THE FUTURE OF NUCLEAR POWER?

PLANNING FOR FAILURE: INNOVATIONS IN SAFETY

100TH ANNIVERSARY OF CHEMICAL ENGINEERING
Dean's Message

The 2011-12 academic year is in full swing at Purdue, and the College of Engineering is busier than it ever has been. The stories in this edition of Impact remind us that so much of what keeps us busy makes a profound impact outside Purdue, around the world, and even beyond our own planet.

In March, when a massive earthquake and tsunami hit Japan, Purdue engineers provided analysis and understanding amid catastrophe and chaos. As you'll read in the cover story, their expertise and ongoing work also will inform future natural-disaster safety strategies.

Safety is a constant concern for Purdue civil engineers whose work creating sound, long-lasting buildings and roads is relied on around the world. This edition of Impact gives you a glimpse into the large-scale research they are doing in Purdue's state-of-the-art Bowen Lab.

Now that we have bid good-bye to NASA's space shuttle program, you can read about how Purdue engineers are helping to guide the move away from NASA's Constellation program by shaping future deep-space research.

I hope that you enjoy reading this edition of Impact. I am always delighted to have the opportunity to share with you a small sample of the exciting, vital work we are doing, and give you a periodic reminder of just a few of the ways that your Purdue College of Engineering continues to make a great impact throughout our world.

LEAH H. JAMIESON
The John A. Edwardson Dean of Engineering
Ransburg Distinguished Professor of Electrical and Computer Engineering
The story about student David Reese and his passion for propulsion is really cool stuff. Great to hear Purdue is leading the field. It makes me want to go back to Purdue and do another Ph.D.

SAM FINEBERG

Bravo (on the Purdue/Colombia partnership)! As a Purdue alumna and as a Colombian, I could not be more excited about the possibilities.

GLORIA VELEZ

What a joy (to hear of the Purdue/Colombia partnership)! I hope to see more collaborations of this kind between Purdue and other Latin American countries.

MARGARITA VLADIMIROVNA

The story about the Purdue/Colombia partnership is fantastic! This is what Purdue’s global mission is all about — developing students and relationships with international partners that benefit mankind and enhance the university’s pedigree and its educational outreach.

Bravissimo!

AL GRATHWOL
Purdue engineers weigh in on lessons learned and what’s next for the industry following the power plant failures in Japan.

BY WILLIAM MENNERS

No news is almost always good news in the world of nuclear power. When word quickly spread in March of the radioactive leak at the Fukushima Daiichi plant following the massive earthquake and tsunami in Japan, the reports both shook the industry and were often in need of expert clarification. Several Purdue engineers continue to help bring about that clarity on one of the world’s most misunderstood industries.

With more than 15,000 reported dead in Japan (mostly from drowning and entire villages wiped out), the nuclear power plants stood up exceedingly well, says Ahmed Hassanein, the Paul L. Wattelet Professor and Head of Nuclear Engineering (see Q&A on page 11). He says there are lessons to be learned from the Japan safety setback at the plants in Japan, though there are no realistic implications to shrinking nuclear power in the United States, which currently provides 20 percent of the nation’s electricity.
WHAT WENT WRONG
Jere Jenkins, director of Purdue’s radiation lab, found himself in the media spotlight talking about the “Fukushima 50” — actually a group of 200 people working in shifts of 50 — trying to maintain water levels in the damaged reactor cores. Jenkins told Chris Matthews of MSNBC’s “Hardball” that the workers were not in as much danger as had been previously reported.

As workers in what is perhaps the most regulated industry in the world, even the Fukushima 50 would have been closely monitored for their daily allotment of radiation doses, Jenkins says. “Radiation has this mystique that any amount of exposure will harm or kill you, but if you spread the doses out and keep them as low as reasonably achievable there’s no concentrated danger.”

Safety remains the utmost priority of an energy business whose history began with the atomic bombs dropped on Nagasaki and Hiroshima, Jenkins says. “Every time there’s an accident it’s good for us to take a step back and see if we’re doing everything to be as safe as possible.”

Audeen Fentiman, professor of nuclear engineering and associate dean of graduate education and interdisciplinary programs, believes the nuclear power plants in the United States might just hold up better. Even so, she says, very few places in the world are likely to have the same earthquake and tsunami events that occurred in Japan. “After the events of 9/11, comprehensive studies were done for all nuclear power plants in the U.S. and additional protective measures were put in place to deal with extremely severe scenarios,” she says. “All of our plants looked at scenarios with loss of off-site power.”

At what Price Progress
It has long been said that Mother Nature always has the biggest hammer. Meta Sozen references the phrase: We live at the pleasure of geology. And Sozen, the Kettleshult Distinguished Professor of Structural Engineering, has seen the devastating effects of geology throughout his career. He is one of the foremost earthquake specialists in world, having been named one of the top seismic engineers of the 20th century.

But how do you plan for the catastrophic? And at what point should worry supersede progress? “Planning is not my strong suit, but I see no reason to stop progress for that reason,” Sozen says. “The wise thing to do is consider multiple options in defense. For example, as in Fukushima, it is too much of a risk to rely on a single source of power, however well it is defended.”

Sozen says he witnessed the absolute worst damage from a 1999 quake in his homeland of Turkey, but a 1972 disaster in Managua, Nicaragua, left a more chilling impression on him. With perhaps the worst of the worst in mind, Sozen proposed building an alternative city for Istanbul, whose domed architecture resides along the North Anatolian fault line. The satellite city, some 20 kilometers outside Istanbul, would transfer the city’s core components — economic, social and educational — to a safe haven.

Makarand Hastak, head of the Division of Construction Engineering and Management (CEM), attended a United Nations’ conference on disaster reduction and training needs for engineering students in constructing safe and efficient nuclear plants that will look into various aspects of construction engineering and management including plant location, safety, vulnerabilities, and more,” he says.

PURE POST-FUKUSHIMA
Hassanein says political pressure has long driven the nuclear power industry. He thinks the experience in Japan might be a blip on the screen, but doesn’t foresee any countries outside of Japan conceiving the idea of a resurgence of nuclear power in the United States, we’re evaluating the education and training needs for engineering students in constructing safe and efficient nuclear plants that will look into various aspects of construction engineering and management including plant location, safety, vulnerabilities, and more,” he says.

Jere Jenkins
Photo by Andrew Hancock

SOURCE FOR DATA: NUCLEAR ENERGY INSTITUTE

NUCLEAR ENERGY IN THE U.S.

The U.S. generates more nuclear energy than any other nation.

545.6 TWh of nuclear energy were produced in 2018.

NUCLEAR ENERGY PRODUCES
72% OF ALL EMISISON-FREE ELECTRICITY

19.6% OF OVERALL ELECTRICITY IN THE U.S.

104 nuclear power plants provide 20% of all U.S. electricity.

we're making a big push into renewable energy. It's not just about the environment; it's about the economy too. We need to start thinking beyond fossil fuels and embracing new technologies. For example, wind and solar power are becoming more affordable and reliable, and could potentially replace nuclear energy in the future.
and Germany slowing down on their plans for building new nuclear plants. Germany has announced its intent to close all of its nuclear power plants by 2022, but China, in particular, is rebuilding the industry. Indeed, in the wake of the Japanese disaster, Tian Jiashu, a Chinese nuclear safety official, was quoted saying, “We’re not going to stop eating for fear of choking.”

One of the challenges, in addition to weathering the current storm, is attracting and training the next generation of workers for the nuclear industry. Hastak is working with faculty in the School of Nuclear Engineering to offer CEM students a minor in nuclear engineering. Nuclear engineering students, in turn, could earn a minor in CEM. He reports that his construction industry contacts are already asking when they can hire these students with the dual expertise.

Fentiman knows the power of the nuclear engineering degree. “Nuclear engineering is an unusual discipline,” she says. “In most disciplines, you study the discipline and then go off and apply it to different things. In nuclear engineering, you study a particular technology and you bring to bear mechanical, chemical, materials, and other engineering disciplines. You’re looking at a system that involves many types of engineering. So a nuclear engineering student typically doesn’t have a hard time finding a job even if there isn’t one in a nuclear business. At one time, we had a lot of nuclear engineering students going into work that required computer skills because they could do computer systems.”

As for the future of nuclear power, Hassanein believes the ever-vigilant industry will continue to enhance safety procedures, plan as best they can for disasters and deliver energy without the carbon emissions.

What are some of those lessons to be learned?
Lessons can be learned in regard to the use of long-term storage of used nuclear fuel and backup power systems. All this can be used to improve the performance of reactors in case of a disaster.

Are you concerned about the coverage of the accident affecting your school’s ability to bring in new students?
Maybe in the short term. And some people will try to put a halt to the progress we’re making. Because of their general open-mindedness, the younger generation realizes the challenges of an energy crisis and eliminating carbon emissions, so they come to understand that nuclear power is a must. I’ve had some younger students ask me about continuing. Even before building any new reactors in this country, we still have 104 nuclear power plants. We need people to continue research and make them even safer.

Several people from the School of Nuclear Engineering were called upon by national media outlets to give some insight into what exactly was happening. What does that say about your department?
Purdue is highly regarded in this area. I received calls from as far away as England. Some of the media understood what was going on, but maybe the rest don’t like good news. There’s this unseen ghost of radiation that fear was simply fueled by careless reports.

■ WILLIAM MINEERS
Fentiman says the background radiation that the average American is exposed to in any given year, a large percentage comes from self-selected medical procedures — the very X-rays, CAT scans and mammograms for which we pay insurance premiums to improve our health. Frequent fliers are exposed to more radiation than people who don’t take to the skies. You’ll get a bigger dosage living in mile-high Denver. You chomp down on it with the potassium in bananas. And all of us are taking in bits of it from outer space in the form of cosmic radiation.

Of the radiation intake (see pie chart), less than one-tenth of one percent comes from all the nuclear operations in the world.

“That’s an inconsequential amount,” Fentiman says.

The National Council on Radiation Protection and Measurement says the average annual radiation dose per person in the United States is 620 millirem (6.2 millisieverts). Fentiman says workers at a nuclear power plant are allowed up to 5,000 millirem per year. A lethal dose, however, is more like 500,000 millirem in a very short time period.

Can radiation exposure over time cause cancer? “Yes,” Fentiman says, “as do so many other carcinogens in the environment.”

As a spokesperson for the technology, Fentiman says the successes of nuclear power far outweigh the accidents. “It’s a heavily regulated business and people in this industry do self-regulation over and above what the government does. The Institute for Nuclear Power Operations circulates information and shares best practices. It’s important for their livelihood. So safety is the number one priority.”

Ultimately, the challenge for the nuclear power industry may reside in education — both training the next generation of nuclear engineers and educating the public about the various facts and fictions of nuclear energy. Jen Jenkins, director of Purdue’s radiation laboratory, the lone reactor in the state of Indiana, sees 1,600 to 1,800 visitors each year touring his lab.

“We are teaching people that radiation is something you have to respect,” Jenkins says. “It’s something that can help or hurt us, but you have to make sure that you know how to handle it.”

For more than half a century, history has shown that radiation has been handled pretty well. The accident at Three Mile Island in 1979, which didn’t take any lives, led to better operational procedures, Jenkins says. “It changed the way we do business.”

The Chernobyl catastrophe in 1986, both deadly and significant, was more indicative of a difference in the way business was done in the Soviet Union than any crack in world-wide industry standards. “We don’t have any plants in the U.S. like the one in Chernobyl because the Nuclear Regulatory Commission won’t license that design,” Jenkins says.

The political fallout from the March catastrophe in Japan may take some time to get sorted out, but Jenkins and his colleagues agree that the nuclear plants weathered the various storms rather well, given the disaster levels of the earthquake and tsunami.

Fentiman believes there are no nuclear plants in the United States positioned for the type of natural disaster that occurred in Japan. Because of the measures taken after 9/11, all have prepared for extremely severe scenarios. “I just wish everyone who had questions about nuclear energy could tour these power plants and see how they operate,” Fentiman says. “Just imagine if everything else in our life was run as efficiently and at that level of excellence.”

Admittedly biased by a technology she finds so compelling, Fentiman marvels at the potential of nuclear energy. “There are no emissions from nuclear plants,” she says. “The volume of the used fuel from a nuclear power plant is small and about 95 percent of it can be recycled.”

And with so many challenges surrounding a worldwide clamor for more energy, Fentiman is happy to continue spreading the word about the plus side of nuclear technology.
Drive to work, to school or on daily errands and you likely take for granted some bridges and roads built in the 1950s. But if any break down, that disturbs our routines, our safety and our economy. Purdue engineering faculty have a long history of researching infrastructure in the U.S. and around the world. Their work on assessing structural safety and developing innovative solutions makes them sought-after experts by local, state and federal government agencies as well as industry.

Robert J. Connor, associate professor of civil engineering, has studied metal fatigue and metal fracture specifically as they relate to bridges, highway sign structures and high-mast lighting towers. Connor conducts much of his research at Purdue’s Bowen Laboratory for Large-Scale Civil Engineering Research. At 66,000 square feet, it is one of only five university laboratories in the country to conduct large-scale investigations. Experts there are shaking, breaking, and even burning full-sized models to gain a greater understanding of how structures behave in crisis moments.

Much of Connor’s current research is looking at the effects of wind on high-mast lighting towers — the structures lining interstate highways and high-speed roadways throughout the country. This summer Connor and two graduate students concluded a two-year study of selected towers in multiple states. Strain gauges and anemometers were installed earlier to measure wind speed and direction in order to find daily stresses on the towers. Also at each site was a cellular modem that worked on Verizon’s 3G network sending back real-time data to a server at Purdue. Ryan Sherman, a research engineer at Bowen Lab, and graduate student Allen Da Schepper drove the mobile lab over 3,000 miles retrieving the equipment. This vehicle is an extension of the laboratory and is outfitted with computers connected to Purdue servers and equipment necessary to conduct assessments in the field.

In addition to fieldwork, tests were done in the lab on a mast tower to simulate wind conditions over a period of years. By operating the test 24/7, results on fatigue and fracture can be gained more quickly and various methods of retrofitting can be studied.

“We tested a high-mast tower in the lab that was retrofitted with bolts at the bottom,” Connor says. “When you have hundreds of these by interstate highways and they begin to crack, what can you do? You can’t just take them down.”

The results of the studies will be sent to a panel at AASHTO (American Association of State Highway Transportation Officials), a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia and Puerto Rico.

“We write the results in specification language that is proposed to AASHTO and they will decide if they want to accept the changes and add it into the code for future design of these towers,” Sherman says. “You really get to see where the rubber meets the road. You have a problem, find a solution and implement it into future design.”

Robert J. Connor, associate professor of civil engineering, discusses high-mast tower retrofitting procedures with Ryan Sherman, a research engineer at Bowen Lab, and graduate student Lindsey Diggelmann.
Feature # Engineering for Safety

Testing Effects of Fire on Steel Structures

For many years Amit Varma, associate professor of civil engineering, has studied the field of fire-resistance research. Bowen Lab allows researchers like him to study the effects of fire on steel structures using a one-of-a-kind heating system and other innovative systems.

Typically such testing is conducted inside large furnaces, but Varma says that provides challenges. “It is very difficult to heat a specimen while simultaneously applying loads onto the structure to simulate the forces exerted during a building’s everyday use,” he says.

To overcome this limitation, Purdue researchers designed a system made up of heating panels to simulate fire. The panels have electrical coils, like giant toaster ovens, and are placed close to the surface of the specimen. As the system is used to simulate fire, test structures are subjected to forces that provide design guidelines for heat straightening repairs, estimating the final residual stresses and evaluating the performance of damaged-repaired steel bridges.

Varma and Connor were called in to evaluate just such a situation after a tanker truck struck a bridge on I-465 in Indianapolis and burst into flames. Increasing truck traffic on highways could mean more such incidents.

But not all failures in bridges are related to intense heat. Growing vehicular traffic and increased weight are causing stress on aging bridges. Through field instrumentation, Connor and his students install sensors on bridges to study stresses and recommend retrofits that can keep a small problem from becoming a catastrophic one.

To study this in the lab, a full-scale bridge deck was constructed and on it was a two-axle vehicle loaded down with the weight that a tractor-trailer would carry. Day after day the vehicle was moved back and forth, simulating the load on the bridge.

Inside and underneath, about 200 sensors were installed, strain gauges that show how the concrete stretches and compresses beneath the truck’s weight. A laser tracked the truck’s position. By shifting the truck’s path from one side to the other, the test provided a full look at how the bridge twists and bends under pressure.

“It allowed us to see how the bridge reacts in real life,” Connor says. “We took that data and compared it to computer models. That data allows us to improve the safety, reliability and durability of bridges so that we can have better infrastructure that will last us decades.”

But what they do in the laboratory is only part of the picture. Sensors also are installed on different types of bridges and monitored to “let those structures tell us how they are responding over time,” Connor says.

Varma and his research team study the effects of fire on steel structures using a one-of-a-kind heating system and other innovative systems.

The team uses coils to simulate fire and then use heat to straighten, repair and rehabilitate bridge girders.

Varma and his research team would continue to study the performance of damaged-repaired steel bridges.

Amit Varma, associate professor of civil engineering, has studied the field of fire resistance research.

In the past, why we aren’t using certain materials or designs anymore, or why we continue to use them.” Sherman agrees. He cites the Tacoma Narrows bridge in Washington as a good example. Built in 1940 and nicknamed “Galloping Gertie,” it collapsed four months after it opened due to vertical movement of the bridge deck. Sherman says, “Knowing the past and doing the research for the future is where it all comes together to improve safety.”

History Lessons for Engineers

The old adage says, “Those who cannot remember the past are condemned to repeat it.” In the case of infrastructure, many of the people responsible for repairing and maintaining roads and bridges weren’t even born when the structures were built. That’s why it’s important, Connor says, to teach students about older materials while at the same time studying new high-performance ones.

“A lot of bridges we work on were built in the 1940s and 50s,” Connor says. “If you don’t know the issues from the past, then you will have a difficult time figuring out what the problems are and making sure that you don’t repeat them in the future. There is a need for students to know what was done in the past, why we aren’t using certain materials or designs anymore, or why we continue to use them.”

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NEW COURSE EMPHASIZES HUMAN ASPECT OF SAFETY

Three Purdue alums who collectively have worked for nearly a century in the chemical engineering field have teamed up with chemical engineering faculty and staff to create a new undergraduate course focused on process safety management. CHE49700, Process Safety, was introduced this past spring and already is receiving praise from students and employers alike.

The course is open to juniors and seniors, many of whom work in internships and co-ops for companies.

Mike Harris, associate dean of engineering for undergraduate education, says the focus is on safety. “Doing things in a systematic way to mitigate hazards and prevent incidents is exactly what process safety management is all about.”

Deb Grubbe (BSChE ’77), one of the alumni who helped to develop the course, says the goal is to make sure that the students “understand what they have to know so that they don’t hurt themselves or someone else in the future.” Grubbe has worked in the chemical engineering field for more than 30 years and owns her own process safety consultancy.

Joining Grubbe were Steve Swanson, who earned bachelor’s, master’s and Ph.D. degrees in chemical engineering at Purdue, and Ron Cutaialli (BSChE ’71), both process safety experts in the oil and gas industry. The three worked with Linda Davis, industrial education director, and Harris to develop the course.

HARRIS SAYS STUDENTS WHO GO INTO CHEMICAL ENGINEERING WITHOUT THIS TRAINING ARE UNDEQUIPED AND FACE A STEEP LEARNING CURVE.

LINDA DAVIS

Harris, herself a chemical engineer with 24 years of industry experience, worked on benchmarking the course. She says that while other university chemical engineering schools have curriculum touching on process safety management, Purdue wanted to delve more deeply into the topic and develop a course from the industrial perspective based on OSHA’s process safety management regulations.

“Students who complete this course differentiate themselves when they graduate and go into industry,” Davis says. “Students who go into chemical engineering without this training are underequipped and face a steep learning curve.”

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Peter MacKee, professor of mechanical engineering and co-chair of Purdue’s Engineer of 2020 Committee, says more than technical knowledge is needed to ensure safety. The focus of a September workshop for faculty, co-sponsored by the National Institute for Occupational Safety and Health, was on safety and how the importance of safety can be integrated into the curriculum. MacKee says that past workshops have focused on multidisciplinary topics, continuous learning, ethics, global issues, environmental and societal impact of engineering practice, entrepreneurship, risk management, leadership and innovation but safety is at the heart of engineering.

“Since many incidents occur during startup, the topics of operator training, operating procedures and checklists are also covered. When students learn and later apply this information, they will not overlook steps or take shortcuts that could compromise the safety of people, company assets and the community.”

LINDA DAVIS

From a minority position as one of only 10 women in a class of 110 chemical engineering graduate students in 1977, Deb Grubbe has gained majority standing in the chemical engineering industry. Having progressed to corporate director roles in engineering, operations and safety at DuPont and vice president of Group Safety for British Petroleum, Grubbe now is president and owner of Operations & Safety Solutions, LLC, a consultancy that offers competitive strategies and methodologies to solve operational issues in the process industries.

With an aptitude for math and science, Grubbe, a Chicago native, considered being a math teacher, but her high school teacher steered her toward engineering. The road to the future became clear when Grubbe saw a female neighbor experience a sharp drop in income following a divorce. “This made a big impression on me, and I wanted to choose a career where I could support myself,” Grubbe says.

Entering Purdue in the fall of 1973, Grubbe spent three semesters studying biomedical engineering, it became apparent to her that to do anything in that field would have required a Ph.D. “I knew I didn’t want that so I transferred to chemical engineering with a biomedical option,” she says.

Grubbe obtained a certificate in post-graduate studies in chemical engineering as a Winston Churchill Fellow at the University of Cambridge, England. The international experience, she says, taught her much more about life and other cultures. It also proved favorable when she interviewed with BP.

“In BP’s eyes, they thought that the fellowship was significant because they saw me as part of their educational system,” Grubbe says.

She credits Purdue with giving her the key content components to be competitive.

“I continue to be delighted by the positive recognition that the university has in the engineering community,” Grubbe says. “Purdue’s engineering program is known as a top-tier school. This gives additional credibility for women who have gone through the program.”

As a business owner and consultant, Grubbe works primarily with chemical, oil and gas industries and large consulting firms. She is often called upon to share her expertise in process safety engineering and operations areas.

Grubbe, who lives in Chadbou Ford, Pa., spends two to three weeks a month in Alberta, Canada, consulting on oil sand projects. She finds great satisfaction in helping people find solutions to their challenges.

“The best part of being a consultant is always helping someone think differently about a situation they are in or use my experience to make it easier,” Grubbe says. “I have always been oriented toward service. One of the reasons I started my business was to give me time and space to enjoy life a little more and to work on projects of significance that I couldn’t do working for a corporation.”

DELLA PACHECO

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DELLA PACHECO
THE FUTURE OF SPACEFLIGHT

As the Shuttle program ends, Purdue research is paving the way for deep-space exploration.

BY LINDA THOMAS TERHUNE AND JENNIFER WHITSON
With the landing of Space Shuttle Atlantis in July, another chapter in United States space exploration, and one that introduced the world’s first reusable spacecraft, came to a close. What lies ahead — or above — is a question as vast as the Cosmos and one that leaves many, including Purdue researchers long associated as collaborators with the National Aeronautics and Space Administration (NASA), guessing.

In 2010, President Barack Obama canceled NASA’s Constellation program, which had focused on human spaceflight, and outlined a new direction concentrating on the design of new, heavy-lift launch vehicles to send humans to prison by the 2025. Among the planned programs are construction of the Multi-Purpose Crew Vehicle, based on the design for the Orion capsule and able to take four astronauts up money for new exploration, he says. “The Constellation program was driving us to the moon and the moon. This is a challenge.”

One downside to retiring the shuttle program, Collicott says, is that the shuttles were the “nation’s only ride to space,” and routinely carried research projects to the space station. Moving forward, NASA will need to find other roles for equipment, but the options currently available are much smaller physically and cannot carry the same weight as the shuttles. On the upside, the end of the shuttle program frees up money for new exploration, he says.

IMPACT OF CHANGING RESEARCH DIRECTIONS

Though some of the designs and research undertaken during the shuttle and Constellation programs will be used, a far amount of work has been halted. This has led to frustration on the part of researchers like Steven Schneide., a professor of aeronautics and astronautics at Purdue since 1991, who co-investigates for ongoing research aboard the Space Station that examines capillary flows and the flows of fluids. The results could improve current computer models used by designers of low gravity fluid systems and may improve fluid transfer systems on future spacecraft. The research, however, could be expanded with a small equipment upgrade, and he needs a way to get it to the space station. This is a challenge.

“For this yet another time a big and sensible program was canceled and redirected. It wastes an enormous amount of money,” Schneide. says.

For those who were working on portions of the Constellation program, most NASA-funded research stopped. Daniel DeLaurentis, associate professor of aeronautics and astronautics, was focusing on the infrastructure necessary to help NASA communicate on the moon and between Earth and the moon.

“The Constellation program was driving a lot of research, quite a bit of research, much inside NASA, but also for universities,” DeLaurentis says. He was able to leverage his work into new funding with the Missile Defense Agency, but not all researchers will be that lucky.

“My own work has adapted to other applic classes of things. The whole thing about having the infrastructure in place so we can do research on human spaceflight is really concerned because NASA has not decided on a strategy and their technology investment ideas have found resistance in Congress.”

START-UPS OFFER NEW OPPORTUNITY

President Obama’s plan for the future includes a focus on commercial companies launching and staffing routine human spaceflight. In the early years of the human spaceflight program, NASA designed, built, launched and staffed all human spacecraft. In the 1990s, that shifted to NASA coordinating all flights but sharing design and building duties with private sector companies. NASA will now focus on cutting-edge design and research and leave more routine spaceflight to the private sector.

“Even though the shuttle program has ended, I think there are good things ahead,” says Sarah St. Clair, a junior studying aeronautical engineering. “We will be able to work on the changes.”

Purdue graduates are heading to smaller startups that are competing to be the next wave of transport spacecraft for NASA. Among these is SpaceX, of Hawthorne, Calif., which won a $75 million NASA contract in April to develop a launch escape system that will enable its spacecraft to carry astronauts. Late last year, SpaceX launched the first demonstration flight under NASA’s Commercial Orbital Transportation Services program.

What these start-ups mean for many students, who once dreamed of becoming astronauts and imagined NASA as the main route to that goal, is that their options are widening. Many are heading to private-sector employers, and that trend likely will increase.

“I think there will be more diversity in employers for future astronauts,” says Janice Voss, a professor of aeronautics and astronautics at Purdue. “The main hurdles will be how much and how consistently Americans are willing to fund human spaceflight. For students and staff who care about human spaceflight, that’s the real sticking point, especially for a generation that grew up only knowing the shuttle program. Colum Weir, a senior in aeronautical and astronautical engineering, speaks for that generation.

“Even though there’s less of a sense of space as being something new and revolutionary, and more of something we’ve already done, I think there will be more diversity in future astronauts.”

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n vol rocket propellant
A rocket propellant made of a frozen mixture of water and "nanoscale" aluminum powder is more environmentally friendly than conventional propellants and could be manufactured on the moon, Mars, and other water-bearing bodies. The aluminum-ice (ALICE) propellant developed by Steven Son, an associate professor of mechanical engineering and associate professor of aeronautics and astronautics, could be used to launch rockets into orbit and for long-distance space missions and to generate hydrogen for fuel cells.

Gelled fuel to improve rocket performance
A gelled fuel the consistency of orange marmalade could improve the safety, performance and range of rockets for space and military applications. Gels are inherently safer than liquids because they don't leak, and they also would allow the military to better control rockets than is possible with solid fuels now used. Motors running on gelled fuels could be turned up and down and controlled more precisely than conventional rockets that use solid propellants. Gelled fuels also could be used in future space shuttle satellites and on NASA space missions. Joseph Halverson, a professor of aerodynamics and astronautics, co-directed an interdisciplinary research team with Paul Solya, a professor of mechanical engineering. Timothy Poupourt, a research assistant professor of aeronautics and astronautics, oversaw a propulsion lab to test the fuels.

In the frontiers of space
Purdue students are also on the forefront of aerospace research. Graduate student Thomas Fedigan and Andrew Rettenmaier are developing a rocket engine that might be used in a vehicle to land on the moon. As part of the NASA-funded Project Morpheus, which includes research to create a vehicle to carry cargo to the moon, Mars or asteroids. The rocket, which will use a propellant of liquid oxygen and liquid hydrogen, was designed and tested using specialized facilities at Purdue's Maurice J. Zucrow Laboratories, including a new facility to liquefy the methane propellant. Both students acknowledge that this is a rare opportunity to get hands-on experience on the road to careers in the aerospace industry.

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Q&A WITH JANICE VOSS

How will the transition from the human spaceflight program, especially the cancelation of the Constellation program, impact Purdue University?

I don't think it makes a big change in Purdue’s position. There have been many transitions. There was a gap between the Apollo and shuttle programs when various programs were canceled, but that hasn’t changed anything for Purdue.

The main reason that we’ve having these challenges in NASA program funding and policy is because of the tight federal budget. The budget debate is huge in Congress and funding overall is getting cut. That could impact Purdue, but that’s not specifically the Constellation program.

Given the gap between retraining the shuttle program and developing new technologies, do you think today’s students still have as good a chance to reach the goal of becoming an astronaut?

Yes, absolutely. The commercial sector is really going to take off. SpaceX launched Falcon 9, a completely privately developed vehicle, into orbit. That’s huge for the commercial industry to have made that first step. The small commercial industry (not Lockheed Martin or Boeing) has never been there before. While it’s built on technology that the government developed, we have a commercially developed spacecraft for the first time. There are three other U.S. commercial companies right on SpaceX’s heels and there are opportunities with those companies to be astronauts.

JANICE VOSS (B.S. ’75, ENGINEERING SCIENCE), IS AN ASTRONAUT AND NASA MISSION SPECIAList, SHE BECAME AN ASTRONAUT IN JULY 1991 AND HAS SPENT MORE THAN 49 DAYS IN SPACE ON FIVE SPACE MISSIONS.

Q&A // NASA SPECIALIST JANICE VOSS ON THE FUTURE OF SPACEFLIGHT

Do you think future careers will look vastly different from, for example, the trajectory your career has taken?

There will be more diversity in employers. Everyone has his or her own career path, but the basic principles shouldn’t be any different. Pursue a field you can be an expert in, be a good public speaker, a team player, stay fit, and I’m certain there will be plenty of opportunities to fly in space. NASA is already discussing the next astronaut class right now. It’s a smaller one, it’s not zero.

Students initial reaction to the cancelation of the Constellation program was that it is bad news. As the dust settles and new goals are set, they seem optimistic that the changes may actually broaden opportunities for discoveries. Your thoughts?

They’re young and haven’t been through this kind of transition before. It looks catastrophic. It just feels like it’s the end of the world when it’s the first time it’s happened, but they’ve still gotten a lot of vibrancy in the human spaceflight program. We have a new space station that we just finished and is ready to use. Watching the advances in the commercial industry is also very exciting. They’ll get a chance to be part of the transition from government programs to the birth of the commercial industry.  

JENNIFER WITTON

NASA continues with its own program and we will have people on the International Space Station. They’ll be launching on Russian vehicles, but we’ve done that before and it didn’t decrease the vibrancy of our space program.
Odio started TicoFrut in San Jose, Costa Rica, with a business partner in 1987. His partner has since died, but the company remains family-owned. Three of his four sons are also engineers and all have earned MBAs. “What we do touches thousands of people in an area of the country that is very poor,” Odio says. “We’ve literally changed the way hundreds of families are living, for the better.”

Costa Rica has long been known for its coffee production, but Odio wanted to build economic stability for lowland farmers. “I saw citrus as lowland coffee,” Odio says. “Growing coffee has contributed so much to my country’s economic, social and political stability, but because coffee can be produced only in high altitudes, this left little or no opportunities for people in the lowlands.”

Within the past few years, TicoFrut has established 11 computer centers in areas surrounding its groves. These neighboring towns, which had no electricity only two years ago, are now able to access the Internet. “With these centers, we are hoping to significantly improve the education of the children in these remote villages, thus helping reduce the gap that continues to develop around the world between those who have and those who don’t,” Odio says.

Ticos (Costa Ricans’ nickname in Central America and the namesake of TicoFrut) are not the only ones who have benefited from Odio’s contribution. In collaboration with Nicaragua’s first democratically-elected government, TicoFrut worked with Nicaraguan citrus farmers to establish orange plantations in their country. “When we started plowing the fields, hundreds of land mines started popping out of the ground,” Odio says. “The land had been mined in the late 1970s to stop supply flow from the U.S. through Costa Rica. Luckily, the mines were dead, none exploded, and now the area is home to a beautiful 17,500-acre orange grove.”

TicoFrut owns all or a portion of 47,000 acres of orange groves and produces 16 different orange products, more than anyone else in the world. Odio says future plans include processing passion fruit, an ideal product for small growers. “It produces in nine months and generates a large income per acre,” he says. “It is an ideal addition, considering where we are in Costa Rica and Nicaragua.”

With common sense and a few lessons from Purdue — including stoichiometry, hydraulics and machine design to name a few — Odio, who was named Purdue’s Outstanding Industrial Engineer in 2010, continues to revolutionize the citrus industry in Costa Rica.

“They say when given lemons, make lemonade. Purdue alumnus Carlos Odio (BSIE ’65, BSCE ’65) instead took oranges and parlayed them into a multinational citrus processing company.”
Focus # Stemming the Engineering Brain Drain

For Beth Holloway the economic logic is just one draw to the field of engineering. Success stories are another. As director of the Women in Engineering Program (WIEP) for a decade now, Holloway (BSME ’92, MSME ’97) has been helping share those stories and hands-on activities with K-12 audiences, along with the existing student body (both male and female) of Purdue engineering students.

Purdue has a historic role in the recruitment of women to engineering. Founded through the former Freshman Engineering Department in 1969, WIEP was the nation’s first such organization. Purdue also has the longest continuously chartered student section of the Society of Women Engineers, which organized nationally in 1994. In 1969, when women made up less than 1 percent of Purdue’s engineering student population, the goal was simply to spread the word in hopes of increasing the numbers. Holloway says that her predecessors set a goal to have 1,000 women enrolled in the various engineering disciplines after five years. They fell six short.

With Purdue’s WIEP as a model and through national networks, a number of universities began their own programs to ease the path of women engineers. Though this may have taken some female engineers away from Purdue, it benefited the profession as a whole, Holloway says.

Holloway says the number of Purdue’s female engineers has fluctuated over the years, the biggest boom occurring in the early 1990s. This year’s freshman engineering class may be as much as 25 percent women. But the calls to increase student totals in the STEM (science, technology, engineering and math) disciplines are louder than ever. In June, President Barack Obama announced plans to train 10,000 American engineers every year.

To ensure that more of those 10,000 are young women, Holloway believes the engineering community needs to change the way it touts itself. “When we look at the data, the women who apply to engineering are absolutely academic superstars,” she says. “The men who apply have a wider range of academic performance. Research indicates that more men are encouraged to go into engineering. If they tink, for example, someone might say, ‘You should be an engineer.’ And while their academic performance is strong, it is not as tightly clustered at the top.”

The lack of encouragement from parents, guidance counselors and even the young women themselves could be keeping them away from engineering studies. WIEP outreach activities through summer camps and after-school programs are designed to spark minds for engineering as young as kindergarten.

Part of stirring the imagination for the possibilities of engineering means eliminating the misconceptions. “A lot of girls think engineering is dull, boring and dirty,” says Jennifer Groh, associate director of WIEP. “They think it’s not creative and you end up working alone.”

What they end up learning, Groh says, is that engineers really make things better. “They don’t necessarily see what the engineers are doing because it’s behind the scenes. But we really showcase how engineering makes a difference.”

Exposure to engineering stories, whether it’s a fifth-grader relating to the studies of a current Purdue student or an undergrad being inspired by a successful alumna, also help separate facts from fiction. Holloway remembers listening to Donna VanKloppenburg (BSME ’82) and Sue Abreu (BS/ME ’78) speaking to her ENGR 194 class, the Women in Engineering Seminar, which still brings in alumni to talk about their diverse careers.

“The alumna are a big part of making our program as successful as it is,” says Holloway, who worked as a research and development engineer at Cummins for nine years before returning to her alma mater. “I don’t think we would have the outstanding participation from students that we do without that alumni involvement.”

Lindsey Diggelmann, a master’s student in civil engineering, will join those Purdue alumna in May 2012, no doubt with her own stories. “If you like engineering, you should definitely pursue it,” says Diggelmann, who majored in civil performance at Michigan State but ultimately got “hooked” on structural engineering. “Don’t listen to anyone who says it’s just a boys’ club. It changes every year and there are more girls.”

William Meiners

The young women participating in each Engineering for Girls in Engineering (EDGE) design and build engineering-based group projects and participate in experiments during laboratory hours. Current Purdue EDGE members are selecting facilitators and mentors. Throughout EDGE and four other programs for girls from K-12, engineering is highlighted as a profession where creativity and imagination are used to solve problems for the betterment of society.

Photos by Mark Simons

Purdue’s Renowned Program Continues to Inspire, Recruit and Retain through Creative Approaches.

What the world may need — now more than ever — is more women engineers. In the United States alone, where women wield more than half the buying power, it makes good business sense. Why not have more women involved in designing the technology and services they’re buying?
By the 1880s, intense competition in the manufacture of chemicals had made the need for engineers with training in chemistry obvious to many observers. George E. Davis in Manchester, England, crystallized the need for chemical engineers with a series of lectures in 1887. The next year, the first curriculum in chemical engineering was established in the chemistry department at MIT.

1902
Percy Evans at Purdue offered a course on Industrial Inorganic Chemistry Lectures that led to the 1907 establishment of a chemical engineering curriculum within Chemistry.

1911
Continual growth in the student body led to the 1911 founding of the School of Chemical Engineering. While many changes have occurred over the century, the same drive for discovery and excellence in education has continued.

1915
In Purdue Hall, CHE had its first lab. Peffer (right) shown with students.

1930
CHE outgrew Purdue Hall and moved into larger quarters in Heavilon Hall, home of the School from 1930 to 1940.

1934
Prof. Harry Peffer died in 1934.

As we celebrate this important centennial, take a look back at significant events that have shaped the school as compiled by Phillip Wankat, the Clifton L. Lovell Distinguished Professor of Chemical Engineering, and Cristina D. Farmus, administrative director in the school.
The world was mired in the Depression and war clouds were gathering. Perhaps because students thought a degree in chemical engineering offered them a better chance for gainful employment, more students entered chemical engineering during the Depression.

### 1951 to 1966

#### Midlife Crisis

By 1951, the soldiers were home, and many of them were finishing college. Normalcy had, to some extent, returned. World War II had spotlighted some of the shortcomings of engineers who had been trained under the old engineering art/shop system. Important groups called for major changes in the way engineers were educated — the engineering science revolution. In coping with these changes, the school went through a somewhat painful midlife crisis.

#### TimeLine / CHE Centennial

1935 to 1950

**The Bray and Shreve Years**

John Bray became head of the school. Elizabeth Henius (BS ’35) was the first alumna of the school.

1940

The CMET building is completed in August 1940. Total cost was $580,000.

1941

Unit Operations Lab. There were few female students in CHE until the mid-70s.

1944

The school was heavily involved in the war effort during World War II. Synthetic Rubber Synthesis in 1944 is shown.

1947

After Bray stepped down due to failing health, R. Norris Shreve became the head. He organized the school into Chemical, Metallurgical, and Engineering Geology divisions that were officially recognized in 1953.

1950

Sarah Margaret Claypool Willoughby (Ph.D. ’50) was Purdue’s first female Ph.D. in Engineering.

1951

Edward Comings took over as head and tried to increase the research orientation of the school. Unfortunately, this effort foundered due to faculty turmoil caused by resistance to the engineering science revolution. During Comings’ tenure, large numbers of GI Bill students graduated.

1955

An ABEE report repeated by a 1957 Purdue report by Dean Hawkins (shown with Golding and Shreve) called for an engineering science revamping of the curriculum that led to a schism in the CHE faculty.

1958

Dr. Henry Sampson (BSECE ’56, Ph.D. ’67 Illinois), the first CHE African-American alumnus, overcame challenges and racism to become a noted inventor.

1959

Comings left and was replaced as head by Brage Golding, a student of Shreve. The school legally split into Chemical Engineering and Metallurgical Engineering during the awkward period when there was no head in Chemical Engineering. During the next seven years, the undergraduate curriculum was modernized, but the graduate program and research stagnated and subsequently declined.

1963

Duncan Mellichamp (Ph.D. ’64) with analog computer. Graduate students were aware of faculty tensions, and many left with an MS.

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Unit Operations Lab.

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1963

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Robert Greenkorn was hired as head and charged with bringing about the rebirth of the school as a modern program by increasing both the graduate program and the research portfolio of the school. This task was successfully continued by Lowell Koppel, who became head in 1973. Many professors hired by Greenkorn and Koppel are still at Purdue.

1967 TO 1987

In the late 1960s, the United States was mired in the Vietnam War, but Purdue was one of the least disrupted colleges in the country. Most Chemical Engineering programs at research universities had become much more research-oriented than Purdue’s. The school’s research and graduate program had recovered and diversified into new areas such as biochemical engineering.

1979-1980

Ron Andres became head and improved faculty morale, but expansion of the research program, particularly experimental research, was severely hampered by space constraints. He stepped down in 1987.

1986

By the end of Andres’ tenure, relief of the space crunch was in sight. Materials Engineering was scheduled to move into the MS&E Building. After building renovations, the space problem was alleviated, but became limiting again by the end of the 1990s.

1987

Sintaras “Rex” Reklaitis became head in 1987, the year before Materials Engineering moved to the new MS&E Building. After building renovations, the space problem was alleviated, but became limiting again by the end of the 1990s.

1981

During Koppel’s tenure, the percent of women students increased dramatically due partly to the Women in Engineering Program. Linda (Russell) Brown (BS ’77) is shown.

1977

George Tsao and his colleagues built the Laboratory for Renewable Resources Engineering (LORRE) into a major force in biochemical engineering research.

1979

Linda Wang, left. (1980-present) met the challenge of being the pioneering female professor in CHE.

1997 TO 2011

By the late 1980s, Purdue, like many other land-grant institutions, had moved away from the state-funded land-grant model. The story of the years from 1987 to the school’s 100th anniversary in 2011 can be distilled into two words: space and money. Near the end of this period, the nation sunk into the Great Recession and economic worries became paramount.

2002

Distinguished Prof. Arvind Varma was hired as CHE head. He has been challenged by economic woes and renovation of CMET.

2004

Forney Hall of Chemical Engineering was dedicated in 2004 shortly after Arvind Varma became head. The new facility helps to attract stellar faculty to Chemical Engineering.

2008

Graduate student Sara Yohna (right) describes biofuels projects lab to President France Córdova during Córdova’s visit to CHE.

2010

As director of the Indiana Advanced Electric Vehicle Training and Education Consortium, Jim Canchiers leads Purdue’s electric vehicle initiative. Its goal is to educate a new generation of highly skilled workers to design, build and service electric vehicles.
President Barack Obama congratulates Purdue’s Rakesh Agrawal (left) during the presentation of the National Medal of Technology and Innovation in Washington, D.C. The award is the highest honor for technological achievement bestowed by the president of the United States. (Photo by Ryan K. Morris Photography)

01

AGRAWAL WINS NATION’S TOP TECHNOLOGY HONOR

Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor in the School of Chemical Engineering, will receive the National Medal of Technology and Innovation from President Barack Obama.

The award is the highest honor for technological achievement bestowed by the president of the United States. Agrawal holds 116 U.S. patents, nearly 500 non-U.S. patents and has authored 93 technical papers.

A citation for the award recognizes him for “an extraordinary record of innovations. These innovations have had significant positive impacts on electronic device manufacturing, liquefied gas production and the supply of industrial gases for diverse industries.”

He is one of five recipients. Seven National Medal of Science recipients also were named in a White House press statement issued Sept. 27.

“Dr. Agrawal is very deserving of this stupendous honor,” says Leah H. Jamieson, the John A. Edwardson Dean of Engineering. “He is not only leading research in his field but also helping to educate a new generation of chemical engineers.”

Agrawal received the award on Oct. 21 with other National Medal of Technology laureates during a White House ceremony.

02

GATEWOOD WING DEDICATED

The Roger B. Gatewood Wing of the Mechanical Engineering Building was dedicated Oct. 21 as part of Homecoming Weekend.

The $34.5 million state-of-the-art addition is the first Purdue building constructed to LEED certification standards. The Leadership in Energy and Environmental Design (LEED) standard is set by the U.S. Green Building Council to verify that a building is designed and built to increase energy savings, improve water efficiency, reduce CO2 emissions, improve indoor environmental quality and be thoughtful of the stewardship of resources and the impact of their use.

The addition adds 41,000 assignable square feet to the Mechanical Engineering Building including flexible classroom spaces, student commons, computer labs, student learning labs, research labs, and many other spaces that will make Purdue’s Mechanical Engineering program a leading institute in its field.

Roger Gatewood, Don and Catherine Feddersen, Dr. Milton B. and Betty Ruth Hollander, and corporate partner Caterpillar Inc. have all made leadership gifts to the project.

Roger Gatewood, a 1968 graduate of the School of Chemical Engineering, is adviser to the students.

03

PURDUE ABE UNDERGRAD PROGRAM RATED BEST IN NATION

U.S. News & World Report’s selection of Purdue’s agricultural and biological engineering program as the best such undergraduate specialty in the country follows the graduate program’s top-ranking earlier this year.

The magazine ranked the specialty engineering undergraduate programs in September as part of its annual listing of the nation’s top universities. It based its specialty rankings on a spring 2011 survey of deans and department heads at peer institutions.

The magazine also rated the Purdue ABE program as the top graduate program in the country in specialty rankings released in March.

04

STUDENTS BUILDING ROCKET FOR MOON VEHICLE

Purdue students are designing and building a rocket engine that might be used in a vehicle to land on the moon.

Graduate students Thomas Feldman and Andrew Rettenmaier are part of a team developing a thrust chamber for NASA’s Project Morpheus, which includes research to develop new technologies for future trips to the moon, Mars or asteroids.

Other students working on the project include graduate students Michael Bedard, Isaac Statnakiev and Emma McKinney and undergraduate David Halley and Ryan Tatro. William Anderson, associate professor of aeronautics and astronautics, is adviser to the students.

The rocket, which will use liquid oxygen and liquid methane propellants, is being designed, built and tested using specialized facilities at Purdue’s Maurice J. Zucrow Laboratories, including a new facility to liquefy the methane propellant.

A development test chamber has been designed and is ready for testing. This heavy instrumented chamber is far bulkier than the eventual flight chamber, and data from upcoming tests will be used to refine the flight engine’s design.

Purdue graduate students Michael Bedard, Emma McKinney, Thomas Feldman and Andrew Rettenmaier are working on a rocket engine as part of the NASA-funded Project Morpheus, which includes research to develop new technologies for future trips to the moon, Mars or asteroids. (Purdue University photo/Mark Simons)
Researchers have created and tested miniature devices that are implanted in tumors to generate oxygen, boosting the killing power of radiation and chemotherapy. The devices were created at the Birck Nanotechnology Center in the University’s School of Electrical and Computer Engineering. “The ultrasound energy powers the device, generating oxygen.”

As football teams take to fields across the nation, Purdue researchers continue work to uncover how repeated head impacts affect high school athletes.

The application could be further developed as a tool for people who have special diets by English speakers traveling in Spain.

The technology is designed to treat solid tumors that are hypoxic at the center, meaning the core contains low oxygen levels.

The application translates it automatically without intervention of on-campus and online delivery. They will download a region- and language-specific configuration and database. From then on, the system can operate without a network connection.

The research has been funded by the American Society of Civil Engineers and the architecture firm Magnuson Klemencic Associates Inc., an international structural engineering and architects firm based in Seattle.

The project aims to develop a new kind of “core wall,” a vertical spine that runs through the center of skyscrapers, says Mark Bowman, director of Purdue’s Robert L. and Terry L. Blow Laboratory for Large-Scale Civil Engineering Research.

The delegation presented Santos with the gift of a Bodektraveler flag, which he held up and draped around his shoulders. Twice within a month, Colombian President Juan Manuel Santos expressed his strong support for Purdue less than three weeks later during the International Conference on Technology Policy and Innovation (ICTP), held in Bogota.

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The new “implantable micro oxygen generator” is an electronic device that receives ultrasound signals and uses the energy to generate a small vialage to separate oxygen and hydrogen from water—a chemical operation called water electrolysis.

“The intent of our project is to be able to construct the core wall system much faster than the traditional system,” says Bowman, professor of civil engineering. “If you were doing a 40- to 50-story building, you might save three to four months of construction time. Even one month would be gigantic in terms of dollar savings.”

Bowman and Michael Kreger, professor of civil engineering, are leading the research, working with doctoral student Salvarejep Ramakrishna, undergraduate David Hoppes and engineers and associates Inc., an international structural and civil engineering firm based in Seattle.

The research has been funded by the Charles Pankow Foundation.

Purdue and NSWC Crane expect the program eventually to lead to a master’s degree in chemical engineering.

The development of electrical- and chemical-based energy storage devices is a critical component of such modern technologies as electric vehicles, plug-in hybrid electric vehicles, solar panels, wind turbines, and diesel and biodiesel generators.

The program began in July with two intensive segments for 16 students at the Crane West Gate Research Park. The summer program was noncredit but offered a certificate. This fall, the students are taking their first credit course toward a master’s degree.

The courses will be taught through a combination of on-campus and online delivery. They will come from chemical, materials and industrial engineering.

The master’s in chemical engineering program will be agreed to take three years to complete. The initial program will be developed for NSWC Crane’s specifications. Other individuals or businesses will be able to participate in future offerings.

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We hope you enjoyed this edition of Impact magazine. We are always eager to share the exciting happenings in the College of Engineering, so we hope you'll bookmark us at www.purdue.edu/engineering.

Don't miss out on the exciting accomplishments of our students and faculty in all the schools, and events on campus and around the world that the college is involved in throughout the year. And, as always, we want to hear from you so if you have an idea for a story for Impact, please e-mail it to us at peimpact@purdue.edu.