

PURDUE'S
ENGINEERING
EDGE

Profiles in Research



PURDUE
UNIVERSITY

COLLEGE OF ENGINEERING

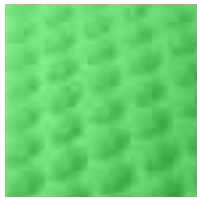
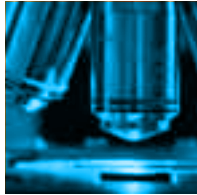
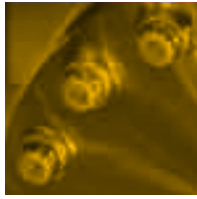


Singular **Breakthroughs**, Collective **Success**

Whether it's a senior faculty member being honored at the White House, a researcher in mid-career on the verge of a laboratory discovery, or an assistant professor contributing expertise to a multidisciplinary call to solve some grand challenge, there's no shortage of researchers doing outstanding work within Purdue Engineering. At all levels. And while the seed of a great idea may come from **someone**, it's more often than not a collective effort that leads to an engineering breakthrough.

The four main sections in this year's version of Purdue's Engineering Edge begin with individuals—two older, two younger—working on the absolute cutting edge of research in fields as diverse as healthcare, energy, infrastructure, and education. Their solitary contributions range from promising beginnings to prolific and mind boggling. But pulling back we see more of the collaboration that takes something from a creative notion to an engineered reality.

What distinguishes the Purdue engineer? No doubt it's some combination of smarts, creativity, and an insatiable curiosity. But of late it's also surely someone willing to step out of his or her comfort zone, to foster a collaboration with someone on the other side of campus, to take a chance on that **collective success**.



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Perspectives



Bill White
President
DuPont, Canada
Purdue ME '74

Leading universities, like Purdue, play a valuable role as research partners for businesses. By working together, we amplify each other's efforts as we explore for solutions, including those that will address some of the world's most pressing needs.

The results of our joint efforts to deliver solutions create jobs and builds economies. They also lead to new insights that can be shared within the academic community to advance our universal body of knowledge.

The full scope of the effort and contribution of research that is required for improvement in our daily lives may not be fully or broadly understood or appreciated. This is probably easy to understand, since most people never see or participate in the intensive processes of innovation and commercialization that are required to bring an idea to the market. This enormous opportunity is most apparent to those of us who have experienced it.

As a science company, we at DuPont have ample evidence about the value of research. Success over our more than 200-year history as a company has depended on using research to identify needs and opportunities, to develop options and opportunities that can fill our research pipeline, and to commercialize products and services that help to meet the challenges faced by society.

We have seen how research can be enhanced through joint efforts with universities, partners, governments, and individuals. Diversifying this mix to engage people from different regions and backgrounds around the world can further multiply the potential for success. Put simply, different people often see things differently. From these differences and varying perspectives, there's an increased possibility that new approaches can emerge.

To make sure that this research continues to take place, it's absolutely critical that there is an ongoing supply of highly skilled researchers who are ready, willing, and able to work collaboratively. Encouraging more young people to study and pursue careers in science and engineering is one key step that can help to ensure that this happens.

Universities have a key role to play in this effort. They challenge and nurture each new generation of young scientists and engineers—many of whom go on to successful careers in business, research, and education—and build the foundation for future discoveries and breakthroughs. Purdue actively addresses this need with its objective to strengthen preparatory education as part of the engagement pillar in the strategic plan for preeminence.

At DuPont, we support this effort through a wide variety of programs, including our DuPont Challenge science essay-writing competition, which has been held every year since 1986. Since its inception, we have recognized more than 100,000 students from grades seven to 12, as well as teachers. Our goal is to stimulate people's interest in the process of discovery and innovation through science, as well as their understanding of its value to society.

Research is a key to the discovery that is required to help society achieve a better future. Working together, we can seek to find the solutions to feed our growing global population, tap our vast renewable resources for energy and materials, provide safer and more secure lives for people, and explore new worlds. ■ **Bill White**

I am pleased to present *Purdue's Engineering Edge*, the sixth installment of our research publication. Purdue Engineering research is touching the world's most pressing problems, from healthcare to energy to the effects of population growth and urbanization. To engineer is to make discoveries that will benefit humanity, and that is at the forefront of our thinking. In the following pages, you will see some of our most striking research, but you will also see that, increasingly, the boundaries between research, education, and engagement are blurring. Research in the field of engineering education informs our teaching and education programs. And Purdue initiatives such as EPICS (Engineering Programs in Community Service), SURF (Summer Undergraduate Research Fellowships), and GEARE (Global Engineering Alliance for Research and Education) all span our learning, discovery, and engagement missions. And you will also see that the contributions highlighted in this publication epitomize Purdue Engineering's new "Think Impact" motto. I hope you'll discover for yourself the impact we're making. ■ **Leah Jamieson**

For five years, I had the pleasure and challenge of overseeing research endeavors within Purdue's College of Engineering. In that time I've witnessed an amazing explosion of multidisciplinary work. From cross-campus collaborations through nationally funded research centers, I've seen researchers who are truly interested in working together to solve grand challenges. And from nanotechnology breakthroughs to our next ventures into outer space, Purdue engineers continue to work on the cutting edge of those challenges. What's more, we're making a significant impact on the marketplace. Startups are helping to revolutionize how engineers can administer better healthcare, better protect and sustain the environment, and use energy more efficiently while at the same time discovering alternatives. Purdue's College of Engineering will always be a place of discovery and breakthrough. I hope you'll read and discover the efforts of a few of the many engineers working here. Their collective success has made my job most memorable. As I step aside from my role as associate dean, I am extremely proud to have served in it. ■ **Jay Gore**

Where do great ideas begin? Did Edison have the proverbial light bulb flashing over his head as he was inventing it? No doubt that illuminating breakthrough, along with his other inventions and innovations, came after exhaustive trial and error in the lab. Likewise, the engineers at Purdue are constantly adjusting to the day-to-day successes and failures that could lead to something bigger. This publication offers an inside look into the processes of a few of the many researchers working on the cutting edge of discovery. From Discovery Park through the Research Park and all throughout the main campus, many roads lead to discovery at Purdue. We're testing out great ideas, collaborating with industry on their implementation, and forever concerned with engineering a better way. I hope you'll take some time to read some of our success stories.

■ **Venkataramanan "Ragu" Balakrishnan**



Leah Jamieson

John A. Edwardson Dean of Engineering and the Ransburg Distinguished Professor of Electrical and Computer Engineering



Jay Gore, 2002-2007

Associate Dean, Office of Research and Entrepreneurship and Vincent P. Reilly Professor of Mechanical Engineering



Venkataramanan "Ragu" Balakrishnan

Associate Dean for Research and Professor of Electrical and Computer Engineering

Service Engineering

Les Geddes

“ I don't think about building a better mousetrap. I think about a better way of catching mice. ”



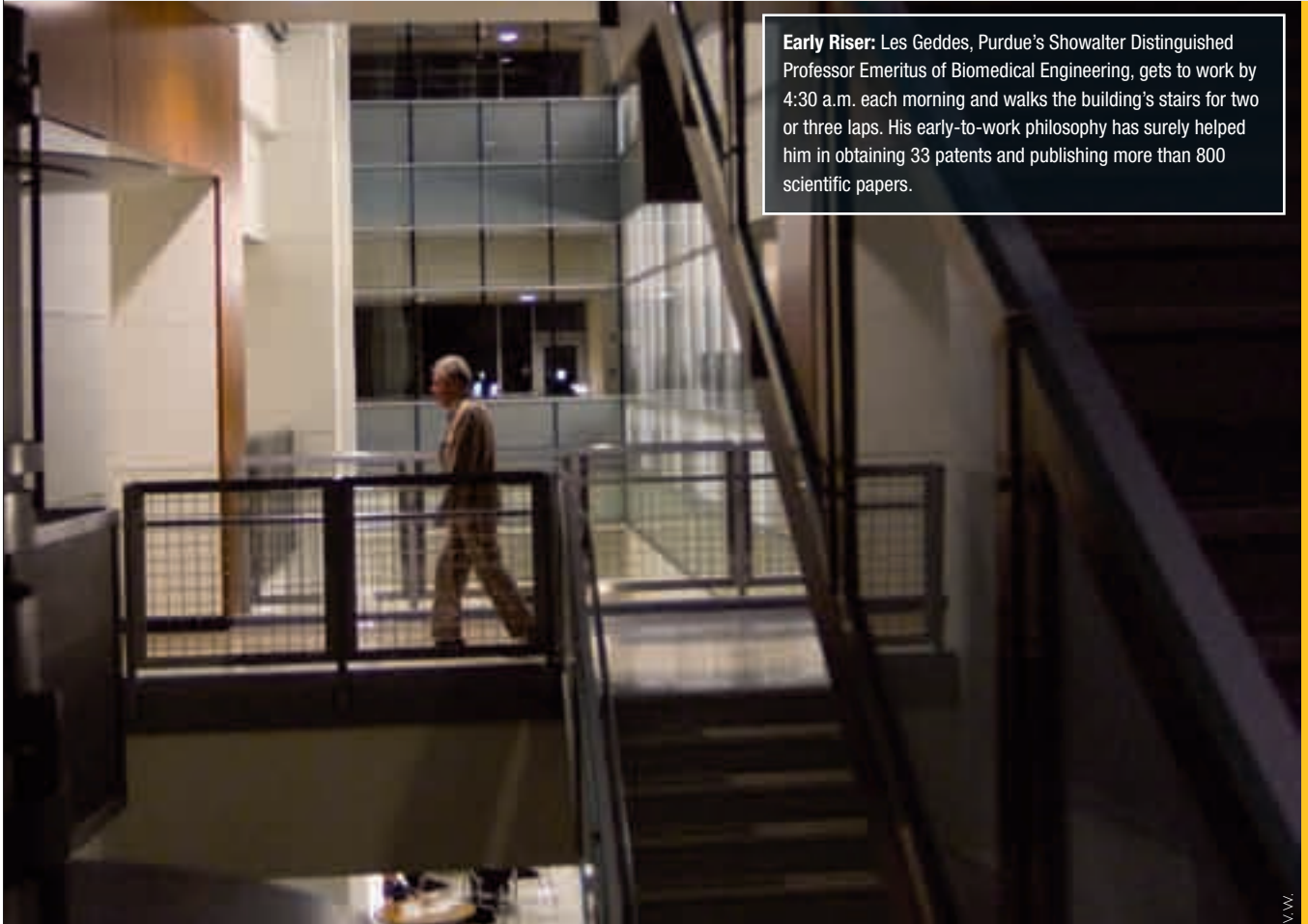
From healthcare engineering developments to technologies that lead to greater satisfaction, collaborations, and community support, Purdue engineers work in the ultimate service industry.



The Innovation Imperative

— GINA P. VOZENILEK

Looking for problems does not necessarily make you a pessimist; it might mean you're an engineer.



Early Riser: Les Geddes, Purdue's Showalter Distinguished Professor Emeritus of Biomedical Engineering, gets to work by 4:30 a.m. each morning and walks the building's stairs for two or three laps. His early-to-work philosophy has surely helped him in obtaining 33 patents and publishing more than 800 scientific papers.

He's up before the sun every day. It's a habit that exemplifies his lifelong devotion to creative problem solving. You see, Les Geddes noticed a problem: "all the time, every day, we're pounded with obligations, always just trying to catch up, with no time for creativity." His solution to this problem? Geddes arrives in his office by 4:30 a.m., and in the quiet interlude before most of us wake up—before the world intrudes via phone, fax, and e-mail—he gets a full day's work done. By the afternoon, after directing students in his laboratory, he goes home, sits down, pours himself a drink, and takes time to think.

"Engineers look at things differently," posits Geddes, Purdue's Showalter Distinguished Professor Emeritus of Biomedical Engineering and a self-proclaimed tinkerer who was building crystal sets at the age of 6. "They want to know: how does it work, what makes it go? I don't think about building a better mousetrap. I think about a better way of catching mice."

And he's caught a lot of them, to be sure. Geddes' rise-and-shine routine may not be for everyone, but it works for this 86-year-old

"retired" professor. He holds 33 patents and has published more than 800 scientific papers. He built the first ventricular defibrillator in Canada in 1947 and has continued to pioneer biomedical technologies throughout his career, inventing things like exercise-responsive pacemakers and miniature monitoring devices for premature infants. In March 2007 Geddes was recognized with the Health Care Hero award by the *Indiana Business Journal*, granted "for a scientific discovery or for development of a new procedure, treatment, or device that can save lives or improve the quality of life for a large number of people." And on July 27, 2007, Geddes was honored by President Bush with the National Medal of Technology, the nation's highest distinction for technical innovation. Geddes' history of impressive achievements as an engineer in service of others stretches out behind him like a wake that keeps rippling onward and outward. He is estimated to have taught more than 2,000 biomedical engineers, about one-fifth of those working in the United States today.

Geddes' current work deals with improving cardiopulmonary

resuscitation techniques, which have a disappointing rate of success (30 percent survival is an optimistic number). Patients requiring CPR often suffer broken ribs, a correlative problem along with the risk of infection from mouth-to-mouth respirations. In a paper to be published in the *American Journal of Emergency Medicine*, Geddes and his colleagues present a different approach they hope will help save more lives. It is called Only Abdominal Compressions (OAC) and involves rhythmic compressions below the diaphragm. With OAC, ribs are spared, respirations result from diaphragm movement instead of rescue breathing, and thoracic circulation increases by 25 percent, sending more life-saving blood to the heart and brain. It's a gutsy move—proposing to rework an entrenched medical protocol, but Geddes is undaunted by big challenges. They inspire him.

Geddes has no plans to quit identifying and tackling problems. "I'll stop when I wear out, not rust out," he laughs. He is excited about the latest idea that came to him in the quiet of his armchair, cocktail in hand. It's one he can't quite talk about yet, except to say, "It's big. It's big big. If we can pull this off, the sky's the limit!"

In the Business of Service

Also thinking big is Nagabhushana Prabhu, the James J. Solberg Head and Professor of Industrial Engineering. He and his interdisciplinary team of experts are motivated to fix a large-scale, multifactorial problem. The trouble centers on the ballooning service sector of the U.S. economy, which represents more than 75 percent of the U.S. gross domestic product and 80 percent of private sector employment in the country.

In this big business of service, quantity does not necessarily bring quality, and tools like the *American Consumer Satisfaction Index* demonstrate that Americans are less than happy with the service they receive. To make matters worse, global trade in services is growing at a furious pace, catalyzed by multinational trade agreements and advances in information and communication technologies. Simultaneously, many American service industries are plagued by high employee attrition rates. All of these factors together "foreshadow a worrisome scenario," notes Prabhu, who knows that the U.S. economy depends on a viable service sector.



National Medal: On July 27, 2007, President George W. Bush presented Geddes with the National Medal of Technology, the nation's highest distinction for technical innovation.

Photography by Ryan K. Morris



John Underwood

Cyber Service: Nagabhushana Prabhu, the James J. Solberg Head and Professor of Industrial Engineering, is leading an interdisciplinary team of experts to overhaul customer service as we know it. “The cyber-infrastructure needed for such a service Internet is complex but within reach,” Prabhu says.

Maintaining service competitiveness involves inducing curvature in a flattening world through innovative advances that keep the U.S. service sector continually ahead of the curve,” says Prabhu’s colleague Sangtae Kim, the Donald W. Fedderson Distinguished Professor with joint appointments in mechanical and chemical engineering. Prabhu agrees. As director of the newly established Center for Service Science Engineering and Management (CSSEM), Prabhu and his team are committed to “the development of novel engineering technologies that enable the modeling, simulation, design, and optimization of service enterprises and service-oriented architectures.”

To start, the team is working to revolutionize the way we access the existing service infrastructure, comprising all service providers and consumers. “Currently, it’s like we’re living in a city without a phonebook,” says Prabhu. “A platform in cyberspace for facilitated networking of services would unleash the trapped synergies.”

Elisa Bertino, a professor of computer science and research director of the Center for Education and Research in Information Assurance and Security (CERIAS), is working with Prabhu to create such a platform. The “service Internet” they envision would make finding and advertising

services easy. It would also level the playing field for small businesses and optimize services nationally. “The cyber-infrastructure needed for such a service internet is complex but within reach,” Prabhu says.

Putting know-how within reach of a new Internet generation of service engineers is Gavriel Salvendy, a professor of industrial engineering and a chaired professor and industrial engineering department head at Tsinghua University in China. Salvendy is leading the effort to create a new academic program geared toward the service sector. “The flat-world service enterprises and networks are becoming increasingly distributed and complex,” says Salvendy. “There is a growing need for a skilled workforce that will design, build, and maintain the next generation of service-oriented architectures.”

Prabhu enjoys the challenge of accounting for the greatest of all engineering variables: humans. “We view the service enterprise as a highly stochastic complex adaptive system,” says Prabhu. “Whereas humans are only the users of other engineering

systems, they are both the users and components of service enterprises.”

Salvendy notes that “the new human component makes service enterprises distinct from other engineering systems, and a new breed of techniques needs to be developed to design and analyze service systems effectively.” Salvendy, a world-renowned researcher in human systems engineering, is working with a team of experts, including Robert Proctor, distinguished professor of psychology; Howard Weiss, a professor and department head of psychology; and Richard Feinberg, a professor of consumer sciences and retailing and the director of Purdue’s Center for Customer-Driven Quality, to build predictive models of human-human and human-enterprise interactions for laying a scientific foundation for service systems.

As other thinkers across the country voice growing concerns about the “gathering storm” on the horizon of the U.S. economy, Purdue researchers are doing what they do best—working to build technologies that will address the grand challenges. In June 2007 the CSSEM hosted a national roundtable focused on radio-frequency identification-enabled service enterprises. Purdue is also leading the organization of a national workshop on service engineering, which is anticipated to provide a clearer understanding of the challenges facing the service sector to policy makers. “The forces that affect the U.S. service sector present a fairly alarming picture,” Prabhu says. “We might be racing toward a precipice. It is time the country sat up and took notice.” *

Nanoscience at Your Service

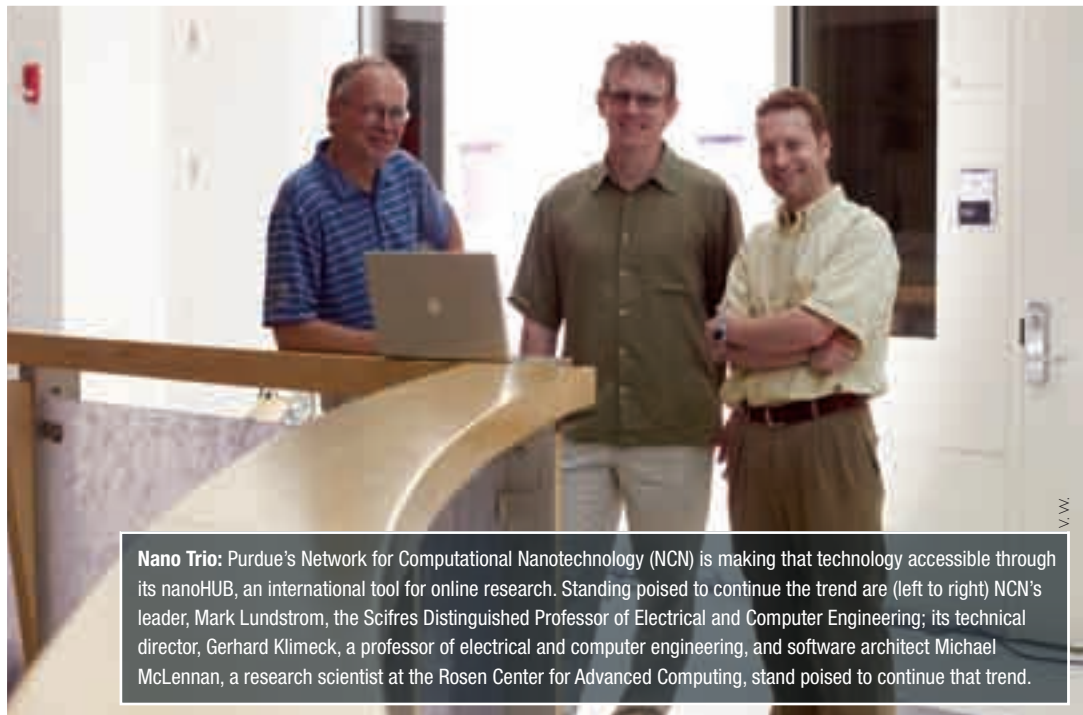
A new grant supports cooperation in nanoscience research.

The beating heart of the microelectronics industry for 30 years has been the silicon transistor. Silicon built the microcomputer age and an entire valley of its own, but researchers at Purdue and five affiliated university centers want to find the next big thing. What will replace silicon in the ubiquitous computer chip?

As researchers are working hard to answer that question, a new injection of funds will help the effort. Scientists at Purdue’s Network for Computational Nanotechnology (NCN) are pleased to claim part of a \$2 million grant from the National Science Foundation and the Nanoelectronics Research Initiative. The other nanoscience research hubs to share in the grant are at Cornell, the University of

California at Santa Barbara, the University of Texas at Austin, Yale, and the University of Nebraska at Lincoln and Omaha.

And speaking of hubs, one powerful way that Purdue contributes to this and other nanoscience research efforts is through NCN’s nanoHUB (www.nanohub.org). Mark Lundstrom, the Scifres Distinguished Professor of Electrical and Computer Engineering who leads the NCN, says, “Researchers in NCN will explore new concepts for electronic devices by extending the theoretical approaches and computational methods that we have developed for silicon transistors. These new simulation capabilities will be provided to the research community through NCN’s



Nano Trio: Purdue’s Network for Computational Nanotechnology (NCN) is making that technology accessible through its nanoHUB, an international tool for online research. Standing poised to continue the trend are (left to right) NCN’s leader, Mark Lundstrom, the Scifres Distinguished Professor of Electrical and Computer Engineering; its technical director, Gerhard Klimeck, a professor of electrical and computer engineering, and software architect Michael McLennan, a research scientist at the Rosen Center for Advanced Computing, stand poised to continue that trend.



science gateway, the nanoHUB. This grant keeps us on the cutting edge of research in this important field of technology, engineering, and science.”

Michael McLennan, NCN software architect and senior research scientist at the Rosen Center for Advanced Computing, notes the remarkable speed of nanoHUB’s growth. “When I joined the project three years ago,” he recalls, “roughly 1,000 people were using the nanoHUB.” These were mostly Purdue students who were plugging into the online system’s early simulation capabilities to complete homework assignments.

McLennan reports that now nanoHUB serves 25,000 users, half of whom are

based in the U.S. The other half is spread around the globe in 172 different countries. And all of the top 50 graduate engineering programs make use of the nanoHUB, which offers complex computing tools for nanoelectronics, nanomedicine, and nanoelectromechanical systems. About 87 percent of the nanoHUB “business” (which is currently free) supports academic endeavors, primarily facilitating research and also innovating the classroom environment.

McLennan offers an analogy of the nanoHUB’s function: “In a way, it’s like a new kind of publishing.” He notes how in traditional academic publishing “Figure 1 is fixed.” With nanoHUB, McLennan illustrates, researchers can essentially

“peel Figure 1 off the paper and make it come alive.” They can change parameters, explore other results, and ask new questions, taking ideas further and even comparing findings against other simulations. “It puts more brain power on the subject,” he says.

NCN wants to grow this cooperative brain power even more. They are aiming for 100,000 nanoHUB users within five years. With more than 50 tools available for use now and 50 more under development, nanoHUB serves engineers and other scientists by allowing them to share ideas and test theories—such as what the computer chip of the future might look like. * **G.P.V.**

Called to Serve

EPICS gets a new director.

William Oakes believes in the power of service. An associate professor of engineering education at Purdue and newly appointed director for Engineering Projects in Community Service, or EPICS, he wants his students to understand that there are larger issues at stake in the world around them. More than that, Oakes believes that service provides students with valuable hands-on experience. “We don’t just do service for service’s sake,” says Oakes. “Service learning is a better way to learn academic material, in our case design. By giving students real customers and authentic experiences, they raise the expectations they have for themselves and their teammates, because they know their work will really be put to use.”

In the EPICS program, teams of undergraduates earn academic credit for multiyear projects that solve engineering and technology-based problems for community service and education organizations. The experience is further enriched by its interdisciplinary nature; 30 different disciplines across the university participate, bringing together the strengths of communications majors, business majors, engineers, and others. This mix of talent simulates the synergy one would hope to experience in a professional setting and challenges students to hone skills they will need in the real world.

Leah Jamieson, Purdue’s John A. Edwardson Dean of Engineering, and Edward Coyle, a professor of electrical and computer engineering, co-founded EPICS in 1995. The

engineering-centered program involves 30 departments at Purdue, 29 local and Purdue partnerships, and has many teams working on projects ranging from homelessness prevention to environmental protection to creating toys for children with disabilities. EPICS programs also now operate at 17 universities in the United States and one in New Zealand.

Oakes notes that volunteerism in this country is near an historic high and speculates that EPICS is tapping into a greater trend of Americans seeking ways to help their neighbors. “We expect a record number of Purdue students to enroll in EPICS this fall,” says Oakes. Enrollment for EPICS is expected to approach 400 in the fall, topping the previous peak of 360 students set in 2002.

That's good news for engineering education, which needs to fill the ranks of tomorrow's engineers. "We are seeing a national decline in interest in engineering, plus many older engineers are retiring," Oakes says. Furthering the challenge, recruitment efforts must regularly battle against negative stereotypes that sketch engineering students as narrowly science-minded and geeky. "EPICS resonates with what students are looking for," claims Oakes, who believes EPICS can bolster engineering recruitment and retention at the undergraduate level. "It's attractive to students to be asked to engage all sides of their personality."

Oakes aims to generate positive buzz about engineering education in even younger minds. He is spearheading a new multi-university initiative to expand EPICS to high schools. Twenty high schools from five states will serve as pilots, thanks to a \$1.5 million Learn and Serve America grant, with which students will design technology-based projects in their communities. "We want students to look at engineering differently, to expand interest on a national level," Oakes says.

Oakes was selected as the first engineering educator to win the Campus Compact Thomas Ehrlich Faculty Award for Service Learning in 2006, the most prestigious national award in service learning. Oakes was a co-recipient of the National Academy of Engineering's Bernard Gordon Prize for Innovation in Engineering and Technology Education in 2005 with Jamieson and Coyle. He also received the National Society of Professional Engineers Educational Excellence Award in 2004, Purdue's Charles B. Murphy Outstanding Undergraduate Teaching Award in 2002, and Purdue Engineering's Dean A. A. Potter Outstanding Teaching Award in 2001. And you could say he's a homegrown talent: Oakes earned his doctorate in mechanical engineering from Purdue in 1997. * **G.P.V.**

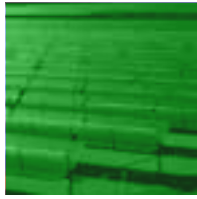


Community Engineer: William Oakes, an associate professor of engineering education and the new director of EPICS, or Engineering Projects in Community Service, believes that "service learning is a better way to learn academic material."

Energy Innovation

Nancy Ho

“The beauty of a biofuel is that it can only be produced locally, with each region basing its fuel on available biomass. Think of recycling corn stalks in Indiana, wood chips in Oregon and Maine, and paper waste from urban areas.”



While Purdue researchers are still looking for ways to make the most of available fossil fuels, alternative energies on the horizon—biofuels, hydrogen, and solar—are tested and refined daily.



More Than Corn in Indiana Energy

— LINDA THOMAS TERHUNE

Purdue researchers look to yeast, soybeans, and agricultural residues for alternative solutions.

Looks do deceive. Diminutive and elegant, Nancy Ho might seem the least likely person to hold the key to the nation's fuel crisis. At 71, she has raised two boys—now both physicians—and is a busy grandmother. That's her private life. In her public life, she is head of the Molecular Genetics Group at Purdue's Laboratory of Renewable Resources Engineering (LORRE) and is recognized globally for her work with a strain of yeast that will convert biomass into ethanol, a process that could fuel American vehicles long after some natural resources are exhausted.

Ho may stand only 5-feet tall, but she has the grit and determination of a giant. These qualities have served her well since she was a child in China more interested in math and problem solving than other youthful pursuits. She considered writing, but was drawn to the black-and-white nature of math and science, where she could check on her work and know whether it was right or wrong.

After college in Taiwan, where she studied engineering, her interest in math shifted toward "something more lively; not just figures." The result was a master's degree in chemistry at

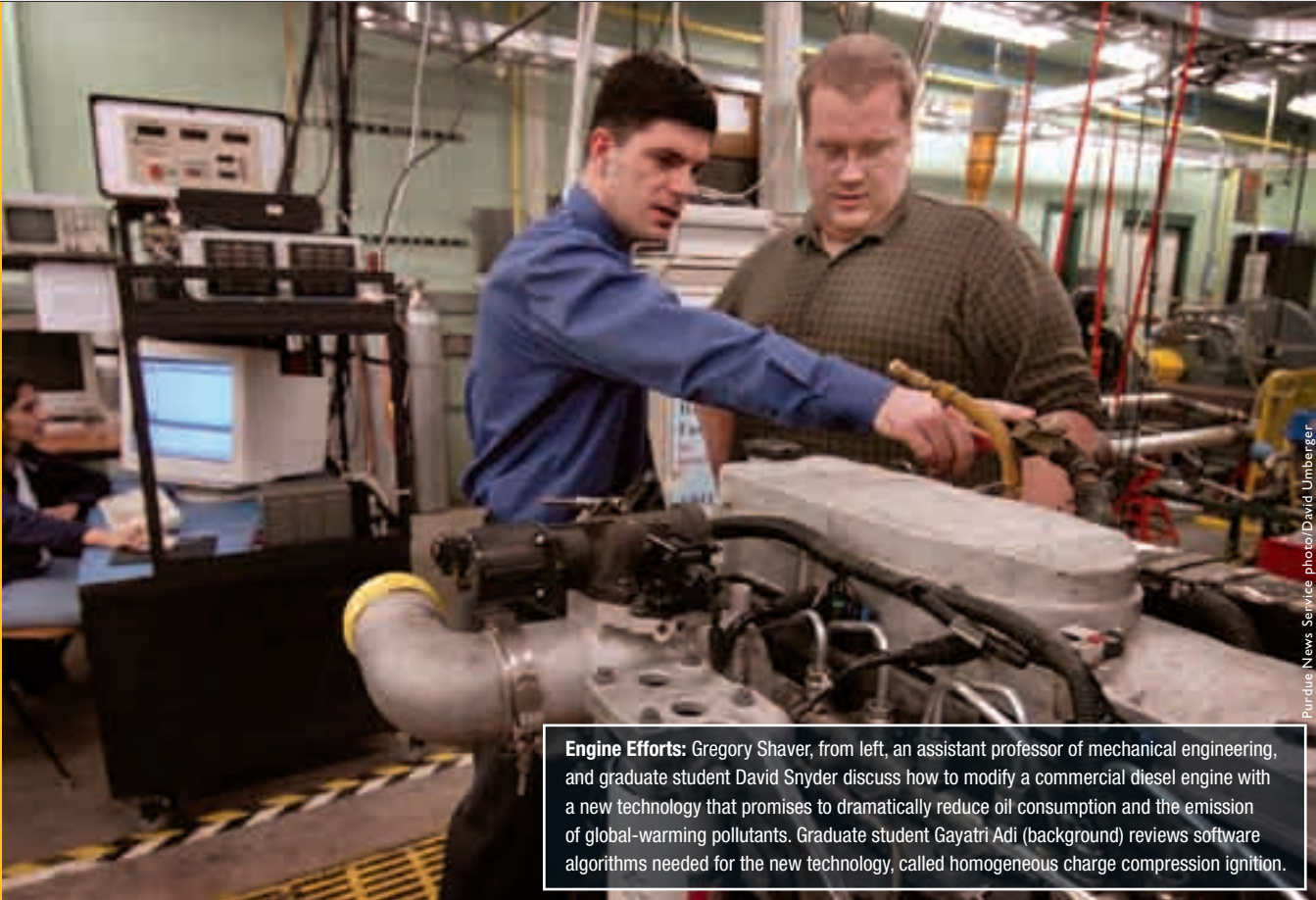
Temple University and then, in 1968, a doctorate in molecular biology at Purdue, where her late husband, Cho-Yen Ho, had landed a position as director of a research center. Her focus was in molecular biology, working with recombinant DNA. It was a fortuitous match.

In the late-1970s, America was wrestling with a fuel crisis, and Ho was looking for a project in which she could apply her DNA technique in an area other than biomedicine. She ended up in an ethanol project with LORRE, now a part of Purdue's Energy Center at Discovery Park. Ten years later, in 1993, Ho and her research team developed the genetically engineered yeast that ferments the two major sugars present in cellulosic biomass. It was a scientifically exciting period for Ho. "Everything I designed has all worked out," she says.

The yeast, named "Ho-Purdue Yeast," was patented in 1993 and since 2004 has been used by the Canadian biotechnology company Iogen in Ottawa. The facility now produces about 700 gallons of fuel a day from straw residue, according to Ho.



Ethanol, Ho! Nancy Ho (left), head of the Molecular Genetic's Group in Purdue's Laboratory of Renewable Resources Engineering, has made breakthrough discoveries on genetically engineered yeast used in the production of ethanol. Shown here in the lab with Hanxiao Jiang, who earned a Purdue chemical engineering PhD, Ho was invited to the White House "State of the Union" address last spring and later received a \$5 million grant from the Department of Energy to help her team continue to improve the yeast's efficiency.



Purdue News Service photo/David Umberger.

Engine Efforts: Gregory Shaver, from left, an assistant professor of mechanical engineering, and graduate student David Snyder discuss how to modify a commercial diesel engine with a new technology that promises to dramatically reduce oil consumption and the emission of global-warming pollutants. Graduate student Gayatri Adi (background) reviews software algorithms needed for the new technology, called homogeneous charge compression ignition.

Naturally occurring yeast converts corn kernels into the ethanol that is now used as a gasoline additive, but it can't ferment a special sugar, xylose, only found in abundance in cellulosic biomass such as corn stalks, wood chips, and waste paper. Ho's yeast, on the other hand, can do the trick, able to ferment xylose to ethanol, providing a fuel that Ho says could replace gasoline at a cost of around \$2.50 per gallon now. The cost for such production is expected to drop considerably when the process is fully developed.

Funding has always been tight for research in Ho's area. By the mid-1980s, in fact, most researchers across the country had left the field to pursue other projects. Ho persevered with small grants from industry. The tide has turned now; so much that she has been called "a visionary researcher" by a White House spokesperson.

In January, Ho was invited to attend President Bush's "State of the Union" address, in which he mentioned the need to create alternative fuels. He encouraged investment in cellulosic-ethanol technology. This recognition was followed in April by a \$5 million grant from the Department of Energy that will help Ho's research team improve the yeast's efficiency.

Ho is also currently working to establish a cellulosic-ethanol company that will soon operate in Indiana. The technology will not compete with existing corn ethanol plants, but will complement them—one uses corn kernels, the other uses corn residues. Her work, too, will likely spread around the world. Inquiries have come to her from Italy, China, Brazil, and other locales.

The beauty of biofuel, she points out, is that it can only be produced locally, with each region basing its fuel on regionally available biomass—corn stalks in Indiana, wood chips in Oregon or Maine, paper waste in urban areas, and so on. "The benefit is that there is a lot more biomass than corn. We just don't have enough resources like corn; everyone realizes that," Ho says.

Corn, however, isn't the only potential alternative energy source. There are more than 75 researchers across the Purdue campus involved with Purdue's Energy Center, which has a mission of developing the science, engineering, and technology of economically and environmentally sound energy solutions.



Biomass Benefits

The interdisciplinary Energy Center was formed in 2005 with seed money from the Lilly Endowment. Its researchers include scientists and political scientists, engineers, and economists. Klein Ileleji, an assistant professor of agricultural and biological engineering, is allied with the center and is focusing in an area that complements Ho's work. Ileleji studies how to economically transport agricultural residues and lignocellulosic biomass feedstocks—such as the corn stalks that Ho's process uses—to ethanol plants.

"Biomass residues are highly combustible, deteriorate fast, and contain a lot of moisture and soil. Stalks and straw are not primary products, and right now there is no incentive to collect them," Ileleji says. "They are expensive to transport. But the use of biomass crops such as corn stover—the residue after corn grain harvest—and switchgrass do provide an alternative for those who worry that biofuel production will cause an increase in food prices."

Ileleji and graduate student Abhijith Mukunda developed the Biomass Feedstock Logistics simulator (BMFLS) model to analyze the transportation and receiving operations of biomass feedstock delivered from on-farm storage locations to cellulosic ethanol plants. It is designed to predetermine bottlenecks and streamline the process.

"We have an abundance of renewable feedstock that is currently under-utilized. Biomass crops are very viable alternatives that will ensure the long-term sustainability of fuel and energy production from biorenewable feedstocks," Ileleji says.

Ileleji hopes the food system will eventually integrate the processing of many agricultural wastes into energy. For instance,

he says manure from a livestock operation could generate power that runs an ethanol plant that processes corn and then sends the leftover unfermentable feedstock that is rich in protein and fiber back to the livestock operation for animal feed. "It's a symbiotic system that makes sense," he says.

Fill 'er up With Plant Oil, Please

With help from Bernard Tao, a professor of agricultural and biological engineering, the biomass researched by Ho and Ileleji could be transported to ethanol plants by vehicles powered by soybeans and other plant oils. It could be part of what Tao refers to as a "green gold"—rather than "black gold"—economy. As the Indiana Soybean Board Professor in Soybean Utilization Research, Tao is developing soybean-based products that will offer alternatives to products traditionally derived from petroleum. Soybeans are a component of biodiesel, which can be mixed with petroleum fuel to run most diesel engines. A jet fuel developed in Tao's lab that is 40 percent biodiesel could also help the aviation industry. This renewable resource is relatively environmentally friendly, resulting in reduced emissions and cleaner engines.

With more than 5 million acres of soybeans planted annually in Indiana, Tao's research at Purdue could translate into an increased number of production and processing jobs as well as a strengthened economy. Tao, who has focused his research in the area of biofuels for the last eight years, sees biomass energy on the upswing. "Globally, it is a movement away from limited petrofuels and environmental issues involved with their use. Nationally, it supports domestic and economic security. And regionally, it supports Midwest agricultural economic development," he says. *

Living Here in BioTown

You may not find BioTown, Indiana, on the map. But it's made a name for itself as the first town in the country with the goal of meeting its own energy needs through biorenewable resources. The cornfields and hog farms that surround the town some 20 miles north of Purdue are, in fact, its energy sources, providing an alternative to dependency on foreign oil.

BioTown USA is, actually, Reynolds, Indiana, a town of 547 people that in September 2005 was chosen by the state

of Indiana to showcase how one agricultural town can find new uses for its products and create more environmentally friendly ways to dispose of its byproducts. Purdue's proximity and its pool of researchers working to develop alternative fuels had a lot to do with why the town was chosen.

BioTown is a living laboratory for Purdue researchers like Klein Ileleji, an assistant professor of agricultural and biological engineering. Students in his graduate-level "Biomass Feedstock Systems Engineering" course studied BioTown the last

two spring semesters. The classes assessed biomass feedstock resources for utilization in the proposed suites of technologies to be built as the second phase of the BioTown project.

The BioTown Technology Suite is a system that converts animal waste (manure), corn residues (stover), and municipal waste (sewage) into heat, steam, or electricity. The third phase of BioTown will continue to emphasize the use of animal waste

from area livestock farms for electricity and natural gas.

"The interaction with BioTown enables students to apply knowledge learned in the classroom on a real-world project (experiential learning)," Ileleji says. "Their engagement with the community they work in also lends itself to service learning where a mutual exchange of knowledge between the community and project team takes place."

Michael Ladisch, whose goal is to make the production of ethanol as efficient and cost-effective as possible, views the community experiment as a great educational opportunity that exposes the general public to the potential of

biofuels. As co-organizer of Purdue's 2007 Bioenergy Symposium, Ladisch, a distinguished professor of both biomedical and agricultural and biological engineering, was also able to bring BioTown before a university audience.

Talk of the Town

"Biofuels: Regional Needs, National Challenges," which took place last May, showcased research activities at Purdue and at other Midwestern universities related to the role of biofuels as an alternative energy source. Among the presentations was an update on BioTown by Andy Miller, director of the Indiana State Department of Agriculture. The two-day event also featured presentations on commercialization and policy issues

regarding biofuels, with an emphasis on dry grind plants, co-product utilization, biodiesel fuel, and cellulose ethanol.

Efforts such as those discussed at the symposium and their real-life application at BioTown are imperative to the future success of alternative energy, according to Ileleji. "For renewable energy to be part and parcel of society, it must be adopted by society and utilized with an energy-efficient consciousness," he says. "This is to say, we can't just produce renewable energy and fuels from the renewable feedstocks and consume at current levels and efficiencies. New ways of energy management and conservation must be part of the equation of utilizing this precious renewable resource." * **L.T.T**

Harvest Time: Klein Ileleji (left), an assistant professor of agricultural and biological engineering, talks biofuels with Keith Johnson, a professor of agronomy, while a switch grass field is harvested behind them at the Throckmorton-Purdue Agricultural Center. In the spring of 2008, researchers will perform a test run at the Purdue Power Plant, turning the biomass into energy.

V.W.

V.W.

Are We on Course for a Hydrogen Economy?

A distinguished professor and National Medal of Technology Laureate is looking to replace gasoline with aluminum pellets.

Imagine a day when gasoline is no longer the primary source of fuel for vehicles. In the hydrogen economy imagined by Purdue researchers including Jerry Woodall, a distinguished professor of electrical and computer engineering, National Medal of Technology Laureate, and honorary member of the Electrochemical Society (the premier international society specializing in electrochemistry and solid-state science technology), drivers could fill up with aluminum gallium pellets and drive 350 miles on a full tank.

Woodall has developed a method that uses an aluminum alloy to extract hydrogen from water for running fuel cells or internal combustion engines. The technique makes it unnecessary to store or transport hydrogen, two of the major challenges facing the hydrogen economy. It is also environmentally friendly, producing no green house gasses and leaving only water as a byproduct.

The technology could be used to drive small internal combustion engines such as those used to power emergency generators, golf carts, lawn mowers, and chain saws. It could also replace the batteries currently used in hybrid cars.

The process has intrigued Woodall since he stumbled on it during his days working as a researcher in the semiconductor industry in 1967. It was while cleaning a crucible containing liquid alloys of gallium and aluminum that he first encountered the process—he added water to the crucible, and there was a violent poof, he recalls.

What he discovered was the process he has studied ever since—hydrogen is

generated spontaneously when water is added to pellets of alloy made of aluminum and gallium. The aluminum in the solid alloy reacts because it has a strong attraction to the oxygen in the water. The reaction splits the oxygen and hydrogen contained in the water and releases hydrogen.

The process does not emit toxic fumes, nor does it create waste other than water. Of further importance is the fact that gallium, which is expensive, does not get used up by the process, so it can be recycled. In the 1960s, this was intriguing but not enough to warrant development and commercialization. That has now changed.

“When global-warming issues got on the radar screen at the dawn of the current millennium, I started thinking about it again,” Woodall says. “I started working on it seriously again in 2005. This is because this process is both renewable

and will not contribute to green house gasses and hence, is a viable large-scale alternative energy source.”

Woodall and his team have started a company, AlGalCo, to market standby power systems. They believe it will be profitable within three years. With ongoing research moving hydrogen-powered cars closer to becoming a consumer reality, Woodall's method could someday power the fuel cells that power cars. The cost would be competitive with gasoline at \$3 per gallon, a reality now all too familiar to consumers around the world.

The estimated cost to fill a tank with aluminum gallium pellets—about 350 pounds of aluminum, or, as Woodall says, the equivalent of a large passenger vehicle—would be \$60. And for that, the consumer would get 350 miles of driving pleasure. * **L.T.T**

Hydrogen Powered: Jerry Woodall, a distinguished professor of electrical and computer engineering, has developed a method that uses an aluminum alloy to extract hydrogen from water for running fuels cells or internal combustion engines. Shown here on the links of the Birck Boilermaker Golf Course, Woodall hopes the same technology used to power golf carts can eventually replace gasoline. He believes his startup company, AlGalCo, which will market standby power systems, will be profitable in three years.



Harnessing the Sun With Nanotechnology

Purdue's solar energy research group looks to make breakthroughs.

It sounds like the stuff of spy movies—a vial, a precious liquid, and the key to the world's energy crisis. It is, in fact, the domain of Purdue chemical engineers Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering, and Hugh Hillhouse, an associate professor of chemical engineering, who have discovered a novel way to harness solar power.

Agrawal and Hillhouse, who direct Purdue's solar energy research group, have created a nanocrystal ink that can be printed or spray painted onto a variety of substrates to create low-cost solar cells with many possible applications.

The solar cells could be used to generate electricity for buildings and harness energy for portable power applications. More importantly, they are an environmentally friendly energy alternative to fossil fuels. The potential uses, from the consumer level to industry, greatly excite the research team. In fact, solar cells may hold the key to developing sustainable methods to fuel our cars.

Agrawal, who came to Purdue in 2004 after working in industry, has also explored ways of combining hydrogen from solar power with biomass to create greater quantities of clean-burning liquid fuel. He has been joined in this research area by Fabio Ribeiro, a professor of chemical engineering, and Nick Delgass, the Maxine Spencer Nichols Professor of Chemical Engineering. The method could yield enough liquid fuel for the entire U.S. transportation sector using the sustainably available annual waste biomass in the country.



Solar Solutions: Rakesh Agrawal (right), the Winthrop E. Stone Distinguished Professor of Chemical Engineering, and Hugh Hillhouse, an associate professor of chemical engineering, have discovered a novel way to harness solar power. They have created a nanocrystal ink that can be printed or spray painted onto a variety of substrates to create low-cost solar cells with many possible applications.



The key to utilizing solar energy, according to Hillhouse, is to make it economical for the consumer. Up to this point, solar cells have been made through energy-intensive processes that involve ultra-high vacuum and high temperature. The process is slow, expensive, and restricts the range of possible substrates. The solar group's ink process uses solution-based chemistry to create nanocrystals that may then be consolidated to yield a thin film that is the active component of the solar cell. It is a cheaper and more efficient approach. This is still the tip of the iceberg, though.

"We are also developing nanostructured solar cells that may be able to exceed the energy conversion efficiency of current technology," Hillhouse says.

Agrawal and Hillhouse are on the leading edge of solar power research in the

United States, largely, Agrawal says, because there isn't a great deal of attention paid to the subject in this country. They share a disappointment that the United States is lagging in implementation of solar energy; Japan and Germany are the world leaders in that area. They hope that the work of their research group and the graduate students who emerge will help define a new era in solar energy utilization in this country.

"We feel the research is very important for the human race in general and the problem facing us today with the energy crisis," Agrawal says. "We can't wait too long, because it will be too late." * **L.T.T.**

Megaproject Management



Srinivas Peeta

“As this summer’s bridge collapse in Minnesota demonstrated so tragically, there’s a massive need for infrastructure renewal in this country.”



With the world's fast pace demanding free-flowing highways and optimal efficiency for the multimillions of megacities, Purdue engineers are gathering to answer the call.



What's Next in Transportation

— WILLIAM MEINERS



The NEXTRANS center hopes to provide integrated and multimodal solutions to ease traffic pains.

Most any commuter caught up in a metropolis snarl, or even smaller-city congestion, can attest to the frustration of the daily ride home. Bumpers sit on bumpers, 18-wheelers duel over noise and ozone damage, and entire tangled messes wait impatiently alongside endless construction zones. It's enough to make a gridlock negotiator lay on the horn. It also begs the question: If we could put a man on the moon nearly 40 years ago, why can't we make our way around planet Earth a little easier?

Transportation solutions on the horizon, brought by the university who can at least claim educational credit for that first man on the moon, are being formed at a new center called NEXTRANS. Introduced by Purdue in November 2006, NEXTRANS, which is named to reflect "next-generation transportation solutions," is a \$13 million collaborative center determined to overhaul the transportation sector with integrated solutions for mobility, safety, and infrastructure renewal in general, and provide a regional focus on intermodal freight and logistics systems.

Following a regional competition, the center was awarded to Purdue by the U.S. Department of Transportation (USDOT). Another installment in Discovery Park, the university's hub for interdisciplinary research, NEXTRANS has two other Big 10 partners—Illinois and Ohio State—along with five other universities: Martin University in Indianapolis, University of Wisconsin in Platteville, Wayne State

University, Indiana University-Purdue University at Indianapolis, and the Illinois Institute of Technology.

But even with all that high-powered brain trust, how will they make significant changes to a freeway system that was designed in the early 1950s? If you ask Srinivas Peeta, the center's director and a professor of civil engineering, he'll tell you it will take a village to straighten out everything that's wrong with traffic. A village, or a center in this case, made up of engineers from all disciplines, as well as research experts from across campus, and industry gurus from the private and public sector, all working to leverage technology to reach that next level in the transportation sector.

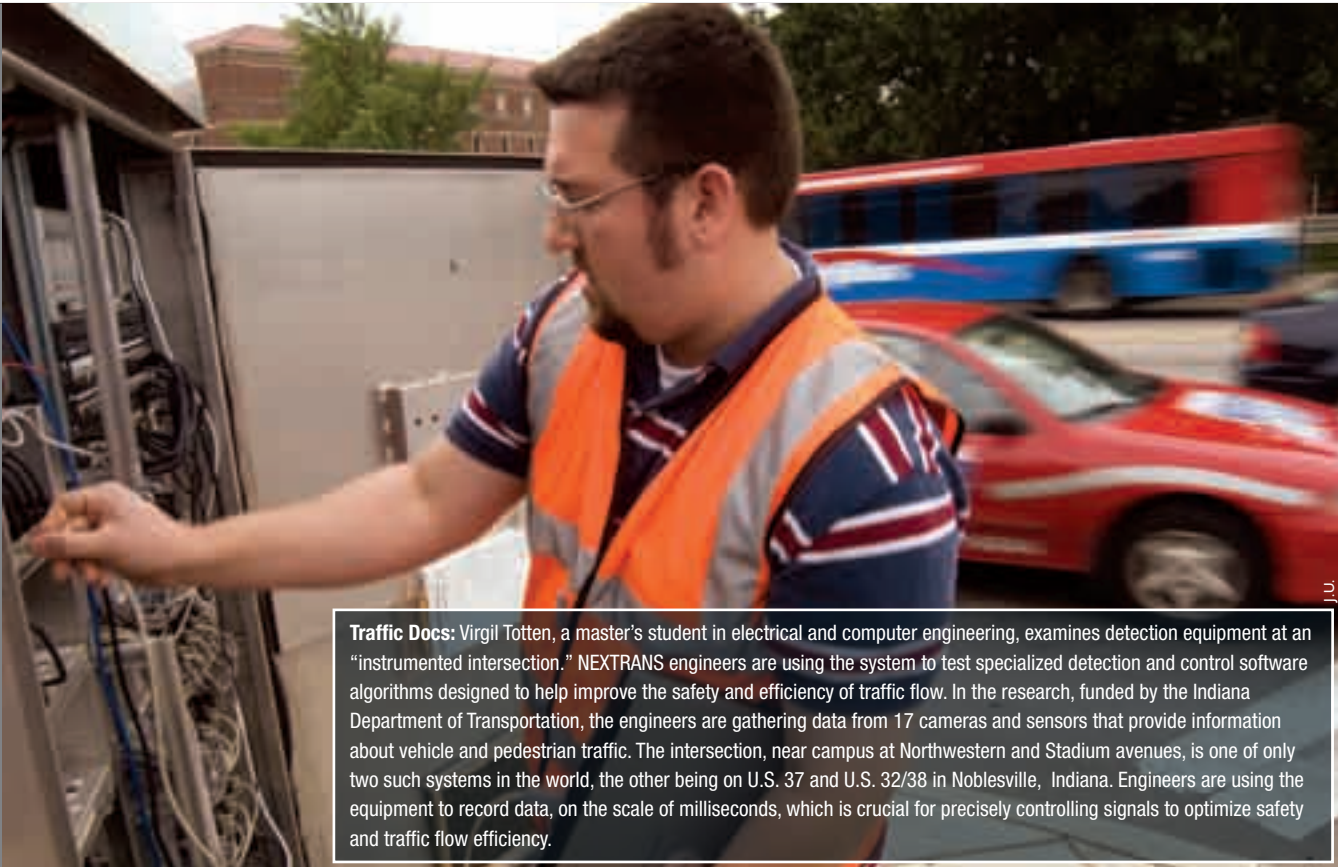
"My domain of expertise has been in transportation and logistic systems. The key word here is systems," says Peeta, the current chair of the System of Systems (SoS) signature area, "because you have to look at problems holistically. We need to find the linkages between seemingly disparate systems. As this summer's bridge collapse in Minnesota demonstrated so tragically, there's a massive need for infrastructure renewal in this country."

And while any math major can tell you we cannot afford to fix all the transportation infrastructure problems at once, the challenge, Peeta claims, is to determine how to resource the



Congestion Relief: Purdue's NEXTRANS Center, so named to reflect "next-generation transportation solutions," is a \$13 million collaborative center determined to overhaul the transportation sector with integrated solutions for mobility, safety, and infrastructure renewal in general. The group will also provide a regional focus on intermodal freight and logistics

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Traffic Docs: Virgil Totten, a master's student in electrical and computer engineering, examines detection equipment at an "instrumented intersection." NEXTRANS engineers are using the system to test specialized detection and control software algorithms designed to help improve the safety and efficiency of traffic flow. In the research, funded by the Indiana Department of Transportation, the engineers are gathering data from 17 cameras and sensors that provide information about vehicle and pedestrian traffic. The intersection, near campus at Northwestern and Stadium avenues, is one of only two such systems in the world, the other being on U.S. 37 and U.S. 32/38 in Noblesville, Indiana. Engineers are using the equipment to record data, on the scale of milliseconds, which is crucial for precisely controlling signals to optimize safety and traffic flow efficiency.

allocation in the most cost-effective manner and maximize the "most fix" for the dollars.

Dead Heads and Dead Ends

To make the most of the technological upswing, researchers are working with industry on both short- and long-term solutions. And much of that focus involves communications work in wireless technologies. "Sensor technologies are increasingly important in the management of transportation infrastructure, as well as helping to improve safety," says James Krogmeier, an associate professor of electrical and computer engineering. "Purdue researchers from civil engineering, electrical and computer engineering, industrial engineering, and mechanical engineering have been working on these challenges for at least 15 years."

Krogmeier's involvement started in the early 1990s with an evaluation of sensor technologies deployed on the Borman Expressway (I-80/94) in northern Indiana. "These sensors were being used to provide traffic counts and individual vehicle speeds for management and traveler information

applications," he says. "We also did some of the early work on the communications systems needed to connect sensor data with central servers located in the traffic management center."

These days, Krogmeier and colleagues are working on signal processing that will enable existing inductive loop sensors to track vehicles for improved travel time estimation and to utilize next-generation in-vehicle sensors, which will be deployed as part of the USDOT's Vehicle-Infrastructure Integration initiative, in a number of additional applications.

For issues surrounding safety and traffic flow, having real-time access to information is critical, allowing travelers to respond to problems and reroute on the fly. "Usually, by the time you are aware of an accident up ahead, it's too late to avoid the area, and perhaps hundreds of vehicles are caught in a traffic jam," Peeta says. "But if I could get that information to you and provide alternate routes, you would probably avoid the region completely."

For many of today's high-tech consumers, personal digital assistants, cell phones, and other devices (akin to the text messaging systems

being used to address campus security) would make these advanced warning systems easily and readily available. And any way to lessen traffic would also benefit all traveling parties, Peeta says. Truckers often travel with empty containers after delivering cargo, also known as “dead-heading,” wasting fuel and losing money. Modern tracking systems, radio-frequency identification tags, and information security protocols would make it feasible to seamlessly coordinate the movement of cargo so that trucking companies could haul freight for a competitor instead of traveling empty.

More and more business travelers might rise above the congestion by taking to the skies in small, affordable jets. Peeta and Dan DeLaurentis, an assistant professor of aeronautics and astronautics, collaborated on a NASA research project to examine the use of such jets. “We focused on multimodal considerations and gathered data on the preference of individuals for an ‘On-Demand Air Service’ through a stated-preference survey,” DeLaurentis says. “The ‘systems’ character of the NEXTRANS charter and mission is key to allowing researchers to build on work exemplified in our NASA study to address cross-mode interdependencies and the economic and policy implications of advanced operational concepts for next-generation transportation.”

Location, Location, Integration

NEXTRANS is one of 10 “regional university transportation centers” in the nation, covering the USDOT’s Region Five, which includes Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. “Each region contains smaller federally funded transportation research centers, and part of our charge is to provide leadership and coordination over the entire region,” Peeta says.

Region Five, as luck would have it, is uniquely located. “As the crossroads of America, Indiana is positioning itself to become the transportation and logistics hub of the world economy,” says former Indiana Department of Transportation Commissioner Thomas Sharp. “With 80 percent of the nation’s population living within a day’s drive of Indiana, our state is positioned to make transportation our competitive advantage in a global

marketplace. To capitalize on our advantage, we need a freight transportation system that runs seamlessly across various modes, and an environment where data is freely shared between the private and public sectors.”

The Indiana Department of Transportation is providing up to \$750,000 a year in matching money through Purdue’s Joint Transportation Research Program (JTRP).

“Because the Midwest region is heavily oriented toward agriculture and manufacturing, we will be concentrating on ways to tackle issues related to those economic sectors,” says Kumares Sinha, the Edgar B. and Hedwig M. Olson Distinguished Professor of Civil Engineering and director of the JTRP. “Long-term issues will include transporting raw and finished products associated with ethanol and biofuels plants. We want to make the best use of our multimodal transportation systems, including highway, rail, water, and pipelines, so that trucking-related congestion can be reduced.”

Sinha is one of the more than 50 researchers involved from the various universities. Elsewhere at Purdue, Ananth Iyer, the Susan Bulkeley Butler Chair in Operations Management, has focused on the logistics of the furniture industry in southern Indiana, which could be applied to other industries in the state. And from his new research base located in Purdue’s Research Park, Peeta is hoping more will join in the collaborative center.

Additional funding for the center is provided by other government and industry sponsors, which include the Central Indiana Corporate Partnership, NAVTEQ Corp., and Honda of America Manufacturing Inc., through the Transportation Research Endowment Program at Ohio State University.

And with all of those interested and interactive parties, the solutions provided by NEXTRANS could make the drive home smoother for everyone. *

Managing Megacities

How Purdue engineers, rallying around a system-of-systems approach, can help the world’s largest cities run at optimum levels.

Traffic is only one of the challenges that befuddle inhabitants of the world’s major cities. Consider the worst-case scenarios

if all the lights went out in Paris, or if the multimillions in Calcutta weren’t able to get enough clean drinking water, or if an

earthquake shook every high rise in Tokyo to its knees. A multidisciplinary initiative gaining momentum at Purdue is a study in

how engineers can effectively manage the infrastructure of megacities.

Megacity isn't a word you'll find in the dictionary, though it could be on *Webster's* radar. If you Google the term, or track it down through Wikipedia, you may find mega-city hyphenated, or as two words, or even mashed together with odd capitalization: MegaCity. Nevertheless, a megacity is generally defined as a metropolitan area with a population in excess of 10 million people. In the U.S., New Yorkers and Los Angelinos can boast megacity addresses; Houstonians can soon do so. According to a United Nations report, entitled *World Urbanization Prospects: The 2005 Revision*, "In 2005, urban dwellers numbered 3.2 billion people, 49 percent of humankind." And by 2030, that urban population is likely to expand to 4.9 billion folks, accounting for 60 percent of the inhabitants on the globe.

For Purdue people like Larry Nies, an associate professor of civil engineering, the megacity phenomenon represents a huge opportunity to deliver resources to people in a very efficient manner. An environmental engineer with an interest in sustainability, Nies also envisions a project that ranges over all the areas within civil engineering. "It provides us with something we can rally around and do together," he says. "From human to social infrastructures, civil engineering is right in the middle."

A city's system of systems

One need only look to disasters to see the chaos that can come from a city disrupted. "Cities are the best single example of a system of systems," Nies says. "You have transportation systems, energy and water distribution systems, along with communication, healthcare, education, and government systems of all levels, to name a few."

With virtually no shortage of individual systems operating at the heart of a city at all hours, their interaction becomes critical. And that's the approach to bring to the megacity project, Nies says. The emerging discipline of System of Systems (SoS), which is also a signature area of the College of Engineering, stems from a philosophy of looking at problems more holistically. As that 60 percent of the world's population in 2030 blossoms to a predicted 80 percent in 2050, the megacities represent an intense vulnerability. "There are more people at risk," Nies says. "There's a greater disparity between the rich and the poor, but there are also more opportunities to address those issues."

Even with civil engineers charging ahead with SoS solutions, the role of social scientists becomes critical in helping negotiate the human factors. Nies saw firsthand in a summer visit to Mexico City

the underground, or cash economy, of the people on the streets trying to eek out a living. As with any good engineering enterprise, the work with megacities will include a humanitarian effort. The opportunities for economic development, Nies says, can lead to marked improvements in standards of living for the poor: access to education, improved healthcare, and decreased fertility rates.

As Nies pitches the idea to colleagues within Civil Engineering and elsewhere on campus, he's conscious of the timing. "The vulnerabilities necessitate us addressing the megacity issues because if we don't and something goes wrong, it's going to be a huge disaster," he says.

From a risk-avoidance perspective, Nies says, it's a no-brainer. And from a possibilities perspective, it's a project that could have some real legs—affecting multimillions. * **W.M.**

Millions Marching: By the year 2030, reports say, 60 percent of the world's inhabitants, some 4.9 billion people, will live in urban areas, or megacities. Purdue people like Larry Nies, a professor of civil engineering, believe the megacity phenomenon offers a huge opportunity to deliver resources to these multimillions more efficiently.



SURF Swells, Again

Purdue's Summer Undergraduate Research Fellowships go global in fifth year.



V.W.

Weather Report: Darryl Smallwood, a junior computer science major at North Carolina A&T State University, explains his research project to Frances González, a junior studying computer engineering at the University of Puerto Rico, Mayaguez. Smallwood's project consisted of utilizing information technology to access, retrieve, and process North American Regional Reanalysis data to improve weather prediction capabilities.

Students are riding the waves of success of the Summer Undergraduate Research Fellowships (SURF) program. Since its inception in 2003, SURF has watched its participation grow, the universities represented expand, and the research opportunities heighten. And, according to Jay Gore, there's nowhere to go but up.

"This year we have 186 students who are just delighted to be a part of SURF," says Gore, the Vincent P. Reilly Professor of Mechanical Engineering and the founder of SURF at Purdue. "Everyone just loves this program."

Launched using a portion of an unrestricted gift from Purdue alumnus Patrick Wang (BSEE '72, MSEE '72), SURF was devised to meet the increasing needs

of academia and industry by providing a dedicated laboratory experience for undergraduate students.

The 11-week program enhances classroom learning, involves undergraduates in hands-on research and problem solving, and helps to pique interest for research careers in science and engineering. "We think that it's important that students have experiential learning activities that will help to enhance what's being covered in the lecture or in the classroom," says Mike Harris, associate dean for undergraduate education and a professor of chemical engineering.

The program began five years ago with 50 Purdue undergraduates. In 2005, the number increased to 162 students coming

from 20 different universities including Purdue, Alabama A&M, Florida A&M, Illinois Institute of Technology, and Notre Dame.

Today, in addition to attracting 150 Purdue students, SURF has gone global. Students hail from Asia and Europe. Several students are participants in the International Association for the Exchange of Students for Technical Experience (IAESTE). "It's very important that we have that global perspective," says Gore.

In addition, domestic students are also arriving from MIT, Cornell University, Johns Hopkins University, Michigan State University, and the University of California, Berkeley. In bringing students to Purdue from other campuses, Harris notes, SURF serves as an effective recruiting tool for the university.

So why do students from these top-ranked programs head to the Hoosier state to SURF? For many who are originally from the Midwest, it's a reason to come home. Once involved in SURF, many students choose Purdue for graduate school.

"We're bringing Hoosiers back," says Gore. "We have students earning their bachelor's degrees at MIT and are now coming to Purdue for their master's degrees. In the past, it was generally the other way around."

Beyond the family ties, it's the unique research opportunity that brings students to SURF. "I think the students enjoy the fact that they have the liberty to try different things," says Harris. "You can ask them to expand and see which direction the research should take."

Along with being paired with a professor and one or more graduate student mentors to work on disciplinary and interdisciplinary projects, students also attend seminars on research methodology, graduate school, and professional development.

There are student poster presentations, social activities, and an end-of-the-summer banquet. Those events that began as fun diversions have developed into much-anticipated traditions.

"We continue to follow the principle of whole-person engagement," says Gore. "We have a really happy bunch."

And the faculty is a pretty happy bunch, too. Professors have lauded the quality of students and the work being done. Graduate students have gained valuable

experience as research mentors, and SURF graduates are returning to serve as graduate student mentors themselves.

These achievements have given Gore perspective on where the SURF program can head. He'd like to see the program develop campus-wide. He also believes SURF can become a stronger recruitment tool for the university at all levels, and he would like to expand the value of undergraduate lab research across the curricula.

As Gore reflects on the progress made in five short years, he knows the partnerships the program is making throughout the university will only further the program's possibilities.

"The number of offices and people contributing to this program is amazing," says Gore. "It's really a program of the institution." * **Sharon L. Martin**



SURF's Up: Having just completed its fifth year, SURF has grown from 50 students to 186, representing some 20 different universities. The 11-week program enhances classroom learning, involves undergraduates in hands-on research and problem solving, and helps pique interest for research careers in science and engineering.

Engineering Education

Monica Cox

“Is there a ‘right’ way to teach engineering? If so, how do you train faculty to teach so that student learning is maximized?”



Attracting children to engineering studies earlier, introducing students to global learning opportunities, and bolstering the PhD program mark a renewed emphasis on how Purdue is educating the next generation of engineers.



Tools of a New Trade

— LISA HUNT TALLY

Purdue researchers are bringing the development and validation of student-learning-assessment tools to the discipline of engineering education.

In education circles, there's a well-known tool for capturing how children perceive practitioners of science: the Draw-a-Scientist Test (DAST). When asked to draw a scientist, kids commonly produce sketches featuring a middle-aged or older white male, bespectacled and crazy-haired, who sports a lab coat and carries a test tube. Typical captions read "Eureka!" or " $E=mc^2$."

Using DAST as inspiration, education researchers in the engineering sphere have created their own tool, the Draw-an-Engineer Test (DAET), which asks participants to draw an answer to the question, "What does an engineer do?" Here, images of building and fixing houses

and car engines predominate, with occasional depictions of trains, train tracks, and train operators. Like DAST, DAET is a fascinating way to probe the stereotypes and preconceived ideas that youngsters bring into the classroom.

Developing and validating such tools is at the heart of Monica Cox's research agenda in Purdue's Department of Engineering Education, where Cox is an assistant professor and the director of assessment for the Institute for P-12 Engineering Research and Learning, also known as INSPIRE.

Set against declining national college enrollments in engineering and corresponding concern about the United States' technological competitiveness, INSPIRE asks two fundamental questions: (1) How can we introduce engineering into a child's world and open that child's eyes to what engineers do and how engineers contribute to everyone's world? And, (2) How do we help children become better problem solvers and functional team members?

INSPIRE seeks answers by conducting basic multidisciplinary research in human cognition and concept development in engineering education. The institute aims



Eye-Openers: The Institute for P-12 Engineering Research and Learning, also known as INSPIRE, seeks to reverse the declining national college enrollments in engineering and corresponding concern about the United States' technological competitiveness. INSPIRE asks two fundamental questions: (1) How can we introduce engineering into a child's world and open that child's eyes to what engineers do and how engineers contribute to everyone's world? And, (2) How do we help children become better problem solvers and functional team members?

Photo provided by INSPIRE





Educational Leader: Kamyar Haghighi, head of Engineering Education, is proud of his department's role in the recent NSF-sponsored Engineering Education Research Colloquies. "It was the first major collective attempt of the engineering education community to develop a cohesive and comprehensive national research agenda," he says.

to inform, at a national level, the design of engineering curriculum, student learning environments, and teacher education—all to motivate new generations of precollege students to embrace engineering. The initiative is a centerpiece of the Department of Engineering Education, the world's first academic department dedicated to the art and science of learning engineering.

Inspired Engineer

Cox, with a BS in mathematics from Spelman College, a master's degree in industrial engineering from the University of Alabama, and a PhD in leadership and policy studies from Peabody College at Vanderbilt University, single-handedly embodies INSPIRE's multidisciplinary model.

"When I was working on my master's thesis in IE," she recalls, "I had the opportunity to work at NASA with ground payload operators for the International Space Station

[ISS]. My goal was to help these operators reduce the number of human errors they made while working with astronauts on the ISS. Reduction of errors was important since operators were required to respond quickly to astronauts and to recall numerous protocols at a moment's notice. Skipping a step in a protocol could alter the results of an experiment that might not be reproducible in space, thereby resulting in a waste of federal funds. It was then that I began to look at ways to reduce human errors through a cognitive lens. More specifically, I suggested that research on memory—for example, chunking large volumes of information into smaller segments—be used to reduce errors of commission and omission at payload operators' workstations. I saw relationships between cognitive psychology and human factors engineering—and that's when I began to understand multidisciplinary learning."

If her multidisciplinary mindset could place NASA employees on the path to fewer human errors, Cox reasoned, maybe it could improve educational institutions as well. "My passion is more educationally focused," she says—and her focus is the assessment of how engineering learning takes place at all levels of the educational pathway: precollege, undergraduate, graduate, and post-graduate. As applied to engineering education research, assessment refers to the collection of data that can be used to answer curricular or research questions. "There aren't many widely disseminated valid tools that have been designed to assess student and teacher understanding exclusively within engineering," says Cox, who is one of just a few researchers in the country working in this area.

She and her research team are at work now examining existing tools for assessing students', teachers', and administrators'

perceptions and understanding of engineering within P-12 environments. Which of the tools—surveys? direct-observation instruments? visually based approaches like DAET?—are appropriate for which situations? Do the tools actually measure what they intend to measure? How can researchers use the data that those tools gather to make improvements within the educational arena?

To gain more insight into the elementary school teacher's world in particular, Cox has traveled to the Boston Museum of Science to engage in its "Engineering is Elementary" teacher workshops. Engineering is a new discipline for elementary school teachers, so workshop sessions introduce them to engineering concepts and skills in addition to reviewing the structure and philosophy shaping the curricular materials, engaging participants in curricular activities, and fostering reflection about appropriate instructional strategies. "I began to think about how such curricula might be used to evaluate the impact that engineering plays upon the development of diverse populations of students," Cox says.

"I want to explore how diverse engineering students respond to various engineering classroom environments," she continues. "Do different styles of instruction affect how well engineering students understand and retain concepts? Is there a 'right' way to teach engineering? If so, how do you train faculty to teach so that student learning is maximized?"

Ask, and You Will Research

Purdue and its Department of Engineering Education are driving forces for framing the right questions and finding meaningful answers. Indeed, the department played a leading role in the recent NSF-sponsored Engineering Education Research Colloquies, which involved 64 STEM scientists and scholars (13 from Purdue) from institutions across the U.S. who collectively

defined five broad research categories: Engineering Epistemology, Engineering Learning Systems, Engineering Learning Mechanisms, Engineering Diversity and Inclusiveness, and Engineering Assessment. A report on the colloquies and details of those research areas were published in the *Journal of Engineering Education* last year.

"This was a tremendous accomplishment, since it was the first major collective attempt of the engineering education research community to develop a cohesive and comprehensive national research agenda that will serve as a guide and framework, particularly at a time that this community is establishing engineering education as a serious and scholarly discipline," says Kamyar Haghghi, head of Purdue's Department of Engineering Education.

Within Purdue, Cox and her colleagues aim to produce a growing body of core, foundational knowledge that guides the engineering community in the production of the best and brightest engineering students. "Ultimately," she says, "my goal is to develop tools that will give us reliable feedback on the questions that we want to answer—and will influence science, technology, engineering, and mathematics education policy. With such empirical findings, policymakers can make informed decisions about initiatives that must be funded to improve engineering education."

We're at the forefront of a new era of discovery about what constitutes effective engineering education, Cox believes. "Engineers in academia have always been labeled as engineering educators," she notes, "but we now have people who are conducting high-quality engineering education research that impacts every aspect of the engineering profession." *

PhDs Rising

Increased research funding and promising opportunities have Purdue engineering students taking their education to the next level.

When the College of Engineering began its strategic planning for 2002-07, increasing doctoral-student enrollment was identified as a key action. Since that time, Purdue Engineering has seen the number of PhD degrees granted increase by more than 50 percent, from 122 in 2001-02 to 192 for the 2005-06 academic year.

"We've been working to increase the number of PhD graduates, and our number of PhD students enrolled has been steadily growing, along with the number of PhDs granted, for the past few years," says Audeen Fentiman, associate dean for graduate education and interdisciplinary programs and a professor of nuclear engineering.



Biomedical Bound: Darryl Dickerson (seated), a PhD candidate in biomedical engineering, shown here with Eric Nauman, an associate professor with appointments in both biomedical and mechanical engineering, is mechanically testing some ligament and cartilage analogues. Dickerson's research on ligament and cartilage reconstruction led to a recently funded Trask proposal, which will help the team develop a commercial product. A New Orleans native, Dickerson received his undergraduate degree from Tulane and, upon graduation, was recognized with five different graduate fellowships. He could only accept two of them, however, from the Whitaker Foundation and the National Science Foundation. In addition to his studies, Dickerson is the chairperson for the National Society of Black Engineers. He looks forward to starting his own biomedical engineering company after graduation.

What accounts for the increase, and why does it matter?

"In our recruiting, we've certainly reached out to other universities in the country—including HBCUs [Historically Black Colleges and Universities]—to encourage strong students to enroll," Fentiman says. "But there's no way we could have increased the PhD numbers this much without having a significant increase in research funding."

Graduate education and research are "absolutely intertwined," she notes. "If you have a lot of strong PhD students, that increases the number of successful projects, leading to more proposals, and bringing in more research dollars. More dollars allow us to hire more students."

More dollars have in fact come in, and that's a result of Purdue Engineering's ambitious strategic plan. The college has seen a 54 percent increase in research expenditures over the 2002-07 time period, including a five-fold increase within the Department of Engineering Education and growth in large-scale research projects, such as the NSF Engineering Research Center for Compact and Efficient Fluid Power, the NSF Engineering Research Center for Structured Organic Composites, and the U.S. Department of Transportation-funded NEXTRANS center.

State-of-the-art facilities, which include the Birk Nanotechnology Center, the Weldon School of Biomedical Engineering, and the Bindley Bioscience Center, combine with the opportunity for doctoral students to collaborate with world-class faculty on interdisciplinary projects—all with a global perspective.

"It's the PhD student who is most likely work with a faculty member to develop truly new and original contributions to knowledge," says Fentiman, "so it's important for us to have as many doctoral students as possible. When you look at the best engineering schools in the world, one of the metrics used to measure their strength is how many PhD students they enroll. A reputation for excellence attracts more and more talented PhD students, resulting in research with greater impact. It all ties together." * **L.H.T.**

Making a World of Difference

Purdue's GEARE program equips tomorrow's engineers for the global workforce.

In today's global workforce it is becoming increasingly common for engineers from different cultures to work side by side on today's most challenging problems. As the engineering environment continues to change dramatically, so too must the context for engineering education. In order to compete in this international environment engineering students must learn to become global engineers.

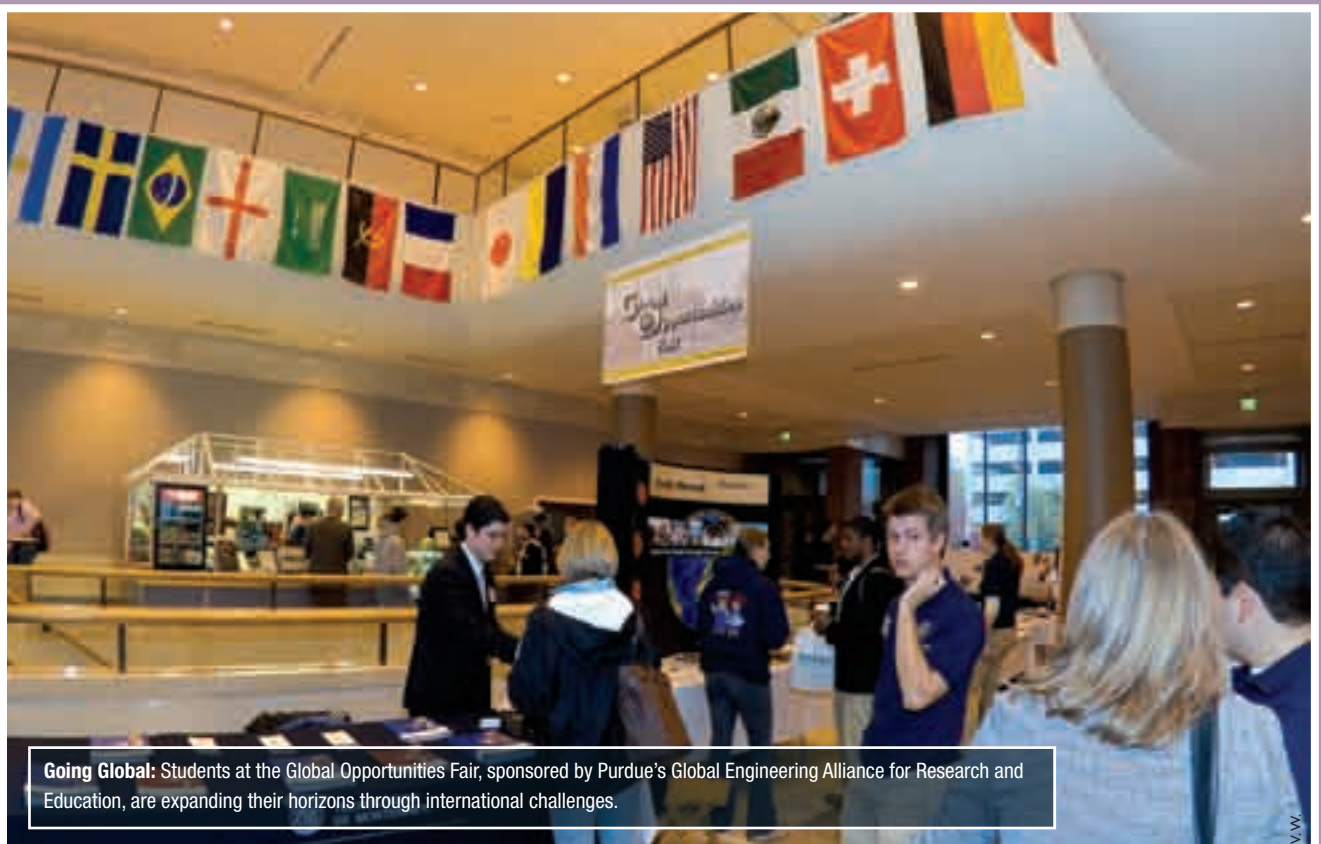
Students participating in Purdue's Global Engineering Alliance for Research and Education (GEARE) are learning just what it means to be a global engineer. Francisco

Montalvo, a mechanical engineering junior who's interning at Siemens in Berlin, has learned that flexibility is key: "The cultural barriers and different ways of thinking that often cause great issues in business, especially at a global level, force us to keep our minds open and use our past experiences to find solutions where all parties can be satisfied."

Launched in the School of Mechanical Engineering in 2003, GEARE supplements the education of engineering students so that they're prepared to function immediately, on graduation, in the global

workplace. "In today's global economy," says Dan Hirleman, the William E. and Florence E. Perry Head of Mechanical Engineering, "we have an obligation to give our students a competitive advantage by providing them with the experience of studying and working with engineers from other countries."

What Hirleman and his founding team from Mechanical Engineering—Professor Eckhard Groll; Jerry Matthews, the director of the school's Office for Industrial Experience; and communications specialist Dianne Atkinson—have created through GEARE is





International Obligations: “In today’s global economy,” says Dan Hirleman (standing right), the William E. and Florence E. Perry Head of Mechanical Engineering, “we have an obligation to give our students a competitive advantage by providing them with the experience of studying and working with engineers from other countries.” To Hirleman’s right is an international partner, José Alberto Sandoval Villarreal of the Tecnológico de Monterrey (standing left), Campus Monterrey.

singular in integrating international-team design and an overseas internship into a comprehensive, 24-month program.

With no time added to the typical engineering student’s four-year plan of study, GEARE students participate in an orientation program, one paid domestic internship, one subsequent international paid internship at the same company, one semester of study abroad, and a two-semester design team project (one semester at the home university, one abroad) with design teams that include students from international partner universities. This means that a Purdue GEARE student learns by working face to face, and shoulder to shoulder, with international students.

Before the introduction of GEARE less than 1 percent of Purdue’s mechanical

engineering students had had a global experience related to the engineering profession. In the past two years, 18 percent of Purdue’s graduating mechanical engineering students have had overseas courses or internships.

Building on that success, GEARE has expanded to include students from other engineering disciplines, including chemical, civil, electrical and computer, and aeronautics and astronautics. In addition, a graduate version of the program has been established with Germany whereby Purdue and Karlsruhe master’s students are paired to work on research projects.

“GEARE tends to attract the upper cut of students,” says Matthews, who handles GEARE’s administrative details and comes to know the Purdue participants well, from the beginning of the application

process through the end of the students’ experience. As for students’ personal growth over the two-year experience, “It’s really amazing,” he says. “They are much more confident and mature in the way they handle themselves. You can tell that something’s happened in their lives that’s made a world of difference.”

John Wall, vice president and chief technical officer of Cummins Inc. can see that difference in Purdue’s graduating engineers. “Cummins always recruits top academic talent,” he says, “but the GEARE students are even more. They are risk takers who challenge their comfort zone by seeking global experiences, they adapt readily to new environments, and they know what it takes to work in teams of international engineers.”

*** Lisa Hunt Tally and Kristen Senior**

Buildings

— WILLIAM MEINERS



From the new Neil Armstrong Hall of Engineering on the north through the Discovery Park facilities on the south end of campus, new and revitalized Purdue Engineering buildings help to further the cutting edge of research.

While it's the people at Purdue who provide our core strength, new buildings throughout campus provide state-of-the-art research facilities to help make the most of that brain power. Much of the money raised in *The Campaign for Purdue*, which totaled more than a billion dollars from 2002-07, has made for quite a campus facelift, helping to both build new facilities and renovate existing structures.

Several new facilities in Discovery Park, a transparent environment for multidisciplinary work in areas of strategic importance, expected to cost more than \$100 million in facilities and \$50 million in programs, are both up and running and on the rise. Discovery Park, which comprises six new centers covering almost 40 acres, is home to the Birck Nanotechnology Center, the Bindley Bioscience Center, the Burton D. Morgan Center for Entrepreneurship, the E-Enterprise Center, the Discovery Learning Center, and the Center for Advanced Manufacturing.



Nanotechnology Home: Completed in September 2005 and a centerpiece of Discovery Park, the Birck Nanotechnology Center expands the frontiers of nanoscale research as one of the most advanced facilities of its kind in the world. The facility provides specialized labs for nanoscale chemistry, biology, and physics; semiconductor-grade clean rooms; and office space for faculty, post-docs, and graduate students from various disciplines across Purdue's campus.



Biomedical Building: Recently renamed for Purdue's last president, the Martin C. Jischke Hall of Biomedical Engineering is a four-level building containing both undergraduate and graduate teaching and research facilities. It's also a first for any academic institution in Indiana. Home to the Weldon School of Biomedical Engineering, the building provides a synergistic environment for all students, faculty, and staff within the school. Located in Purdue's Discovery Park, Jischke Hall will link the school with many of the life science and nanotechnology initiatives occurring campus-wide.





The doors to the Neil Armstrong Hall of Engineering opened in fall 2007. As the academic gateway to Purdue Engineering, Armstrong Hall will be where many take their first step in their pursuit to become engineers. The dynamic facility will house Engineering Administration, Aeronautics and Astronautics, Engineering Projects in Community Service (EPICS), Engineering Education, Materials Engineering, the Minority Engineering Program, and the Women in Engineering Program. *

Armstrong Hall: Named for perhaps Purdue's most famous alumnus, the Neil Armstrong Hall of Engineering was designed to provide the unique educational and research facilities dedicated to teamwork, hands-on learning, building community relationships, and establishing interdisciplinary connections necessary for educating the next generation of engineers. The building will have 109,000 assignable square feet, including more than 20,000 square feet dedicated to research labs and more than 60,000 square feet of undergraduate teaching facilities, and discipline-specific design labs. In eight classrooms, Armstrong Hall will feature learning spaces that facilitate student teamwork, especially for design work, one of the most important facets of engineering education.





Chorafas Winners

Purdue doctoral students compete for, and win, an international award.

Two Purdue students won the Dimitris N. Chorafas Foundation doctoral dissertation award, which was established to encourage the development of promising graduate researchers in engineering.

Tengfei Zhang, mechanical engineering, and Arijit Raychowdhury, electrical and computer engineering, were selected for the monetary prize. The prize money is intended as co-funding for the students' advanced studies and/or research.

The Chorafas Foundation was created in 1992, and prizes are awarded to students at more than 20 universities around the world for exceptional doctoral research projects and to help stimulate research among young doctoral candidates.

Candidates must be planning to graduate between May 2007 and August 2008. Their research should be in the advanced stages, according to the foundation's rules.

Dimitris Chorafas is an internationally recognized consultant who has advised financial institutions and industrial corporations on strategic planning, risk management, computer and communication systems, and internal controls since 1961. He has authored more than 100 books.

Purdue's College of Engineering also recognized nine other students with cash prizes and certificates for their dissertation proposals selected from nominations for the Chorafas competition. These prizes were given by the College of Engineering.

James Sisco, from aeronautics and astronautics, received a prize for the Top Dissertation Award from the college. Additional outstanding dissertation prizes were given to Baratunde Cola, mechanical engineering; Nathaniel Pettis, electrical and computer engineering; Jung Eun Oh, civil engineering; Silas Leavesley, biomedical engineering; Watcharapol Chayaprasert, mechanical engineering; Mihidhar Rayasam, mechanical engineering; Alok Joshi, mechanical engineering; and Yu-Sung Wu, electrical and computer engineering.



Dissertation Champions: Tengfei Zhang (left) and Arijit Raychowdhury, doctoral candidates in mechanical engineering and electrical and computer engineering, respectively, were selected for the monetary prize of the Dimitris N. Chorafas Foundation doctoral dissertation award. The prize money is intended as co-funding for the students' advanced studies and/or research.



CAREER Makers

For young researchers, a CAREER award from the National Science Foundation is a prestigious badge of honor that recognizes outstanding potential in a particular field. The five-year grants provide a jumpstart on both research and career paths. Of this year's winners with ties to Purdue Engineering, three come from electrical and computer engineering and another each from chemical and civil engineering.

Engineering Clays: Marika Santagata (top), an associate professor of civil engineering, earned her CAREER award that will help her examine the behavior and performance of clay-based fluids employed in trenchless technologies (microtunneling, pipejacking, horizontal directional drilling). These fluids play a critical role in the construction and rehabilitation of underground utility infrastructures. The total length of such structures is estimated to exceed 20 million miles in the United States alone. The title of her project: "Linking Rheology to Performance: An Integrated Approach to the Evaluation and Design of Trenchless Technology Fluids."

Three ECEs: For Jianghai Hu (background), Xiaojun Lin (foreground), and Mithuna Thottethodi, all assistant professors of electrical and computer engineering, the CAREER award brings them eagerly to their laptops in the morning. Hu won for his project titled "Reachability Analysis and Optimization of Stochastic Hybrid Systems." Lin found success with his project called "A Theoretical Foundation for Supporting Delay-Sensitive Applications on Wireless Networks." And Thottethodi earned his CAREER award for a project titled "Cross-Layer Schemes for Flexible Resource Sharing in Multicore Systems."

Chemical Excellence: Chelsey Baertsch, an assistant professor of chemical engineering, received her CAREER award for her project "Designing Partial Oxidation Catalysts for Selective Gas Microsensors." Her millimeter-sized sensors will improve the safety and efficiency of a variety of chemical processing systems by providing portable detection capabilities for hazardous and flammable gas contaminants.



Signature Research

The College of Engineering continues to hire young, bright minds to address problems of national importance.

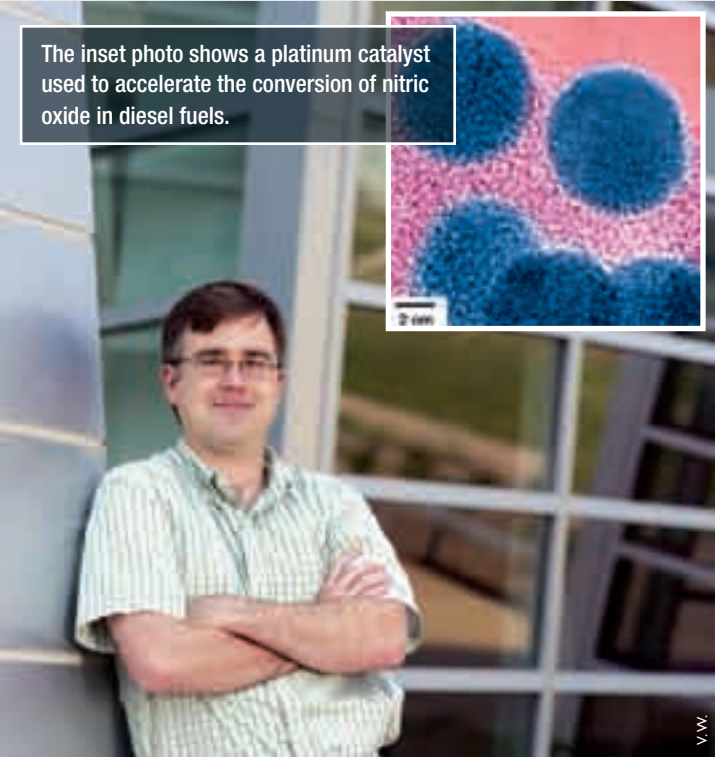
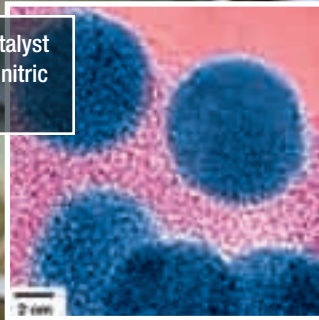
In 2003, Purdue's College of Engineering was looking to link like-minded researchers with research projects that address some of the biggest challenges facing humanity. The resulting eight signature areas (with a ninth added later) set off a cluster-hiring process that helped to break down the stereotype of the academic silos. Multidisciplinary by nature, these new hires are setting the pace for field-defining research, educational innovation, and intellectual property spin-offs. To follow is a list of the signature areas, along with a few of the faces at work behind them.

- Advanced Materials and Manufacturing
- Energy
- Global Sustainable Industrial Systems
- Healthcare Engineering
- Information, Communications, and Perception Technologies
- Intelligent Infrastructure Systems
- Nanotechnologies and Nanophotonics
- System of Systems
- Tissue and Cellular Engineering

System Linkages: William Crossley (left), an associate professor of aeronautics and astronautics, has not only been at the forefront of Purdue's work in the System of Systems (SoS) signature area, but he's also helped recruit new research talent to the faculty like Dan DeLaurentis. Tackling problems such as air transportation, the SoS approach seeks to find the links that allow various independently operating systems to collaborate in achieving a larger goal. For insight on how DeLaurentis, an assistant professor of aeronautics and astronautics, sees how small jets can help negate highway traffic, see the story on page 23.



The inset photo shows a platinum catalyst used to accelerate the conversion of nitric oxide in diesel fuels.



Nanotech Solutions: Shown here in front of his research base at the Birck Nanotechnology Center, Eric Stach, an associate professor of materials engineering, was one of the first signature area hires in Nanotechnologies and Nanophotonics in 2005. He utilizes advanced electron microscopy techniques to observe how materials crystallize at the atomistic scale during the creation of new nanostructured materials. These observations allow improvements in the performance of new materials in electronics applications.

Materials Gain: Researchers in the Advanced Materials and Manufacturing signature area, as one might surmise, bring a materials perspective to manufacturing research. And for Marisol Koslowski (left), an assistant professor of mechanical engineering, and Lia Stanciu, an assistant professor of materials engineering, that's a perspective often linked to nano-structured materials. This research has the potential to advance the processing science necessary to manufacture materials that can meet society's demands for bridging the gap between the synthesis of new nanoscale materials and their ultimate use in real-world technologies.



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