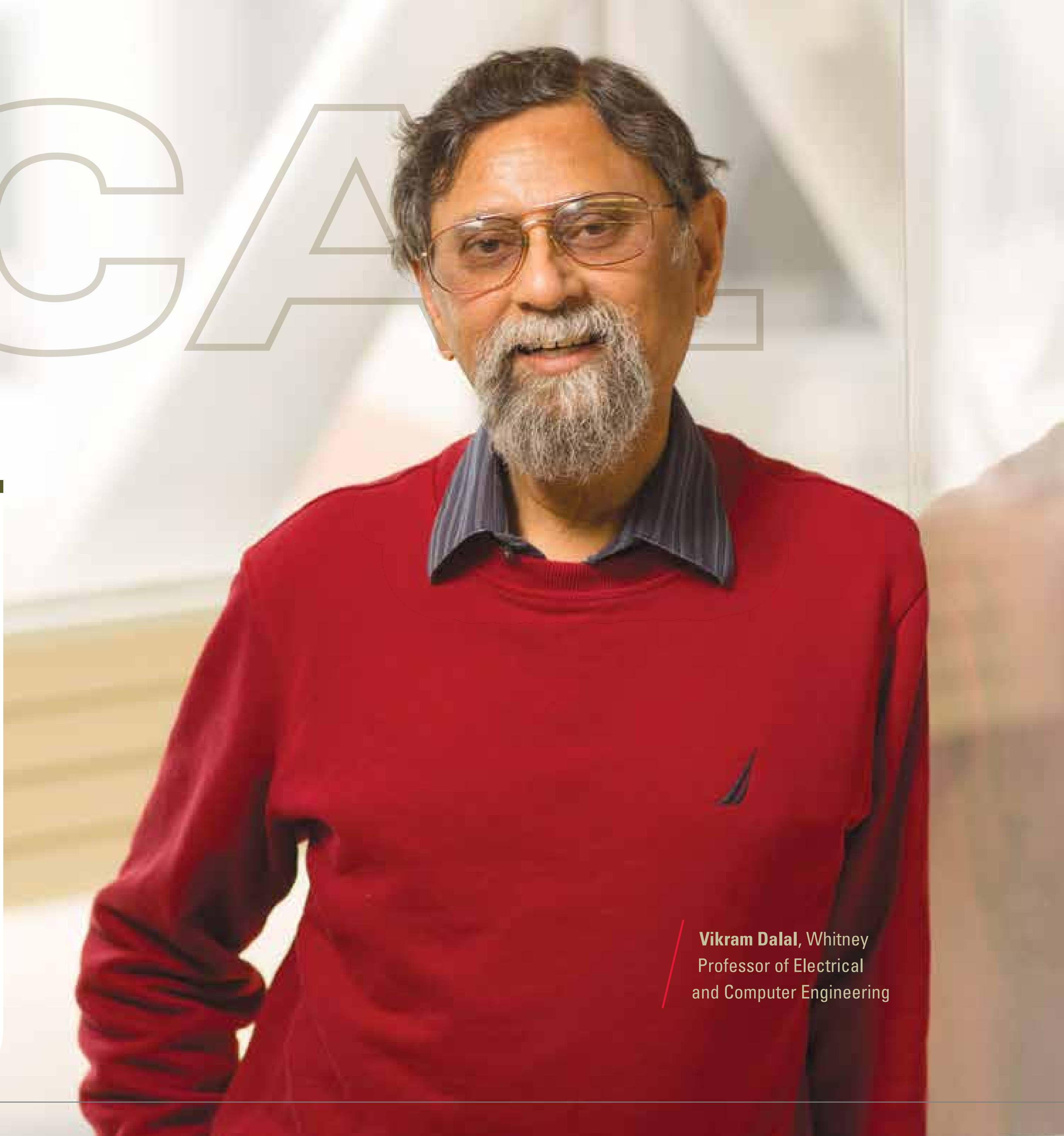
Perovskites are a new system of materials that are increasingly efficient at converting solar energy into electricity. When perovskites are combined with thin-film silicon cells, which use amorphous silicon that is only a few hundred nanometers (a billionth of a meter) thick, or organic solar cells that are applied to a semi-transparent panel to absorb sunlight, there is potential for these cells to convert 20 percent of the light they absorb into electric energy.

That would match the efficiency of conventional solar panels, something that has yet to be done with newer technology. In addition, these cells would be more cost-effective, requiring less expensive material than the silicon crystals currently in use.

A major problem facing both organic and perovskite cells is that they degrade rapidly in performance due to environmental factors such as moisture and light exposure. Not much is known about the fundamental physics of why these cells degrade, so Dalal's research is working to understand these phenomena. Over time, he will then design new materials and device structures that are much more stable with the goal of reaching a 20-year life for these cells.

"We have many challenges to overcome, both in improving efficiency and achieving much better stability. That's why we've begun working with several disciplines, including chemistry and physics, and we are forming new partnerships, like that with Nazarbayev University, a new university in Kazakhstan's capital city of Astana," he says. Dalal adds that bringing together experts in organic and perovskite solar cell research will help advance the technology.

"Making solar energy better and cheaper will allow solar to penetrate the large-scale utility market as well as be widely utilized in developing countries. It's something I've been working on for a long time, and these new cells could be the solution."



Vikram Dalal, Whitney Professor of Electrical and Computer Engineering

NEWS B

IOWA STATE PART OF $320 MILLION NATIONAL MANUFACTURING LAB

Students assemble parts in a virtual factory created by Iowa State's METaL virtual reality facility. Judy Vance (right) directs the facility, which will contribute research to the Digital Lab for Manufacturing.

Iowa State University is a tier 1 partner in the new Digital Lab for Manufacturing that is based in Chicago with affiliated partners across the country.

A $320 million enterprise, the Digital Lab has been created by University Industry LABS, a Chicago-based research and commercialization collaborative, with support from a $70 million grant from the U.S. Department of Defense. The remaining support comes from industry, academic, government and community partners.

Designed to be the country's flagship research institute for digital manufacturing and design innovation, the lab applies computing and data analysis to improve manufacturing machines and factories. The lab focuses on three technical areas: advanced analysis, intelligent machining and advanced manufacturing enterprise.

As a tier 1 partner, Iowa State holds seats on lab boards and committees. Additionally, researchers from around the university, including three university centers—the Center for e-Design, the Virtual Reality Applications Center and the Center for Nondestructive Evaluation—offer unique resources and expertise to the lab. Iowa State also offers strong K-12 outreach and workforce development experience.

Janis Terpenny, director of the Center for e-Design and Iowa State's Joseph Walkup Professor and Department Chair of Industrial and Manufacturing Systems Engineering, will provide technical leadership for the Digital Lab's work in the advanced manufacturing enterprise area.

"This is public-private partnership on a grand scale," Terpenny said. "One capable of providing the significant resources and talents for advancing research, effecting change for manufacturers large and small, and preparing the next generation for the multi-faceted demands for a new type of workforce."

ITES

IMPROVING HVAC SYSTEMS

Graduate student **Kahni Pr'Out** first experienced Iowa State in 2010, when she came to campus that summer to participate in a National Science Foundation Research Experiences for Undergraduates program. She says she immediately connected with mechanical engineering faculty and staff, including Assistant Professor **Baskar Ganapathysubramanian**, who has since become her major professor.

Now, she's exploring ways to make heating, ventilation and air conditioning systems more efficient. Her research analyzes placement of sensors that communicate an area's temperature to the main system. They are also looking for an ideal number of sensors to best control temperature.

"Right now, about 40% of costs for maintaining a building go into heating and cooling," she explains. "If you can reduce energy consumption, it saves money, but more importantly, it's great for the environment."

QUICK HITS

ISU one of six core universities in PEGASAS: The FAA Center of Excellence on General Aviation

Faculty from civil, construction and environmental engineering are collaborating with researchers from Iowa State's Institute for Transportation to carry out two PEGASAS funded projects: investigating the economic and technological feasibility of heated airport pavement systems and developing a mobile app to assess the quality of airport pavement markings.

Record enrollment

More students than ever before are enrolled at Iowa State's College of Engineering. In 2013-2014, 7,123 undergraduate and 1,161 graduate students were enrolled in the fall.

HPC@ISU increases access to powerful computational resources

The High Performance Computing initiative, supported by institutional and grant funds, provides the ISU research community opportunities to share computational resources and create collaborative partnerships.

Initiative for a Carbon Negative Economy continues exploring biochar as a carbon sequestration agent

Through workshops, national panels and research grants, Iowa State engineers and scientists are collaborating to find a way to reduce carbon emissions and provide economic growth. Right now, they are focusing on biochar, a byproduct of biomass pyrolysis that can enhance soil fertility and increase crop yields.

College helping centers grow

Iowa State's Center for Nondestructive Evaluation, Information Assurance Center and Microelectronics Research Center are now integrated into the College of Engineering. This structure will offer new research opportunities for faculty and students, allowing the centers to expand their research programs.

IOWA STATE UNIVERSITY
College of Engineering
104 Marston Hall
Ames, IA 50011

BIOSCIENCES & ENGINEERING / ENERGY SCIENCES & TECHNOLOGY / CRITICAL INFRASTRUCTURE / INFORMATION & DECISION SCIENCES / SUSTAINABILITY