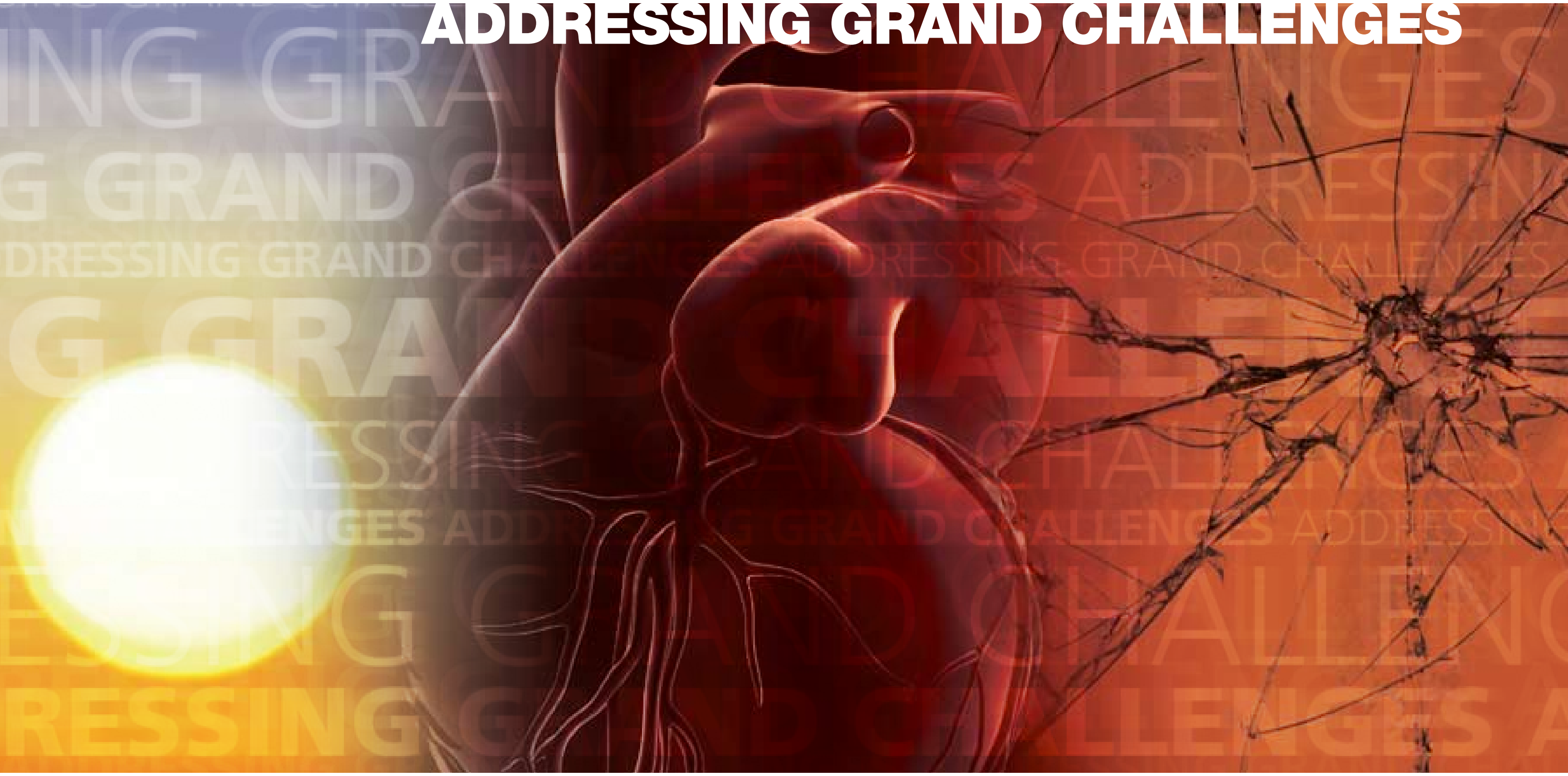
Purdue's Engineering Edge → December 2008



PURDUE ENGINEERING™

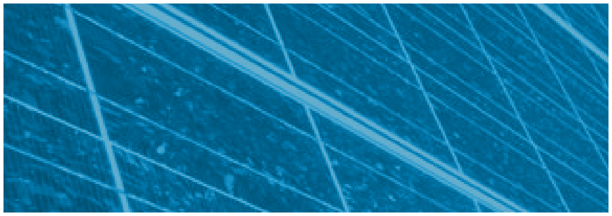
ADDRESSING GRAND CHALLENGES

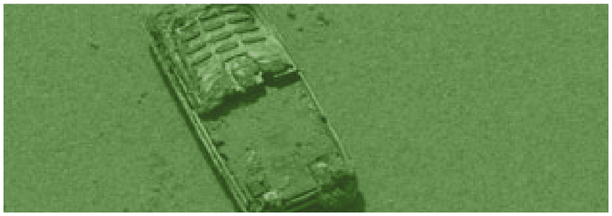
They're thinking about what we're thinking about. The think tanks, the national academies and agencies—many well known by their acronyms—are all working hard to address the concerns that cross many of our minds on a daily basis. How much is it going to cost me to fill up my tank today? Will my aging parents be able to meet their healthcare needs? Would my kids' school be safe in case of a disaster? What can I do to leave less of my own carbon footprint? And who's going to come along and engineer better solutions for all of the above?

Researchers within Purdue's College of Engineering are also focusing on these daily concerns in need of long-term solutions. The motto "Think Impact" is alive and well across our campus as we continue to foster collaborations that address grand challenges, such as those identified by the National Academy of Engineering in 2008.

This issue of *Purdue's Engineering Edge* highlights a number of our researchers who are working toward breakthroughs in fields ranging from energy to the environment, from safety to healthcare. As educators and mentors, they are also addressing the needs of an ever-evolving engineering education curriculum. And there's much to be said for crossover success. When we build for safety with an eye toward sustainability, we also become more energy efficient and environmentally friendly. Overhauled systems can likewise revolutionize healthcare and help educate an innovative breed of new engineers.

There are no easy solutions to grand challenges. But we're proud of the Purdue people who eagerly put forth the discovery efforts to find answers to those nagging questions.





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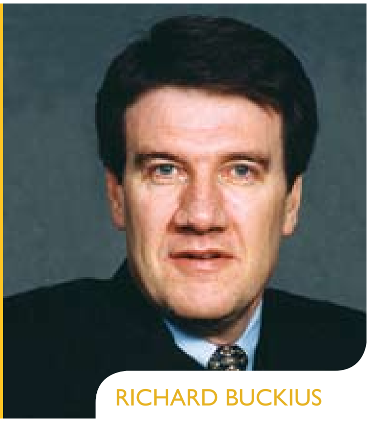


RICHARD BUCKIUS

Vice President for Research, Purdue University

I am pleased with the opportunity to contribute a perspective based on my previous appointment as assistant director for the National Science Foundation's (NSF) Directorate for Engineering, and as a new member of Purdue's robust research community.

Many of the technological advances that we enjoy today were built on the legacy of Purdue engineering faculty and alumni. There is little doubt that the new discoveries and innovations by Purdue engineers and investigators from multiple disciplines will contribute to solving many of the grand challenges facing us today.

At the request of the NSF, the National Academy of Engineering (NAE) created a list of grand challenges in engineering. As you will see in this publication, Purdue engineering educators, investigators, and students are vigorously addressing many of these grand challenges. Discovery efforts are leading them to cross disciplinary boundaries and build lasting collaborations with public and private institutions of all types.

The NAE study was designed to define the needed engineering innovations to both solve some of the problems of today and enable future research needs. The NAE accomplished this goal by convening an international and diverse committee of engineers and scientists to evaluate the 21st century's grand challenges in engineering.

The project resulted in what the NAE project committee members consider to be 14 achievable and sustainable grand challenges in engineering.

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

Based on the type of grand challenges noted, broad collaborations that include teams from multiple disciplines will be required. A recent study published in *Science* [316: 1036–1039 (2007)] focused on the number of authors included on research publications. After examining 20 million publications over the last five decades, the data revealed that the number of publications by science and engineering teams increased from 50 percent in 1955 to more than 80 percent by 2000; other disciplines showed a significant increase as well. In addition, the number of members on a team has almost doubled over the same period.

A review of NSF funding trends showed that 47 percent of NSF sponsored grants are awarded to teams of investigators in FY 2007. In 1984, awards to teams were in the 18 percent range. Over the past 24 years, NSF sponsorship on collaborative projects has more than doubled.

To meet the grand challenges, discovery efforts will require an even greater impact from collaborative teams. In addition to the collaborative efforts of engineering and science teams, social scientists, economists, communication specialists, and professionals in human behavior, and policy will be tagged to bring their expertise to the table. The inclusion of fields covering a comprehensive study of factors will be of critical importance to addressing the grand challenges of our day.

Richard Buckius began his role as vice president for research at Purdue this past fall. As the assistant director of the NSF's Directorate of Engineering Buckius had a key role in setting the agenda for engineering research and education and overseeing the foundation's more than $600 million engineering research and education budget. As Purdue's vice president for research, he is charged with assisting faculty and staff in their research efforts and leading research administration and oversight, research development and proposal preparation, funding opportunities, and private sector partnerships.

LEAH JAMIESON

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

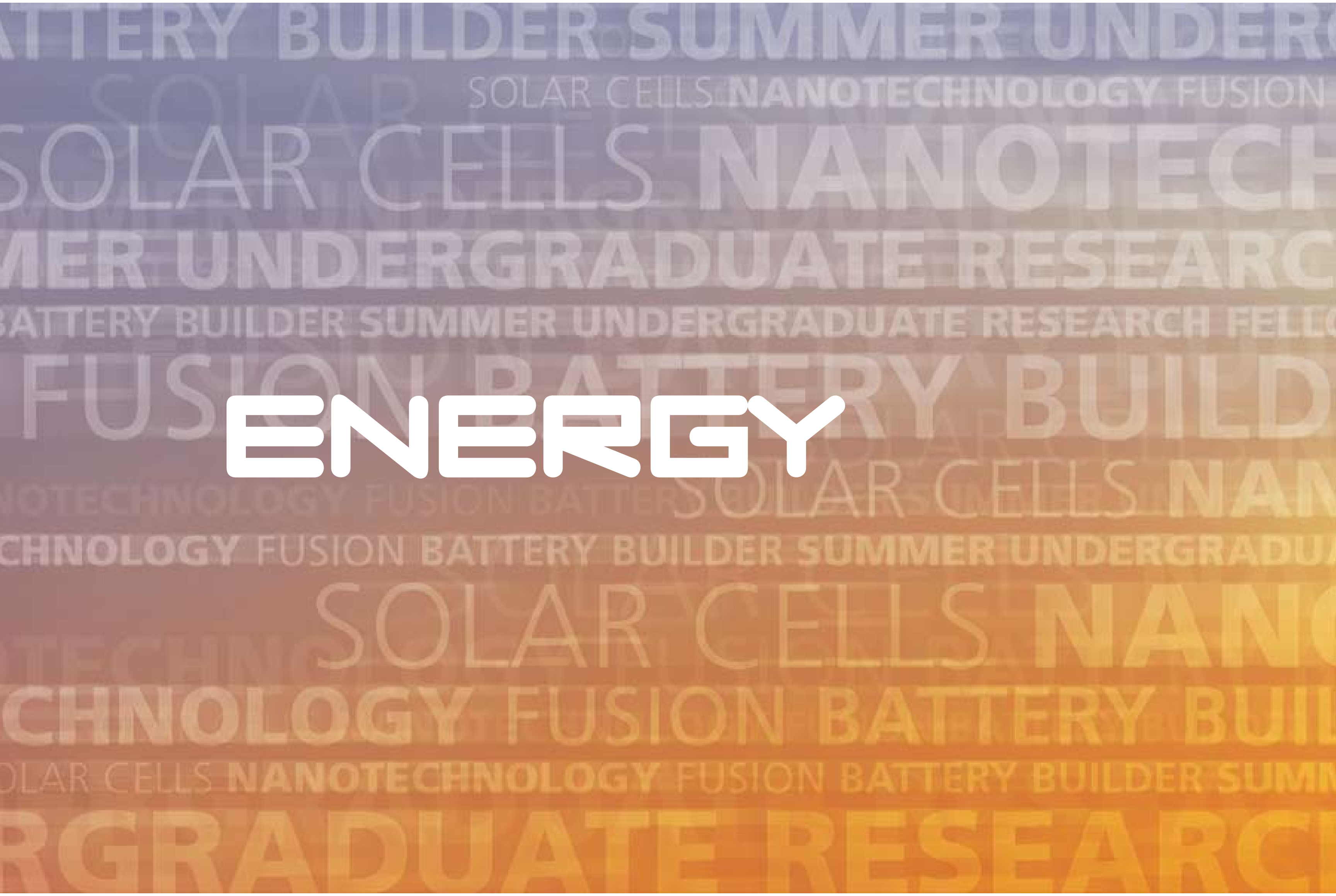
Welcome to our seventh edition of *Purdue's Engineering Edge,* the College of Engineering's annual research publication. With a nod to the National Academy of Engineering's grand challenges, the following pages provide examples of how Purdue engineers are addressing some of the biggest problems facing humanity. As a college we're not only thinking impact, but fully committed to making impact on a global scale. This overarching theme is shaping our emerging strategic plan as well. As an institution we need to encourage innovation, collaboration, and even responsible risk taking in field-defining research. By making strides in signature area research, continuously responding to industry needs, and evolving a curriculum that will lead to the best trained, most successful Renaissance engineers of tomorrow, we know we are heading in the right direction. With nearly 350 faculty members on campus, it's not possible to share all of their success stories here. I do hope, however, that you will get a chance to read about some of our passionate, determined engineers working on the cutting edges of their respective fields for the benefit of the world.

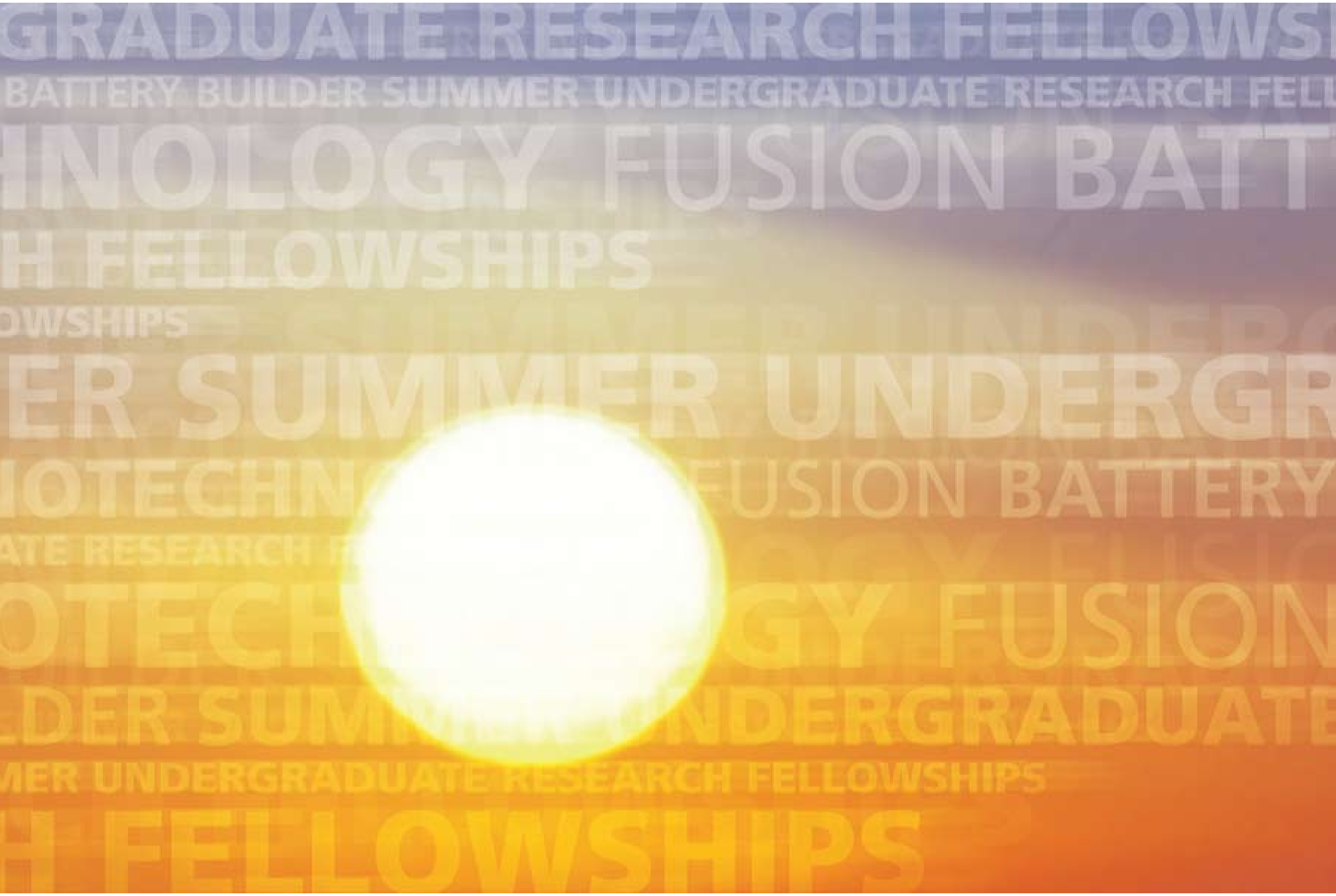
VENKATARAMANAN "RAGU" BALAKRISHNAN

Associate Dean for Research and Professor of Electrical and Computer Engineering

The proverbial "whole being greater than the sum of parts" is especially true with research institutions, where the ability to bring together various researchers and resources is integral to success, particularly when tackling grand challenges. The enormous impact of Discovery Park, where engineering plays a major role, serves as literal witness to this observation. Within engineering, the many glass walls of Neil Armstrong Hall, besides giving passersby a real sense of Purdue engineering, also promote a sense of togetherness among our researchers. We continue to promote this synergy via community building exercises, both virtual and otherwise. We are proud of what our researchers have been able to accomplish together, and are eager to share our success stories, with both campus visitors and readers of our research publication. If engineering is truly about improving humanity, you will find no greater examples than in the breakthrough successes of Purdue engineering researchers. Several of their stories follow.

ENERGY

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By **Patrick Kelly**

Staring at the Sun

Purdue engineers are looking for more efficient and economical ways to tap into our solar system's largest power source.

As a power generator, the sun far surpasses anything humans will ever engineer. But through engineering advances, we can learn to better harness that largely untapped power, paving the way toward a future less dependent on fossil fuels and entirely more sustainable. According to the National Academy of Engineering, solar power currently accounts for well below one percent of America's total energy consumption. As people throughout the world become more attuned to environmental issues ranging from air and water pollution to rising carbon dioxide levels to climbing costs of oil and gas, harnessing non-traditional power sources like the sun and wind become increasingly attractive—and necessary.

On the surface, solar energy seems almost too good to be true. It's environmentally clean, we receive its unbridled power every single day, and it comes streaming down completely free of charge.

So what's the hold-up? The barriers standing in the way of solar energy's proliferation fall into three broad categories: capturing the sun's power, converting that raw power into energy we can use, and storing the energy for use when sufficient sunlight isn't available. Then there's the matter of efficiency—right now, commercial silicon-based solar cells convert sunlight into electricity with only a 10–20 percent rate of efficiency. Add to that the reality of high manufacturing costs for these cells, and solar energy, in its current state, ends up costing between three and six times *more* than its fossil fuel counterparts.

Engineers therefore face not only the challenge of increasing efficiency in the areas of capturing, converting, and storing the sun's power but of making those advances while lowering manufacturing costs. No easy task, for sure, but several Purdue researchers have taken on the challenge.

Distinguishing Power and Energy

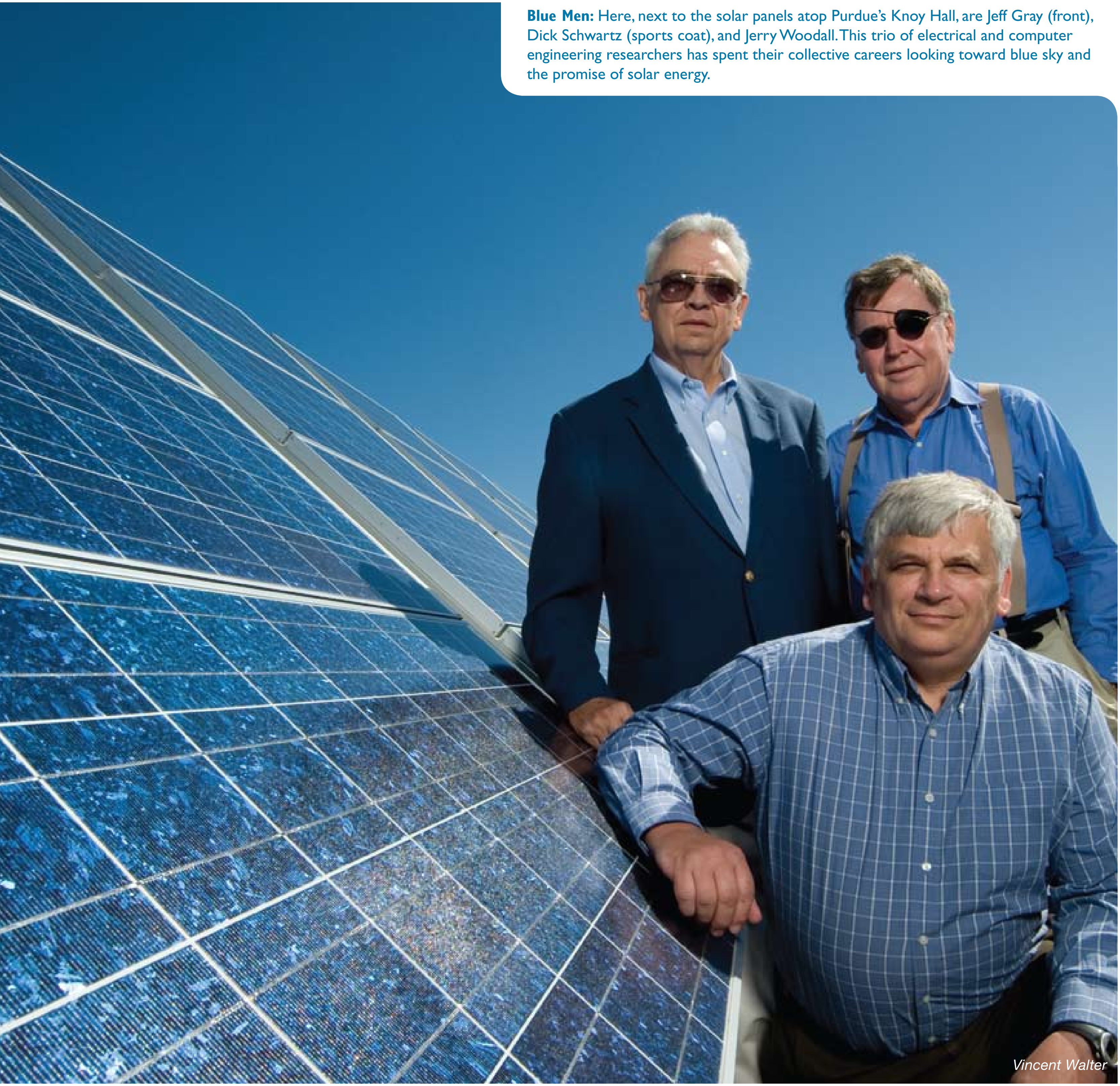
Jerry Woodall, who before coming to Purdue played an instrumental role in developing the world's most efficient solar cell while working at IBM, stresses that the real hurdle engineers face with regard to the sun is converting power into usable energy. "What we get from the sun are photons that come to us as watts, which is power," says Woodall, the Barry and Patricia Epstein Distinguished Professor of Electrical and Computer Engineering and Director of Purdue's high efficiency solar cell research group. "Energy is something you can put in a can, like oil or natural gas. These are energy and therefore already in a usable state. That's why they've always been our primary energy source. With solar, we have to convert power into energy and do it in a way that's both efficient and economical."

When thinking about the economics, Woodall has a very specific number in mind. "The price of a photovoltaic cell has to be low, and the efficiency has to be relatively high. If the cell converts with a rate of less than 10 or 12 percent efficiency, you could give it away for free and nobody would take it. But when you get above that efficiency rate and if the cost to manufacture it is still low, then you're talking about a usable device. And that's what engineers have been working on since the 1950s."

Incremental Improvement

Bell Labs created the first version of the modern, silicon-based solar cell in 1954. Since then, photovoltaic cells have made advances, but they've made them slowly and incrementally. As Dick Schwartz, a professor of electrical and computer engineering who's been involved with solar cells from the beginning, says, "It's been a series of small steps over the past decades."

Blue Men: Here, next to the solar panels atop Purdue's Knoy Hall, are Jeff Gray (front), Dick Schwartz (sports coat), and Jerry Woodall. This trio of electrical and computer engineering researchers has spent their collective careers looking toward blue sky and the promise of solar energy.



Vincent Walter

Timothy Sands agrees. The Basil S. Turner Professor of Engineering with appointments in electrical and computer engineering and materials engineering notes that the same principles of solar energy researched in the late 1970s and early 1980s still apply. The sun and its corresponding solar spectrum certainly haven't changed. And our primary photovoltaic medium—silicon—is still widely used. What has changed, says Sands, is our knowledge in the field of nanotechnology.

"The problem—how to best capture solar power and convert it into usable energy—is the same," says Sands, also the director of the Birck Nanotechnology Center. "But we have new knobs to turn now in 2008 that we didn't have in 1980. And the main knob is size. For example, we now know that when you make certain materials on a scale of nanometers, the materials behave differently than they do at a larger scale. Applying the principles and methods of nanostructuring to materials that absorb light much better than silicon—such as copper indium gallium selenide [CIGS]—is generating a new wave in solar cell concepts. Much less material is required compared to crystalline silicon solar cells, and the nanostructured materials can often be assembled using low-cost and low-temperature processing."

One application of nanotechnology to solar energy has been developed by chemical engineers Hugh Hillhouse and Rakesh Agrawal. Hillhouse, an associate professor of chemical engineering, and Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering, lead another solar energy research group at Purdue. They've created a nanocrystal ink that can be sprayed or painted onto a variety of surfaces and could be used to create localized energy for buildings and portable power applications.

But for wide-scale use in large solar arrays that supply power directly to the energy grid—the ultimate goal as far as global sustainability goes—there is a particular relevance in creating models, another arena where Purdue has come to the forefront.

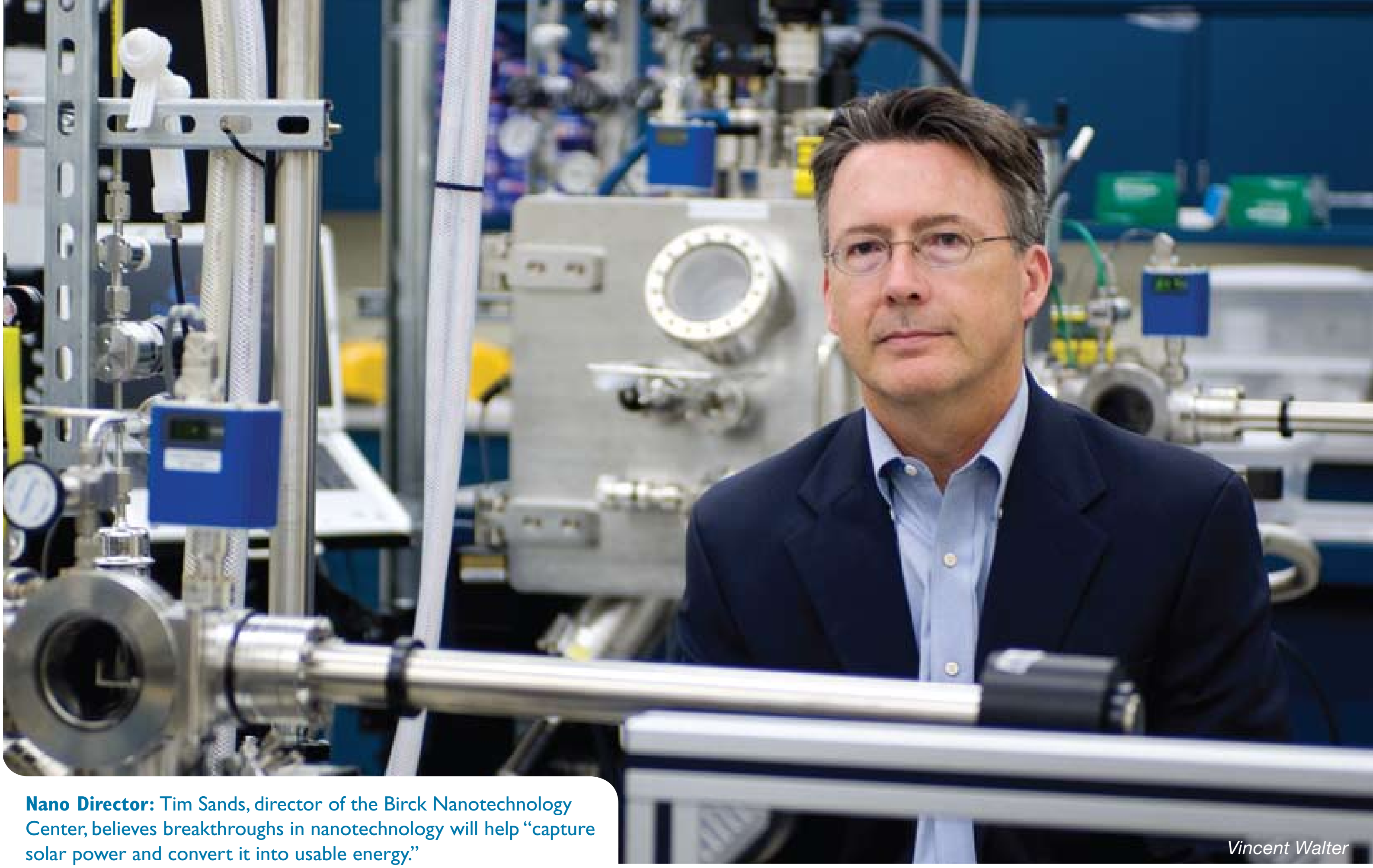
> ***"Only a small fraction of the sun's power output strikes the earth, but even that provides 10,000 times as all the commercial energy that humans use on the planet."***
>
> From the National Academy of Engineering Web site on "Engineering Challenges"

Jeff Gray, an associate professor of electrical and computer engineering, is one of the researchers leading that charge. "The reason we undertake detailed modeling," explains Gray, "is so we know exactly what photons are doing inside semiconductor materials—where they're moving to, and understanding the internal dynamics of the device so we can make predictions for the actual production of the cells."

Any engineer working on solar cells will tell you the goal is to reach an efficiency mark of near 50 percent. From Gray's perspective, there are a number of ways to make a run at that mark. "Silicon has a band gap of 1.1 volts," he says. "That tells you which part of the solar spectrum silicon can capture photons from. In some ways, that's limiting. But we also create multi-junction models—materials with different band gaps—so you capture a much broader array of the solar spectrum."

The Silicon-CIGS Debate

Ultimately, it all comes back to how the cells are built and what materials are used. Schwartz has been working with silicon since the beginning, though he doesn't discount the contributions that other materials can make in the quest for 50 percent efficiency. "Currently, we're actually involved in a project with DARPA [Defense Advanced Research Projects Agency] where we're using multiple band gaps to get very high efficiency rates in the lab," he says. "Our two-to-three year goal is 40 percent to 50 percent. Of course, what you achieve in the lab today is still three-to-five years away from being in the field. Typically, when you're dealing with much larger areas, you won't get the same levels of efficiency as with lab models."



Nano Director: Tim Sands, director of the Birck Nanotechnology Center, believes breakthroughs in nanotechnology will help "capture solar power and convert it into usable energy."

Vincent Walter

Schwartz is also adamant that although the United States lags behind countries like Japan and Germany in the area of solar energy production, the U.S. leads the world in solar energy research. "Those countries had a number of external factors—many political—that drove down the cost of producing solar, which in turn drove production up," he says. "But we're working with the same if not more advanced technologies here. It's just a matter of time before we can catch up on the production side of things."

Woodall, for his part, says that getting to 50 percent efficiency can't be done with a single material like silicon. "The ways the multi-gap materials work is essentially you stack four materials, all with different band gaps, on top of each other. So the silicon still captures its share of the photons, but the ones it doesn't capture get picked up by the materials behind the silicon that have different band gaps. When you do that, you increase efficiency."

One caveat about these more efficient cells is that to offset their production costs, they're employed in systems that concentrate sunlight about 100 times with lenses or mirrors. This means that the systems need to move along with the sun's path in order to receive the most direct light. "Solar tracking is another consideration here, but by no means is it an impediment," says Woodall. "It is just another engineering challenge we can solve."

In the end, even when 50 percent efficiency can be achieved, it looks as though solar energy alone is not the answer to the world's burgeoning needs. "The reason we're able to live on this planet is because the concentration of the sun's power is actually pretty low," says Woodall. "Getting to 50 percent would be a milestone, but it's not the only answer."

Not the only answer, no, especially with recent developments in wind energy. But certainly a crucial piece of our 21st century energy puzzle that's just now beginning to come into sharper focus, at Purdue and around the world. ■

By **Gina Vozenilek**

The Plasma Path

Two nuclear engineers seek "the way" to a fusion solution.

Their paths first crossed at Argonne National Laboratory in Illinois, where Ahmed Hassanein was the director of the fusion power program and Jeffrey Brooks was a key senior researcher. In late 2007, Hassanein moved their research program to Purdue, where he has recently established the Center for Materials Under Extreme Environment.

Now their path leads all the way to France, where construction will begin in 2009 in Cadarache on the 15-story, $15 billion ITER, the International Thermonuclear Experimental Reactor. ITER, which means "the way" in Latin, promises to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. "Fossil fuels will not last," Hassanein, a professor of nuclear engineering, says. "Basically, there will be no choice but to find an alternative."

Hassanein and Brooks join ITER as it unites the efforts of the U.S., Japan, Russia, China, South Korea, India, and Europe to provide the know-how to someday build the first electricity-generating power station based on magnetic confinement of high-temperature plasma—in other words, capturing and using the power of the sun on earth.

"This is the most complex technology made by man," says Brooks, a research professor of nuclear engineering, "and it's also one of the most important."

Stephen Dean, president of Fusion Power Associates, a nonprofit research and education foundation, compares the importance of ITER to the discovery of fission, lasers, or semiconductors. He agrees with scientists around the globe who see ITER as a "major stepping stone between where we are today and the ability to make electricity from fusion technology."

Dean regards ITER as a hopeful moment in global scientific cooperation. "Look at all the involved countries—ones who have not historically worked well together—dedicating their best minds to ITER," says Dean. "This is a truly historic effort." He notes that the work of Brooks and Hassanein is "critical to the success" of this international venture.

For ITER, Hassanein is studying the effect of plasma instabilities on the longevity of plasma-facing components. Brooks is devising the right recipe for the material inside the fusion reactor. "Designing the plasma-facing surfaces of the reactor remains one of the biggest challenges in developing reliable nuclear fusion," Brooks says. The plasma is confined by magnetic fields, but it interacts with the surfaces it touches. Such contact can be harmful both to the walls, which are subject to erosion from intense heating, and to the plasma, which is easily contaminated and cooled by impurities. The trick for Brooks, as the chair of the Department of Energy's Plasma-Facing Component Systems Group, will be to determine the best design for a surface material that can stand up to these forces and protect the plasma so it can one day be harnessed to produce energy.

Together Brooks and Hassanein are also creating mathematical models on super computers to focus ITER research. An ITER experiment will cost about $1 million per "plasma shot." In a shot, the plasma is turned on for 400–1,000 seconds. By applying data from computer simulations, Brooks and Hassanein hope to "optimize the shot," that is, guide the parameters of the experiment to minimize the experiment's time and cost.

The promise of fusion energy is tantalizing to scientists like Brooks and Hassanein. Very little long-term nuclear waste is produced with fusion, and no greenhouse gases are released during the reaction. "If fusion works, the impact will be tremendous," Brooks says. "The fuel comes mostly from water, the fuel is essentially free, and the possibility exists for an unlimited source of energy. It would be an extremely important addition to the world's energy portfolio." ■

Fusion Horizon: Ahmed Hassanein (left) and Jeffrey Brooks, both nuclear engineering researchers, are working in Purdue's Center for Materials Under Extreme Environment. There, through advancements in fusion, they are trying to capture the power of the sun on earth.

Vincent Walter

By **Sharon Martin**

You've Come a Long Way, Battery

A weekend experiment on a rechargeable battery turns into a lifelong passion for a materials engineer.

R. Edwin García had a slightly different career path in mind until a colleague challenged him to take a look at how he might tackle improving a rechargeable battery. In one weekend, García was hooked, and he's been hooked on creating more efficient energy sources ever since.

García, an assistant professor of materials engineering, is focusing on how to pack more energy into rechargeable batteries through innovative microstructural designs. The work is part of a larger project that applies theoretical and computational methods to understand better the relations between material properties and microstructure. The goal is to combine materials to create new energy sources.

So when fellow researcher and collaborator Quinn Horn imaged the inside of a rechargeable battery, García could hardly contain his excitement—and his work took on new dimension.

The microstructure of the battery showed three layers: the anode, a separating region, and the cathode. "Improvements to the battery have been mostly to the chemistry," says García. "It wasn't until 10 years ago that people started to look the structure of the battery at this level."

With the image, García was able to make the jump from using average properties to represent and engineer a battery to resolve the details and the local electrochemical interactions, and thus how they are working—or fail when working.

More Power, More Energy

Resolving the microstructure is important, because researchers can now tweak the arrangement of the particles within the anode and cathode to increase the energy of the battery. Through García's numerical model, virtual experiments can be performed, such as eliminating the separator region, thus allowing the anode and cathode to intersect, ultimately assessing if such changes will improve the power and energy of the device.

Why improve both? "Traditionally, when you engineer a battery, you engineer it for power or you engineer it for energy, but never for both," says García. "In this case, we have the opportunity to do both. The chemistry can give us so much, but by tweaking the order or the arrangement of the particles, the performance can be improved." This application is both exciting and promising of what a battery can do in the future.

"What we're really aiming for is to provide the means to the community to be able to understand and engineer new power sources, which is a hot topic," says García. "Tools like this will empower the community to provide new science [and thus improved power sources]."

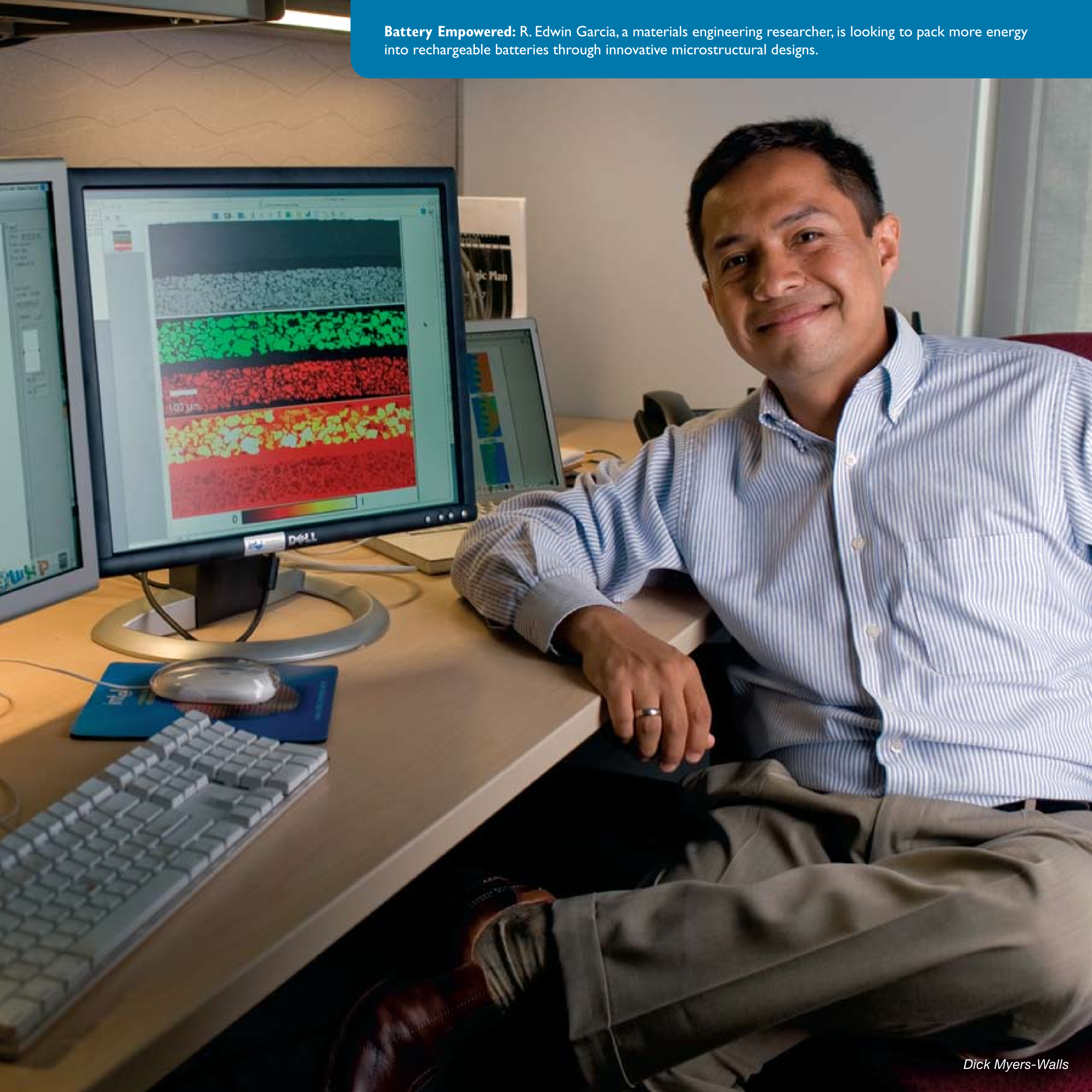
García sees that empowerment leading to a shift from analyzing one single technology to combining several in the next five to 10 years.

"Batteries have their own benefits and shortcomings, as do fuel cells and every other power source," explains García. "Just as there are hybrid cars that use gas with electricity, there will be other technologies that will incorporate different types of materials to optimize performances. The way electronics were incorporated into a single chip, the same will happen with this technology. It's inevitable."

After jumping into the field seven years ago, García is very motivated. He enjoys engineering and materials and understanding how things work.

"I think this research is important because it allows you to first understand why something is working or not working," he says. "It allows you to make a sound judgment and smart decision on how to fix it or how to improve it."

Ultimately, García wants to provide better technology. "As an engineer, you want to really help people. I consider this my baby, and it's come a long way." ■



Battery Empowered: R. Edwin Garcia, a materials engineering researcher, is looking to pack more energy into rechargeable batteries through innovative microstructural designs.

Dick Myers-Walls

By **William Meiners**

SURF to Success

Purdue's renowned undergraduate research program steers students toward graduate school and research careers.

Justin Wirth wasn't looking to solve the energy crisis when he signed up for Purdue's Summer Undergraduate Research Fellowships (SURF) program two years ago. He simply wanted to make his own summer more productive. Now, after testing the research waters, the senior in electrical and computer engineering has his sights set on graduate school and important breakthroughs on the solar energy front.

After getting up to training speed in 2007 with the clean room procedures of the Birck Nanotechnology Center, Wirth was able to apply those skills last summer to solar cell research under the direction of Minghao Qi, an assistant professor of electrical and computer engineering. The goal of their research is to make solar cells cheaper. Using a laser to construct the solar cells, the team then tested the effectiveness of a new backing designed in Purdue labs.

The hands-on time really paid off for Wirth. While he admits he had abstract notions as a younger student of what research encompassed, he says his SURF summers helped set things straight. "They showed me what graduate students really do and what research actually is."

Since launching SURF in 2003, program administrators have attempted to refine a matchmaking system that allows researchers and undergraduate students to connect through the Web. "Professors can post a research project on our Web site that students can view," says Vicki Leavitt, program coordinator who has been involved with the program since 2005. "Students can then choose up to three projects they're interested in. Professors then review the students' applications and interview them. By the time the match is made, both student and professor are pleased with the arrangement."

The program, open to both Purdue and visiting students, has also attracted a number of students from historically black colleges who are studying the various fields of engineering, science, and technology. Eleven weeks of hands-on learning experience in world-class laboratories, sponsored outings, and a summer-ending research symposium are all selling points for an exploding program that went from some 50 students in 2004 to nearly 200 in 2008. The jump in numbers makes the matchmaking challenging, but Leavitt sees the benefits of a program that is continually building on its own success. Former SURF students have become graduate mentors to new students, inside as well as outside the lab. "Every year we hire graduate assistants to help with the program, and this year two previous SURF students helped administer the program," she says. "These graduate students can empathize with the undergraduates, and it seems to be their way of giving something back."

The ultimate goal of any undergraduate research endeavor, however, is to increase the overall interest in graduate school and research careers. Since 2005, 20 percent of SURF participants have been visiting scholars from other institutions. Of those students who have graduated, Leavitt says that 27 percent have enrolled in graduate programs at Purdue.

And while Wirth is uncertain whether he'll stay at Purdue for graduate school or venture elsewhere, he is certain of the possibilities of a career path. "I would like to do research and development, because it is both interesting and beneficial to society," he says.

A Visitor's Return

Many people can trace successful career paths back to childhood interests and dreams. By the time he was 10 years old, Joseph Moore probably knew more about the space program than most adults do. "I used to watch a lot of NASA documentaries," says Moore, now a master's student in aeronautics and astronautics whose research in solid propellants dovetails nicely with a lifelong interest in rocket launches.

Erin Ingram

Solar SURF: Justin Wirth, a senior in electrical and computer engineering, demonstrates some of the solar cell testing he did in Purdue's Summer Undergraduate Research Fellowship program.

John Underwood

Aeronautical Ambitions: Joseph Moore, now a graduate student in aeronautics and astronautics, spent a summer in Purdue's SURF program as an undergraduate at Auburn University.

It may have been a chance encounter, however, that brought Moore to Purdue's SURF program. As an undergraduate at Auburn University, he dropped by a Purdue table at the 2007 National Society of Black Engineers conference to learn more about the Big Ten school he says he had only heard of through their football rivalry with his family's favored Ohio State. After being accepted to the SURF program on the spot, Moore went home, looked up the rankings, and learned of Purdue's preeminence in aeronautics and astronautics.

Indeed, the School of Aeronautics and Astronautics ranks high in both academic circles and with employers. The school jumped from number six to number four in *U.S. News & World Report* this year and was voted tops in an August 2008 survey of employers. An *Aviation Week* workforce study asked aerospace and defense companies where they recruited and why. Purdue's school moved to the top from number four in 2007, in part, the article states, for producing students who display diversity in how they think—both in approaching problems or reacting to challenges.

For Moore, one SURF summer working under the direction of Stephen Heister, a professor of aeronautics and astronautics, at Zucrow Laboratories—"one of the best propulsion labs in the country," he says—helped him decide to attend graduate school in West Lafayette. But it was a very human factor that helped seal the deal. "The people were very nice," he says. "I felt like I was the only person they were recruiting."

Now crossing disciplines to work with Steven Son, an associate professor of mechanical engineering, Moore knows that not even the sky is the limit for someone interested in rocket research. An internship last summer at a General Electric lab in Cincinnati gave him a taste of his dream job and career he could launch in research and development before soaring into management.

And whether their futures include cutting-edge research that will improve the cost and efficiency of using solar energy or working on propellants that will take the next NASA rockets to the moon, Wirth, Moore, and hundreds of students like them may one day look back to SURF as their starting point for success. ■


NEERING MDS PHARMACEUTICAL
BIOMATERIALS DELIVERY SYSTEMS
BIOMATERIALS DELIVE
ACEUTICAL GURU GLOBAL ENGIN
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GURU GLOBAL ENGINE


HEALTH

By Gina Vozenilek

Special Delivery

Purdue engineers are researching the best ways to bring medical care and technologies to patients efficiently and effectively.

In 1900, the average life expectancy in the United States was 47 years. By 2000, that number was 77. A century of engineering innovation that boasts cardiac defibrillators, new medicines, imaging technologies, dialysis machinery—to say nothing of the health benefit of systematic water supply and distribution—has contributed to longer, healthier lives for Americans.

But as healthcare science races into the next century, is there a robust delivery system to ensure that good care reaches those who need it? In the Spring 2008 issue of *The Bridge,* a publication of the National Academy of Engineering (NAE), W. Dale Compton, Purdue's Lillian M. Gilbreth Distinguished Professor Emeritus of Industrial Engineering and NAE home secretary, and program office director Proctor Reid acknowledge that, "Despite rapid advances in medical procedures and the understanding of diseases and their treatment, the efficiency, safety, and cost-effectiveness of the delivery of health care have not kept pace."

The turmoil of the healthcare delivery system is partly addressed by two of the NAE's grand challenges: engineer better medicines and advance health informatics. From the cellular to the systemic level, healthcare engineers are seeking better ways to deliver medicine and quality care where and when they are most needed. In so doing, they will create a new century of progress.

Straight to Cells

Brandon Seal, an assistant professor of biomedical engineering, is bringing medicine down—all the way down to the cellular scale. He wants to understand how cells interact with their environment. What signals stimulate them? What mechanical stresses work on them? And then Seal asks the big question: "How can we manipulate cells to make them do what we want?"

Answering these questions supports Seal's principle aim: to design and characterize materials that mimic biological function. Rheumatoid arthritis is one health problem Seal is addressing. At the cellular level in this disease, cytokines trigger an inflammation, creating a feedback loop that releases proteins, which in turn degrade the cartilage in joints. Seal has developed a promising compound that can permeate cells, decrease cytokine levels, and therefore suppress the inflammatory response. The compound is in early preclinical trials.

Understanding the subtleties of the cellular matrix is the foundation of Seal's work, which focuses on the delivery of medicine to the precise point where it can have maximal effect. "We really try to think about not just creating a drug but about how to deliver it to be effective," says Seal, who experiments with tablet, capsule, and gel forms, among others. "Localized drug delivery is an emerging approach; if you can deliver a drug where and when it is needed," he reasons, "you can reduce the dose required and mitigate side effects."

Seal is also devising ways to deliver pharmaceutical biologics, such as antibody drugs and disease-specific medications, without using an injections. "The Holy Grail of drug delivery is oral delivery," says Seal. People would rather take a pill than get a shot, the current way such medicines are delivered.

But the acids of the digestive tract create a harsh environment for biologics; new delivery modes must be engineered to withstand such an environment. Seal uses his background in materials engineering to investigate layered polymers that dissolve at different rates. Such materials could be used to make capsules that would protect and deliver the biologic ingredient so patients can swallow

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Vincent Walter

Pill Possibilities: Brandon Seal, a biomedical engineering researcher, is devising ways to deliver pharmaceutical biologics, such as antibody drugs and disease-specific medications, without using injections. "The Holy Grail of drug delivery is oral delivery," says Seal. People would rather take a pill than get a shot.

their medicine rather than roll up their sleeves. Seal appreciates the multidisciplinary nature of progress in this area of healthcare. "There's a lot of overlap of specialties," says Seal, "so there are a lot of collaborative opportunities."

Allocation, Allocation, Allocation

Nan Kong, an assistant professor of biomedical engineering, is working to improve healthcare at the systems level. "In a nutshell, I apply mathematical models to large-scale problems in the service sector, primarily in healthcare. Operations research provides a set of tools to improve design and control of complex systems," says Kong. One such system Kong is studying is organ allocation. In the United States today, nearly 100,000 patients are waiting for life-saving organ transplants. "Organs are rare resources," says Kong. "Many people wait, and many die waiting."

Kong considers organs "perishable goods" that need to be distributed from 58 national procurement centers to transplant centers where they can be given to candidates. Kong applies concepts similar to political districting to organ allocation. His equations are complicated by many factors, including the relative health of patients and their physical proximities to the available organs. He believes that by restructuring or "gerrymandering" geographic organ distribution regions using complex mathematical models, more patients can be matched with more organs.

Further complicating his calculations are the ethics of organ transplantation. Kong is developing stochastic models for measuring so-called equity in transplantation. Geography, health status, racial and cultural memberships, and socioeconomic status are just some of the variables that must be factored.

Kong is also using operations research to study the State of Indiana's Medicaid program, exploring the best way to allocate budgetary funds to satisfy the demands of at-home care for dementia patients. As the population ages, greater numbers of such patients will need varying levels of care to stay in their homes—including services like laundry, cooking, and bathing.

The state's challenge is how to plan ahead to pay for this care. How many patients will be eligible for benefits in a given year, and, since each patient has different needs, how should the state optimally allocate funds? At-home care for dementia sufferers is just one example of the country's many medical needs. "As medical technologies improve, people live longer," Kong says, "but we still need to be able, as a society, to afford their care."

Savvy Scheduling

The doctor's office door should be the gateway to healthcare, but access is limited by how many patients can squeeze into the day's clinical schedule. Mark Lawley, an associate professor of biomedical engineering, together with Laura Sands of Purdue's School of Nursing, DeDe Willis of the Indiana University School of Medicine, and Kumar Muthuraman of the University of Texas, is working to optimize patient scheduling in physician offices. Ayten Turkcan, a research scientist for the Regenstrief Center for Healthcare Engineering and Bo Zeng, a post-doctoral researcher in biomedical engineering, are also taking lead roles in the research.

Funded by the Regenstrief Foundation of Indianapolis and a grant from the National Science Foundation, Lawley will try to overhaul the systems that schedule patients into time slots for their appointments. The big problem with one patient per slot is what happens to the schedule when patients fail to keep their appointments.

These "no-show" events, which account for between 20 and 40 percent of all appointments made, severely jeopardize the efficiency of healthcare delivery in doctors' offices. Not counting psychiatric clinics, there are more than 200,000 clinics nationwide, which magnifies those percentages to a large-scale problem of inefficiency.

"We believe our impact can be great if we develop scheduling techniques that really improve patient access and figure out how to transfer them to clinics around the U.S.," says Lawley. He also points out that the highest no-show rates tend to be found in clinics with some of the most pressing needs for improved healthcare access in this country: pediatrics clinics and those whose patients represent the lowest socioeconomic status.

Schedule Optimizers: Mark Lawley (second from the left), a biomedical engineering researcher, is leading an interdisciplinary team attempting to overhaul the systems that schedule patients into time slots for appointments. "No show" events, which account for between 20 and 40 percent of all appointments made, severely jeopardize healthcare efficiency.

Dick Myers-Walls

Turkcan lists the factors that seem to predict no-show events: historical data, diagnosis, demographic data, geography, lead time, and weather. "Just ahead of the weather factor," says Turkcan, "the most predictive variable for a no-show is lead time." Patients who make appointments further in advance than one week are most likely to become a no-show.

Zeng notes that the popular "open-access" scheduling strategy, wherein patients call on the same day they need the appointment, can become unwieldy if deployed by itself. "Past research shows that a hybrid of open-access scheduling with restricted lead time scheduling seems to work best," says Zeng, who favors laying aside a portion of the daily capacity for open access patients and reserving the rest for those with slightly longer-range plans, generally patients with chronic conditions.

Understanding the no-show likelihood of each patient will assist Lawley and his team in creating scheduling techniques that mitigate this negative effect by combining patients in the schedule in ways that account for their likelihood to default on their appointments. These methods optimally balance the costs of patient waiting time and staff overtime with clinic reimbursement. The team plans to validate the impact of their research and follow up with more studies over the course of the three-year project. But they are already working with commercial software developers to write, install, and maintain scheduling programs that make their complicated predictive models portable, applicable, and transparent, so that one day clinics around the country can rely on more efficient scheduling, and, therefore, improve access to healthcare.

"Better scheduling means better utilization of physician and staff time, shorter waiting times, better access, and generation of greater revenue," Lawley says. It also means avoiding the one thing the healthcare system can afford no more: the expensive cost of missed opportunity. ■

By **Emil Venere**

Purdue and IU's Healthy Collaboration

An NIH grant will strengthen the state schools' program to educate physician-scientists.

There's a late-November football Saturday every year where the two largest schools in Indiana knock helmets, intent on delivering pain in the battle for the Old Oaken Bucket. But in the research field, the two universities are uniting two of their strongest suits—Indiana medicine and Purdue engineering—for a winning combination on the healthcare front.

An Indiana University School of Medicine program that partners with Purdue to train the next generation of physician-scientists has been given national recognition with a prestigious grant from the National Institutes of Health (NIH). IU's MD/PhD program, in which students receive both degrees in seven to eight years, has received a five-year, $1.25 million Medical Scientist Training Program award from the NIH, one of only 40 such grants to medical schools nationally.

The IU program is highly competitive, admitting just five recent undergraduates annually from more than 125 applications. Although many are from the Midwest, the program attracts applicants from across the country and from many of the nation's elite universities. The NIH funding will enable the program to expand its enrollment.

Ten graduate school programs participate in the program in addition to the School of Medicine, including the Weldon School of Biomedical Engineering at Purdue.

The collaboration between the two universities was recognized by the NIH review panel as a compelling strength of the MD/PhD program, one of the few in the nation to incorporate a strong engineering program in a significant way, says D. Wade Clapp, program director, Kipp Professor of Pediatrics, and professor of microbiology and immunology at the IU School of Medicine. The program was also recognized for strengths in the IU School of Medicine clinical and graduate programs.

"Support from the NIH-sponsored Medical Scientist Training Program is recognition of the quality of our students, the program, and the commitment made by IU and Purdue to meet the need for scientists who have received excellent training in both basic science and clinical research," says Clapp.

"We're delighted with the recognition from the NIH of the quality and potential of our joint program," says George Wodicka, head of the Weldon School of Biomedical Engineering. "The cooperative Indiana University medicine and Purdue biomedical engineering educational component provides unique opportunities for the training of physician engineers."

Having a sophisticated understanding of both medicine and biomedical engineering gives graduates the tools they will need to develop new treatments using nanomedicine, neuroengineering, tissue engineering, and imaging techniques, Wodicka says.

About 10 students are now pursuing biomedical engineering doctoral degrees at Purdue through the program. The program's goal is to enroll three new engineering students each year and have 21 students enrolled at any given time.

Started in the 1960s, the MD/PhD program was transformed in 2002 with funding from the Indiana Genomics Initiative (INGEN), the $155 million initiative funded by grants from the Lilly Endowment. Support from INGEN, along with additional support from the School of Medicine, individual graduate programs, and private philanthropy, substantially increased the level of scholarship support for the program, resulting in a tripling of applications.

With the appointment of Clapp and Maureen Harrington, a professor of biochemistry and molecular biology, as directors, the program's educational curriculum has been revamped, the collaboration between IU and Purdue strengthened, and new opportunities for research, mentoring, and interactions with leading physician scientists from across the country have been added. The program has boosted efforts to recruit top applicants, resulting in more applicants from across the country. Seventeen percent of those enrolled since 2002 have been minority students. ■

Indiana Connection: Purdue and Indiana University (IU) are teaming up on a program that will school and train engineering medical doctors, allowing students to earn dual degrees. Here, Aimee Mayeda (left), MD, a professor of psychiatry at IU, is working with Kari Kernek, now an MD, then an IU resident.

Provided by IU Med School

By **Gina Vozenilek**

Particulate Matters

An Aussie engineer arrives at Purdue and a campus he considers the center of gravity for both industry and research in pharmaceutical drug delivery.

Jim Litster is partial to particles. Specifically, he is an expert in the granulation and agglomeration of the particles of active pharmaceutical ingredients (APIs). A professor of chemical engineering and of industrial and physical pharmacy, Litster came to West Lafayette all the way from his post as head of the School of Engineering at the University of Queensland in Australia.

That's a long way from home, but it was the right move for him. "Purdue is the center of gravity for both industry and research in this area," he explains, "and that is why I came here."

With colleagues in chemical engineering and industrial pharmacy, he is driven by an ambitious vision: to transform the pharmaceutical industry with quantitative engineering approaches. He hopes his research with APIs will "improve the health of the community, speed drugs to market, and optimize the cost-effectiveness of manufacturing processes."

Litster was recruited to Purdue to take part in the multi-university Center for Structured Organic Particulate Systems (CSOPS), a partnership funded by the National Science Foundation. The group includes 40 faculty members representing eight scientific and engineering disciplines from Purdue, Rutgers, New Jersey Institute of Technology, and the University of Puerto Rico.

"Much money and effort is being directed toward drug discovery," Litster notes, "but, in fact, for drugs to be effective, you need more than their chemical properties to fight disease. You need a safe and effective way to deliver them." He notes that in the U.S. in particular there is a gap between drug discovery and delivery. CSOPS will try to address this issue. Part of the work that goes into re-engineering drug-delivery systems is gaining greater understanding of particle granulation and agglomeration—getting the particles to either flow freely or stick together, depending on the application. He says, "Granulation is a key part of the manufacture of oral medications," which traditionally take the form of tablets and capsules. CSOPS is interested in exploring delivery options with other modalities as well, such as inhalation dosages and gel strips similar to the breath freshener "papers" that melt on the tongue.

Researchers like Litster must be able to observe, predict, and ultimately manipulate APIs on multiple levels: on the molecular level, on the particle level, and in the dosage form. Hitting the correct design for a pharmaceutical particle requires both product and process engineering; that is, finding the right formulation for the drug and choosing the best process for the design and scale-up required to manufacture it.

Litster is excited to be working in pharmaceutical engineering at a time when novel approaches to drug delivery are on the horizon. "We are working on a lot of interesting science and engineering," says Litster. One new buzzword intriguing and challenging the engineering community is "personalized medicine," in which the drug is formulated for the individual patient at the point of delivery.

Crystallization of APIs has historically been accomplished in huge industrial vats. But engineers have begun to think inside a smaller box. "Now we are working with tiny drops that are each microcrystallizers," explains Litster, who describes related work by colleagues at Purdue in which desktop inkjet printer technology is used to customize formulations in very small drops and deposit them on a gel strip. The formulation and dosage of some APIs will thus be able to be tailored to the individual needs of patients, a bold step forward in the reengineering of drug delivery systems worldwide. After all, Litster says, "Good engineering helps make good medicines." ■

Outback Engineer: Jim Litster, a chemical engineering researcher as well as an industrial and physical pharmacy researcher, came to Purdue from Australia to work in the multi-university Center for Structured Organic Particulate Systems, which he says is "the center of gravity for both industry and research in this area."

Vincent Walter

By **Linda Terhune with William Meiners**

A Cooling Solution

An international team of students offers up a special delivery on the healthcare front.

When vaccines are transported to remote villages in developing countries, as much as 60 percent of the medicine is spoiled before it gets to its destination. That means lives that could have been saved are being lost. But a solution could come from a group of mechanical engineers.

During spring semester 2008, a team of three Purdue mechanical engineering seniors and four students from Karlsruhe University in Germany put their minds to this medical matter and designed what they have dubbed the "vaccine cooler." The students were partnered through Purdue's Global Engineering Alliance for Research and Education (GEARE) program, which was launched by the School of Mechanical Engineering in 2003. The cooler concept was developed within their senior global design course, which requires student teams to come up with engineering designs based on their four years of study.

The team started from scratch, knowing only that their project would relate to their interest in heating and cooling systems. They tossed a variety of ideas around and initially settled on a portable refrigerator box designed to cool beverages. Later, they chose a more humanitarian application: a mobile cooling box for use in the final stage of the vaccine transport process—the trip from the plane to a village—which can take up to five days. The initiative was funded by a humanitarian project grant from Shell Oil Company.

"What we found was a project that used cooling technology and could benefit many people," says team leader Laura Palac. The device—about the size of a picnic cooler—has an internal cooling system that runs on a low-power battery. Vaccines must be kept at a stable temperature between 2 and 8 degrees Celsius. Most are currently transported on ice, which can freeze and destroy the medicine or melt and render it useless.

When the destination is reached, the vaccines require storage in refrigerators, which need a power source to operate. The team's design allows for steady temperatures and has its own power supply, and the cooling system uses absorption technology based on ammonia and activated carbon. Air is circulated in the cooler via a fan driven by a battery that can be recharged using solar power. The cooler, which can store 30 vaccine packages, could be produced at a relatively low cost using commonly available materials.

While the vaccine cooler project called on mechanical engineering skills, it also introduced the team to real-world challenges, such as constraints on the design imposed by World Health Organization specifications on how vaccines are transported. The seniors explored that topic as well as more familiar areas, such as basic structure, heat exchange, temperature control, and cost issues.

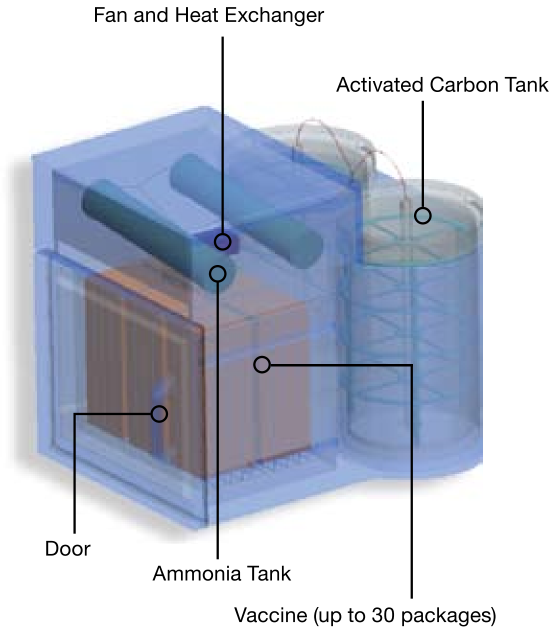
Ben Borgmann says the experience was not only instructive but good for the heart. "Engineering is not all about working on fast cars," he says. "You can reach out to a lot of people. It's pretty cool to see."

World Changing

The vaccine cooler project was awarded second place in the first annual Innovation in Mechanical Engineering Award competition sponsored by Thomas J. and Sandra H. Malott. The team received a $750 cash award. With the semester over, the vaccine cooler project came to an end. However, Eckhard Groll, the mechanical engineering professor advising the group, says he would like to see another senior design team continue to work on the cooler, with the hope of some day getting the technology out into the field.

Getting a product to market is the tricky part, says Groll, who is also the director of the Office of Professional Practice. "We would need to find a company or an organization that is interested. But if the technology is patentable, then Purdue's Office of

Humanitarian Effort: An international team from Purdue's Global Engineering Alliance for Research and Education led by Eckhard Groll (second from the right), a mechanical engineering researcher, designed a vaccine cooler that could be critical in delivering better healthcare to remote areas of developing countries.



Commercialization and Technology can jump in to help find industrial partners."

For Groll, however, one of the best things to come out of the GEARE experience is the cross-cultural exchange between the U.S. and German students. The international team worked together for two semesters: sping 2006 in Germany and spring 2007 at Purdue. "The change in students is phenomenal," he says.

He especially notices how Midwestern students start to come out of their shells. "By the end of their senior year, they begin looking for international assignments with global companies," he says. "They become open to the world and what's around them. And they have a whole different perspective on how engineering problems are solved. If you go to a foreign country and work with students together on a project, you will see that other cultures tackle problems from a different angle."

Because students have to make sure they're understood, and perhaps by someone who doesn't speak their native language, their communication skills improve significantly. The learning, therefore, says Groll, pays off on many different levels. And should such collaboration lead to healthier outcomes in developing nations, then it can truly be considered a worldwide success. ■

- An estimated 2.1 million people around the world died in 2002 of diseases preventable by widely used vaccines.
- In 2004, nearly 50 percent of Gambia's yellow fever vaccines were spoiled due to weaknesses of the cold chain.
- A one-week supplemental immunization activity against measles carried out in Kenya in 2002—in which 12.8 million children were vaccinated—could prevent 3,850,000 cases of measles and 125,000 deaths over a 10-year period.

Source: World Health Organization


SAFETY


EXPERT CONSTRUCTION
NUCLEAR SECURITY EARTHQUAKE EXPERT
STRUCTURE STABILITY
ENGINEERING
EARTHQUAKE
STRUCTURE STABILITY
CONSTRUCTION ENGINEERING MANAGEMENT
STRUCTURE
EARTHQUAKE EXPERT
EARTHQUAKE EXPERT CONSTRUCTION ENGINEERING
ENGINEERING

By **William Meiners**

Break and Burn to Learn

Researchers in Purdue's Bowen Lab are testing large so buildings and bridges can better withstand disasters.

Whether it's the work of mad men or Mother Nature, catastrophic destruction has torn many paths throughout cities and countrysides all over the globe. From the ashes of 9/11 to the devastation of worldwide earthquakes to a collapsing bridge's reminder of the aging infrastructure of the United States, these tragic events too often call for postmortem examinations to determine what went wrong. There are many, however, including researchers at Purdue, who are proactively working toward safer construction solutions that could help keep our houses, workplaces, and roadways from turning into deadly falling objects.

The National Academy of Engineering must have had its collective eye on curbing at least two disaster scenarios with the grand challenges: prevent nuclear terror and restore and improve urban infrastructure. Engineering expertise is needed on both fronts in not only responding to disaster but somehow becoming better equipped to avoid it. Agencies like the American Society of Civil Engineers are also concerned about building safely and efficiently while keeping sustainability in mind.

As a senior engineer in the construction technical program of the American Iron and Steel Institute, Farid Alfawakhiri works with both institutions and investigators alike to promote the use of steel construction through research and development. He's also interested in the standards and codes that lead to better practices. "The major safety issues are in the seismic and fire-resistance fields," Alfawakhiri says.

Much of the research money has traditionally gone toward seismic research because of the scale of earthquake events. "The social and political consequences of an isolated fire are much smaller," Alfawakhiri says. "A fire is usually not devastating for a town. It often results in only a lost building."

The obvious exception of 9/11, Alfawakhiri says, spurred interest (and dollars) so researchers could gain a better understanding of what happens inside a building as it burns. Research breakthroughs, consequently, could lead to buildings that stand taller in cases of fire disasters.

Size Matters

The square footage alone in Purdue's Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research—some 66,000 feet—allows for big-time testing. From the three-story, 32-foot building model tested for its resistance to earthquakes to the numerous projects that call for a large-scale examination, Bowen Lab facilitates big breakthroughs. Consider it supersized research, as experts here are shaking, breaking, and even burning full-sized models to gain a greater understanding of how structures behave in crisis moments.

"The size of the [Bowen] facility allows us to test components or portions of buildings and bridges at full scale, rather than testing them at reduced scale," says Michael Kreger, the director of Bowen Labs and a professor of civil engineering. "That removes much of the uncertainty about how we might expect these components to behave in actual structures. When you do this work at a small scale, sometimes questions arise about how components may behave in an actual structure."

It's also a facility that attracts some of the top civil engineering researchers in the world. Kreger says Bowen Lab researchers are able to significantly impact the professional field. "It was an attraction for me," he admits. "You have an opportunity to test at a scale that can only be done at a handful of places in the country or the world."

Concrete Overview: Researchers and graduate students in Purdue's Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research can test components of buildings at full scale.

Feel the Heat

One such researcher intent on making an impact is Amit Varma. An associate professor of civil engineering, Varma has ventured into the field of fire-resistance research. His unique research inside Bowen Lab is gathering attention as the first of its kind and scale. He's also attracting the attention of both sponsors and colleagues. And should you borrow from the parlance of sportswriters, you might even say this researcher is on fire.

Ushered into the 21st century as we were with the images of the twin towers of the World Trade Center collapsing upon themselves, the interest in fire-structure stability has likewise exploded. Builders want to know: Is my structure safe? Will it be adequate in a design-level fire? And Varma's sponsors—the National Science Foundation, the National Institute of Standards and Technology, and the American Institute of Steel Construction among them—are more than just funding sources. They're eager to find answers.

For Varma, those answers are being found in a cutting-edge, fundamental approach that takes into account the whole building's stability, not just columns or small sections. "We're evaluating the performance of building structures under realistic fire loading," he says. "This is a multidisciplinary field of structure-fire interaction. It involves mechanical engineers who work in the field of combustion, computational fluid dynamics, and heat transfer analysis, along with structural engineers who are experts in experimental behavior of structures and collapse and the stability analysis of structures."

As compared to how buildings stand up in other extreme events, such as earthquakes or dangerous winds, the understanding of structural fire design in the U.S. has been somewhat limited, according to Varma. "It's not that it hasn't been good," he explains. "It's just that the technology is not based on a fundamental understanding of structural behavior and collapse."

To get at that better understanding, Varma designed a large-scale experimental approach specifically tooled for use in Bowen Lab. Using a radiation-based heating system, which Varma compares to an electric stovetop that many of us use in our kitchens, his team can literally bring the heat to an entire floor system measuring out at 100-square feet. An open flame would be much harder to control, not to mention particularly dangerous in a structures lab. The radiation-based heating, however, actually allows the researchers to apply heat, and more of it, to a very confined setting. And as a structural engineer intent on gaining a physical understanding of how things fail, this close proximity and hands-on research is a great aid pinpointing both where failure initiates and how it propagates.

Over the next four to five years, Varma, with up to five PhD students, will perform various experiments on columns, subsystems, composite beams, and floors. It's all work that has been bolstered by state-of-the-art computer simulations that the team has run over the past year and a half. "We use the results of the computer simulations to define our experiments," Varma says. "The purpose of the simulation is to find out how the building behaves and what its weakest link is."

If Varma can make the weakest link stronger, the overall structure can be improved. "A building is not a single column," he says. "Our experimentation is focusing on a more fundamental understanding of a building's overall performance."

Earthquake Expertise

Elsewhere in the busy Bowen Lab are the remnants of the many seismic experiments taking place: the recent dismantling of a three-story building, along with the various hard hats, hammers, and computerized tools of the trade of these hands-on researchers. Purdue fields experts from all over the world who (perhaps not without coincidence) have often come from areas that have been devastated by deadly assaults from one of nature's biggest hammers. When it comes to speaking about the structural impact of earthquakes, you'd be hard pressed to find a more knowledgeable group than those who've left Purdue to

Vincent Walter

Fire Starters: Amit Varma (seated foreground) is a civil engineer working on some hot research in Bowen Lab. He and his graduate students can heat an entire 100-square-foot floor system to test a building's fire-structure stability. Once the team identifies the weakest link in the structure, the overall structure can be improved.

scour through the rubble of ravaged cities throughout the world.

Santiago Pujol and Julio Ramirez, an assistant professor and a professor of civil engineering, respectively, have cut their teeth in earthquake analysis and structural design. And Mete Sozen (see profile on page 36), the Kettelhut Distinguished Professor of Structural Engineering, foresees such devastation in his homeland of Turkey that he, along with a team of international experts, has suggested that the city of Istanbul build a second, satellite city.

Istanbul, which lies just north of the North Anatolian fault, is at high risk for a major earthquake within the next 20 years, Sozen says. "It is exciting to think about building a new city using completely new technologies," he says. "It would use modern information technologies and be environmentally friendly. It would be safe, secure, and modern. But more important is that this city would provide a refuge and emergency services in the event of an earthquake."

It's those modern and environmentally friendly technologies that can indeed help build a better world. And should Bowen Lab's best researchers and students have a hand in that, then that's all the better. ■

By **Emil Venere and Phillip Fiorini**

MEMS the Word in Nuclear Security

Purdue leads a center to simulate behavior of micro-electromechanical systems.

Last March, the National Nuclear Security Administration (NNSA) awarded a $17 million cooperative agreement for a research center at Purdue's Discovery Park to develop advanced simulations for commercial and defense applications. The center will focus on the behavior and reliability of miniature switches and is one of five new Centers of Excellence chosen by the NNSA.

About 35 researchers at Purdue, including faculty members, software professionals, and students, will be involved in the new Center for Prediction of Reliability, Integrity, and Survivability of Microsystems, or PRISM. The University of Illinois, Urbana-Champaign, and the University of New Mexico will collaborate.

"The center takes advantage of Purdue's interdisciplinary strengths and considerable expertise in computational modeling and nanotechnology," Purdue President France Córdova says.

The center will advance the emerging field of "predictive science," or applying computational simulations to predict the behavior of complex systems, says Jayathi Murthy, director of the new center and a professor of mechanical engineering.

The new center will develop advanced science and engineering models and software for simulations needed to predict the reliability and durability of "micro-electromechanical systems," or MEMS. Researchers also will develop methods associated with the emerging disciplines of verification and validation and uncertainty quantification.

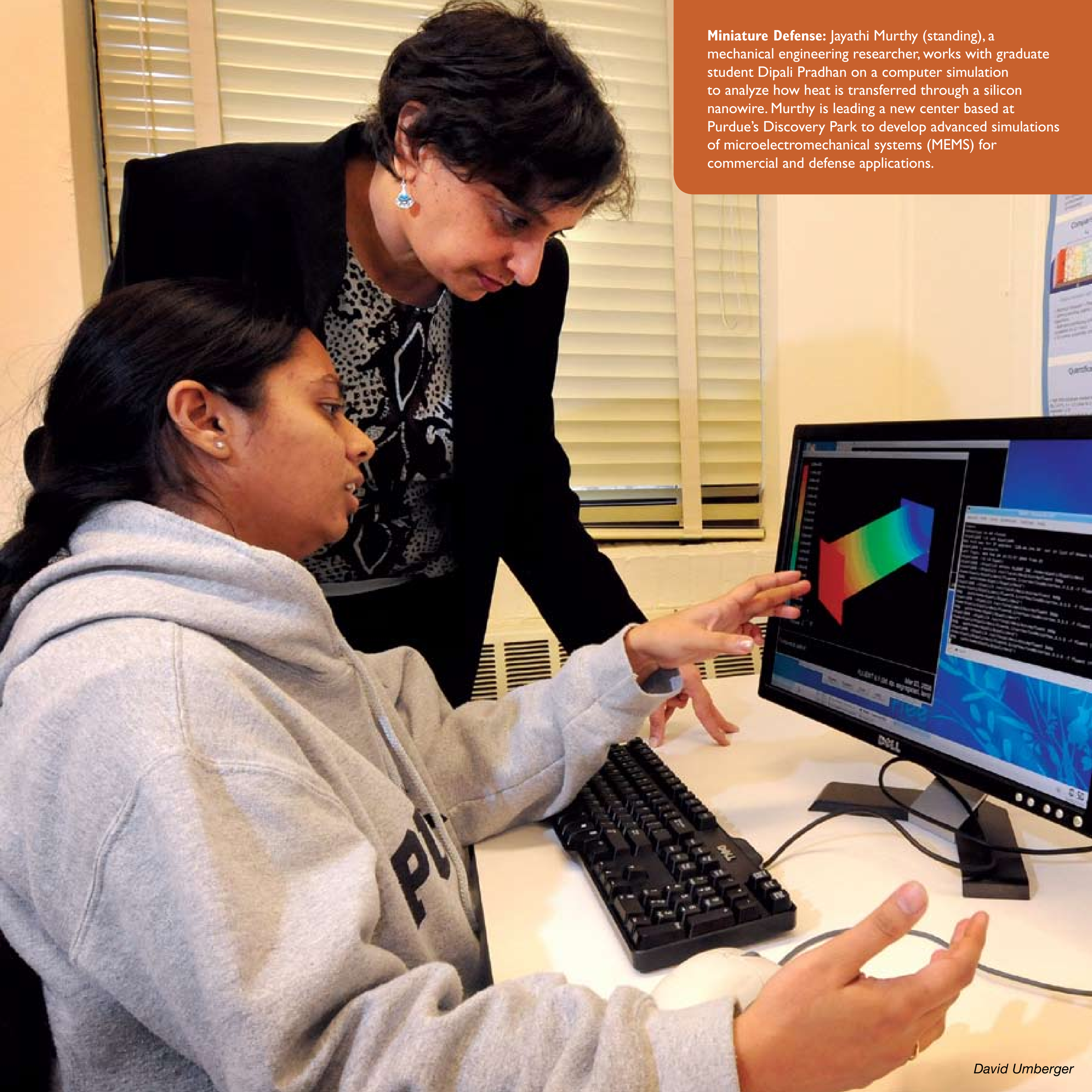
"The goal of these emerging disciplines is to enable scientists to make precise statements about the degree of confidence they have in their simulation-based predictions," Murthy says.

The NNSA PRISM will be based at the Birck Nanotechnology Center and also is affiliated with the Energy Center, both in Purdue's Discovery Park. The center is funded with $17 million over five years from the NNSA's Office of Advanced Simulation and Computing through its Predictive Science Academic Alliance Program. Purdue and its partners are also providing $4.2 million in matching funds. PRISM and the other four newly selected centers will focus on unclassified applications of interest to NNSA and its three national laboratories: Lawrence Livermore, Los Alamos, and Sandia.

Under PRISM, the miniature switches, called MEMS devices, are being created to replace conventional switches and other electronic components. MEMS are machines that combine electronic and mechanical components on a microscopic scale. The MEMS are far lighter and smaller than the conventional technology and could be manufactured in large quantities at low cost, Murthy says. "Research is needed, however, to improve the reliability, ruggedness, and durability of the devices."

The new simulations will make it possible to accurately predict how well the MEMS devices would stand up to the rigors of varying and extreme environments and how long they would last in the field. Devices in many environments must withstand crushing gravitational forces, temperature extremes, radiation, and shocks from impact.

"Reliability pertains to long-term performance," Murthy says. "Improving the integrity and survivability relate to the fact that MEMS get used in very adverse conditions. You don't want the MEMS to fail before the systems in which they are embedded are deployed. MEMS have many potential important applications in civilian and defense applications."■



Miniature Defense: Jayathi Murthy (standing), a mechanical engineering researcher, works with graduate student Dipali Pradhan on a computer simulation to analyze how heat is transferred through a silicon nanowire. Murthy is leading a new center based at Purdue's Discovery Park to develop advanced simulations of microelectromechanical systems (MEMS) for commercial and defense applications.

David Umberger

By **Patrick Kelly**

Until the Earth Stands Still

A structural engineer explains his fascination with earthquakes—and keeping their toll to a minimum.

"I tasted earthquakes at a very early age." So begins the story of Mete Sozen, Purdue's Kettelhut Distinguished Professor of Civil Engineering. Growing up in Istanbul, Sozen recalls the marvelous examples of Medieval architecture that surrounded his childhood and adolescence. He also remembers the irreparable damage visited upon those very structures following large-scale earthquakes.

Istanbul sits precariously close to the North Anatolian fault line, where two tectonic plates, the African and the Eurasian, have been pushing against one another for millions of years. Several resulting earthquakes have devastated the city over the centuries, and many scientists predict another large magnitude earthquake will strike Istanbul by 2025. Sozen traveled to a site 200 kilometers from the city's center in 1999 to investigate the damage of a fresh earthquake there, a research activity in which he's been engaged for more than 40 years.

"The first earthquake I studied in person was in 1963 in Skopje, Yugoslavia," says Sozen. "In the '60s we knew so little about the effects of earthquakes in urban areas that just about every earthquake site was worth visiting. I would go there and try to find out exactly what happened. Once you understand why the earthquake affects the city in a certain way, you then go home and develop new technologies to ensure that scale of damage doesn't happen again."

One of Sozen's most recent—and ambitious—ideas about saving his home city from another catastrophic earthquake involves the construction of a satellite city some 20 kilometers from the center of Istanbul. This "new" city, in effect, would transfer the city's core components—economic, social, and educational—to a safe haven outside the city where people could evacuate and continue living even if an earthquake leveled historic Istanbul. Sozen brought his idea to the prime minister of Turkey, and then presented it to a national security council comprised mainly of Turkish military generals.

"The Turks are historically a nomadic people, so I explained to the generals my plan in terms of that background as well as in military terms they could better understand," says Sozen. "Nomads don't hold a line, they hold an area. If they can't hold the line, they retreat to another part of the area. We are confronted with the choice of holding the line in Istanbul or retreating. But we can't leave things as they are."

Domestically, Sozen says that the common perception is that earthquakes will do the most damage on the West Coast, but that's not necessarily the case. While the San Andreas fault is due for seismic activity at any time, most large metropolitan areas in California are structurally designed to withstand high-magnitude events. The same cannot be said for the New Madrid fault area in the Midwest. An earthquake there, such as the ones in 1811 and 1812, would cause far more damage to cities like St. Louis, because those cities have not been structurally prepared to deal with large-scale earthquakes.

When asked about his success—including being named one of the top seismic engineers of the 20th century—Sozen remains modest. "It is luck to have that title," he admits with a laugh. "The important thing is that I have always found the research quite exciting. The only reason I would return home to sleep at midnight was so I could wake the following morning to get back to it. Otherwise I could stay all night, researching, trying to work toward new solutions. But then I wouldn't be able to do it the next day, so I made myself sleep."

Fitting, since through his work over the course of several decades, he's contributed enough advances in engineering structures to better withstand large-magnitude earthquakes that he's enabled people around the world to sleep soundly as well. ■

Seismic Scientist: Purdue's Mete Sozen, here in front of Bowen Lab, is a world-renowned earthquake specialist. Having spent more than 40 years engaged in research, Sozen says, "Once you understand why the earthquake affects the city in a certain way, then you go home and develop new technologies to ensure that scale of damage doesn't happen again."

Vincent Walter

By **Sharon Martin**

Students Under Construction

Purdue undergraduates gain real-building experience, while graduates are helping to set critical safety standards.

Junior Jennica Greffe didn't spend her summer soaking up the sun at the beach. Instead, she was working 11-hour days on a highway construction project in downtown Orlando.

Greffe is a student in Purdue's Construction Engineering and Management (CEM) undergraduate program. Respected by leaders in the construction industry as one of the best, the program requires students to complete three internships within the industry prior to graduation.

This was Greff's second summer with PCL, a large construction company. As a sophomore, she worked in Tampa on preconstruction projects. This year she returned to work on two interstate interchanges in Orlando. PCL placed responsibility squarely on her shoulders as she took quantities, measured concrete, and tracked schedules and material costs to present to the owner.

"The experience is irreplaceable," says Greffe. "I learned so much. I learned how important communication is between the owner and the contractors and how the general public is resistant to change." When a two-way street was changed to one way, Greffe watched in disbelief as motorists drove around the barriers and headed into one-way traffic.

It's that real-world experience that Deanna McMillan, director of internships, wants for the students. "It's the defining factor of our program," says McMillan.

With more than 60 active sponsor companies, McMillan personally matches each student with a company upon completion of the student's freshman year. Placement is based on the student's interests, aptitudes, attitude, and goals. Nearly 80 percent of the students choose either building construction or heavy highways, while others pursue mechanical and electrical internships.

"The sponsor companies tailor-make the intern experience to be progressive in nature," says McMillan. "They agree to provide a certain level of exposure and experience."

Each summer, more than 130 students head to different job sites around the country, with the majority in Indiana, Illinois, and Ohio. No matter where they land, the students receive a plethora of opportunities. McMillan visits students during the 12 to 13 weeks spent in the field and shares in the students' excitement as they describe their responsibilities.

"These companies recognize that these students are coming back," says McMillan. "It allows for greater exposure that will benefit the company when they return. They allow students to flourish and attain leadership positions."

Students also head to the field with Occupational Safety and Health Administration (OSHA) 10-hour training. "They get their OSHA cards before they go in the field," says McMillan. "It gives them credibility and speaks to the integrity of the program and our commitment to safety."

Nina Klepczarek, a junior from the Chicago area, also carried her OSHA card into the field. She worked with DPR Construction on two buildings for the Department of Forensic Science for the State of Virginia. In addition to learning about construction and safety, she also discovered something about herself.

"I learned I can't be shy," says Klepczarek. "It was tough. I was one of very few girls, and I'm half the age of those big guys. But I had to get over it. With 300 employees, I couldn't ignore it if something wasn't going right."

That confidence-boosting experience taught Klepczarek how to lead to get the job done. She now enjoys supervising and plans to go into management.

Dulcy Abraham, a professor of civil engineering and construction engineering and management, believes that allowing students to discover their interests while reinforcing lessons learned in the classroom is what makes the program so successful.

Summer Working: Israel Lopez, a senior in construction engineering management, worked three summer internships for Turner Construction in Chicago.

Smartly Dressed: In a project sponsored by the National Institute for Occupational Safety and Health, civil engineering graduate students (left to right) Varun Kishore, Vanessa Valentin, and Maria Peralta, all working under the guidance of Dulcy Abraham, a professor of civil engineering and construction engineering and management, tested various safety outfits on dummies positioned in nighttime construction zones. They visited eight sites to gather data and speak with workers about the dangers involved.

"This progressive internship experience aligns with the curriculum, so internships offer a deeper level of understanding," explains Abraham. "It's a good combination of academic principle, faculty research, and industry practice."

Upon graduation, students will have 36 weeks of on-the-job work experience in addition to their academics. And with 100 percent placement in the construction industry, students rest easy knowing they have a job waiting upon graduation.

Job Safety

In addition to teaching, Abraham oversees research projects dealing with construction safety. Funded by the National Institute for Occupational Safety and Health, one of her current research projects involves a five-year study focusing on the safety of nighttime construction in highway work zones.

"One of the major themes in our classrooms is safety," says Abraham, who adds that the construction industry is one of the nation's most dangerous fields, with a high number of fatalities. That's why research is critical.

The project focuses on issues relating to lighting, personal protection equipment (PPE), traffic control, speed control, and safety training.

"We are evaluating different types of PPE, as well developing tools for assisting contractors and the Indiana Department of Transportation with strategies to develop safe night work zones," she adds.

Vanessa Valentin, a doctoral student in civil engineering, assisted Abraham on this project. This summer, Valentin and two other graduate students made eight site visits to nighttime construction zones to gather data, speak with workers, and gain firsthand knowledge about the dangers involved.

Varun Kishore, a master's student in civil engineering whose undergraduate background is in architecture, gained a different perspective.

"After getting in the field and seeing how work is done, I've seen how different projects interact and the amount of collaboration," says Kishore. "And I learned that even if I don't know construction, I can still be a leader and learn at the same time."

In its fourth year, findings have led to the development of PPE alternatives, analysis of speed control options in construction zones, and an Internet-based tool to assist contractors with developing safety strategies and training.

"I've been very impressed, especially by the graduate students who have worked on this project, with how they handle working in difficult environments, collecting the data, and representing themselves to workers and supervisors in the field and the owners of the construction projects. I'm very grateful to the graduate students and for the work they do," adds Abraham.

The students are grateful, too. "It's a good experience," says Maria Peralta, a doctoral student in civil engineering. "What you learn in class complements what you learn in the field, and what you learn in the field complements what you learn in class." ■


REMOTE SENSING
SUSTAINABLE MANUFACTURING
SUSTAINABLE
SENSING ARTISTIC SCIENTIST
SENSING ARTISTIC SCIENTIST
TECHNOLOGIES
SUSTAINABLE
REMOTE SENSING
SUSTAINABLE
LEED TECHNOLOGIES


ENVIRONMENT

By **William Meiners**

Turning Old Gold and Black Green

An interdisciplinary group of environmental engineers is spearheading a charge for better designs on the front end and recycling on the back end in both consumer products and office buildings.

The Earth has a good track record of existence. Dinosaurs gave way to generations of humanity that have continued to live out lifetimes throughout its lands. But exploding populations and the demands of industrializing nations around the globe could pose a threat to faraway futures, and there's a great deal of concern about just how much of our natural resources we're using and abusing. Sustainability—our collective way of meeting current needs without endangering our grandchildren's grandchildren—calls for a number of engineering solutions.

Indeed, six of the National Academy of Engineering's 14 grand challenges touch on issues related to the environment. Four of the calls to action (to provide access to clean water, develop carbon sequestration methods, restore and improve urban infrastructure, and manage the nitrogen cycle) are motivated by environmental protection. Two others (to make solar energy economical and provide energy from fusion) look to reduce the damage from burning fossil fuels.

Going green is more than putting our recyclables next to the Monday morning trash. It's now part and parcel of big business. Eric Schmidt (IDE '76) is helping lead that charge at Georgia Pacific Corporation. As senior director of remediation, acquisitions, and divestitures, Schmidt is not only helping keep the forest product company in line with current environmental codes but also identifying cleanup needs of the past (though adequate at the time) that can only now be measured in the laboratory.

The company is also being proactive about contamination problems. "We try to anticipate where the next remediation challenge is going to come from and work with our facilities [some 200 throughout North America] so we don't have to do remediation," Schmidt says. "Don't put it out there in there to start with. We put an extraordinary amount of effort into pollution control equipment and goals for air, water, and solid waste."

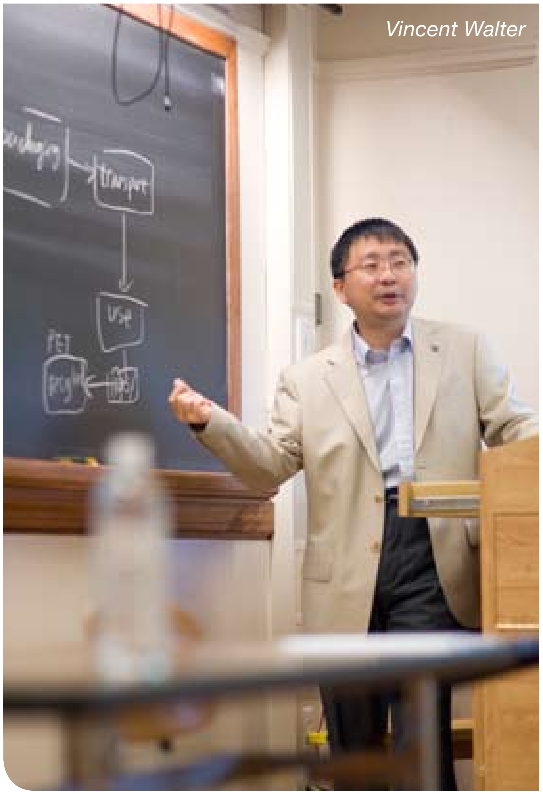
By working with researchers who continually redefine the parameters they can test in labs, companies like Georgia Pacific can reduce the carbon footprint they leave behind. Purdue's Division of Environmental and Ecological Engineering (DEEE), led by interim head Inez Hua, also a professor of civil engineering, will help provide those parameters (see story on page 50).

Avoiding a Technological Wasteland

Can you imagine 4 billion cell phones washed ashore, on any shore? Their plastic casings and toxic batteries bleeding back into the beach and water. While that's not a graphic representation of pollution you'll likely ever see, the effects of such consumer technologies do cross the minds of researchers like Fu Zhao. For Zhao, an assistant professor of mechanical engineering also working alongside colleagues in the DEEE, the 4 billion cell phones—and the numbers are growing exponentially—are indicative of the need to take a closer look at the lifelong environmental effects of products.

"The problem is that most people will have a cell phone for two years and then replace it," Zhao says, usually for another with upgraded features. Some companies "recycle" cell phones and perhaps less than 10 percent inspect them and replace the batteries. "Many cell phones, however, are sold to developing countries like Brazil and India."

While this affords people in other parts of the world access to modern technology, the adverse side of the tradeoff, Zhao says, is the ultimate addition to their garbage heap as the transported cell phones remain there until the



Vincent Walter

Pollution Solutions: Fu Zhao, a mechanical engineering researcher, uses the example of where 4 billion cell phones might end up, so students in his sustainability class consider the entire life cycle of a product. To design products that are more environmentally friendly, it's important to examine the cradle-to-the-grave effects of such products.

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Ocean Dump: Suresh Rao, a researcher in civil engineering and agronomy, points to the environmental damage of the Great Pacific Garbage Patch. There, trapped by currents of the North Pacific Gyre, floats extremely high concentrations of suspended plastics and other debris.

end of their lives. "And most of these places do not have proper waste-disposal facilities."

It's part of Zhao's job to consider the entire life cycle of a product. In order for engineers to design products that are more environmentally friendly, it's important to examine the cradle-to-the-grave effects of such products.

For Suresh Rao, the Lee A. Rieth Distinguished Professor with joint appointments in agronomy and civil engineering, a real and frightening example of environmental destruction can be seen in the Great Pacific Garbage Patch. There, trapped by currents of the North Pacific Gyre, floats extremely high concentrations of suspended plastics and other debris.

So how do you design for sustainability when the numbers seem so stacked against you? "There are multiple solutions," Rao says. "This question applies to most consumer things. What do you do with computers, TVs, etcetera? You try to recycle as much as you can and take things like precious metals and contaminants out of the waste loop. But, it is essential that changes also be made on the front end by rethinking product design, materials use, and manufacturing processes."

A "green design," says Rao, who is also collaborating with Zhao on a biomass energy project and co-teaching a class on sustainable design and manufacturing, uses fewer materials and processes that pollute less and recycle easier.

Environmentally friendly designs will likely come out of the growing environmental engineering programs around the nation. This semester, Rao is collaborating with Bryan Pijanowski, an associate professor of forestry and natural resources, as part of the Ecological Science and Engineering Interdisciplinary Graduate Program, to offer a seminar series on land-use sustainability in the Midwest. Some 35 graduate students from science, engineering, and agriculture are stepping outside of their comfort zones to examine past practices and future options from a holistic, socio-ecosystem's perspective. And hopefully come up with some sustainable solutions.

Taking the LEED

Elsewhere on campus, Purdue officials seem to be putting "green" where their mouths are in terms of campus expansion. The addition rising this semester on the Mechanical Engineering Building will be the first LEED-certified facility on campus. LEED, an acronym for leadership in energy and environmental design, was developed by the U.S. Green Building Council, a nonprofit organization dedicated to sustainable building design and construction. LEED addresses issues such as water conservation, natural lighting, use of recycled materials, and other steps to conserve energy and resources.

"Buildings use a very large fraction of the energy that the U.S. consumes," says Daniel Hirleman, professor and William E. and Florence E. Perry Head of Mechanical Engineering. "When you want to conserve energy and reduce a carbon footprint, buildings offer an excellent beginning point."

Hirleman says that LEED technologies require that all construction materials are audited and recycled to account for all the materials. The donor for the addition, for whom it is being named (also a builder who has done some green development), was enthusiastic about making the Roger B. Gatewood Wing of Mechanical Engineering green.

Even campus icons, such as the Ray W. Herrick Laboratories, which celebrated its 50th anniversary as an industry-oriented research hub last summer, are looking at the prospects of greener futures. Herrick Labs, currently housed in a brick horse barn built a century ago, will take on a new home where offices and meeting rooms will constitute a "living" laboratory that will help bridge the gap between prototype technologies arising from fundamental research and those technologies used in new buildings.

"This will involve reconfigurable heating, ventilation and cooling systems and building envelopes so that new concepts can be tried out in a realistic setting," says Patricia Davies, Herrick director and a professor of mechanical engineering. "Actual energy efficiency, occupant comfort, and productivity in a working building can be monitored and the information used to make refinements to proposed technologies. This will ensure much more successful and predictable implementation of new technologies in buildings."

For Davies, however, the overall concept should "go beyond green" with the new Herrick Labs. "We want to learn through research how to further increase energy efficiency and lower environmental impact but also integrate occupant comfort and productivity into building design objectives so that you can design spaces that people actually want to be in," she says. "The living lab is important because we want to be able to demonstrate that concepts work and identify where the problems are so that they can be addressed."

Campus Calls to Action

Any revolution needs great leaders; an environmental revolution is no exception. As part of Purdue's Green Week last September, Thomas Friedman, a Pulitzer-Prize winning author and journalist, visited campus to talk about his new book *Hot, Flat, and Crowded: Why We Need a Green Revolution and How It Can Renew America.*

The week's host of activities—ranging from clean-up efforts, recycling opportunities (including a collection of unwanted cell phones), and incentives for trying alternative transportation—sought to raise environmental awareness on campus and in the Greater Lafayette community. For most, it was a call to action. "We need to all start talking about what we do every day," says Robin Ridgway, Purdue's environmental regulatory consultant and chair of the Purdue Sustainability Council.

Vincent Walter

Green Wing: The Roger B. Gatewood Wing of Mechanical Engineering, for now just beyond a hole in the ground, will be the first LEED-certified building (which stands for leadership in energy and environmental design) on Purdue's campus.

On February 19, 2009, another famous speaker, Robert Kennedy, Jr., will come to campus to speak on the topic of "Our Environmental Destiny." Sponsored by the College of Engineering, Kennedy will visit campus as part of National Engineers Week.

Regardless of who's at the podium—should they be authors, politicians, or lecturers—the response from the audience is of the utmost importance. Sustainability, after all, is a grand challenge that calls for both individual commitment and collective effort. ■

By **Emil Venere**

Buckyball Breakthrough

Purdue environmental researchers are learning how the synthetic carbon molecule may have high potential to accumulate in living tissue.

Research at Purdue suggests synthetic carbon molecules called fullerenes, or buckyballs, have a high potential of being accumulated in animal tissue, but the molecules also appear to break down in sunlight, perhaps reducing their possible environmental dangers. Buckyballs may see widespread use in future products and applications, from drug-delivery vehicles for cancer therapy to ultrahard coatings and military armor, chemical sensors, and hydrogen-storage technologies for batteries and automotive fuel cells.

"Because of the numerous potential applications, it is important to learn how buckyballs react in the environment and what their possible environmental impacts might be," says Chad Jafvert, a professor of civil engineering.

The researchers mixed buckyballs in a solution of water and a chemical called octanol, which has properties similar to fatty tissues in animals. Jafvert and doctoral student Pradnya Kulkarni were the first to document how readily buckyballs might be "partitioned," or distributed into water, soil, and fatty tissues of wildlife, such as fish. Findings indicated buckyballs have a greater chance of partitioning into fatty tissues than the banned pesticide DDT. However, while DDT is toxic to wildlife, buckyballs currently have no documented toxic effects, Jafvert says.

"This work points out the need for a better understanding of where the materials go in the environment," Jafvert says. "Our results show they are going to be taken up by fish and other organisms, possibly to toxic levels. This, however, indicates only the potential of buckyballs to bioaccumulate. They could break down in the environment or in an organism once taken up."

Researchers do not yet know whether buckyballs will break down in the environment or will be metabolized by animals, which would reduce the risk of accumulating in fatty tissues. "For example, we don't bioaccumulate sugars because we process sugars, but we do bioaccumulate other compounds that we don't metabolize," Jafvert says. "If we have the ability to metabolize buckyballs, we won't bioaccumulate them."

Findings were detailed in Jafvert and Kulkarni's research paper that appeared in August in the journal *Environmental Science and Technology*. The researchers determined the "octanol-water partition coefficient," which enables them to show how readily buckyballs would be partitioned.

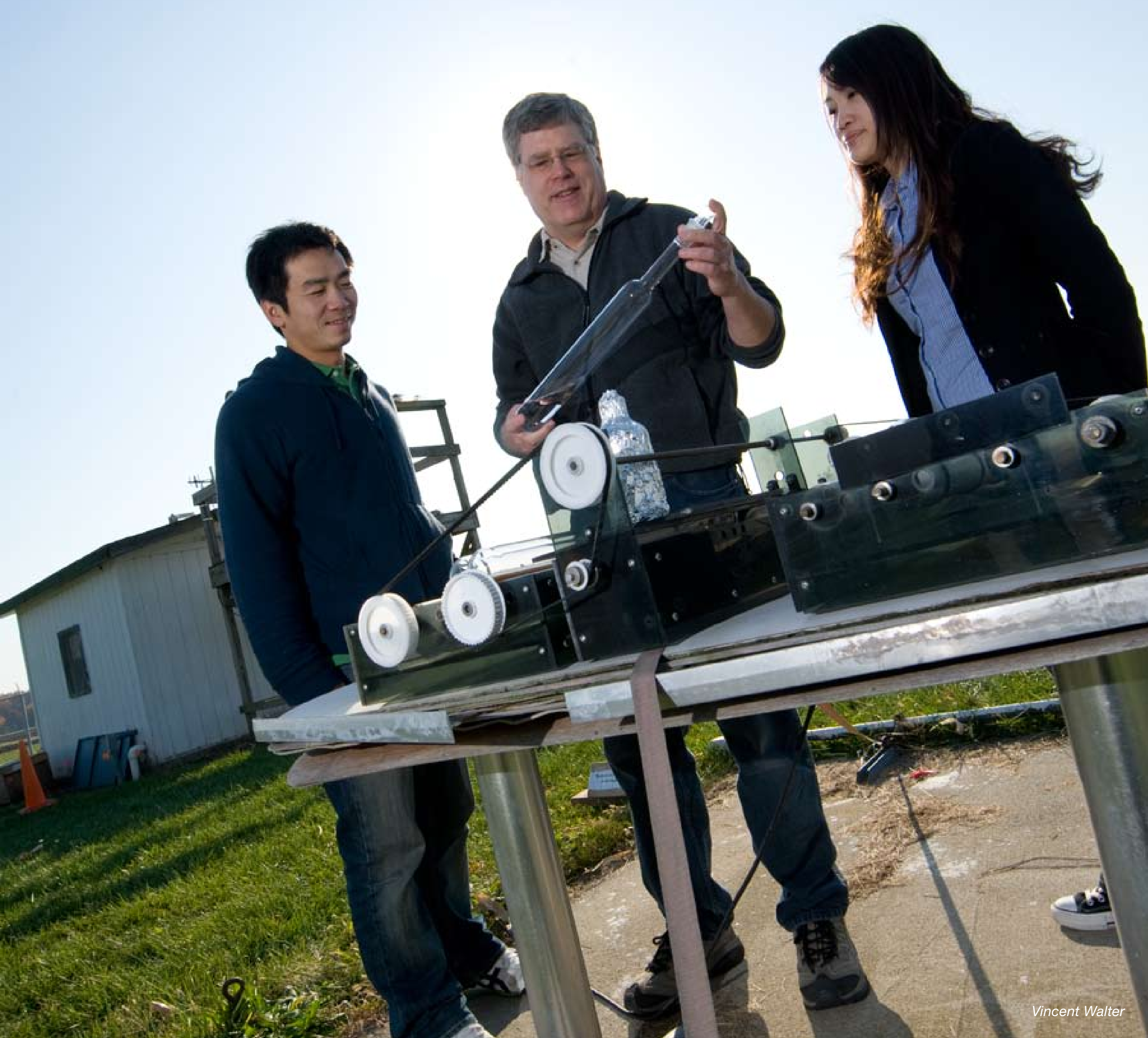
"The bottom line is that if buckyballs partition favorably from water to octanol, they are also likely to partition favorably from water to fatty tissues," Jafvert says.

The researchers also are investigating whether sunlight breaks down buckyballs and other structures called carbon nanotubes, which also could have widespread industrial applications. "We need to learn how reactive these materials are in the environment," Jafvert says. "Do they break down? What kinds of products do they form? We have learned so far that buckyballs absorb light, and they do photoreact. That's potentially a good thing, because it means they won't hang around for a long period of time, reducing the exposure concentration, which would then reduce any potential toxicity that they may or may not have."

Named after architect R. Buckminster Fuller, who designed the geodesic dome, buckminsterfullerenes, or buckyballs, are soccer-ball-shaped molecules containing 60 carbon atoms. A buckyball has a width of about 1 nanometer, or one-billionth of a meter, which is roughly 10 atoms wide.

The researchers determined precisely how soluble the buckyballs are in water and confirmed that the molecules form clusters, which complicates efforts to understand how they might be dispersed by water in the environment. "Typically, buckyballs are not found in water because their solubility is so low, but the same could be said of DDT," Jafvert says. "DDT is found in sediment, so you would assume buckyballs would also end up in sediments. That means there is also a chance that marine organisms, like worms that are eating sediment, are going to be potentially accumulating buckyballs unless they break down in the environment." ■

Sun Studies: Chad Jafvert, a professor in civil engineering, and students study how man-made chemicals behave in the environment, including the phase distribution and photochemistry of buckyballs out at Purdue's Agronomy Farm.



Vincent Walter

By **Gina Vozenilek**

The Art of Metal

One materials engineering researcher makes a career of her interdisciplinary passions.

You might think of Carol Handwerker as an alloy of art and science. The accomplished professor of materials engineering came to Purdue from the National Institute of Standards and Technology (NIST), where she helped to find the best substitute for lead in solder when the European Union banned the metal. But her first bachelor's degree, curiously enough, was in art history.

"My particular expertise," says Handwerker modestly, "is discovering patterns and trends. Studying how a material's structure will change over time is not unlike seeking the details of an artist's style as it evolves with the dynamic internal and external forces on the artist."

This sentiment could apply to Handwerker's own career development. In high school, she researched water pollution, and in college she followed her twin passion, art. It was a last-minute organic chemistry course that invigorated Handwerker's fascination for structure and pattern on the small scale. It was not long after that that Handwerker realized her true calling. "I thought, 'I'm never going to be happy unless I am in science,'" she recalls.

That moment came one day at the Boston Museum of Fine Arts. "My specialty was Eastern art and architecture, and as I was looking at one of my favorite Japanese scrolls, a little flake popped off. As I watched it flutter down," she says, "I thought, 'I'd really like to do art conservation.'"

But that job would wait. Upon graduation, Handwerker took an administrative position with a small air and water pollution prevention startup. On the second day of the job, the head of the company, who knew of her early research, asked her solve a water-pollution problem for a client. She did it handily, and more opportunities followed. Soon she was back in school, working her way up from a programming job in the computer center at the Massachusetts Institute of Technology to a PhD in materials science engineering from that university.

While a postdoctoral student, Handwerker became a research associate at the Smithsonian Institute, where at last her worlds converged in ancient Korean celadon vases. There she investigated how artists engineered ceramic powders to look like jade.

At NIST, Handwerker served as a senior scientist and chief of the Metallurgy Division. She had to "find the right ingredients from the periodic table" to make a new alloy for solder when legislators forced the industry to lose the lead. "We studied the performance, toxicology, and the environmental impact of the possible alternatives to find the best one," she says. The medal-winning metal recipe turned out to be tin, silver, and copper.

Handwerker's research continues as she seeks to increase the durability of the new solder that now is used extensively in consumer electronics. "I'm passionate that in the future we make the right choices about the materials we use," she says.

As the solder work continues, Handwerker is developing a new combination of another kind. With H. Kory Cooper, an assistant professor of anthropology, she is developing a new course in archeometallurgy and culture. Together they will show a diverse group of undergraduate engineers and liberal arts students how ancient civilizations mined and smelted ores, used metals to make useful handicrafts and tools, and traded them. It will be a hands-on laboratory course and will rely on students from vastly different backgrounds sharing their knowledge with one another. "We will team students up so they can teach each other from their own strengths," says Handwerker excitedly. Clearly, this kind of multidisciplinary love of learning has been with her from the very beginning. ■

Atom Passion: "My particular expertise is discovering patterns and trends," says Carol Handwerker. Here, the researcher uses a model of an atom to demonstrate how materials science links properties in a range of scales. "Studying how a material's structure will change over time is not unlike seeking the details of an artist's style as it evolves with the dynamic internal and external forces on the artist."

Vincent Walter

By **William Meiners**

Living, Learning

Brought together in both academic and residential realms, a community of first-year engineering students is exploring better ways to care for the planet.

Kenneth Okine and Jana Skiles come from different parts of the world. Raised in Ghana, Okine graduated from high school in Cincinnati before turning down Ivy League offers to come to Purdue. Skiles, a Pittsburgh native, came to West Lafayette in hopes of playing golf, but has decided, for now, to concentrate on her freshman studies. Both first-year engineering students plan to pursue different disciplines within the College of Engineering—Skiles bound for chemical engineering while Okine has his studies set on electrical and computer engineering. But their shared desire to keep the world a hospitable place has brought them together as part of a new learning community called "Engineering for the Planet."

Sponsored by the Division of Environmental and Ecological Engineering (DEEE), this learning community is bringing together like-minded students throughout engineering to introduce them to the multidisciplinary efforts that make up the field of environmental engineering. The students live together, with the men in Benjamin Harrison Residence Hall and the women in Amelia Earhart Residence Hall. Extra-curricular activities, such as a tour of Purdue's Power Plant and participation in last September's "Green Week"—including attendance at Thomas Friedman's speech (see story on Purdue's burgeoning green efforts on page 42)—give students a holistic look at the challenges of how one might actually engineer for sustainability.

Learning communities first started taking shape at Purdue about 10 years ago. "We decided to work on course clusters linked to two or three classes so that groups of 20 or so students could take the classes and we could link them to residential options," says Andrew Koch, who is director of Student Access, Transition and Success (SATS) in Purdue's Office of Engagement.

By intentionally situating the students together, they tend to talk about classes, study together, and sometimes even eventually marry (though Koch says that's not a selling point). The academic realm tied to the residential arrangement has proven, Koch stresses, to enhance academic success.

From that first year with one theme and two communities of 46 students, the Boilermaker learning communities have grown to some 1,450 in 2008. With the intent to form a real community, the SATS staff does a targeted search of admitted students. "At some level the communities are a byproduct of their applicant pools," Koch says. "We often have larger female and minority enrollment in the learning communities."

Whatever their overall makeup, the learning community students tend to fare better from a retention and grade-point-average standpoint, Koch says. "It seems to be an good option for attracting the best and the brightest and keeping them here."

Sustainability Philosophy

The College of Engineering has an impressive history of learning communities, with renowned successes related to Engineering Projects in Community Service, the Women in Engineering Program, and the Engineering Honor's Program, to name a few. Koch admits that the "Engineering for the Planet" wasn't a "hard sell" to admitted students. Forty two students have joined the inaugural program this fall.

"There seems to be a resurgence in obtaining minors," says Inez Hua, interim head of DEEE and a professor of civil engineering. "They offer an additional credential for students. Environmental engineering as a field means different things to different people. You cannot get your degree in the field yet, so we're starting with the minor."

Community Learners: Jana Skiles and Kenneth Okine, both first-year engineering students, talk textbooks in the lobby of the Amelia Earhart Residence Hall. Skiles lives in Earhart with other women in their learning community.

Vincent Walter

Dick Myers-Walls

Power Hour: Carl Hartman (beard), an assistant operations supervisor at the Wade Utility Plant, leads students from the "Engineering for the Planet" learning community on a tour of the Purdue Power Plant.

Even with just a minor in environmental and ecological engineering, which is available to students beyond engineering, the multi-disciplinary nature of the work is attracting both researchers and students from all over campus. With the division's alignment with Purdue's Center for the Environment and a very real strategic plan push for both an increasingly green campus and environmental research breakthroughs, DEEE is primed for a growth spurt.

For Hua, whose research interests include a myriad of environmental challenges, including water treatment, fate and transport of chemical contaminants, inorganic and organic environmental chemistry, groundwater and soil remediation, sustainability, and industrial ecology, there is no time like the present to step up the green research. And what better way than to introduce that philosophy to first-year students? "Protecting and enhancing the environment depends upon the talents of students in all of the engineering disciplines," says Hua. "Starting earlier in a college career teaches students the necessary perspective on the environment through which they can view engineering activities."

Both Hua and Larry Nies, an associate professor of civil engineering, teach separate sections of the introductory "ENGR 103" course, and students from each of those sections take introductory classes together in either English or communications, where they learn the basics of writing and speaking about "green" topics. Another important part of the learning community, says Hua, is "bridging the disciplines" of engineering and liberal arts to enhance the holistic education.

So can an electrical engineer and a chemical engineer really save the planet? They could lend helping hands. Perhaps Skiles could follow the lead of Hua's research to reduce harmful chemical uptake in plants and various species. Okine talks about investigating new types of energy that would be more environmentally friendly. But they've got a long way to go. For now, both students seem to be adapting to the challenges of college life and first-year engineering homework.

Skiles says her "tightest friends have come through the learning community," and Okine enjoys the "peer-to-peer discussions" he's having with new friends that may or may not even revolve around the planet. And here's another thing they have in common: both are young people who, through an engineering education, are planting the seeds for a sustainable world. ■


ENGINEERING ATTRIBUTES
ARNING GLOBAL PHILOSOPHER
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EDUCATION


PHILOSOPHER NASA'S
VIRTUAL LEARNING GLOBAL PHILOSOPHER NASA'S
IDEAS TO
REDUCED GRAVITY
STUDENT FLIGHT OPPORTUNITY
GLOBAL
TO
NASA'S REDUCED GRAVITY STUDENT FLIGHT
GLOBAL PHILOSOPHER NASA'S REDUCED GRAVITY
REDUCED

By **William Meiners**

Learning Revolutionized

First-year students working in design teams in the newly constructed Ideas to Innovation Learning Laboratory of Purdue's Neil Armstrong Hall of Engineering are tackling grand challenges, emulating the working world, and acquiring the professional attributes of tomorrow's engineers.

None of the grand challenges explored in this publication will be solved anytime soon. The efforts to provide energy more efficiently, to deliver better healthcare, to make our cities safer, and to keep the planet cleaner will require multidisciplinary breakthroughs on many fronts—political, scientific, engineering, and otherwise. And the future engineers who will have a hand in solving those problems need an education strong in both theory and design. With an evolving classroom equivalent to hands-on design, Purdue is training students through experiential learning.

Early in the fall 2008 semester, a group of Purdue first-year engineering honors students gather for a Friday afternoon class in the design studio of the Neil Armstrong Hall of Engineering. After listening to instructions from Sean Brophy, an assistant professor of engineering education, 15 three-to-four person teams go about assembling an experimental biomedical engineering device that measures finger strength. Being all first-year students, this particular class is likely unaware of their historic role in the history of engineering at Purdue. Not even the former freshman for whom the building was named and dedicated at Homecoming 2007 got a chance to wrap his hands and mind around design problems in such a state-of-the-art classroom.

An evolving engineering education, necessitated by such grand challenges as those identified by the National Academy of Engineering (NAE), is behind the Purdue rationale for building such facilities, along with labs dedicated to design and creative problem-solving. "Design is important for students to think about early, so they can find out more about what engineering is," says Michael Harris, the associate dean of engineering for undergraduate education and a professor of chemical engineering. "We have the abstract concepts where they have to integrate math, physics, and chemistry. But then how do you use that to make something tangible? We find that a number of students are more visual learners. They see how you can apply engineering principles to actually make something. It whets their appetite for engineering."

Engineering Attributes

The first-year engineering program is not only helping to develop hungry engineers but also giving them a taste of all of the disciplines within the college. At Purdue, engineering students don't select a major until their sophomore year. Harris had an eye toward longer-term needs when he co-chaired the Engineer of 2020 committee with James Jones, an associate professor of mechanical engineering. Picking up where the former chair, Leah Jamieson, the John A. Edwardson Dean of Engineering, left off, Harris and the committee tried to determine what target attributes the Purdue engineer should possess by the end of the next decade.

Not surprisingly, the two-year study revealed some of the important knowledge areas of science and math, engineering fundamentals, and analytical skills that are desirable for these future Purdue alumni. But strong communication skills and leadership abilities, along with innovative and adaptive qualities, could be attributes demanded by an increasingly fast-paced, global marketplace.

"We don't think of some of these attributes as something you can develop in a normal lecture-hall situation," Harris says. "How do you teach leadership? Do we continue to save design for the senior year or start as freshmen?"

Problem Solvers: First-year engineering students make use of the floor-to-ceiling dry erase boards in the new state-of-the-art labs of the Neil Armstrong Hall of Engineering. By introducing design work and creative problem solving in the first year, "students lead their own learning," says Teri Reed-Rhoads, an engineering education researcher.

For engineering researchers and educators like Teri Reed-Rhoads and P. K. Imbrie, the question of how to teach leadership begs other questions about not only how but where they teach. How could they design spaces that optimize an engineering education? “One way of thinking about it is that students lead their own learning,” says Reed-Rhoads, the assistant dean of undergraduate education and an associate professor of engineering education. “It’s the shifting paradigm from teaching to learning.”

Reed-Rhoads and Imbrie, an associate professor of engineering education, wanted to start by, if not outright eliminating, at least minimizing the massive lecture halls where the proverbial “sage on a stage” tries to engage and connect with some 400-plus students. Roaming teaching assistants might be able to confiscate the *Purdue Exponent* and even discourage texting and Web surfing among this large student body, but the transfer of knowledge is bound to suffer in such a setting.

By contrast, one relatively large classroom in Armstrong, which holds 120 students (40 in three tiers), was designed to create a collaborative environment. With two rows of tables within each tier, students have the ability to participate in team activities. Flexibility of space is an important part of the new classrooms and labs. Students can turn in their seats from a lecture and—without scooting chairs across the floor—jump immediately into group discussions.

And the designers behind these rooms want it to be a selling point for the school. “We have a problem with engineering in that non-engineers don’t really know what we do,” says Reed-Rhoads. “How do students learn engineering? So we’re trying to make this very visible. When the big yellow school bus pulls up out front, we want the kids to be able to see what we’re doing. We recruit out of this space.” Glass walls and doors will allow that vision to be seen by others.

I2I Learning Lab

Also in the lower level of Armstrong Hall, the Ideas to Innovation Learning Laboratory, known in shorthand as I2I, emulates the workplace and puts design at the heart of the educational process. Built to be flexible, collaborative spaces, a design studio, an innovation studio, an electronics studio, a rapid-prototyping studio, fabrication and artisan laboratories, and a demonstration studio all support progress through each stage of the design cycle. Students can ask questions and define their goals for success. They can create potential alternatives, anticipate and plan for a chosen option, build and test a prototype, evaluate those outcomes, and refine as needed.

And what will get students started on the innovative designs? “We’re focusing our classes around the NAE’s 14 grand challenges,” Reed-Rhoads says. “Obviously the projects are going to be small, but we want them to think along the lines of the grand challenges.”

Some 1,800 first-year engineering students are addressing the biggest problems facing humanity this year through team-based projects. The rooms are equipped with moveable storage carts and enough containers to allow student teams to work on “something up to the size and weight of a lawnmower engine from one week to the next,” Reed-Rhoads says.

Tables wired for tablet personal computers, projectors, and floor-to-ceiling dry erase boards all around keep the tools of the trade close at hand and encourage group creativity. The variety of the work also helps students in declaring their majors as sophomores. “We try to highlight all the disciplines, so they can make informed decisions the next year. One of our biggest recruiting advantages at Purdue is that students don’t have to know their chosen discipline in the first year,” says Reed-Rhoads. “But it’s imperative that our students have an appreciation and understanding of multiple disciplines, because that’s life and that is how they will be working.”

Both Harris and Reed-Rhoads are hopeful that the revamped first-year engineering program will lead to better retention rates. “Retention is always a big thing,” Harris says. “If we can do anything to help that, we should, and I think this will. By creating excitement early on, students are more likely to stay throughout their engineering studies.”

Some students will learn—perhaps the hard way—that engineering simply isn’t for them. “We don’t mind losing students who make informed decisions,” Reed-Rhoads says. “We don’t, however, want to lose the 4.0 students who could have been engineers but didn’t see it in themselves due to lack of information.”

Team-Based: Working in three-to-four person teams, students are assembling experimental biomedical engineering devices that measure finger strength. The Ideas to Innovation Learning Lab emulates the workplace, putting design at the heart of the educational process.

Vincent Walter

Writing's on the Wall

Back in Brophy's class, the teams are putting together their biomedical devices, discussing both pitfalls and potentials of the various designs. Some take advantage of the write-able walls, sketching diagrams, maybe trying to convince a teammate of a better way through the problem. Another student, perhaps feeling far removed from his own first-year engineering experiences, walks through the class offering assistance as a peer teacher. Bernie Davila, a junior in mechanical engineering, says his transition from high school to college engineer was "a little harsher" than what his slightly younger colleagues are experiencing. His memories are lined with more lecture halls and computer labs.

"I see a lot of potential in this new facility for students." Davilia says. "You could only use computers in the labs I was in. Everything else was separate. Those setups didn't contribute to the hands-on design philosophy."

The educational architects behind the classrooms and learning labs in Armstrong are banking on a revolutionary philosophy that can develop those less tangible attributes in future engineers. They're excited to see how flexible space can lead to greater adaptability in students. To see how leaders can emerge from a creative, team-based atmosphere. And even learn for themselves how ideas can lead to innovation.

Whether or not they realized it on this particular September Friday, these first-year engineers are potentially laying the groundwork for great careers and—should these first forays into design lead to the cutting edges of a respective engineering field—perhaps even something along the lines of a grand-challenge breakthrough. Because as history has shown, that is what we have come to expect from Purdue engineers. ■

By **Barbara Leonard**

Education Redefined

Purdue's nanoHUB.org is changing the way engineers learn.

Purdue's nanoHUB.org project is building innovative Web technology and publishing simulation tools and educational materials to change the way students learn nanotechnology. A product of the Network for Computational Nanotechnology (NCN), nanoHUB connects faculty, students, and professionals for collaboration, sharing resources, and real nanotechnology science and engineering.

"Today, nanoHUB.org hosts over 1,200 resources, including 104 simulation tools," says George Adams, deputy director and associate director for programs at the NCN. "The nanoHUB user community now numbers 72,000 from 172 countries. There are users at all *U.S. News & World Report* top 50 U.S. engineering schools and over 14 percent of all U.S. higher education institutions."

Part of a vision shared by Mark Lundstrom, the Scifres Distinguished Professor of Electrical and Computer Engineering, and Supriyo Datta, the Duncan Distinguished Professor of Electrical and Computer Engineering, the teaching and learning materials available on nanoHUB are redefining engineering education in semiconductor materials, devices, circuits, and systems for the nanotechnology age. One of nanoHUBS's educational initiatives is "Electronics from the Bottom Up"; which starts with the behavior of atoms and builds to the nanoscale electronic devices that are the foundation of today's leading-edge technology and to the understanding that will lead to tomorrow's new devices.

Launched in 2006 with additional support from the Intel Foundation, "Electronics from the Bottom Up" includes online modules and supporting course notes, homework assignments, and online simulation exercises on both nanoHUB.org and the Intel higher education Web page.

"The nanoHUB also supports existing curricula in semiconductor device education, quantum mechanics, and even freshmen chemistry and enhances the students' learning through interactive tools," says Gerhard Klimeck, a professor of electrical and computer engineering and associate director for technologies at the NCN. "To learn new concepts, students ask 'What if?' questions through simple button clicks without having to install software or read hundreds of pages of software manuals."

David Radcliffe, a professor of engineering education, and Sean Brophy, an assistant professor of aeronautical and astronautical engineering and engineering education, are investigating the benefits and impact of nanoHUB resources for educating a wide range of learners from novice to expert. Radcliffe studies the social, cognitive, and technological facets of a virtual organization, such as the community of nanoHUB users that leads to sustainability and effectiveness. Brophy surveyed 100 students in nanodevice and chemistry courses using nanoHUB. He found classroom demonstrations using simulation improved students' comprehension of concepts better than traditional lectures without simulation.

Students interacting in the nanoHUB environment have access to four research themes: nanoelectronics, NEMS/nanofluidics, nano-bio devices, and nanophotonics. Online workshops and tutorials are available free of charge to students and anyone with an interest.

Bigger than simply an online learning environment, the nanoHUB setting offers students access to collaborative tools and opportunities to take part in a community of scholars, professionals, and fellow students—a real-time conversation unimaginable just a few years ago. The project successfully links learning with research and collegial partnerships, giving students a broader view of how their class work relates to real-world applications and, more importantly, how their contributions play a role in the larger nanoscience conversation.

The use of nanoHUB in research is documented in over 265 citations in the research literature. About 60 percent of the citations are from authors outside of the NCN, 80 percent of the citations reference the use of nanoHUB resources for nano research, 8 percent for use in education, and 12 percent cite the nanoHUB as an example for cyber infrastructure.

Housed in the Birck Nanotechnology Center in Purdue's Discovery Park, the NCN is funded by a five-year, $18.25 million grant from the National Science Foundation. ■

nanoHub Guru: Gerhard Klimeck, the associate director for technologies at the Network for Computational Nanotechnology, says Purdue's "nanoHUB supports existing curricula in semiconductor device education, quantum mechanics and even freshmen chemistry and enhances the students' learning through interactive tools."

John Underwood

By **William Meiners**

Engineering a Worldview

The success of Purdue's Global Engineering Program hinges on transformations in learning, discovery, and engagement.

If Rabi Mohtar's best plans come to fruition, the Purdue engineer will become synonymous with global impact. A tall order perhaps, but something Mohtar, a professor of agricultural and biological engineering and the new director of the Global Engineering Program (GEP), believes to be achievable by transforming how students learn, as well as how they are engaged in research.

"Part of what we want to have our engineers do is assume leadership roles in a global setting," Mohtar says. "Our engineers should be flexible, adaptable to change, and able to communicate across cultures."

Mohtar points to the attributes of the future Purdue engineer and to those described in the National Academy of Engineering's *The Engineer of 2020* as the same that will help transform the profession. "You cannot achieve those attributes without having a diverse global learning portfolio," he says.

Many might associate a global engineering program with the international study and internship options that take Purdue engineering students throughout the world. Americans abroad, for example, immerse themselves into other cultures, simultaneously gaining technical skills and working outside their own familiar surroundings. And just as it's easier to learn another language by placing oneself in a country of its native speakers, the emerging global engineer learns to communicate with engineers abroad while being exposed to different work styles. These mind-opening experiences only enhance the technical skills that Purdue engineering programs have long delivered to graduates.

But Mohtar says the study abroad programs are just part of the global learning portfolio. Some students may not have the option to leave the country for many months at a time. They can, however, participate in global design teams working with international partners. Mohtar offers up the recent example of five agricultural and biological engineering students who worked with a non-governmental organization (NGO) on the West Bank in Palestine to deliver effectively clean drinking water to a community of 2,200 residents. For four straight months, the students made phone calls and collaborated with the local NGO before ultimately designing a filtration and disinfecting unit that made the formerly polluted spring water safe for use. The students did travel to Jordan for 10 days at the end of the project, but the bulk of their global experience came through the cross-cultural exchanges via telephone calls and emails.

The learning portfolio for undergraduates could also include international internships and industrial experiences ranging from a few weeks to several months. From the classroom standpoint, Mohtar expects that courses designed to help students achieve the global engineering attributes will become a part of a changing curriculum. "If you look at the teaching plan, one of our goals is to provide opportunities to all Purdue engineering students with a global experience," he says.

The ultimate success of GEP is dependent upon taking the program beyond the learning initiative.

"Most people have approached global engineering from an educational perspective," says Mohtar, who wants to broaden that perspective to include global research and engagement experiences.

Named director last spring, Mohtar admits that transforming a culture doesn't happen overnight. But by mobilizing the most successful faculty within the College of Engineering, the idea of a global engineer addressing grand challenges will build upon the GEP's strategic plan. "The historical strength of our college comes in research, learning, and engagement," Mohtar says. The "broad alley of experiences," currently being developed in the GEP, is relying on that three-pronged strength to develop big-picture thinkers.

In redefining the engineer of 2020 and working in the context of curriculum, Mothar and his group are zooming in on the attributes that lead to those wider worldviews. If followed through properly, Purdue could indeed become a cradle of global engineers. ■

Global Thinker: Rabi Mohtar, director of the Global Engineering Program, is adamant about Purdue engineers assuming leadership roles in a global setting. "Our engineers should be flexible, adaptable to change, and able to communicate across cultures," he says.

Provided by UNS

By **Barbara Leonard**

A Weightless Approach to Learning

Purdue students lead the nation in NASA's zero-gravity experiments.

For the past 11 years, Purdue has been sending students into space—not space exactly, but into a program that replicates the weightlessness of space travel. Led by Steven Collicott, a professor of aeronautics and astronautics, Purdue's participation in NASA's Reduced Gravity Student Flight Opportunity Program has given nearly 150 students the chance to learn and conduct original research in zero-gravity conditions.

The program, introduced by NASA in 1996, annually solicits proposals from student teams to conduct original experiments that require zero gravity. Proposed experiments would be performed within 25 seconds of weightlessness created in a NASA airplane. Winning teams from across the country are then granted the opportunity to fly in the C-9B zero-gravity aircraft, sometimes called the "vomit comet," which induces weightlessness for use in training and experiments.

Purdue students head the pack when it comes to submitting successful proposals to NASA. To date, Purdue is the leading university in this annual nationwide competition for zero-gravity flight test time.

Historically very competitive to get into, the program offers not only a once-in-a-lifetime opportunity to experience weightlessness; it also offers a myriad of educational and learning opportunities for the students who participate. Students in Collicott's "AAE 418" Zero-Gravity Flight Experiment course, the feeder class for students interested in competing for a spot in zero gravity, work on real-life experiments from start to finish.

Along with the possibility of winning a spot on the NASA plane, it is the team-centered, hands-on approach that makes the experience so valuable for students. Students come out of the program better prepared for engineering jobs, because they have already designed and built experiments in teams, organized just like the teams at NASA, where each member of the team specializes in specific aspects of the experiment.

Collicott, who was inducted into *Purdue's Book of Great Teachers* in August, recognizes great educational value in the experience. "From my 11 years of observations, the students grow tremendously, because the experience is a long-term, team-based, multidisciplinary, original, no-answers-in-the-back-of-the-book, external evaluation, competitive, creative, and exciting engineering experience," he says. "The excitement of the unique zero-gravity flight test opportunity leads most students to dive into the work wholeheartedly and to excel beyond their expectations at the start of the semester."

This fall, the classroom space dedicated to zero-gravity research and teaching moved from the Purdue airport to state-of-the-art facilities within the new Neil Armstrong Hall of Engineering. Previously, Collicott taught the zero-gravity course in a hallway at the Purdue airport. To say he and his students are excited about using the project-class teaching space in Armstrong Hall is an understatement.

"As the student machine shop in the basement of Armstrong Hall becomes operational this year, we will see our students have these tremendous engineering educational experiences with so many of the required resources located nearby," says Collicott. "Students will have a wonderful range of fabrication, computation, and human resources to draw on. I do feel good knowing that the great work our students have done for 11 years under inefficient conditions sets a high bar for the newer students to clear."

To date, the nearly 150 students, part of 40 Purdue teams, have gone to Houston to fly in the zero-gravity plane. According to Collicott, their combined experience totals 34.2 hours in weightlessness, 2.4 hours in lunar gravity, and 1.7 hours in Martian gravity.

The most recent success came in the summer of 2008, when two student teams from

Vomit Comet: Since NASA began its zero-gravity experiments in 1996, nearly 150 Purdue students, part of 40 different teams, have experienced weightlessness while conducting experiments.

Purdue performed experiments onboard the zero-gravity plane. The first of these involved studying two porous-electrode electrolysis methods for zero-gravity life-support systems. The second project measured wicking rates of specific liquids in networks of grooves.

The value of research-based learning is not lost on Collicott's students either. Every detail, from designing the experiments, writing the proposal for NASA, and conducting the experiment in low-gravity conditions, provides an opportunity to grow professionally. "Hands-down, the zero-gravity program was one of the most valuable parts of my Purdue education," says Andrew Maurer (BSAAE '06), a zero-gravity veteran. "No other course provides such a high-fidelity simulation of what students will encounter in industry."

Testing the experiments in low gravity prior to potentially moving forward to the NASA plane, students look forward to the rare opportunity to reproduce the weightlessness experienced by space-shuttle astronauts flying in orbit around Earth, Mars, or the Moon. "With that gained perspective, my education no longer became just equations and lectures, but rather a tangible understanding of the actual environment that space systems and astronauts are challenged to work in," says Kimberly Hicks (BSAAE '06), also a past student of Collicott's.

NASA also recognizes the tremendous value of student-based research to the success of its programs. In fact, due to the success of Purdue's zero-gravity program, NASA headquarters recently recommended to Congress that one significant way to increase the educational impact of the International Space Station operations is to launch student-built experiments to the space station. According to NASA, Purdue's "AAE 418" course is the ideal way to begin this student space-station experiment program.

Alumni and friends can aid this exciting program in numerous ways. Collicott points out that travel to NASA's Johnson Space Center in Houston, Texas, for 10 to 14 days costs approximately $8,000 per team. Over the years, gifts to the department or college and grants from the Indiana Space Grant Consortium have been instrumental in students' success. Collicott and his students also welcome input from alumni and friends who have zero-gravity or two-phase fluids research, "so that our student proposals can continue to focus on important experiment topics."

Despite its name, NASA's "vomit comet" is more than a fast ride on a high-tech plane; it is an opportunity to expand education beyond the classroom and to introduce hands-on, real-world research into the realm of learning. ■


CAREER AWARD WINNERS
NATIONAL ACADEMY OF ENGINEERING INDUCTEES
NATIONAL
WINNERS SIGNATURE AREA
NSF CAREER AWARD WINNERS SIGNATURE AREA
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SIGNATURE AREA

PEOPLE

NAE Elected

Two accomplished Purdue researchers earn one of the nation's highest distinctions for engineers.

Kumares Sinha

Andrew Weiner

Last February, the National Academy of Engineering (NAE) elected two Purdue engineering professors into its society. Kumares Sinha, the Edgar B. and Hedwig M. Olson Distinguished Professor of Civil Engineering, and Andrew Weiner, the Scifres Distinguished Professor of Electrical and Computer Engineering, were among the 65 new members and nine foreign associates elected to the academy this year.

"Election to membership in the National Academy of Engineering is one of the highest distinctions that can be bestowed on an engineer," says Leah Jamieson, Purdue's John A. Edwardson Dean of Engineering and a 2005 academy inductee. "Professor Sinha was elected for his contributions to the advancement of highway infrastructure engineering and management and to the education of transportation professionals worldwide. Professor Weiner was elected for his contributions to the development of femtosecond optical-pulse shaping technology."

Sinha has been on the Purdue faculty for 32 years. For the past 12 years, he has served as the director of the Joint Transportation Research Program, a collaboration between Purdue and the Indiana Department of Transportation. His research on system performance, costing, and network optimization are used worldwide and have been adopted in pavement, bridge, and safety management systems developed by the U.S. Army Corps of Engineers, Federal Highway Administration, and National Research Council.

"I am humbled by this honor, because the recognition comes from my peers," Sinha says. "Purdue is known for its outstanding engineering programs, and it's gratifying to be part of this team."

Weiner has taught at Purdue since 1992 and served as vice president of the International Commission on Optics from 2002–2005. His leadership in the field of lasers and optics dates back to 1988, when he served as a distinguished lecturer for the Institute of Electrical and Electronics Engineers' Laser and Electro-optics Society. Weiner has served on or chaired numerous conferences, research review panels, professional society awards committees, and conference program committees connected with the laser and optics field.

Weiner's technology creates and controls ultrafast laser pulses for applications including advanced sensors, more powerful communications technologies, and more precise laboratory instruments.

Weiner holds nine U.S. patents and has won numerous awards for his research, including the International Commission on Optics Prize in 1997, the William Streifer Scientific Research Achievement Award in 1999 and the Alexander von Humboldt Foundation Research Award for Senior U.S. Scientists in 2000.

"I feel the work that I and other colleagues have done in this technology has created something that has been widely useful to a lot of people," Weiner says. "It is very gratifying to see the broader engineering community recognize that impact." ■ **Clyde Hughes**

Career Developers

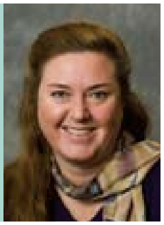
The National Science Foundation gives a financial boost to young research faculty.

This year, six of the eight Purdue faculty members who won the National Science Foundation's most prestigious honor for outstanding young researchers, the Faculty Early Career Development award, are professors in the College of Engineering. These awards provide from $300,000 to $500,000 in research funding over four or five years.

Purdue's award-winning engineers include Robin Adams and Monica Cox, both assistant professors of engineering education; Inseok Hwang, an assistant professor of aeronautics and astronautics; Dan Jiao and Dimitrios Peroulis, both assistant professors of electrical and computer engineering; and Chang Lu, an assistant professor of agricultural and biological engineering.

■ **Emil Venere**

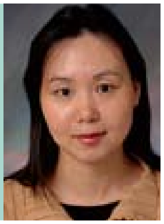
Cross-Disciplinary Thinking: Robin Adams will investigate why and how people become good cross-disciplinary teachers, workers, and students. The aim of this research is to open up the complex "black box" of cross-disciplinary thinking to better enable effective cross-disciplinary practice and learning at the undergraduate, graduate, and post-graduate levels.



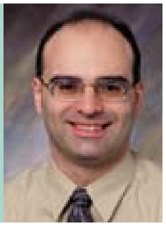
Career Preparation: Monica Cox is learning how to better prepare graduate engineering students effectively for careers in academia and industry. The research will identify norms, skills, and attributes that experts in academia and industry believe are essential for individuals with engineering doctorates to succeed within a changing academy and society.

Complex Networked Systems: Inseok Hwang will develop theory to describe the workings of "mobile networked embedded systems" and create efficient numerical algorithms and experimental testbeds to help improve the systems. The complex networked systems include the next-generation air traffic control system, networked robotics in factories, sensor networks, and biological systems.

Next-Generation Chips: Dan Jiao will develop advanced algorithms for simulations to analyze the performance of next-generation computer chips. Integrated circuits generate electrical and magnetic fields, but conventional techniques analyze these fields separately. Jiao's algorithms will simulate both electrical and magnetic fields simultaneously, requiring less time and computer memory than conventional algorithms.



Liquid Circuits: Dimitrios Peroulis is developing a new class of liquid electronic circuits and devices for high-frequency wireless communications. The research merges two technologies, high-frequency electronics and "microfluidics," to create liquid circuits that are powerful, reconfigurable, and effectively cooled. The liquid radio components would easily meet differing standards from multiple countries.



Opening Pores: Chang Lu will improve electroporation, a process where cells are sent through channels within a microchip and electrical pulses open pores in cell membranes. These openings allow researchers to insert relatively large molecules into the cells, a necessary but difficult step in the study of gene functions and pharmaceuticals and other research.

NSF Fellows: Encouraged to graduate school success with fellowships from the National Science Foundation are (left to right): Zubin Olikara and Loral O'Hara, both from aeronautics and astronautics; Catherine Whittington, from biomedical engineering; Ruth Pinto, from agricultural and biological engineering; and Tyler Voskuilen, from mechanical engineering.

NSF Recipients

The National Science Foundation Fellows contribute to the future of Purdue's success.

Research on the cutting edge could not possibly happen without the help of dedicated graduate students. The National Science Foundation's (NSF) Graduate Research Fellowship Program provides such students with three years of funding for research-focused masters' and PhD degrees in the STEM fields—science, technology, engineering, and mathematics.

Five Purdue NSF recipients, beginning research in fields ranging from tissue engineering to space travel, are representative of the best of our best, says Audeen Fentiman, the associate dean of graduate engineering and interdisciplinary programs. The graduate students, on the brink of their research futures, include Loral O'Hara and Zubin Olikara, from aeronautics and astronautics; Ruth Pinto, from agricultural and biological engineering; Tyler Voskuilen, from mechanical engineering; and Catherine Whittington, from biomedical engineering.

"NSF fellowships are important on many levels," says Fentiman, also a professor of nuclear engineering. "They are important for the nation, for Purdue, and for the students who receive them. NSF fellowships are awarded to the most outstanding young people who are expected to prepare themselves to become national leaders not only in technical fields but in society as a whole.

"The NSF Fellows on campus are a tremendous asset to Purdue. They make significant, often groundbreaking, contributions to our research, and simply having them as part of the campus community enriches the educational experience for everyone who has an opportunity to interact with them. Finally, winning an NSF fellowship identifies a student, for life, as a valuable resource for the nation; 'NSF Fellow' on a resume can help open doors to rare opportunities to make contributions and provide leadership." ■ **William Meiners**

Research Community Building

Through the signature areas, the College of Engineering continues to recruit multidisciplinary researchers.

The strength of Purdue engineering research can be seen in its signature areas established in 2003: 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; and Tissue and Cellular Engineering.

Venkataramanan "Ragu" Balakrishnan, the associate dean for research, knows that essential to solving grand challenges is the continued need to work better as research communities. For Balakrishnan, also a professor of electrical and computer engineering, the growth in signature area research becomes a real selling point for attracting top faculty to Purdue. "We have invested significantly in the signature areas," he says. "Now we are trying to leverage those investments."

Many of the new faculty hires are coming to Purdue to work in those signature areas. A few of their stories follow. ■ **William Meiners**

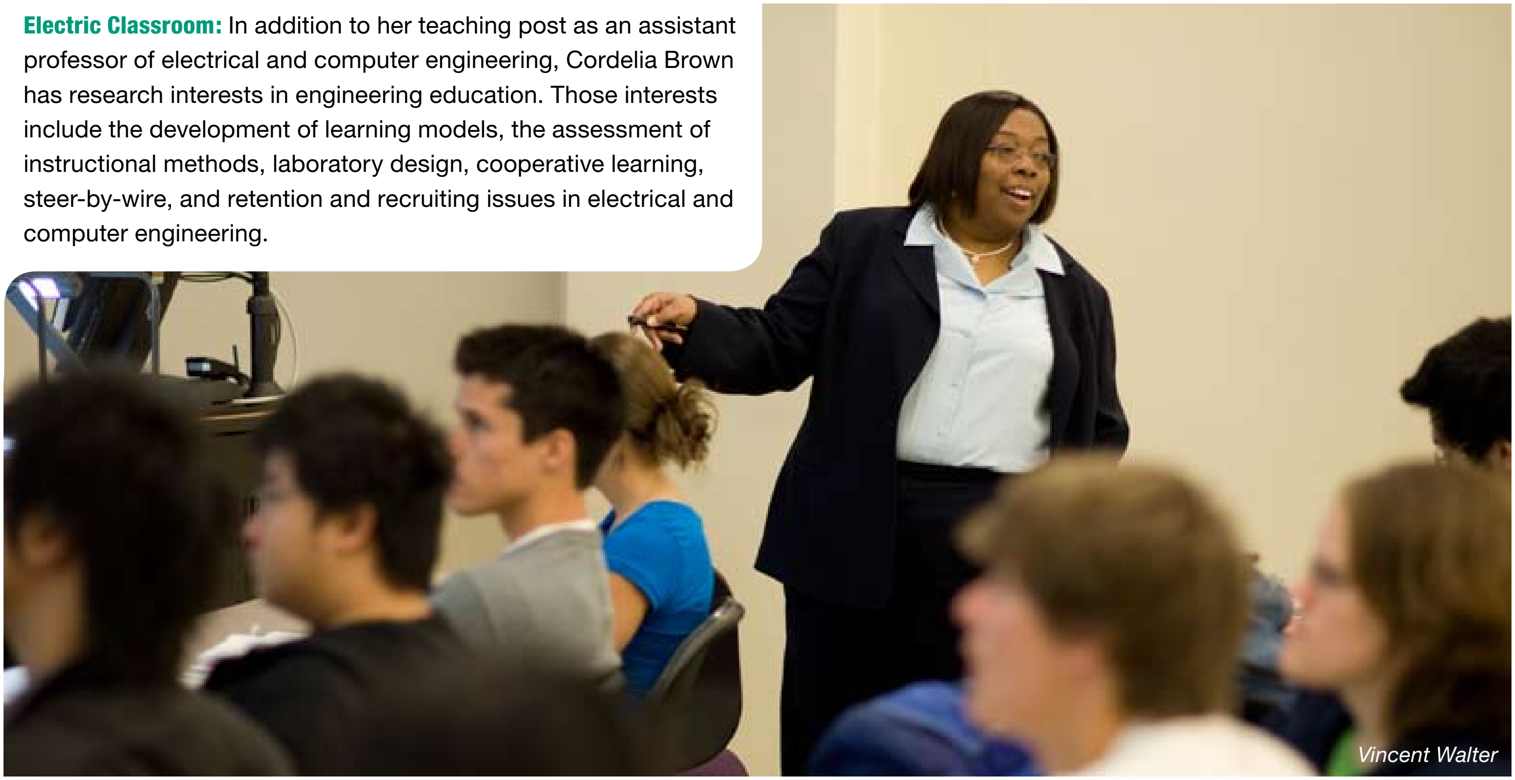
Hurrying Hydrogen: Timothée Pourpoint, a Purdue PhD now an assistant professor of aeronautics and astronautics, is leading research teams in Zucrow Labs to realize the benefits of hydrogen in the Energy signature area. In one project, Pourpoint is developing safe and efficient ways to use high-pressure hydrogen in vehicles through a combination of gas and solid-state storage approaches.

Vincent Walter

Tissue Engineering: Julie Liu, an assistant professor of chemical engineering, brings her considerable talents to the Tissue and Cellular Engineering signature area. In addition to tissue engineering, her interests include stem-cell biology and regenerative medicine. Her research goals include engineering biomimetic materials that direct differentiation of stem cells into skeletal cell fates.

Vincent Walter

Electric Classroom: In addition to her teaching post as an assistant professor of electrical and computer engineering, Cordelia Brown has research interests in engineering education. Those interests include the development of learning models, the assessment of instructional methods, laboratory design, cooperative learning, steer-by-wire, and retention and recruiting issues in electrical and computer engineering.



Vincent Walter

Healthcare Engineers: Nelson Uhan (left) and Ji Soo Yi, both assistant professors of engineering, hope to bring a systems approach to the Healthcare Engineering signature area. Uhan's research interests generally lie in the area of combinatorial optimization. In particular, he is interested in mathematical programming and combinatorial approaches to problems in scheduling, game theory, logistics, transportation, and network design. Yi's research interests include various topics in human-computer interaction, such as information visualization, mobile computing, and universal design. Together, the two young professors are applying their expertise to the challenge someone might have in choosing a nursing home for a loved one.

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