Running on Empty

A world without fossil fuels is on the horizon.
There’s no more pressing subject these days than energy. The Energy Policy Act of 2005, record-high prices at the gas pump, Hurricane Katrina—every news story, it seems, is an energy story. Energy expert Dan Kammen told *National Geographic* recently that the United States acts like a hunter-gatherer when it comes to power policy but should really behave more like a farmer. In that vein, we’ve devoted this issue of our magazine, now called *Impact*, to the College of Engineering’s role in cultivating new energy technologies. Some of those technologies aim to provide us interim solutions and, others, to make renewable energy sources viable. Given our Renewable Energy and Power Systems signature research area and our newly formed, DOE-funded Energy Center, we’re well positioned to assume leadership in providing energy solutions. There’s no greater challenge we could take up for the benefit of our nation and for our neighbors around the world.

Linda P. B. Katehi  
John A. Edwardson Dean of Engineering
VANTAGE POINTS

Pipeline and Pedagogy
As America’s engineering workforce dwindles, Purdue makes a bold counter-move: offering the world’s first graduate degrees in engineering education.

According to the ACT, the standardized-test provider, applications to engineering programs across the country have dropped 35 percent during the past 10 years. More international students are opting for universities outside the U.S., and engineering enrollment in China and India is on the rise.

“We ignore these enrollment trends at our peril,” says Linda P. B. Katehi, Purdue’s John A. Edwardson Dean of Engineering.

Taking up the challenge, Purdue’s year-old Department of Engineering Education gained approval from the Indiana Commission of Higher Education to offer three new graduate degrees: a master’s of science, a master’s of science in engineering education, and a doctorate in the field. They're the world’s first degrees ever offered in engineering education.

The field “is emerging as a discipline focused on providing a strong research base for guiding engineering practice, preparing expert engineering education practitioners, and developing curriculum leaders in engineering education,” says Purdue provost Sally Mason.

“These degrees help Purdue answer the national call for engineering education reform.”

Achieving successful reform includes developing more broadly educated engineers who can assume leadership roles in technology development and enabling the engineering profession to ensure a well-prepared, motivated, and diverse K-12 pipeline of future engineering students.

Purdue students in the new graduate program will explore such questions as:
  - What constitutes fundamental knowledge of engineering?
  - How do we know if students have gained conceptual understanding?
  - Do engineers learn similarly to, or differently from, students in other disciplines?
  - How so?

“This program, and others like it, will provide engineering education graduates with the knowledge and abilities needed for the challenges they will face in the 21st century,” says

What’s the longest you’ve ever studied straight through for an exam?
There was a thermo test I was particularly unprepared for, and I sat in the Union studying for about 12 hours. I got there at noon and didn’t leave until midnight. I ate there and everything.

What would you study if you weren’t in engineering?
I would probably do design, art. Most likely art school. Right now I plan to do facilities design and human interface design.

Is there anything that you are dreading in the near future?
Graduation. (Laughs.)

Why is that?
College life is…fantastic!

—KALLI SCHEFFEN

IE senior Rachel Larson on Purdue profs and post-exam rituals.
September 14, 2005 • 10:30 p.m. • Outside the Potter Engineering Library

Tell us a little about yourself.
I’m in industrial engineering. I’m a super-senior, so I graduate in December. I am also from Minnesota.

What class are you preparing for right now?
I have an EE 201 exam tomorrow. I was studying for EE at work.

Do you or your friends have any traditions before or after an exam?
Yeah, after the exam we usually go to the bars! Especially after a really hard exam.

How do you feel about your professors this semester?
My IE professors are all pretty laid-back. My EE professor is really strict, but I like him. He scares me, but he’s fair. I have a lot of respect for him.

How do you describe being an engineering student in three sentences?
Working really hard, partying really hard (to make up for it), and trying to get as much sleep as possible.

Kamyar Haghighi, head of the Department of Engineering Education. “We’re working to develop a foundation of theoretical knowledge that will drive the practice of engineering learning and teaching and that will best prepare engineers for their role in society.”

The school enrolled an inaugural class of 11 graduate students this fall. Future plans for the department, in collaboration with Purdue’s College of Engineering and College of Education, are to educate and certify high school teachers with an emphasis in engineering by 2007.

—CYNTHIA SEQUIN
Civil engineers at Purdue are using a specialized laboratory to test a 32-foot-tall structure resembling a portion of one type of U.S. Army barracks built on the West Coast to determine the susceptibility of aging military buildings to earthquake damage.

“This project came about because the military has some barracks built in the late 1950s and early 1960s, before the development of current building codes, and there is interest in understanding the integrity of those structures,” says Michael Kreger, a professor of civil engineering and director of Purdue’s Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research.

Features in the laboratory, completed in 2004, include a testing area with a “strong floor” and 40-foot-high “reaction wall” containing numerous holes in which to anchor powerful hydraulic actuators that apply forces to large-scale structural models.

The engineers constructed a 32-foot-tall building model in the lab resembling a portion of the interior of Army barracks built in states on the West Coast. The hydraulic equipment will be used to simulate the lateral loads induced by the ground motion of earthquakes.

Earthquakes cause portions of a structure to momentarily deform. The engineers are using various instruments attached to the structure to determine precisely how much deformation takes place in different parts of the building when subjected to the forces.

“One advantage of having a lab like this is that, instead of testing small models, we can test full-scale structures, which yields the most accurate data possible,” says Mete Sozen, Purdue’s Kettelhut Distinguished Professor of Civil Engineering. “There are only a handful of university labs in the country that could enable you to perform this kind of full-scale testing.”

Officials are concerned that a powerful enough earthquake could cause supporting columns in the barracks to separate from the reinforced-concrete floor slabs, resulting in collapse.

“If we determine that this structure could potentially collapse when it experiences extreme deformations, the Army could then go back and rehabilitate these structures to make the barracks more resistant to earthquakes,” Kreger says. “We know much more about earthquake-resistant design today than we did 50 years ago, when these buildings were constructed.”

— Emil Veneré

Up to Code?
Purdue civil engineers test the earthquake resistance of Army buildings.

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— Emil Veneré

Starburst
A signature quilt graces Purdue’s new Energy Center.

All of our forms of energy, whether fossil fuels or hydroelectric renewables, trace their origins to the sun. Hanging at Purdue’s new Energy Center, this quilt (left) gracefully reminds us of that fundamental dependence. The center was announced in July as a focal point for engineers and other researchers across campus who are pursuing next-generation energy technologies (see cover story on page 10). One group, led by Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering, Jerry Woodall, Distinguished Professor in Electrical and Computer Engineering, and Richard Schwartz, co-director of the Birck Nanotechnology Center, is researching high-efficiency, low-cost solar energy devices. “We hope that soon there will be other quilts that represent bio, wind, coal, fossil, conservation, and other aspects of energy,” says Jay Gore, the center’s interim director and Purdue Engineering’s associate dean for research and entrepreneurship, whose wife, Medha, crafted the sun quilt. “We hope to connect with folks through the use of a complete Energy Center quilt set.”

— Lisa Hunt Tally
SURF’s Up
A Purdue outreach program puts engineering undergraduates from around the country in the role of researcher.

Summer’s end on the Purdue campus saw some 160 engineering undergraduate students gathered to present findings on a host of research projects. How to build a more fuel-efficient rocket for space missions? How to develop an internal-combustion engine that doesn’t rely on moving pistons or spark-based combustion? How to develop a 3-D structure for studying DNA sequences more efficiently?

These projects, and many others, were part of Purdue’s two-month Summer Undergraduate Research Fellowships (SURF) program, which connects students directly with faculty researchers. The projects must have practical application to everyday life.

“Most undergraduate students don’t have the opportunity to do this type of research,” says Jay Gore, associate dean for Purdue’s College of Engineering and founder of SURF. “The goal is to introduce undergraduate students to the concept of graduate and post-graduate research projects and have the opportunity to be mentored by university professors and researchers.”

Students in the summer program come from 19 universities, including Purdue, Michigan, Minnesota, Notre Dame, Alabama A&M, Rutgers, Pennsylvania State, Florida A&M, the Illinois Institute of Technology, and the University of Miami.

“The research I’ve done through this program has given me a new understanding of how research is conducted,” says Rob Anderson, a Purdue student studying rocket propulsion at the Maurice J. Zucrow Laboratories.

“Participating in SURF will help me decide if I want to go into private research or work in the public sector, for an agency like NASA, for example.”

SURF was founded in 2003 through a gift from Purdue alumnus Patrick Wang (BSEE ’72, MSEE ’72), then expanded through the sponsorship of Intel Foundation, the National Science Foundation, DaimlerChrysler Corporation, the College of Engineering’s Office of Research and Entrepreneurship, and departments within the College of Engineering and College of Science. Students in the program receive a $1,000-per-month stipend and attend weekly professional development seminars.

—C.S.

Honoris Causa
Meet these eminent Purdue Engineering alumni, who received honorary doctorates at Purdue’s May 2005 graduation ceremonies.

Robert V. Adams  
BSME ’54  
Chairman, Adams Capital Management

- Spent most of his career with Xerox, pioneering strategy in the fields of electronic printing, desktop publishing, and document management
- A visionary and leader in developing technologies for the Information Age

Ali S. Argon  
BSME ’52  
Professor of Mechanical Engineering, MIT

- Research involves metals, ceramics, glasses, polymers, and composites
- One of the world’s foremost experts in the mechanical behavior of engineering materials
Technology Goes Green

Purdue announces a new Center for the Environment.

On June 30 Purdue announced a new Center for the Environment, a focal point both for those who wish to harness the planet’s resources and for those who wish to preserve them.

The goal, says interim director Bernie Engel, head of Purdue’s agricultural and biological engineering department, is “to replace the traditional notion that environmental stewardship is a cost of doing business with a new paradigm: that protecting environmental integrity is essential to prosperity.”

Purdue has some 200 researchers involved in environmental research. Initial funding of $10 million from the Lilly Endowment will start up the center, along with three others: the Cyber Center, the Oncological Sciences Center, and the Energy Center. All four centers are part of Purdue’s Discovery Park research complex. (See cover story on page 10 for more on the Energy Center.)

Indiana, says Engel, has an opportunity to grow if it embraces changes toward environmental sustainability in the business environment. General Electric, for one, pledged in May to double its environmental research budget to $1.5 billion by 2010 and cut its greenhouse gas emissions 1 percent by 2012.

“Indiana’s economy currently is in a transition period in which our traditional agricultural, manufacturing, and transportation infrastructure is struggling to remain competitive,” Engel says. “Indiana carries many scars from past impacts of industrial and agricultural activities on ecosystems. But the ‘greening’ of Indiana and the transformation of our state economy to a globally competitive, productive, and ecologically sustainable system will require considerable technological innovation. Purdue is uniquely positioned to provide these innovations.”

Center activities will focus on research, entrepreneurship, and engagement involving policy analysis, regulatory guidance, and public education. Students as well can contribute to the center.

“Imagine classically trained ecologists with a clear understanding of the needs of the manufacturing community; imagine civil engineers with the training to address the political and social ramifications of the technologies that they develop. The Center for the Environment is the place where this will all happen,” Engel says.

“Our students will realize the opportunities associated with conducting interdisciplinary environmental research. They will be better and more broadly trained than their contemporaries at other institutions and will become leaders in the emerging areas of inquiry that the center will foster and develop.”

—CHAD BOUTIN

James D. Raisbeck
BSAAE ’61
Founder and CEO, Raisbeck Engineering and Raisbeck Commercial Air Group

- Led Raisbeck Engineering in the design and production of the first supercritical wings to be used in general and commercial aviation
- Led Raisbeck Commercial Air Group in post-9/11 production of armored cockpit security systems for installation in existing commercial airliners

Gordon M. Binder
BSEE ’57
Venture Capitalist, Coastview Capital LLC

- Retired chairman and CEO of biotech powerhouse Amgen Inc.
- Led Amgen in its development of breakthrough drugs for treating anemia, cancer, and other diseases
TechVisionaries
Purdue’s 2005 Distinguished Engineering Alumni.

In its 42nd year, Purdue’s Distinguished Engineering Alumni convocation, held in February, celebrated the accomplishments of seven “TechVisionaries”—individuals who ably combine technological know-how with creative vision. They imagine what others can’t see. They overcome obstacles to their vision. And they make it happen. Here, a look at these remarkable alumni:

Paul Bevilaqua (MSAAE ’68, PhD ’73): As chief engineer of advanced development projects for the Lockheed Martin Skunk Works, Bevilaqua pioneered a truly transformational technology: the lift fan propulsion system used in the Defense Department’s Joint Strike Fighter Program. The technology enabled the success of the first aircraft with both vertical lift and supersonic flight capabilities.

Art Bond (BSEE ’68, MSEE ’69, PhD ’74): This dean of engineering and technology at Alabama A&M University is a nationally recognized leader in engineering education for minorities. In addition to leading the accreditation of Alabama A&M’s engineering program, Bond founded, at Purdue, the country’s first chapter of the Society of Black Engineers, in 1971.

John Bratt (BSME ’65): In Bratt, the founder and CEO of the Indianapolis-based Tenax Corporation, engineering and entrepreneurial expertise have combined to produce success in the manufacturing industry and economic growth for Indiana. Tenax is a parent organization including Dual Machine Corporation and Hoffco/Comet Industries Inc., a manufacturer of power transmission equipment and cabs for off-road vehicles.

Charles Davidson (BSChE ’72): As president, CEO, and chairman of Noble Energy, Davidson has implemented innovative business solutions that dramatically expanded and redefined the role of this major oil-and-gas corporation in the international market.

Warren Hill (BSME ’63): This president and CEO of Hill Mechanical Group has applied his engineering and managerial expertise to ensure his company’s leadership role within the heating-ventilation-and-air-conditioning market. He also holds the distinction of being a literal Boilermaker: Hill Mechanical Group’s activities include the design and construction of large boiler plants.

Cynthia Niekamp (BSIE ’81): As president and general manager of BorgWarner’s TorqTransfer Systems Drivetrain Group, and a vice president of BorgWarner, Niekamp has applied her executive skills and strategic planning expertise to emerge as a leader in the nation’s automotive industry.

Research Group and a distinguished member of the technical staff, Jakowatz has gained renown—including membership in the National Academy of Engineering—through pioneering research in analytical and applied signal processing for sonar and synthetic aperture radar.

—L.H.T.
MILESTONES

Named a historic site: The Purdue University Airport, by the American Institute of Aeronautics and Astronautics. Amelia Earhart left on her last flight from the facility; Neil Armstrong (BSAE ’55) took a class in hangar one.

Ranked: Purdue, as the country’s 10th best graduate engineering institution (April 2005) and 8th best undergraduate engineering institution of those offering doctoral degrees (August 2005), by U.S. News & World Report.

Animated: Images of 3-D clouds for the Disney movie Valiant, thanks to software created by electrical and computer engineering student Joshua Schpok and professor David Ebert.

Appointed: Arden Bement, the David A. Ross Distinguished Professor of Nuclear Engineering, as director of the National Science Foundation. Bernie Engel (right), as head of the Department of Agricultural and Biological Engineering. Sangtae Kim, the Donald W. Fedderson Distinguished Professor of Mechanical Engineering and Distinguished Professor of Chemical Engineering, as director of the National Science Foundation’s Shared Cyberinfrastructure Division. Alexander King, head of the School of Materials Engineering, as a Jefferson Science Fellow (see story on page 24).

Elected: Leah Jamieson, the Ransburg Professor of Electrical and Computer Engineering, as 2006 IEEE president-elect.

Get Online
Stay connected through the Purdue-alumni Web Community. Log in to the new online directory that’s free to members of the Purdue Alumni Association, President’s Council, Chancellor’s Council, John Purdue Club, Varsity P Club, and Purdue University Retirees. Through the online directory you can forward e-mail, update your information online, and search for long-lost classmates and friends by first and last name, student activity, class year, or campus and major. Ready to get connected to your fellow Purdue engineers? Visit www.purdue.edu/alumni

LEE LAMB

VANTAGE POINTS

Inducted: Leah Jamieson, the Ransburg Professor of Electrical and Computer Engineering and the College of Engineering’s associate dean for undergraduate education, and David Landgrebe, professor emeritus of electrical and computer engineering, into the National Academy of Engineering.

Awarded: The National Academy of Engineering’s 2005 Bernard M. Gordon prize, to Ed Coyle (above right), professor of electrical and computer engineering, Leah Jamieson, the Ransburg Professor of Electrical and Computer Engineering and the College of Engineering’s associate dean for undergraduate education, and Bill Oakes, associate professor of engineering education, for “innovations in the education of tomorrow’s engineering leaders by developing and disseminating the Engineering Projects in Community Service program” (EPICS).

—L.H.T.
Albania to Zimbabwe: Purdue Engineers Around the World

Purdue Engineering’s reach is truly global. Our alumni hail from 104 different countries, our students from 94. You could catch up with a Purdue engineer on the beaches of the Cayman Islands, share a coffee in Colombia, or travel to the South China Sea in search of any one of our 203 Malaysian engineering graduates. (Malaysia has the third-highest number of Purdue engineering alums outside the U.S., after India and Taiwan.) As with our international alums, Asia supplies more students than any other region.

—K.S.
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Proportion of International Purdue Engineering Students to All Purdue Engineering Students

- 8,481
- 2,071 (24.4%)

Proportion of International Purdue Engineering Alumni to All Purdue Engineering Alumni

- 71,442
- 3,212 (4.5%)
Nothing concentrates an American’s mind on energy like $3-a-gallon prices at the gas pump. But a half-century ago, when a gallon of gas cost 30 cents and the U.S.—the world’s leading oil producer at the time—was awash in homegrown “black gold,” Shell Oil geophysicist M. King Hubbert had already put his mind to work on the country’s collective energy future.

A modern-day Cassandra, Hubbert published a graph charting the end of America’s oil dominance. The plot, a bell curve now known as “Hubbert’s Peak,” predicted that the rate at which oil could be extracted from the lower 48 states would peak in the early 1970s and decline rapidly after that. The prediction was largely ignored. U.S. oil production in fact peaked in 1970 and has decreased ever since, with depleted reserves expected by this century’s end.

Applying Hubbert’s approach globally, the Association for the Study of Peak Oil and Gas calculates that the world faces a peak rate of oil production around 2007 and a peak rate of natural gas production between 2010 to 2020.

Meanwhile, the Earth’s population is growing. The count by 2050 could reach nine billion people, and developing countries, understandably, want their piece of the prosperity pie.

China, with its booming economy, is now the world’s second largest consumer of energy, accounting for 12 percent of global energy use, and its demand will increase sharply. Other urgent issues—the environment, poverty, international relations, Hurricane Katrina’s aftermath—are inextricably tied to energy.

Indeed, energy, says Lefteri Tsoukalas, Purdue’s head of nuclear engineering, “is the grand unsolved challenge of this civilization.”

Developing renewable energy resources now for the long term is a must. So is developing shorter-term but nonrenewable resources like clean coal.

“The conventional oil, the low-hanging fruit, has been picked,” says Tsoukalas. “We need to have diversity, a basket of energy suppliers.”

How to fill that basket—and with what (solar? hydrogen? nuclear? biofuels?)—are questions that Purdue Engineering is taking up. Each alternative comes with trade-offs, and time is short.

But no matter how the road to our energy future bends, Purdue Engineering intends to be out in front, mapping the way.

Destination: Energy Independence
For decades, engineers at Purdue have pursued energy-related research, whether as a matter of course (as with natural gas engineering, a 1920s-era research interest in the School of Chemical Engineering) or as a result of increasing concern over the environment and our finite supply of hydrocarbons (as with solar).

A signature research area—Renewable Energy and Power Systems—is in place within the College of Engineering, focusing on stationary power, such as power plants, and motive power, which ranges from automobiles to airplanes to spacecraft. Tsoukalas himself leads research on updating the country’s power grid, and chemical engineering faculty members at Purdue’s Center for Catalyst Design have been researching ways to improve a low-polluting energy technology that combusts natural gas more cleanly than conventional methods.

In July, though, Purdue and the College of Engineering reached a milestone when the University announced a new Energy Center. A component of Purdue’s Discovery Park research complex, the center is created from seed money from the Lilly Endowment and will share $85
To ethanol could produce an additional five to 15 billion gallons of the fuel, enough to have a significant effect on the amount of petroleum used in the U.S. Currently accounting for 3 percent of U.S. energy production, bioenergy can provide heat; make fuels, chemicals, and other products; and generate electricity. Although the availability of land for growing biomass is a limiting factor, biofuels like ethanol and biodiesel are the easiest fuels to slot into our existing fuel system.

“The U.S. ethanol fuel industry represents an ongoing success story for the production of renewable fuels, and demand for fuel ethanol is expected to increase,” says Michael Ladisch, distinguished professor of agricultural and biological engineering and the director of Purdue’s Laboratory for Renewable Resource Engineering (LORRE), now attached to the Energy Center. “In addition to ethanol, 40 chemicals and chemical feedstocks have been identified as potential fuel products of renewable plant biomass.”

Through bioengineering, LORRE is helping to turn agricultural waste into transportation fuels. These biofuels include ethanol derived from corn, cellulose, and corn waste, as well as diesel fuel made from soybeans. An ongoing initiative explores how genetically engineered yeast can convert the sugars xylose and glucose into the gasoline substitute ethanol. Research also includes the transformation of biomass, ethanol, and soy-diesel into sources of hydrogen.

“LORRE provides an environment and the leadership to catalyze multidisciplinary research for converting cellulose to sugars, genetically engineering microorganisms that readily transform sugars to fuels, and separating ethanol from water in an energy-efficient, cost-effective manner,” says Ladisch.

### Coming Clean

At the Energy Center’s Coal Transformation Laboratory, the aim will be to make better use of plentiful Indiana coal, which accounts for 3.5 percent of U.S. coal production.

Coal, of course, is abundant, energy-dense—and a key culprit in environmental degradation around the world, not to mention in the Earth’s atmosphere. As the world runs out of oil, we’ll be forced to rely even more heavily on coal than we do now. (Coal supplies more than half the electricity consumed by Americans.) But new technologies hold promise for cleaning up this nonrenewable resource and buying us time to develop reliable renewable energy sources.

“The Coal Transformation Laboratory will develop technology to convert coal into combustible gases and liquids that can be burned away cleanly while meeting the demand for electric power, heating, and transportation,” says Tom Sparrow, professor of industrial engineering and the director of Purdue’s Center for Coal Technology Research.

Indiana, which annually mines more than 35 million tons of coal, is one of several Midwestern states involved in the world’s leading coal-chemical enterprise: the Tennessee/Eastman regional coal chemical complex in eastern Tennessee, says Ron Rardin, a researcher at the coal center and a professor of industrial engineering.

“This complex is an important resource to draw upon as we develop aspects of coal...
transformation technology.”

The U.S. Energy Policy Act of 2005 supports a collaboration among Purdue’s Energy Center, the Southern Illinois University Coal Research Center, and the University of Kentucky Applied Energy Center to develop transportation fuels from the Illinois Coal Basin, including Fischer-Tropsch fuels that powered Germany’s Panzers during World War II.

The Illinois Coal Basin deposits, which extend into Indiana, hold more than 130 billion tons, or 25 percent, of the total coal reserves in the country, enough to meet current U.S. coal demands for more than 100 years.

**Fission and Fusion**

On the nuclear front, researchers at Purdue are focusing on making this energy source safer. Today, nuclear power provides about 20 percent of the nation’s electricity. It may well provide more in the future as the country shifts from its dependence on oil.

Mamoru Ishii, the Walter Zinn Distinguished Professor of Nuclear Engineering and director of the Purdue Institute of Thermal Hydraulics, is developing a computer tool that can help ensure the safety of future nuclear power plants. The tool will help engineers design nuclear plants that have “passive cooling systems,” which require no pumps and will keep running during electrical-power interruptions.

Colleague Karen Vierow, an assistant professor of nuclear engineering, is leading research to improve three computer programs needed to prevent Three Mile Island–like disasters. The complex programs, or “reactor safety codes,” are used to simulate severe accidents and, in the process, provide data needed to ensure that power plants are designed properly.

And in a radical departure from fission-based work, Purdue’s Rusi Taleyarkhan, the Arden L. Bement Professor of Nuclear Engineering, is pursuing sonofusion, or “bubble fusion.” The research has sparked controversy in the academic community but may promise a new source of clean energy (see “Sonofusion: Creating a Star in a Jar,” page 13).

**Other Players: Solar Cells, Electrochemical, Hydrogen...**

And what about Earth’s ultimate source of all energy: the sun? Only about a hundredth of a millionth of a percent of the sun’s energy strikes the Earth, but that tiny fraction supplies, in 60 seconds, enough energy to meet the world’s demands for an entire year.

Purdue Engineering’s solar research focuses on solar cell, or photovoltaic, technology, which converts sunlight directly into electricity. Solar cells, whether arranged singly or in modules or arrays, can provide tiny amounts of power for watches, large amounts for the electric grid, and everything in between.

Current technology provides about 18 percent cell efficiency in laboratory environments (see “Solar Voltaics: At the Tipping Point,” page 17).

“This efficiency drops to 10 percent when the solar cells move into public usage, and a challenge in this research is to find out why this happens and to increase the efficiency of solar cells in different environments,” says Rakesh Agrawal, Purdue’s Winthrop E. Stone Distinguished Professor of Chemical Engineering. “Another challenge is to reduce the size and cost of solar cells.”

At the Energy Center, Purdue researchers will continue solar-cell research and also explore advanced electrochemical methods and hydrogen energy systems that change the way we generate, store, and use energy (see “Mike Ramage and the Road to the Hydrogen Economy,” page 15). On the agenda: solar hydrogen, electrosynthesized materials, photo-bio-electro-chemical hydrogen generations, fermentation of biomass-based hydrogen production, and biofuel cells.

The College of Engineering’s Purdue Hydrogen Economy initiative, for example, is taking up President Bush’s 2003 call to achieve sustainable development through this most plentiful of elements.

In August, Purdue researchers under the direction of chemical engineering head Arvind Varma, the R. Games Slayter Distinguished Professor of Chemical Engineering, announced a new way to produce hydrogen for fuel cells that will extend the charge of wireless electronics—no wall outlet required. (The work received a “Technology of the Year” award from Industry Week magazine.)

**Hubbert Revisited**

So amid this multitude of emerging technologies, what’s in store for us when we reach the bottom of the curve that M. King Hubbert so presciently plotted? No oil, no natural gas—but, if our ingenuity and persistence pay off, we’ll have created the “basket of energy suppliers” to which Purdue’s Lefteri Tsoukalas refers.

Taking that basket from metaphor to reality will require the best efforts and, indeed, breakthrough conceptual insights of researchers from across the College of Engineering and their colleagues on campus and beyond.

Fortunately, more than 40 companies, including Rolls-Royce, Cummins, energy utilities, steel companies, and nuclear reactor designers, have shown interest in working with Purdue’s Energy Center. Momentum’s gaining. The need is urgent. And the payoff in a secure energy future? Immeasurable.

—LISA HUNT TALLY WITH CYNTHIA SEQUIN
Sonofusion: Creating a Star in a Jar

Rusi Taleyarkhan’s research has provoked intense debate in scientific circles. If his experiments in desktop fusion are found scalable, though, sustained fusion as a clean, limitless energy source may be in our future.

Even during the summer session, Rusi Taleyarkhan’s lab is full of activity. Student papers and posters are hung prominently on the walls; students busily work on projects related to nuclear fusion, and Taleyarkhan, the Arden Bement Jr. Professor of Nuclear Engineering, stops to listen to a question or to discuss a problem. Amidst this flurry, on an old office desk sits a small glass jar which just might hold the solution to the world’s energy problems.

The process that takes place within the jar is called sonofusion, and it’s the first successful experiment in desktop thermonuclear fusion. Nuclear fusion is nature’s atomic power.

“The very engines of energy in the universe lie in the stars: extremely high states of pressure and temperature,” says Taleyarkhan. “The ultimate hope of mankind is to be able to get to those conditions in a controlled and sustained fashion and then produce nuclear fusion.”

Yet while traditional fusion reactors require the space of several football fields and billions of dollars in funding, Taleyarkhan’s device, nicknamed “star in a jar,” produces the same effect in a beaker and at a fraction of the cost.

Sonofusion was inspired by Taleyarkhan’s previous work with sonoluminescence, in which the bubbles in a liquid emit light when they are forced to expand and collapse by sound waves. (Light from sound: sonoluminescence.) In sonofusion, this method is intensified by over a million times. The process uses high-energy neutrons to bombard heavy hydrogen in a beaker of acetone, causing tiny bubbles of gas to expand to 100,000 times their normal size. Taleyarkhan explains, “It is like taking a slingshot and stretching the slingshot from Mother Earth all the way to the nearest star and then letting go.” When the bubbles collapse, the heat and pressure are similar to the interior of the sun, causing the deuterium atoms to fuse together, the same way hydrogen atoms fuse in stars, and releasing neutrons, and tritium, in the process.

Despite its limitless potential, sonofusion underwent a trial by fire. When Taleyarkhan and his team first announced sonofusion to the world in 2002, their experiments were met with skepticism. Taleyarkhan’s article was reviewed by over 100 referees, his labs were audited, and his conclusions were rejected as impossible even before the first article appeared. The level of skepticism and the volume of the debunkers would weigh anyone down, but Taleyarkhan took heart in the lessons of history.

“When Sir Isaac Newton first announced that he could split light into seven colors, scientists of the day thought that he was a gone case,” Taleyarkhan explains. It took years for Newton to convince the scientific community that light was composed of colors, but if Newton faced similar skepticism and persevered, Taleyarkhan could too.

“History is comprised of these kinds of things,” he says. “So you take comfort in the fact that temporary setbacks are not to be taken too seriously if you really believe in what you are doing. And now I believe that we can certainly make sustained fusion happen.”

Taleyarkhan’s dedication paid off in 2004, when several developments occurred that helped back up his initial conclusions. With more funding and better equipment, Taleyarkhan and his team released a new article in 2004, which added more evidence to their claim and began to turn the tide of sonofusion’s acceptance. “Whereas previously 90 percent of the readers were skeptics, and 10 percent believers, now it was the other way around,” Taleyarkhan says.

In the last year, nuclear chemists from the University of Illinois at Urbana-Champaign confirmed that conditions inside of the imploding bubbles could reach those as hot as the interior of the sun and were able to detect plasma states, a requisite for fusion. More recently, an independent team of researchers at Purdue was able to reproduce Taleyarkhan’s experiments providing independent confirmation of the same results. Several more institutions are currently working to the same end.

If we could learn to use it, one cubed mile of seawater contains enough heavy hydrogen to create energy for the entire world for centuries. For sonofusion to become a new energy source, however, Taleyarkhan’s team must first get beyond the break-even point so that the energy produced by the process is more than that consumed.

In the meantime, Taleyarkhan is working with the Purdue Research Foundation and other private entities to market the more immediate applications and continues to train teams from all over the world on his techniques. Students at Purdue and even local high schools have been inspired by sonofusion’s potential and develop aspects such as automating the process as well as conjecture how sonofusion could be used to fuel everything from cars to the space shuttle.

Until these become feasible, however, the team continues to work on both the immediate uses and the potential for expanding sonofusion to create a new virtually limitless energy source, making the star within the little jar one of the most important potential energy solutions of the 21st century.

—MICA GOULD
TIMELINE: ENERGY ACROSS THE MILLENNIA

- **c.1,000,000 BCE**
  - Homo erectus learns how to control fire.

- **1000 BCE**
  - The Chinese first use coal for fuel.

- **700 BCE**
  - The Greeks use mirrors to focus sunlight to burn the sails of enemy warships.

- **400 BCE**
  - Oil is used in lamps.

- **100 BCE**
  - Waterwheels are first used in what is now central Turkey.

- **65 BCE**
  - Windmills are first used in Greece.

- **100**
  - Roman historian Pliny the Younger builds the first solar home, using glass to keep heat in and cold out.

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**Mark Engstrom’s summer building a Kansas wind farm helped put a new spin on his view of energy.**

Latham, Kansas. The population of this little town hovers right around 60 people. “I didn’t even think there were towns that small,” jokes construction engineering and management sophomore Mark Engstrom. But Latham is where Engstrom spent the summer of 2005 building a wind farm as an intern for M. A. Mortenson Company.

The massive wind turbines Engstrom helped erect were 80 meters tall (around 230 feet), and the three blades at the top of the tower each extend 127 feet. “Everything is big and heavy!” says Engstrom. The lightest component of the tower: the base tower section, weighing in at 84,000 pounds. This particular wind farm eventually will contain 100 towers, each yielding roughly enough energy to provide 400 to 500 homes with electricity.

During the height of the operation, the site had over 200 people and hundreds of semi-truck loads coming in, and construction occurred in several phases, beginning with preparing the foundations for the towers. Engstrom finds many people are misinformed when it comes to this aspect of wind farms.

“Somebody thought that the foundations go down 30 feet deep, when in reality it is less than 6 feet deep,” he says. “So they might think that putting them in is causing harm to the environment, but really you can use all the land around it. The farmers use the land, and they get paid to have the turbines on the land.”

Before getting to that point, though, engineers scoped out the area, measuring wind speed with an anemometer. “Kansas is pretty flat,” says Engstrom, “and they usually place the towers on a ridge line to catch the most wind possible.” The giant wind turbines can protect themselves against high winds, but an ideal wind speed is less than 25 miles an hour.

Engstrom admits to never having thought much about wind power before his experience at Mortenson. “I would see wind turbines alongside of the road, and I always thought they were cool. I never really thought about wind energy before, though.” Now he looks forward to the possibility of continuing his career and education in wind energy. “I would definitely go back to work on a wind farm. There’s a learning curve, but once you get in that flow, the momentum of the project just carries you through.”

What attracts Engstrom to wind power is its apparent benefits and eco-friendly attributes. “It’s good to know you are reducing the need for fossil fuels, because they’re in limited supply,” he says. “Wind is something that will always be there.”

Wind energy has seen a surge in popularity—worldwide, it’s grown 31 percent annually over the last five years—and the statuesque towers form a striking image on the landscape. Asked what he thinks about the future of this alternative energy source, this young engineer declares, “It’s here to stay.”

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Mark Engstrom, far left, says wind power is here to stay.

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Mark Engstrom, far left, says wind power is here to stay.
As chair of the National Research Council’s committee on the hydrogen economy, this retired ExxonMobil executive and Purdue alumnus articulated for Americans the opportunities and obstacles inherent in a future powered by the universe’s most abundant element.

When he joined Mobil Corporation in the 1970s as a young chemical engineer fresh out of Purdue, Mike Ramage (BSChE ’66, MSChE ’69, PhD ’71) distinguished himself as a petrochemicals innovator. He helped develop the petroleum industry’s first reforming model based on fundamental kinetics and went on to receive ten patents in refining technology and published over 20 papers in the field of catalysis and reaction engineering.

Three decades later, the retired executive vice president of the ExxonMobil Research and Engineering Company—a member of the National Academy of Engineering and a 1996 recipient of a Purdue honorary doctorate—remains a force in energy innovation.

America’s impetus toward a hydrogen economy got a $1.2 billion boost when President Bush announced in his 2003 State of the Union address an initiative to develop, by 2020, the technology for viable hydrogen-powered fuel cells for automotive, home, and commercial use. (Fuel cells combine hydrogen and oxygen to produce electricity. Hydrogen’s primary use as a fuel now is in the U.S. space program.)

Ramage led the National Research Council’s Committee on Alternatives and Strategies for Future Hydrogen Production and Use, which issued a 2004 report—“The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs”—providing recommendations to the U.S. Department of Energy. He also addressed the U.S. House of Representatives’ Committee on Science about the subject.

“DOE leadership is critical to setting up a hydrogen economy for the future. The current DOE program has tried to establish activities in too many areas,” Ramage says. “Also, the program’s odds of success will be greatly increased if DOE partners with a broader range of academic and industrial organizations.”

The study made 46 specific recommendations to the DOE on its hydrogen program, and the department has already implemented over 40 of them.

A transition to hydrogen as a major fuel in the next 50 years could significantly reduce air emissions and expand domestic energy resources, but technical, economic, and infrastructure barriers need to be overcome. In the best-case scenario, the transition would take many decades, and any reductions in oil imports and carbon dioxide emissions are likely to be minor during the next 25 years.

“Our study suggests that while hydrogen is a potential long-term energy approach for the nation, the government should keep a balanced portfolio of research and development efforts to enhance U.S. energy efficiency and develop alternative energy sources,” Ramage says.

Hydrogen can be produced using fossil fuels such as natural gas and coal; renewable energy sources such as wind, organic matter, and sun; or nuclear energy. Currently hydrogen is produced in large quantities at reasonable cost for industrial purposes by breaking down natural gas into hydrogen and carbon dioxide. But to achieve widespread use of hydrogen, especially as a fuel for automobiles, it must be produced cost-effectively either in large plants or in smaller facilities at or near vehicle fueling stations. If the hydrogen is produced in large plants, infrastructure must be put in place to distribute it to fueling stations. And hydrogen storage technologies must be developed for vehicles that will give consumers the range between refuelings that they expect.

“We are facing a ‘chicken and egg’ problem that will be difficult to overcome,” says Ramage. “Who will invest in the manufacture of fuel cell vehicles if there’s no widespread hydrogen supply? At the same time, who will invest in facilities to produce hydrogen if there aren’t enough fuel cell vehicles to create sufficient income for the hydrogen producers?”

—L.H.T
can our national energy policy move us beyond fossil fuels?

A reaction to the Energy Policy Act of 2005 by the head of Purdue’s School of Nuclear Engineering.

For the first time in more than a decade, the U.S. has a national energy policy. Signed into law by President Bush on August 8, 2005, the Energy Policy Act provides the framework for a comprehensive energy strategy designed, in the President’s own words, “to offer more affordable and reliable sources of energy in order to make sure that our economy continues to grow.”

Trying to read through the bill’s more than 1,700 pages, one eventually becomes dissatisfied with its vastness and the sheer number of particulars such as “Naval Petroleum Reserves,” “Intermittent Escalator Studies,” and “Orphaned, Abandoned, or Idle Wells in Federal Lands.” Understandably, the bill was greeted with both criticism and enthusiasm. Nevertheless, there is a hint that solutions are sought not for particulars alone but for what underlies them as a whole: chronic underinvestment bordering on neglect in the national energy infrastructure and the environmental and geological limitations of hydrocarbons.

Energy is the bloodline of modern civilization and energy growth a sine qua non for economic growth. In recent decades, innovations in information technology and financial engineering have given rise to complex, liberalized, and deregulated markets which are allocating energy resources via price while hedging or laying off financial risks. But while the markets have proved successful in resource allocation, they are less capable of directing capital to infrastructural investments and addressing long-term structural risks.

Investment risk coupled with a byzantine environmental regime has impeded the development of new refineries in the U.S. since the 1970s. In fact, their numbers declined from over 300 to under 150 while the U.S. population grew by nearly 50 million over this period. Currently, even though American refineries are close to 100 percent capacity, we still have to import growing quantities of refined products. As a result of chronic infrastructural underinvestment, safety margins in many important energy capacities have been diminished. Any perturbation in the system, whether an Ivan- or Katrina-like hurricane or the threat of terrorism, can lead to disruptive price volatility and, even worse, shortages. In recent years we have seen a growing number of dangerous situations and close calls, including blackouts, escalating gas prices, and swelling costs for natural gas and heating oil.

The world today is characterized by an unusual, perhaps unprecedented, combination of energy challenges and risks, both domestic and global. Whatever the relevance of peak oil and global warming in the energy discourse, it remains that they both represent the perception of significant structural risks associated with limits to growth. Although never explicitly mentioned in the text, the Energy Policy Act of 2005 does much to put in place economically doable and technologically feasible mitigation strategies for both.

The plethora of incentives, tax credits, and programmatic actions include, but are not limited to, new ethanol production to stretch transportation fuels; new nuclear power stations to shift electric output to emissions-free non-fossil fuel generation; and conservation measures affecting energy consumption without the kind of demand destruction that risks economic decline.

The price tag for all this is over $14.5 billion. If implemented well, the energy act will impact the energy landscape of the country and maybe even prepare the world to address the inescapable environmental and geological limitations of fossil fuels.

—LEFTERI TSOUKALAS
All of our energy supplies—whether fossil fuels or hydroelectric renewables such as biomass and wind—trace their origins to the star at the center of our planetary system. And how prolific is our star when it comes to energy? In a two-hour period, the energy of the sun’s light shining on the earth’s land surfaces alone matches what the world’s current population consumes in an entire year. The electrical power amounts to about 14 terawatts (14 trillion watts).

Just over 30 years ago, three scientists at Bell Labs captured a sliver of that energy by producing a 6 percent-efficient crystalline-silicon solar cell. That was the origin of the 1.2 gigawatts of photovoltaic (PV) modules—composed of more than 800 million cells having an area of more than 2.5 billion centimeters squared—that sold around the world this last year alone.

PV cells, which produce electricity when exposed to light and find common use in watches, calculators, and some generators, are at a tipping point for world market penetrations, depending critically on policy investments as well as on several research-and-development tipping points that will determine technology directions and success.
The “here and near” technologies: Crystalline silicon, a first-generation technology, accounts for 93 percent to 95 percent of current PV sales in what is a $12 billion industry worldwide. But long-term economic requirements can’t be met by current crystalline-silicon approaches; better materials use is needed without sacrificing performance. Second-generation approaches, mainly thin-film technologies, involve compound semiconductors, most notably cadmium telluride and copper indium gallium diselenide. These technologies require continued applied R&D to further improve module performances to the 15 percent-efficiency level.

The next generations: Third-generation approaches, which are in research labs now, are evolving the devices—the upstarts and wild ideas lined up in a marathon struggle—that will enable the terawatt production needed 20 to 50 years from now.

- Multiple-junction II-V-based devices have displaced silicon in outer space and reached 39 percent efficiency in terrestrial concentrator PV applications.
- Others, like the much vaunted nanotechnology “quantum dot” solar cells, have yet to produce current and voltage but do hold impressive promise.

In a two-hour period, the energy of the sun’s light shining on the earth’s land surfaces alone matches what the world’s current population consumes in an entire year.

- Biomimetics (mimicking nature’s use of chlorophyll) underlies the first nanotechnology approaches to evolve ultra-low-cost technologies. A prime example is the dye-sensitized solar cell developed in the early 1990s. Such cells have reached 11% efficiency, but more work is required.
- Organic PV cells have reached efficiencies between 3 percent and 5 percent, and R&D has combined pure organics with inorganic quantum dots, rods, pods, and nanotubes to improve performance. Unrolling solar cells in a form something like Saran Wrap remains the dream.
- Multiple-junction solar cells: Some varieties are approaching efficiencies as high as 40 percent. The concept is to “tune” each junction to a different portion of the solar spectrum (the top cell to blue, the middle to the yellow-green, and the bottom to the red) to increase conversion efficiencies.

Making it happen: Currently, PV embodies a complex network of codependent and intimately related tipping points. First, although it is a real business, it needs the support of government policy as well as growth in consumer awareness to take it to the next levels. Such pushes will be necessary to make PV spread like wildfire, beyond the successful bonfires that have been lit in Germany, Japan, and California. Second, PV has to tip to its next stages of technology development. Here the need is for R&D to improve the current and near-term technologies and to develop the next-generation technologies that will fuel the wildfire of business and deployment. PV has the potential to grow 50-fold or more. However, we need to provide the technical expertise, the resources, the creativity, and the will to see photovoltaic gain prominence as a vital part of our clean-energy future.

—LAWRENCE KAZMERSKI
Sixty Years Later

Lyle Albright remembers the Manhattan Project.

Sixty years after the bombs fell on Hiroshima and Nagasaki, Lyle Albright, professor emeritus of chemical engineering at Purdue, still remembers his work on the Manhattan Project and the events surrounding those few short weeks in the summer of 1945 that brought about the end of World War II.

Shortly after graduating with his master’s degree in 1944, Albright went to work at the Hanford Engineering Works located near Richland, Washington, the plant that created the plutonium that would be used in both the test bomb and the Nagasaki bomb. Information regarding the project was given strictly on a need-to-know basis.

“We were told only what we needed to know for our job, nothing more,” Albright says. Since the beginning of his work at Hanford, Albright knew he was dealing with atomic power: “I thought initially that it would probably go to fuel boats or planes or tanks.” In the fall of 1944, however, Albright was promoted to the Health Physics Group, which was assigned to protect personnel from radiation, and at this point he was informed about the main objective of the Manhattan Project: the atom bomb.

Until July 1945, when the test bomb was exploded in New Mexico, no one knew what kind of power an atomic bomb would have. “They didn’t even know it was going to work,” Albright explains. “It had never been tested. When they were working in the New Mexico desert, some thought it would be bigger than the bombs they had already been dropping on Germany and Japan, but this was many, many times bigger.” According to an inconspicuous article in the local newspaper, the explosion was caused by an ammunition dump catching fire. Although by this time Albright had been admitted into a classified loop, he, like his co-workers, had no reason to question the report.

Albright still remembers the day that he found out how powerful the bomb really was from a special edition of the Spokane Daily Chronicle, which was released after the Hiroshima bombing on August 6, 1945. “We never read the Spokane paper. They never sent us any, but we got a special edition,” says Albright as he pulls from his files a yellowed, crumpled copy of the paper with the shocking headline: SECRET OF HANFORD REVEALED AS ATOMIC BOMB RIPS JAPAN.

There was no need to wait for news of the Nagasaki bomb, however. The shock waves from the Hiroshima bomb had been great enough that a seismograph in Hanford had picked up the tremors. “Three nights later, as I was getting on the bus, the plant manager tapped me on the shoulder and said that we had got the same seismographic indication that we had gotten out of the Hiroshima bomb,” says Albright, “and I knew what it was.”

Although saddened to this day by the destruction and loss of life that occurred that summer in 1945, Albright knows that there were benefits to the research as well. “I believe President Truman handled the situation well,” writes Albright in his memoirs. “Without the two bombs, we would almost certainly have needed to invade Japan.”

The Manhattan Project advanced peacetime energy efforts as well, and within a decade after the war, America opened its first nuclear power plant. Today, of course, nuclear power fuels some of the Navy vessels that Albright first suspected the Manhattan Project was working toward developing. In addition, recent evidence shows that the atomic bombs used in World War II helped to keep the Cold War from becoming a hot one.

“I like to rationalize,” Albright says, “that as bad as the bomb was—and I’ll admit that I’ve had thoughts on it—with as many people as we killed, probably it saved a lot of American and Japanese lives, and it ended the war almost immediately. That’s how I like to think about it.”

—MICA GOULD
Engineering a Safer Indiana

A conversation with Purdue alumnus Eric Dietz, director of the state’s Department of Homeland Security.

In March 2005, Indiana governor Mitch Daniels named Eric Dietz (PhD ’94, Chemical Engineering) the first director of the state’s Department of Homeland Security. It’s the country’s first such comprehensive department at the state level, combining planning, training and exercise, emergency response, and fire and building safety. Before assuming his position, Dietz was managing director of the Purdue Homeland Security Institute (see box on facing page). A retired lieutenant colonel in the U.S. Army, he oversaw a number of technology-oriented projects while serving in the military, including chemical demilitarization and the development of decision-making software, military power sources, and detection programs for weapons of mass destruction.

What lessons can we learn from Hurricane Katrina?
Hurricane Katrina teaches us that the notion of teamwork to coordinate response with unity is of utmost importance. In addition to teamwork, we also see the need to make effective and timely decisions. Indiana’s concept for functional reorganization—planning, training and exercise, emergency response, and fire and building safety—is the right method for approaching these issues. Katrina shows us just how valuable and essential the emergency management discipline is to homeland security. Without rapid, effective emergency response in a disaster, we could find the entire social fiber of our country starting to crumble.

What’s Indiana’s highest-risk terrorist target?
I’m not sure I’d give you that list if I had it, but certainly when you look across the state, the population densities are important. Indianapolis is important, Fort Wayne as the second-biggest city is important, “the region” in the Chicago area—those are Indiana’s big population centers. We’ve also got the Newport plant. [The Newport Chemical Depot stockpiles VX nerve agent, one of the deadliest chemicals known.] It’s the Army’s responsibility to maintain security there, and we work with the Army and the counties that surround the plant to make sure that it’s as safe as it can be.

What role can engineering play in homeland security?
Engineering is basically a systems analysis kind of field. We’re trying to make sure
that homeland security is looked at as a system—it’s built into the system, so it’s not necessarily a layer added after you design a plant or city or fire system. That’s the only way we’re really going to be able to afford public safety, not as a layer of extra cost and extra bureaucracy. A broad group of folks across the College of Engineering at Purdue—Joe Pekny in chemical engineering, Jay Gore in mechanical engineering, and many more—do systems engineering.

**What’s been your involvement in planning for disasters?**

I’ve participated in the Purdue Homeland Security Institute’s “Measured Response” simulation exercise, last year as staff and this summer as an external participant. In the scenario for this summer’s exercise, a dirty-bomb explosion, a chemical gas blast, and a contamination of the food supply hit at three locations around the state. The Measured Response modeling work allows us to look at how society would react. For instance, in the case of a bio-event, people inherently find a way around a quarantine.

We’ve also been involved with our counties and 10 Homeland Security Districts in planning for 15 scenarios that the U.S. Department of Homeland Security has determined that states need to be able to address. Several of those scenarios are nuclear-related: anything from the brilliant white flash to the dirty bomb. Indiana doesn’t have commercial nuclear reactors, but there’s one place where we do have some radiological material, and that’s at Purdue’s nuclear reactor. Purdue’s nuclear program is both an asset—because you’ve got people who know how to respond—but it’s also a risk, even with the wonderful security precautions there.

So we’ve contributed to a consolidated risk plan for Indiana’s District 4, the area including Tippecanoe County and Purdue. We factored in the special hazardous-materials risks that come with the university and also the capabilities—the airport, fire department, radiological monitoring folks, and the technical experts who could help out in an emergency on campus or around the area.

**What WMD experience did you have in the 1990 Gulf War?**

When the war started, I was stationed at the Aberdeen Proving Grounds in Maryland, working in an R&D lab where we were building a chemical-detection vehicle that was designed to find weapons of mass destruction that were used on the battlefield. The typical acquisition cycle at that time was 10 to 15 years. We had been working on this thing about four years when Saddam invaded Kuwait. That vehicle became one of the most important things to get over there, because we knew Saddam had chemicals, we didn’t think he had nuclear, we thought he might have biological. This was the closest thing to a system that we had to get into the field.

I deployed to Saudi Arabia with that vehicle. Fortunately, it was already being used in large numbers in the German army, so what we did was we pulled them from the German army, put U.S. radios and machine guns on them, trained our troops, and sent them to Iraq. Because of the short time frame, we didn’t have a chance to train the folks to maintain them. I went to manage a maintenance contract and hired contractors to maintain these things. Fortunately, we didn’t need the vehicles. There were not any widespread detections of chemicals on the battlefield.

**When you think about Indiana’s safety and preparedness, what keeps you up at night?**

The evil’s out there, and we’ve got to figure out how we’re going to protect the public from it. If an event happens, we’ll all come together and do the right thing, but before an event, we need to come together and prove that we’re ready and that we’re trained to work together. That’s the biggest challenge that I’ve got.

—L.H.T.

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**Purdue Homeland Security Institute: Engineering’s Contribution**

Researchers from Purdue’s School of Aeronautics and Astronautics are working with the U.S. Air Force to develop the aerodynamic design and control system for a new high-altitude airship. The helium-filled craft will be designed to hover in the same location at altitudes above 65,000 feet for up to a year at a time for applications including surveillance and homeland security.

Part of the university’s Discovery Park research complex, the Purdue Homeland Security Institute draws experts from across campus (some 45 from the College of Engineering alone) to work on biosecurity, sensor technologies, infrastructure security, economic security, cyber security, power-grid security, and food and plant security, as well as the annual Measured Response simulation exercise. Purdue Engineering-related research includes projects on neural networks, fuel cell systems, and simulations of grid systems and high-altitude airships.
In two museum exhibits, Purdue takes engineering on the road and plants it smack-dab in front of kids (and other naturally curious humans).

Rube Goldberg Machine
It’s corny. It’s complicated. And it’s a real-live entry from Purdue’s annual Rube Goldberg Machine Contest, a paean to the cartoonist whose screwball drawings depicted convoluted machinery performing mundane tasks. The job at hand? Cast a ballot at “Rube’s County Fair” for best-in-show farm animal. Purdue’s chapter of the Society of Professional Engineers inflated that ballot-casting assignment into 60 twisted steps, listed below. You can see the machine in action for yourself at the Muncie Children’s Museum, where it’s on permanent display.

Casting your ballot in 60 steps
1) Pull down the voting arm to start the machine. 2) Voting arm pulls metal pin. 3) Pin releases spring-loaded scissors. 4) Scissors cut County Fair ticket. 5) Ticket allows weight to fall. 6) Weight compresses syringe, juicing lemon. 7) Lemonade fills cup, extending second syringe. 8) Second syringe pushes billiard ball “lemon” out of cup and onto roller coaster. 9) Billiard ball turns on hand mixer. 10) Hand mixer winds rope. 11) Rope pulls roller coaster car to top of machine. 12) Car releases billiard ball to travel down roller coaster track. 13) Billiard ball hits swiveling arm ballast stand. 14) Swiveling arm releases hot air balloon. 15) Balloon rises, settling into cowboy hat. 16) Cowboy hat tilts, allowing ping pong ball to roll around brim. 17) Ping pong ball falls into CD tower. 18) Ping pong ball falls through CD tower, triggering mousetrap on main stage. 19) Mousetrap throws green flag. 20) Flag hits cable in front of tractor, starting tractor pull. 21) Cable pulls pin from trap door. 22) Trap door releases weight.
23) Weight falls, pulling tractor up hill and allowing ball bearing to fall. 24) Ball bearing rolls down tube into tractor. 25) Tractor rolls down hill, dropping ball bearing into funnel. 26) Ball bearing rolls down horizontal track into second funnel. 27) Ball rolls down second horizontal track into bowl. 28) Bowl falls, pulling pin. 29) Pin releases frog-flipping catapult. 30) Catapult launches flying frog across machine. 31) Flying frog lands on lily pad, scarifying hopping frog. 32) Hopping frog jumps off second lily pad, hopping down ramp. 33) Hopping frog hits ear of corn. 34) Ear of corn rotates in hand, releasing thumb. 35) Thumb flips quarter across machine. 36) Quarter lands in token booth. 37) Quarter is exchanged for token. 38) Token rolls down track toward Ferris wheel. 39) Token falls off track, landing in light socket. 40) Token completes circuit, activating Ferris wheel. 41) Ferris wheel spins, dropping ball bearing. 42) Ball bearing rolls down two tracks and across xylophone. 43) Ball bearing trips switch, releasing Purdue hammer. 44) Hammer falls, hitting red “macho man” target. 45) Red target opens water valve. 46) Red water fills “macho man” strength meter, lifting ping pong balls. 47) Ping pong balls tilt red track. 48) Log floats down water slide, landing in duck pond. 49) Log triggers launch of air cannon. 50) Air cannon projectile hits furry creature. 51) Furry creature topples over, pulling pin. 52) Pin releases spring-loaded dowel rod. 53) Spring-loaded dowel rod releases CD jewel case. 54) Jewel case releases selected animal candidate into little red wagon. 55) Animal hits pin, releasing wagon. 56) Wagon slides down rails, stamping the ballot. 57) Wagon hits board, spinning large pulley. 58) Large pulley tugs on wire. 59) Wire opens clipboard. 60) Ballot slides out of clipboard into ballot box.
Nanotechnology: The Science of Making Things Smaller

How do you explore the nanoscale, where the building blocks for new inventions—atoms and molecules—occupy only a few billionths of a meter? By using a scanning probe microscope (SPM), the “eyes” and “fingers” for measuring and manipulating such tiny, tiny objects. With support from Purdue’s College of Science and College of Engineering, the NASA Institute for Nanoelectronics and Computing, and the NSF Network for Computational Nanotechnology, a team of Purdue EPICS (Engineering Projects in Community Service) students used Legos to create a functioning model of an SPM. It’s the centerpiece of a nanotechnology exhibit that also features hands-on workbenches and video animations. The Children’s Museum of Oak Ridge (Tennessee) hosted the exhibit in April and May.
Washington, D.C., is supposed to be quiet in August, with Congress in recess and the president vacationing in Crawford, Texas, but since the business of government never really stops and it is still a big city, anyway, it is very busy by comparison with West Lafayette, Indiana. It is also hot, which is why the elected officials and their staffs leave town at this time of year. The heat index was over 105 when I arrived.

I am at the start of a year as a Jefferson Science Fellow, working in the State Department. The Jefferson Science Fellowship program is a collaborative venture created a year ago by George Atkinson, the science advisor to the secretary of state, in collaboration with the National Academies, the Carnegie Corporation, and the MacArthur Foundation. The main goal of the program is given in the words of Thomas Jefferson himself: to articulate “accurate science for statecraft” to policymakers.

There are five Jefferson Science Fellows each year; this is the second year of a three-year pilot program. If the first three groups of fellows can demonstrate some impact on international affairs and foreign policy, fulfilling the vision of the program’s creators, then the financial backers will consider extending it or perhaps modifying it to provide greater impact.

So, given that there is a little pressure to perform, what will I be doing, exactly?

The State Department is organized, broadly, into “functional” units (with responsibility for matters like international trade, economics, the environment, arms control, etc.) and “regional” units, which have responsibility for African Affairs, European & Eurasian Affairs, etc.

I persuaded the Bureau of African Affairs to allow me to spend the year seeking and developing new avenues for science and technology cooperation between the U.S. and Africa. Back in 2002 I visited Senegal, where the African Materials Research Society was being launched, and I was impressed with the possibilities that the continent has, and also the problems that it faces in realizing them. As the State Department’s only science fellow in the Africa Bureau, I have to cover a wide range of topics on a day-by-day basis, but materials scientists are well trained to interact with almost all types of science and engineering, and I will make use of the breadth of that experience more than the depth of my expertise in materials. Africa is rich in materials resources but also faces issues across a very wide spectrum of scientific specialties.

There will be some travel, which I always enjoy. And there will probably not be a great deal of contact with Condoleezza Rice. After the reception at which she introduced this year’s fellows, a staffer indicated that we might only see her “tail-lights and wing-lights” for the remainder of the year. She has been described as the rock star of the Bush administration, and indeed, the day after our reception, she met in the same room with Bono, of the Irish rock band U2. The pictures from that meeting were posted to the State Department Web site within hours. A single photo of the Jefferson Fellows reception took several weeks to appear, so there remains some work to do in raising the profile of science and technology within the administration.

For now, I feel like a freshman starting college for the first time all over again. I hope that this Purdue engineer has a lot to contribute, and I am sure that I will have a lot to learn. With a little luck, I will bring some useful new skills, knowledge, and contacts back to Purdue when I return in Fall 2006.

—ALEX KING
Weldon School Venture—Giving Back and Paying Forward

For two entrepreneurs, contributing to Purdue’s School of Biomedical Engineering may be the most satisfying investment yet.

Norman and Thomas Weldon are medical-device masterminds, specialists in taking start-up companies from nifty invention to market sensation. Combined, they’ve launched more than 13 medical-device companies with products ranging from diagnostic catheters to noninvasive cures for depression. They’re the quintessential entrepreneurs.

And in that spirit, father and son—along with their family Weldon Foundation—stepped forward to boost the biomedical engineering (BME) school at Purdue University with a $10 million gift to The Campaign for Purdue. Their generosity led to a new name for BME—the Weldon School of Biomedical Engineering—and to BME’s status as the first named school within the College of Engineering. In many ways, the school is like the start-up companies the two venture capitalists assist.

“The school has just been named, it’s starting as a formal program, and it’s like any early-stage business: you’re trying to get recognized and build that brand,” says Tom (BSIE ’77).

Today’s formal program traces its origins to Purdue’s Biomedical Engineering Center, created in 1972.

Norm, then president of CTS Microelectronics in West Lafayette—and an associate of then engineering dean John Hancock—advised on establishing the biomedical engineering niche and recruiting Les Geddes from Baylor University. Geddes, the Showalter Distinguished Professor Emeritus of Biomedical Engineering at Purdue and an active presence on campus to this day, led research into automatic implantable defibrillators that put Purdue on the biomedical engineering map.

“The initial decision to bring Les Geddes on board enabled Purdue to establish a world reputation,” says Norm (BS ’56, Agriculture; MS ’62, Management; PhD ’64 Economics). “I think the reputation he established will increase along with the scope of the work that’s being done.”

Norm’s admiration for Geddes was part of his motivation to give to Purdue. For Tom, it was his admiration for Norm. “I was interested in doing something to honor my father,” says Tom. “He’s been involved with the university for a long time and in the industry for about 40 years. We’ve both made meaningful money in the medical-device business, and doing something to help biomedical engineering seemed extremely relevant to us.”

Seeing results from their investment in Purdue is relevant as well. “We’re hopeful that we’ll be able to help develop this into a school that not only has the quality Les brought to the program, but one that can turn out enough students with the capability to succeed in the industry,” Norm says.

Those students are on their way. Audrey Djibo, a junior in biomedical engineering from the Ivory Coast, is in the first class that will graduate from the Weldon School. “I’m really grateful for this gift,” she says. “It will help the quality of the program and the classes offered and, by that, it will attract more students.”

Nurturing innovation, enabling possibilities, improving lives—these satisfactions drive the Weldons both in business and as philanthropists. And by their lights, there couldn’t be a better reward.

—AMY PAGE CHRISTIANSEN
In September NASA announced its next choice for space exploration vehicles: a four-seat astronaut capsule and a heavy-lift, cargo-carrying system based on shuttle technology. That plan is launching a discussion of the vehicle’s merits, with these Boilermakers weighing in.

Steve Schneider

- Purdue professor of aeronautics and astronautics
- Served on a team providing technical assistance to NASA during the August 2005 Discovery flight to determine if the shuttle’s gap fillers should be removed before returning to Earth.

**Answer: Design minimizes new technology, but makes good sense.**

“The new vehicle must separate crew from cargo, so it can be much smaller, as much as 10 times smaller, because we only need to carry a half-dozen astronauts instead of astronauts plus 50,000 pounds of cargo. And NASA is proposing a smaller crew vehicle, a capsule.

“That poses some challenges, because a capsule has minimal lift. This gives less control over the trajectory and higher g-loads in reentry, and less flexibility in adjusting to weather, errors in the incoming orbit, and other off-design conditions. NASA is proposing land recovery, as with the Soyuz, since sending a fleet to recover it after splashdown would be expensive.

“Although a lifting body like the X-38 would give greater flexibility in trajectory design, the capsule is easier to integrate with a launch-escape rocket, easier to scale to moon and Mars entries, even simpler to develop, and makes it easier to protect the heat-shield from micro-meteor impacts in space. It’s sensible.

“I’ve worked on one aspect of reentry, so I’m not an expert on the overall system. This design appears to be a reasonable way to access the space station, the moon, and Mars at the lowest development cost. However, many of us are increasingly concerned that NASA is becoming an agency for space science and human space flight, while minimizing or abandoning its historical role in the development of new aerospace technology. We will watch closely to see how the new agenda is implemented.

“It is important to the United States to maintain a leading position in aerospace technology, and this requires research and development funding for new technologies and systems. It’s very important that this be done well. We would be better off to have no access to the space station or to go up on Russian craft than to rush into it and end up with another space shuttle. We need to be efficient and not get too arrogant.”
**Guy Gardner**  
Director of Super Project Development for Purdue’s Discovery Park  
NASA astronaut from 1980 to 1991; flew on shuttle missions in 1988 and 1990  
MSAAE ’70

**Answer: A larger capsule, multi-part vehicle or one large vehicle would work.**

“We need a vehicle whose primary purpose is transporting people to and from lower Earth orbit, with the capability that it could take them beyond lower Earth orbit and back to the moon. We also need to separately launch large cargo into lower Earth orbit and beyond.

“The space shuttle was a nice idea, but it turned out not to be the most efficient or effective way to colonize space.

“I don’t know what a new vehicle should look like or be like. NASA is proposing a larger version of the capsules from the older days in the U.S. and current days in Russia, so it could carry more people and supplies. When we went to the moon, we had a capsule and service module.

“A multipart vehicle or one larger vehicle might work, too. Those are design tradeoffs that need to be made.

**Michael Moses**  
Flight Director, NASA Johnson Space Center  
BS ’89 (Physics), MSAAE ’95

**Answer: An Apollo-style capsule for crew and lifter for cargo are the right choices.**

“The shuttle has served in its designed role extremely well over the years, but we will need new launch vehicles and spacecraft to execute the vision for space exploration: return to the moon and press on to Mars.

“The next design should include both a crew launch vehicle and a heavy lift launcher, because the design requirements for each function are not the same. The analogy would be that you don’t need to use 18-wheelers to drive to work, and you don’t want to haul freight in the family sedan.

“Basing the technology on existing shuttle hardware makes a lot of sense because you can build on the years of operational experience you already have, as well as take advantage of some of the existing launch and support infrastructure.

“The crew vehicle should be like the Apollo-style capsule, the simpler the better.

“I’m in strong favor of continuing on with human exploration. I also think NASA shouldn’t be the only one taking humans into space from the U.S. I’m a big proponent of private ventures. I think there’s a future for commercial endeavors, for lower Earth orbit travel as tourism and for private research.

“NASA’s role is to go beyond that, to the moon and Mars or wherever, and expand the horizons of where people can travel.”

—KATHY MAYER

**What do you think about NASA’s plan?**
Write to us at peimpact@purdue.edu