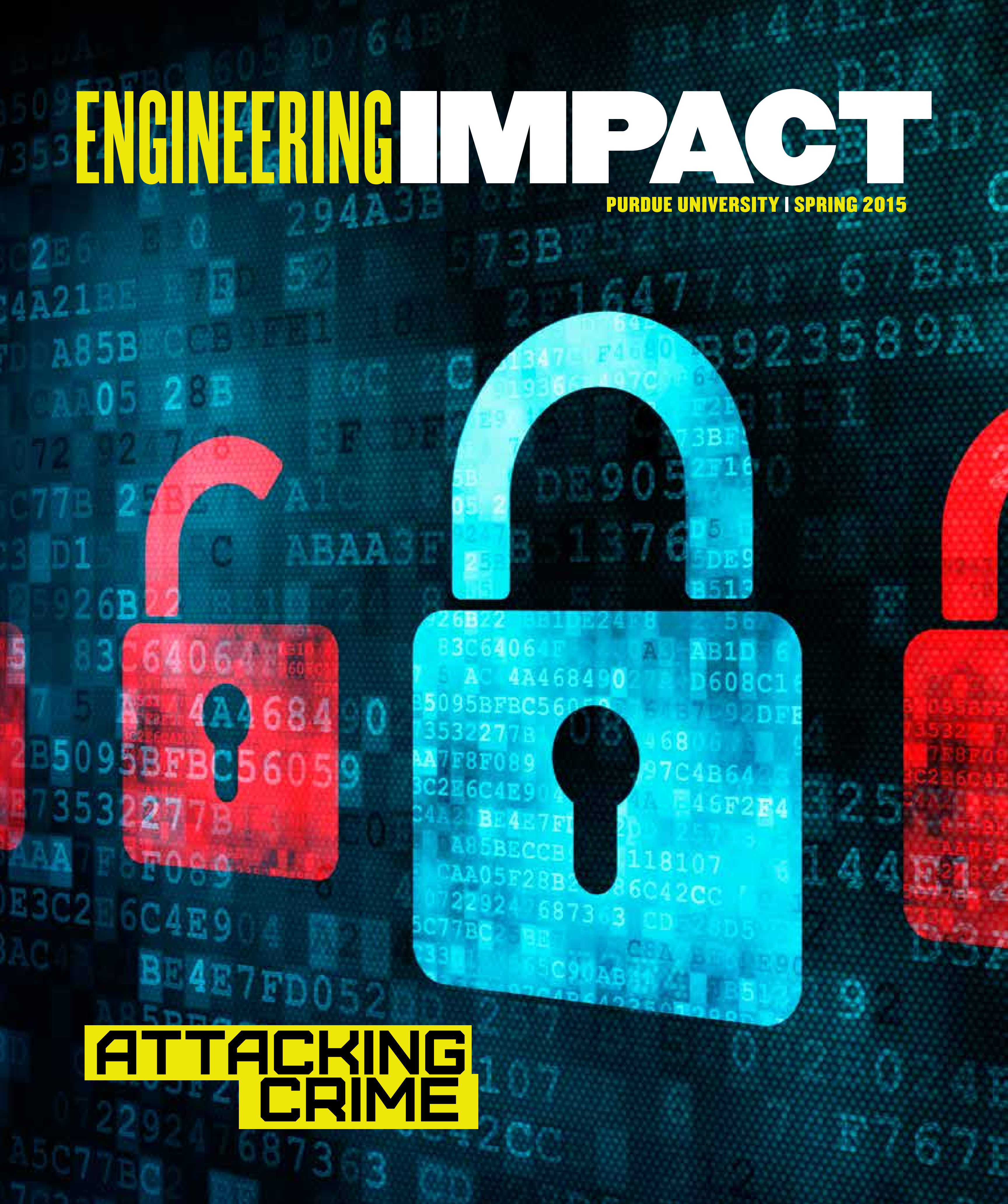
ENGINEERING IMPACT

PURDUE UNIVERSITY | SPRING 2015



ATTACKING CRIME

LEAH H. JAMIESON

The John A. Edwardson Dean of Engineering

Ransburg Distinguished Professor of Electrical and Computer Engineering

DEAN'S MESSAGE

These are thrilling times in Purdue's College of Engineering.

All of the stories you read in this edition of *Engineering Impact* magazine, and indeed everything that is happening in the College of Engineering today, is taking place in the context of our strategic growth initiative.

Begun in 2012, our initiative to grow the college capacity to educate, conduct world-changing research, and engage with partners ranging from K-12 schools to local and global industries is increasing the breadth and depth to which we will attain our strategic vision to be known for our impact on the world.

And by broadening and accelerating our impact, we also are answering an urgent national call. The U.S. Council on Jobs and Competitiveness has asked for an additional 10,000 engineers a year to grow the nation's innovation economy. The College of Engineering's expansion will help to meet that need with Purdue-educated engineers who are well prepared to become leaders among their peers, accounting for 1 in 20 of the new engineers.

Specifically, from 2012-13 to 2016-17, Purdue will invest more than $150 million for an addition of up to 107 new faculty, 105 staff, and 88 half-time teaching assistants in the college, as well as for bold renovations of our core spaces. We hope to match the University's $150 million investment with gifts of at least $150 million from you, our alums and friends.

And speaking of gifts: In a landmark announcement in February 2015, the Lilly Endowment has awarded $40 million to Purdue, with $25 million supporting Engineering's expansion. The Lilly Endowment funds for an expansion of the Maurice J. Zucrow Laboratories and a new Flex Lab will significantly expand our capacity for research, which is critical to recruiting and retaining top faculty. Support for the Innovation Design Center will help create new innovative experiential education spaces for our students. You can read more about this transformative gift on page 6.

High on our priority list is reinventing our space on campus. On page 24 you can read about how we are accomplishing this through flexible facilities like Wang Hall and the renovation of Grissom Hall, which is the first in a series of extreme makeovers.

I invite you to stay abreast of our strategic growth online at purdue.edu/engineeringstrategicgrowth.

The Four Stories of Purdue Engineering's Strategy for Impact *frame everything we do in the College. As we grow, the spirit captured by the four stories continues to serve as the guiding vision for the College and for this magazine, as we use these icons to connect to our Four Stories.*

Always@PurdueEngineering. Create and sustain the human, intellectual, and information infrastructures that connect people and Purdue for life.

OurPeopleOurCulture@PurdueEngineering. Engage our people to transform our culture, because empowered people radiate passion that energizes them to change the world.

Innovate@PurdueEngineering. Build an innovation ecosystem and nurture a culture of creativity that takes us far beyond where we are today.

ChangeTheWorld@PurdueEngineering. Reshape our research universe and bring solutions to the globe.

08

ATTACKING CRIME

Purdue researchers fight cybercrime on multiple fronts.

06

MAJOR GIFT

A $40 million gift from the Lilly Endowment creates new learning and research spaces for Engineering's landmark expansion.

20

MATERIALS WORLD

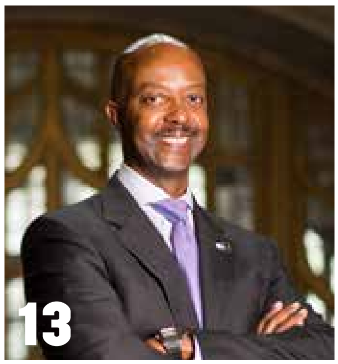
Faculty couple shares research and personal bond.

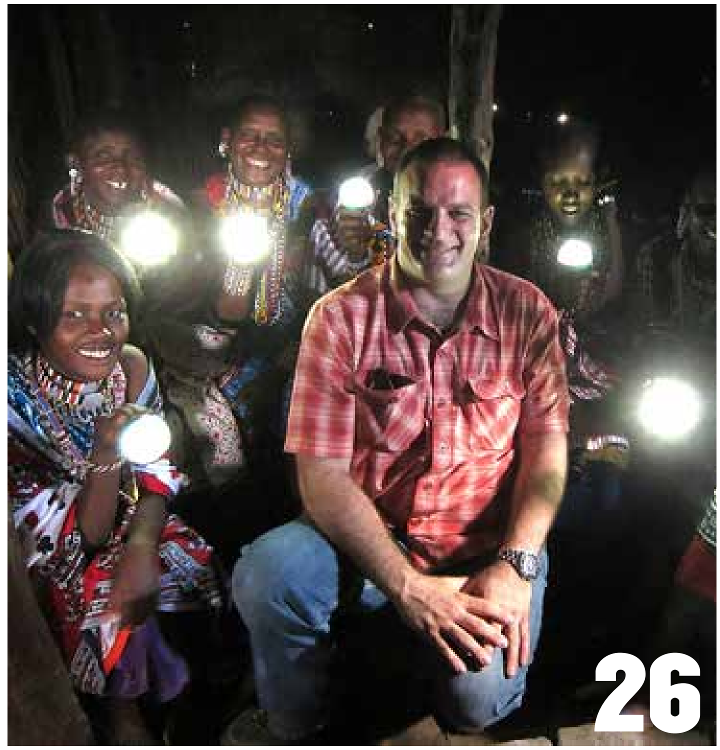
26

FATHER OF INVENTION

Alumnus Stephen Katsaros is bringing light to the 20 percent of the world without power.

DEPARTMENTS





16.
FEATURE //
BETTER MEDICINES
From Earth and Beyond

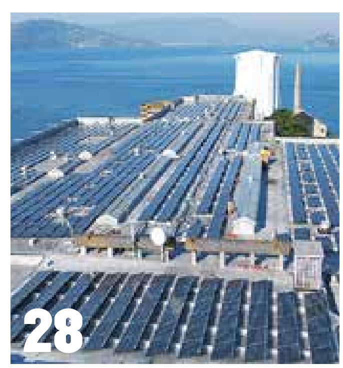
18.
FEATURE //
BETTER, SAFER BATTERIES
In Charge

22.
PREEMINENT TEAMS //

25.
ALUMNI PROFILE //
TYLER (BSME '03) AND TREVOR (BSMET '01) BACK

28.
ALUMNUS PROFILE //
PAUL CLOYD (IDE '76)
The Greening of Alcatraz

30.
SPOTLIGHT NEWS //



AS OF FALL 2014, THE COLLEGE OF ENGINEERING HAS:

410 FACULTY
OF WHICH 73 ARE WOMEN
[A HIGH FOR THE COLLEGE]

11,083
STUDENTS THIS YEAR
[A RECORD HIGH]

UNDERGRAD ENROLLMENT
UP 12%
IN THE COLLEGE
OVER THE LAST FIVE YEARS

MORE THAN **1 IN 4**
PURDUE UNDERGRADUATE STUDENTS
AND 3 IN 8 GRADUATE STUDENTS
ARE STUDYING ENGINEERING

YEARLY RESEARCH EXPENDITURES
UP 64%
SINCE THE BEGINNING OF THE STRATEGIC PLAN IN 2007

GRADUATE ENROLLMENT
UP 27.5%
IN THE COLLEGE
OVER THE LAST FIVE YEARS

WE WOULD LOVE TO HEAR FROM YOU.
Include your name and address and send to:
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West Lafayette, IN 47907-2025 **e-mail:** peimpact@purdue.edu.
We may edit letters for length and clarity.

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LILLY ENDOWMENT GIFT MOVES PURDUE ENGINEERING FORWARD

PURDUE'S LARGEST-EVER CASH GIFT FUNDS RESEARCH AND LEARNING SPACES THAT EXPAND THE COLLEGE'S IMPACT, CREATING NEW OPPORTUNITIES FOR STUDENTS AND SPURRING ECONOMIC DEVELOPMENT IN INDIANA AND BEYOND.

The biggest single cash gift in Purdue University's history — $40 million from Lilly Endowment Inc., to be distributed in the College of Engineering, the College of Technology and Purdue Libraries — is helping to transform engineering at Purdue.

With other countries outpacing the U.S. in the production of engineers, Purdue is stepping up to help address the problem through a revolutionary expansion to dramatically increase the number of students and faculty with the passion, curiosity and drive to engineer pathways to change.

Pursuing strategic growth that will make Purdue's engineering program the third-largest in the nation, the College of Engineering also is poised to create educational and economic opportunity for the citizens of Indiana.

"This is an important moment in Purdue history," says Purdue President Mitch Daniels. "It's now our duty to turn it into a significant event in Indiana history, by delivering even more world-class engineers, technologists and leaders of all kinds, along with the discoveries, innovations and new jobs that great research produces."

Here, a look at how Lilly Endowment's generosity will make a difference for Purdue Engineering.

COLLEGE OF ENGINEERING FLEX LAB ($13.5 MILLION)

The proposed 75,000-square-foot Flex Lab will enable teams to collaborate on research that may range from advanced manufacturing to imaging, and from information technology to medical devices. Designed to be responsive to every type of evolving research, this facility will house configurable wet-lab, dry-lab and open collaboration spaces that support many disciplines.

The lab will accommodate a growing world-class engineering faculty, boosting Purdue's research capability and economic impact as the College embarks on more funded collaborations and intellectual property development.

INNOVATION DESIGN CENTER ($13 MILLION)

Dedicated to hands-on learning, the Innovation Design Center is a concept developed by and for Purdue students. A partnership between the College of Engineering and the College of Technology, the center will provide students large, open-bay space and other resources — collaborative areas, CAD studios — in which they can design, develop, build, and test extracurricular projects (for example, Grand Prix and Solar Car), as well as course-based design projects.

The benefit? Much-needed learning and hands-on opportunities to be competitive immediately as students enter the workforce.

The Innovation Design Center will be physically located in the Student Success Corridor among campus buildings, residence halls and off-campus housing. It will be accessible to students 24 hours a day, seven days a week.

ZUCROW LABORATORIES EXPANSION ($5 MILLION)

With far more demand from corporate and government partners than available research space, the expansion of Zucrow

Laboratories will significantly advance research in gas turbine combustion and propulsion.

Developed in 1964 as part of the Apollo program, Zucrow's High Pressure Lab is a crucial resource for industry and government partners, providing scalability (and test conditions at 30 atmospheres) that enables researchers to study basic combustion processes. GE, Rolls-Royce, Siemens, NASA and the Department of Energy are eager collaborators.

A joint facility of the School of Aeronautics and Astronautics and the School of Mechanical Engineering, Zucrow's expansion will include five new test cells (500 square feet each) and the Tebbe TDI Laser Lab. Laser diagnostics have been a key differentiator for Purdue, especially for partners such as GE, and the new site will provide the environmental controls that currently don't exist.

Increased research capabilities make the labs more valuable to industry and government partners, cementing links with Indiana's high-tech employers.

All three of the projects — Flex Lab, Innovation Design Center and Zucrow Labs expansion — are targeted to open their doors in 2017.

NEW MOMENTUM

"This support from the Lilly Endowment propels Engineering's expansion forward in dramatic ways that will make a real difference for our students and drive innovations that will have impact in our state and the world," says Leah Jamieson, the John A. Edwardson Dean of Engineering and Ransburg Distinguished Professor of Electrical and Computer Engineering. "Growing engineering contributes to economic development, both through our graduates who are so highly valued in the workforce and our research that moves the world forward."

The Endowment is a longtime supporter of initiatives at Purdue, including a nearly $26 million grant in 2001 that launched Discovery Park, the University's complex for advanced interdisciplinary research and education.

ABOVE: The new Flex Lab will enable teams to collaborate on research and will accommodate a growing world-class engineering faculty. BELOW:The expansion of Zucrow Laboratories will advance research in gas turbine combustion and propulsion providing students and faculty research capabilities that make the labs more valuable to industry and government. (Purdue University photos/Mark Simons)

ATTACKING CRIME

Purdue researchers fight cybercrime on multiple fronts

■ WILLIAM MEINERS AND DELLA PACHECO

Cybercrimes are on the rise and offer hackers a seemingly endless variety of options beyond electronic bank heists, credit card fraud and commonplace identity theft. Anthem, the nation’s second-largest health insurance company, announced in February 2015 that hackers have stolen members’ Social Security numbers, names, birthdays, medical IDs and more sensitive personal information in a massive data breach affecting as many as 80 million people.

In another security breach, cybercriminals hacked Sony Pictures in December 2014 not only releasing private information of more than 47,000 people, but also compromising intellectual property rights by leaking five “unreleased” movies, as well as working scripts and embarrassing in-house memos.

Purdue researchers across campus have taken a multidisciplinary approach to discovering technology to fight cybercrime. For Jan Allebach, George Chiu and Edward Delp, a trio of collaborating engineers, proven video and printer-fraud technologies can be reapplied to combat several high-tech criminal activities.

FOILING CYBERCRIMINALS

Edward J. Delp, the Charles William Harrison Distinguished Professor of Electrical and Computer Engineering and professor of biomedical engineering, has worked extensively on state-of-the-art technology to analyze images and video and develop surveillance detection methods to foil cybercriminals. He directs the Video and Image Processing Laboratory (VIPER), which is equipped with state-of-the-art technology to digitize, store, process, steam and display digital images and video. VIPER supports multidisciplinary research in these areas.

Delp is an expert in digital watermarking and steganography, a procedure in which hidden patterns are embedded into an image or document on the Web. The patterns can be used to verify whether or not the image is authentic.

He says that printed materials can be a direct accessory to many criminal or terrorist acts. For example, forgery or alteration of documents can hide identities, and printed material may be used in the course of conducting illicit or terrorist activities. The ability to identify the exact printer or camera can provide a valuable tool for law enforcement and intelligence agencies.

"Through digital watermarking, it is possible to identify the specific printer or camera used in the criminal activity through the device's intrinsic signature and trace it back to the owner," Delp says.

Digital media can also be screened for hidden terrorist messages by using steganalysis, the science of finding hidden messages in data.

"Cybersecurity means a lot more than hacking," Delp says. "I would argue that it has a lot to do with surveillance." He and his research partners have an ongoing project called re-identification that relates to surveillance.

The researchers are looking at ways to use surveillance to identify criminals and observe crowds to determine any abnormalities that would trigger an alert.

Professor Edward J. Delp, director of the Video and Image Processing Laboratory (VIPER). He recently was named the 2015 Scientist of the Year by the Society for Imaging Science and Technology (IS&T), and SPIE, the international society for optics and photonics.

CLOSING SUPPLY CHAIN LOOPS THROUGH TECHNOLOGY

Sometimes, researchers use "cyber smarts" to fight crime on a number of fronts. Jan Allebach, the Hewlett-Packard Distinguished Professor of Electrical and Computer Engineering, as the named professor title might suggest, has worked on the cutting edge of printer technology with HP for 22 years. Funded by the National Science Foundation, his teams have used printer-level metadata embedding techniques to allow information that is imperceptible to the viewer to be extracted from a scan of the document via image analysis methods. This information can be used to authenticate the document by checking it against records stored in the cloud when the document was printed.

But when it comes to cybercrime, Allebach says there's no perfect security tool. "They all have weaknesses," he says, "and it's a continual cat-and-mouse game of trying to stay ahead of 'the bad guys.' The tools also have to be a bigger part of infrastructure or a supply chain."

Through Purdue's large push to improve nanomanufacturing efforts, Allebach believes there's a new space for those embedded printing technologies in food packaging and security and pharmaceutical areas. Specifically, he believes they can make a difference in keeping supply chains safer.

In the growing global business of pharmaceutical fraud, any castoff bottle could be refilled with counterfeit pills. The counterfeiters have even become adept at re-creating company logos for bottles and designing fake pills.

Allebach says his team circled their wagons back to the technologies they developed for printing when it came to brainstorming solutions for the pharmacy industry. "We came up with the idea that you can actually mark each tablet with a unique identification, similar to a QR code," he says.

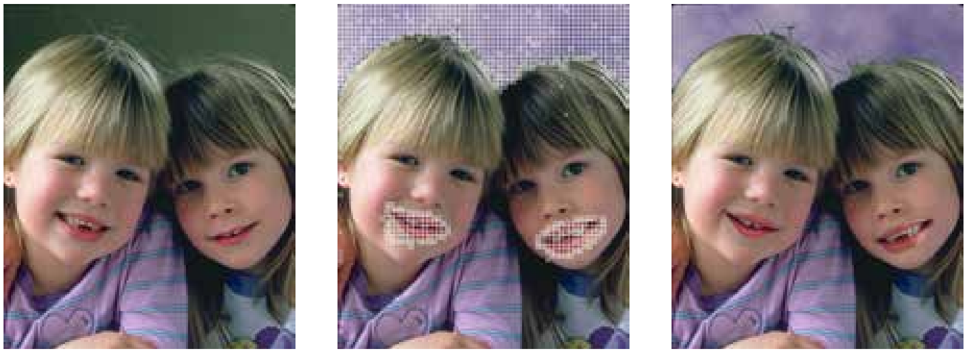
Using smartphones, people would take pictures of prescribed pills before ingesting them. The images would be uploaded to a database and verified by codes. If a code proves invalid or has already been submitted, the user would be alerted to the counterfeit.

Allebach believes they can apply the same principles to emerging 3-D printing technologies and things related to intellectual property rights. In the art world, for example, where it's important not to be visually intrusive, technology can embed invisible security codes to authenticate a piece of art.

"It comes down to using printing technologies to provide counterfeit deterrents," says Allebach, who calls it "closing the loop" because users capture the digital image at the end, bringing the supply chain full circle.

Still, the challenge remains building security tools robust enough to fend off the criminals. "It's like building a fortress," Allebach says. "You've got to have an outer wall, an inner wall and so forth."

Marking pharmaceutical drugs with QR codes can aid in foiling counterfeiting.



Digital watermarking and steganography, a procedure in which hidden patterns are embedded into an image, can verify whether or not the image is authentic.

PARTS MANAGEMENT IN THE NANOMANUFACTURING WORLD

The digital revolution will have lasting effects on the industrial world as well. Additive manufacturing essentially enables the desktop designing of parts that can be shared worldwide in real time. Computer-aided design and 3-D printers can expedite a process that previously relied on a great deal of trial and error. But that same immediacy and accessibility to manufactured parts also can lead to them being compromised and stolen.

George Chiu, professor of mechanical engineering, has been working with digital and functional printing for two decades. “I work as part of a multidisciplinary team to develop scalable nanomanufacturing technologies for the production of laminates and films that use environmentally friendly nano-cellulose material to replace plastic in vacuum or thermal forming packaging materials,” he says.

Through the development of inkjet printing processes, Chiu and his team have been able to apply print to materials that are far from regular ink, including metal, polymer, hydrogels and carbon nanotubes. “Our focus is on high throughput and high-yield patterning of functional material to a wide variety of substrates through integrated modeling and control of the material, substrate and printing process.”

A particular challenge of additive manufacturing and functional printing is the need for the authentication and tracking of parts, Chiu says. A simplified supply chain requires only the raw material. However, the information on how to make a part or product is now in a digital file that can be easily copied and duplicated by cybercriminals.

“Ensuring that a part is made with the proper composition, material type and specifications is similar to authenticating a printed document,” Chiu says. “The electronic version of the document can be easily copied, modified and printed.”

His work with Allebach and Delp has helped to embed an unperceivable signature in a printed document to facilitate authentication and forensic investigation. “We are considering leveraging our expertise to functional printed devices that are manufactured with additive technology,” Chiu says.

Like his colleagues, Chiu believes the security measures can be applied to the pharmaceutical supply chain, which could help companies stay one step ahead of the counterfeiters.

FIGHTING CYBERCRIME IS ‘CERIAS’

The Center for Education and Research in Information Assurance and Security (CERIAS) is viewed as one of the world’s leading centers for research and education in areas of information security. CERIAS is unique among such national centers in its multidisciplinary approach to the problems related to cybersecurity. Research conducted through CERIAS includes faculty from six different colleges and 20-plus departments across campus.

Eugene Spafford, professor of computer science and, by courtesy, professor of electrical and computer engineering, is the founder and executive director of CERIAS. He is a former member of the national President’s Information Technology Advisory Committee and a frequent presenter on topics related to cybercrime.

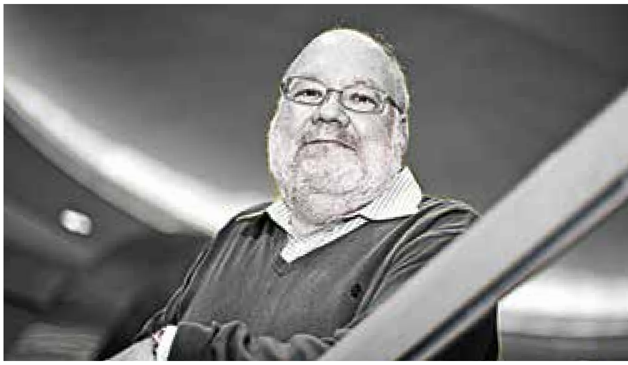
He says that theft of intellectual property from companies has been on the rise. “The loss of economically important data, and its use to advance non-U.S. industries that then compete with the U.S., could damage the health of our economy and the balance of trade,” Spafford says.

Decision makers and the general public are beginning to understand the deeper issues that result from inaction, he says. But in spite of this, it has been “easier to get congressional attention for existential threats, for example military threats, than criminal activities.”

“Put a line of four-star generals in uniform in front of Congress expounding a cyber Pearl Harbor and they garner more attention than law enforcement officers in suits and ties warning of cybergangs stealing property.”

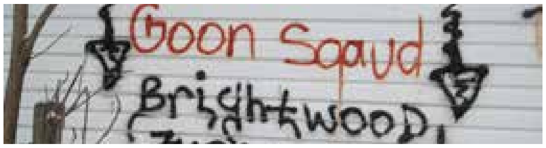
Law enforcement agencies and investigators, he says, must have the tools and funding necessary to address this complex threat. Spafford warns that increased federal funding for education, advanced research and regulation must occur to get beyond “catch-up” patching.

“The U.S. government is of the people, for the people,” he says. “Citizens must press their government and private vendors for better security and privacy.”



Professor Eugene Spafford, executive director of the Center for Education and Research in Information Assurance and Security (CERIAS).

AIDING LAW ENFORCEMENT IN GANG IDENTIFICATION



Researchers in VIPER are using the knowledge gained from work in mobile devices and applications to develop a mobile-based system capable of image analysis. This system will provide an accurate and useful output to a user based on a database of gang graffiti images.

Gangs are a serious threat to public safety throughout the United States. According to research from the National Gang Threat Assessment, there are approximately 1.4 million active street, prison, and outlaw motorcycle gang members in more than 33,000 gangs in the United States. Gangs are responsible for an average of 48 percent of violent crime in most jurisdictions and up to 90 percent in several others, according to NGIC analysis.

Street gang graffiti is their most common way to communicate messages, including challenges, warnings or intimidation to rival gangs. It is, however, an excellent way to track gang affiliation and growth, or even sometimes to obtain membership information.

“The idea of the project is that you literally take a picture of the gang graffiti with a mobile phone and then the system interprets the images,” Delp says.

The image analysis includes obtaining the metadata (geoposition, date and time) and extracting relevant features like color and shape from the gang graffiti image. The information is sent to a server and compared against the graffiti image database. The matched results are sent back to the device where the user can then review the results and provide extra inputs to refine information. Once the graffiti is completely decoded and interpreted, it is labeled and added to the database.

Law enforcement and public safety officials are testing the portable systems in the field.

The project is funded by the Department of Homeland Security’s Visual Analytics for Command, Control and Interoperatibility Environments Center of Excellence (VACCINE) at Purdue. ■

RESEARCH AIMS TO BLOCK MEDICAL DEVICE HACKERS

Researchers at Purdue and Princeton universities have created a prototype firewall to block hackers from interfering with wireless medical devices such as pacemakers, insulin delivery systems and brain implants.

The team had previously demonstrated how medical devices could be hacked wirelessly, potentially leading to catastrophic consequences.

What motivated us to work on this problem was the ease with which we were able to break into wireless medical systems,” says Anand Raghunathan, professor of electrical and computer engineering. “While the benefits of using medical devices greatly outweigh the risks, the growing concern about wireless attacks needs to be addressed.

Raghunathan is working with Princeton professor of engineering Niraj K. Jha, and Princeton graduate students.

The potentially vulnerable devices include pacemakers and continuous glucose monitoring and insulin delivery systems for patients with diabetes, now in use by hundreds of thousands of people. Brain implants under development to control epilepsy and “smart prosthetics” operated using electronic chips also could be vulnerable to similar attacks.

The team has created a prototype system called MedMon, for medical device monitor, which acts as a firewall to prevent hackers from hijacking the devices. The MedMon prototype was demonstrated to protect a diabetes therapy system consisting of a glucose monitor, a remote control and an insulin pump, which communicate with one another wirelessly.

In the near term, MedMon could be designed as an additional device that you could wear, so it would require no change to existing implantable devices or external readers that interact with them,” Raghunathan says. “It could be worn as a necklace, or it could be integrated into your cell phone, for example.

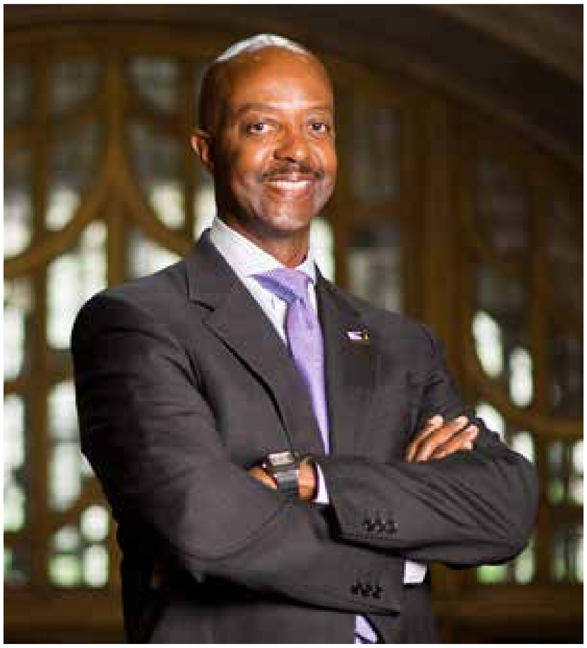
HOW IT WORKS

Many implantable devices have wireless transmitters and receivers, which enable health care providers to perform diagnostics and to download data. That wireless access also opens the door to potential hackers, who might alter the insulin dosage or direct pacemakers to malfunction, harming or killing a patient.

The MedMon prototype monitors communications going into and coming out of any implantable or wearable medical device. It uses multi layered anomaly detection to identify potentially malicious transactions. Upon detecting such an activity, the firewall can raise an alarm to the user or block “malicious packets” from reaching the medical device by using electronic jamming similar to technology used in military systems.

The team is working on miniaturizing the prototype. A patent application has been filed on the concept.

■ BY EMIL VENERE



ENGINEER AND ENTREPRENEUR

ALUMNUS COMBINES ENGINEERING SKILLS, BUSINESS ACUMEN TO LEAD GLOBAL SECURITY EQUIPMENT COMPANY

As a child growing up on the South Side of Chicago, "the hood," as he calls it, Tony Harris spent time playing basketball and tennis, drawing comic books and listening to Motown music. He loved math and dreamed of becoming an architect, but his high school drafting teacher suggested that engineering might give him more opportunities.

An academic scholarship led him to earn a Purdue bachelor's degree in mechanical engineering, which he followed with a master's degree from the Harvard Business School. In this way, he was able to satisfy a parallel interest in entrepreneurship.

As president and chief executive officer of Campbell/Harris Security Equipment Company (CSECO), Harris now oversees the manufacture of equipment that detects contraband, explosives and dirty bombs. The company's clients include U.S. Customs and Border Patrol and law enforcement agencies at home and abroad. His firm currently markets to 70 countries.

"My engineering education gave me an approach to problem solving that has been applicable to every business problem I have ever faced," Harris says. "It also gave me a language and source of credibility needed to manage other technical professionals, and it gave me confidence in my ability to master complex concepts," something that has served him well in dealing with regulatory bureaucracy.

"Our primary product contains a radioactive isotope, so there are regulatory hurdles that determine procurement, manufacturing and shipment of products that contain these isotopes," he says.

"While our products and services began almost exclusively aimed at drugs and money trafficking, the technology has been effectively applicable to explosives trafficking," Harris says of the company's expanding area of business.

As the company has grown, marketing to international clients requires understanding rules of law in diverse markets.

"I rely on my large network of Purdue and Harvard alumni and other business associates to meet individuals within those international markets who understand what is required to sell in those markets," Harris says.

One of those networks is one he helped to create while a student at Purdue — the National Society of Black Engineers (NSBE). With over 30,000 members and chapters on five continents, NSBE is now the largest student-run organization in the country. He is understandably proud of his involvement with the organization and says that over the last three decades it has kept him focused on engineering, despite time spent in other fields.

CSECO isn't Harris' first attempt as an entrepreneur. In fact, as he talks to students, he counsels them not to be anxious about that first job, thinking that it will impact their future profession.

"That couldn't be further from the truth," Harris says. "There is no way I could have tracked my career to where I am today."

He advises students to do their very best and learn from mistakes.

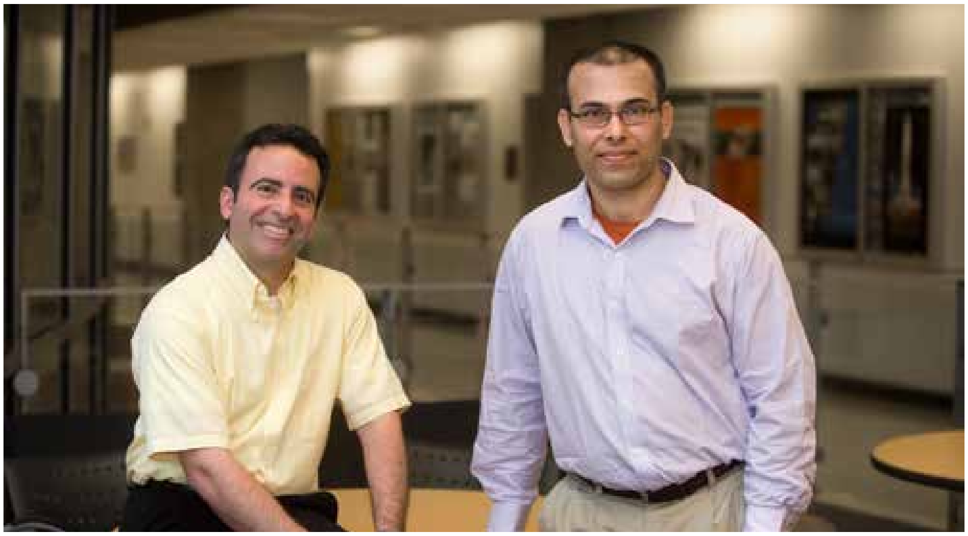
"I had three or four other companies where I totally failed before I got to this company that is tremendously successful," Harris says. "From each one of those failures I learned what I liked and didn't like, what I was good at and what I wasn't. Those failures were more valuable than the successes I have had to this point."

■ BY DELLA PACHECO

GUARDING AGAINST THREATS

RESEARCHERS PEER INTO THE FUTURE TO HELP THE U.S. FOIL ENEMY MISSILE ATTACKS

BY EMIL VENERE



Daniel DeLaurentis, left, associate professor of aeronautics and astronautics, and Saurabh Bagchi, professor of electrical and computer engineering, are working with the U.S. Missile Defense Agency to help the United States foil enemy missile attacks. (Purdue University photo/Mark Simons)

"OUR MISSION IS TO LOOK INTO THE FUTURE."

— DANIEL DELAURENTIS

Working with the U.S. Missile Defense Agency, a Purdue research team is creating software that makes it possible to pose various "what if" questions — scenarios that explore plausible future missile advances in adversarial nations and the defensive capability of the United States.

"Our mission is to look into the future, to say, for example, what if we had some new missile technology, or what if a country had the capability to launch a number of missiles at the United States? What would we have to do to shoot them down?" asks Daniel DeLaurentis, associate professor of aeronautics and astronautics.

The research focuses on how to defend against attacks called "raids" in which many missiles would be launched against the United States, says Saurabh Bagchi, associate professor of electrical and computer engineering.

"The system must be able to handle a raid environment, based, in part, on the assumption that our potential adversaries will expand their missile capabilities in the future," he says. "So we are developing a battle management system that is flexible enough to work for decades from now. The biggest challenge is trying to do decision making under conditions of uncertainty. There is uncertainty about what the enemy will be able to do in the future and what we will be able to do in the future."

DeLaurentis and Bagchi are leading the project, working with Stephen D. Heister, Purdue's Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration; Joseph Pekny, professor of chemical engineering; two research scientists; and about a dozen doctoral students.

The project began in 2010 and was funded with a four-year, $4.8 million grant from the Missile Defense Agency, which is part of the U.S. Department of Defense.

Scenarios have included hypothetical attacks by North Korea and Iran. The United States can launch interceptors from Fort Greely in Alaska and from Navy Aegis destroyers and cruisers equipped with the Aegis Ballistic Missile Defense Weapon System. The nation's anti-missile system is designed to locate missiles, track them and launch intercepting missiles to shoot them down.

"The earlier the intercept after enemy missiles are launched, the greater the probability of mission success," DeLaurentis says. "Otherwise they fan out more and have greater opportunity to further complicate the engagement. Additionally, the closer they get to our friendly positions, the more you have to worry about additional factors like potentially dangerous debris."

The project is inherently interdisciplinary because it requires expertise in aerospace and computer engineering.

"You need aerospace for things dealing with missiles and the operation of satellites, sensors and radars," Bagchi says. "You need computer science and computer engineering to run algorithms that will decide which weapons to fire and at which missiles and also to fend off simultaneous cyberattacks against our command and control computers."

Specialized software designed for "enhanced command and control" includes algorithms for aerospace modeling of the flight characteristics of enemy missiles and interceptors. The complex software needs to function within a global network of many computers and sensors including radar and satellite surveillance systems. A key challenge is to create algorithms that are able to function in such distributed environments.

The researchers use a high-performance computer cluster managed by Information Technology at Purdue, or ITaP. The project uses intensive long-running simulations, which make it possible to assess the performance of the U.S. missile defense system using as few field tests as possible.

"This is important for several reasons," DeLaurentis says. "Field tests are expensive, so you want to use them sparingly. At the same time, the simulations allow us to run many more experiments than would otherwise be possible with field tests alone, and this yields a lot of data to improve the system." ■

APPROVED FOR PUBLIC RELEASE, 13-MDA-7340 (10 JUNE 13).

Alina Alexeenko and her team, including graduate student Andrew Strongrich, use this vacuum chamber in the Aerospace Sciences Laboratory at the Purdue University Airport. The research, which includes work to develop tiny microthrusters for miniature satellites, has recently been selected for funding through the NASA Smallsat program. (Purdue University photo/Mark Simons)

FROM EARTH

AND BEYOND

RESEARCH AIMS TO IMPROVE LONGEVITY OF DRUGS, SOLVE MYSTERY OF MASS EXTINCTIONS

■ BY EMIL VENERE

ALINA ALEXEENKO is applying her expertise in aeronautical engineering to areas as diverse as pharmaceutical manufacturing and miniature satellites, nanotechnology and the mass extinction of species from asteroid impacts.

An associate professor in the School of Aeronautics and Astronautics, she specializes in fluid mechanics, or the study of how fluids and gases behave. Equipment in her lab recreates the partial vacuum of low Earth orbit.

"It turns out that some of the tools we use to learn how spacecraft behave at high altitude also are applicable to many other areas of research, such as pharmaceutical manufacturing and atmospheric changes due to catastrophic asteroid impacts," Alexeenko says.

She won a 2011 National Science Foundation Faculty Early Career Development award, among the most prestigious honors for outstanding young researchers. She is using the grant to learn how to apply the principles of "Knudsen forces," or forces exerted by the movement of gas molecules, to the field of nanotechnology.

Knowledge about the forces is needed to design high-precision thermal sensors, miniature motors and tiny machines called microelectromechanical systems, or MEMS, and to improve the accuracy of a widely used research tool called an atomic force microscope.

Textbooks contain little information about the physics of Knudsen forces, although they can profoundly influence the motion of MEMS components in the presence of heating or cooling. The project includes curriculum development and work to create simulation tools and the world's largest and smallest Crookes radiometers, ornamental devices consisting of a sealed glass chamber housing metallic vanes that spin when exposed to sunlight. Knudsen forces cause the vanes to spin inside the devices.

The Knudsen forces also could make possible creation of a new type of "energy harvesting" technology that would use waste heat to generate electricity.

Alexeenko will develop online simulation tools for students and other researchers, and the tools will be made available on nanoHUB.org, a Purdue-based interactive website providing scientific simulations, seminars, interactive courses and other specialized nanotech-related materials.

"This project aims to quantify and exploit Knudsen forces but also to advance the methods that allowed people to work with and study the phenomenon," she says. "Now there is no commercially available tool to calculate Knudsen forces."

The research is performed in a high-vacuum laboratory at the Purdue Airport. The facility also is being used in work aimed at improving the quality and quantity of certain types of injectable drugs while reducing cost. The drugs are created as a liquid, frozen and then "sublimed" in a vacuum to remove water. The vacuum is required for sublimation, which converts a solid directly to a gas, eliminating the need for evaporation.

"Evaporation is a very aggressive process that breaks molecular bonds, and this is not good for preserving certain large molecules in pharmaceutical products," Alexeenko says. "This includes a lot of injectable pharmaceuticals such as cancer drugs. You need to remove water for prolonged shelf life."

Graduate student Andrew Strongrich prepares a sample to test on a "microNewton thrust stand." Below, Alexeenko holds a component for a satellite microthruster. (Purdue University photo/Mark Simons)

The method, called vacuum freeze drying, is widely used in food processing to increase shelf life without adding preservatives. However, it is one of the most expensive manufacturing processes for injectable pharmaceuticals.

“We are working with several companies to better understand and improve the process,” she says.

LOOKING TO PAST TO IMPROVE FUTURE

The research harnesses equations developed more than a century ago by Austrian physicist Ludwig Boltzmann. The Boltzmann equation describes fluid flows on the molecular level and is more general than the Navier-Stokes equations that are widely used.

“If you want to compute aerodynamics for a car, you can use Navier-Stokes, but for aerodynamics of a space station in low Earth orbit, one would have to solve Boltzmann,” she says.

Alexeenko and her students are creating simulations based on the Boltzmann equations that could be used by pharmaceutical companies for drug manufacturing and development.

“We are trying to come up with quantitative tools to design these processes,” says Alexeenko of her work with Elizabeth Topp, head of the Department of Industrial and Physical Pharmacy and the Dane O. Kildsig Chair in Industrial and Physical Pharmacy.

Much of the freeze-drying research is being performed by doctoral student Arnab Ganguly, who recently received the Baxter International Inc. Young Investigator award for his work in collaboration with Indiana-based drug maker Baxter BioPharma.

In other research, she is working with Jay Melosh, Distinguished Professor of Earth and Atmospheric Sciences, Physics, and Aerospace Engineering, to study how an asteroid impact led to the mass extinction of marine organisms about 66 million years ago.

“We are looking at the chemical transformation of the atmosphere that happened because of the re-entry of particles called spherules,” she says.

The spherules were particles created when the asteroid crashed into the Earth, vaporizing rock that expanded into space as a giant vapor plume. Small droplets of molten and vaporized rock in the plume condensed and solidified, falling back to Earth as a thin layer. The spherule particles re-entered the atmosphere at several times the speed of sound, fast enough to break apart molecules in Earth’s primordial atmosphere, possibly forming nitric oxides that cause acid rain. The acid rain would have turned the oceans acidic enough to kill off many life forms.

“We are applying aerospace engineering tools that are typically used for analysis of re-entry of spacecraft to analyze re-entry of spherules,” Alexeenko says.

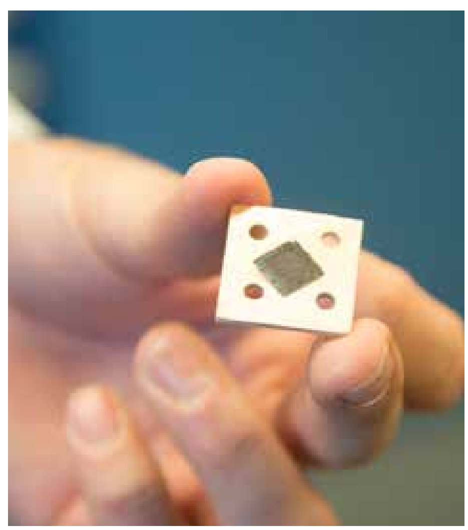
Doctoral student Devon Parkos led the aeronautics portion of the study and recently won a National Science Foundation graduate research fellowship.

Alexeenko also is using aerospace engineering tools for other research, including a study to learn why Earth’s atmosphere evolved differently from those of Mars and Venus.

“All three planets started out with similar conditions, having atmospheres of carbon dioxide and nitrogen,” Alexeenko says. “We believe that a process we call hypersonic chemosynthesis could have played a major role in the formation of the first organic compounds on Earth.”

Asteroids collided with all three planets. However, the ejecta spherules would have behaved differently. For example, she says, because the escape velocity on Mars is half that of Earth’s, more of the spherules would have been thrown deeper into space, never to return to the planet’s surface. Fewer spherules would have resulted in less chemosynthesis.

Alexeenko also is involved in research to create a propulsion system for tiny “nano-satellites,” working with Stephen Heister, the Raisbeck Engineering Distinguished Professor for Engineering and Technology Integration, and graduate student Tony Cofer. The cube-shaped satellites weigh about one kilogram (about two pounds), and measure roughly 10 centimeters (four inches) on each side. The propulsion system merges two technologies: MEMS and aeronautical engineering. ■



IN CHARGE

RESEARCH IMPROVES SAFETY, FUNCTIONALITY OF LITHIUM-ION BATTERIES

BY EMIL VENERE

From autos to aerospace, laptops to smartphones, lithium-ion batteries power our lives. Purdue Engineering faculty are determined to make these batteries safer and more reliable.

James Caruthers, the Gerald and Sarah Skidmore Professor of Chemical Engineering. (Purdue University photo/Mark Simons).

James Caruthers, the Gerald and Sarah Skidmore Professor of Chemical Engineering, is co-inventor of a new tool to detect flaws in lithium-ion batteries as they are being manufactured. It's a step toward reducing defects and inconsistencies in the thickness of electrodes that affect battery life and reliability.

The electrodes, called anodes and cathodes, are the building blocks of powerful battery arrays like those used in electric and hybrid vehicles. Electrodes have a metal-like copper on one side and on the other side a black electrode paint that can store lithium. Lithium ions travel from the cathode to the anode during charging and in the reverse direction when discharging energy.

The anode and cathode materials expand as lithium ions are incorporated into it, and this causes mechanical stresses that can cause damage and shorten battery life.

The coating is a complex mixture of carbon, particulates that store lithium, chemical binders and carbon black. The electrodes' quality depends on this "battery paint" being applied uniformly.

"A key challenge is to be able to rapidly and accurately sense the quality of the battery paint," Caruthers says.

Caruthers and his research team, which included former Purdue professor Douglas Adams, have developed a system that uses a flashbulb-like heat source and a thermal camera to read how heat travels through the electrodes. The "flash thermography measurement" takes less than a second to reveal differences in thickness and composition.

Findings were detailed in a research paper presented during the 2013 annual meeting of the Society for Experimental Mechanics. In their method, a flashing xenon bulb heats the copper side of the electrode, and an infrared camera reads the heat signature on the black side, producing a thermal image.

The researchers found that when the "battery paint" is spread unevenly during the manufacturing, a flash thermography measurement can readily detect these flaws — flaws that degrade battery performance. Findings show the technology also is able to detect subtle differences in the ratio of carbon black to the polymer binder, which could be key in quality control.

The technique also has revealed other factors that could diminish battery performance and reliability, such as scratches, air bubbles and contaminants. The thermal imaging process, for which Purdue has applied for a patent, is ideal for a manufacturing line because it is fast, accurate and can detect flaws before assembly.

CONTROLLING DENDRITES TO IMPROVE PERFORMANCE, SAFETY

Controlling or eliminating formation of "dendrites" that cause lithium-ion batteries to fail is at the heart of additional research led by R. Edwin García, associate professor of materials engineering. If realized, this would improve safety and could take the charge time down to a matter of minutes rather than hours.

Dendrites are lithium deposits that form on electrode surfaces and can grow until they cause an internal short circuit, which results in battery failure and possible fire.

Researchers have created an analytical theory that shows how to design experiments to study ways of controlling dendrite growth. The theory allows researchers to predict early stages of dendrite formation.

"We believe that this work is the first of its kind because, prior to its publication, work on this area had heavily relied on anecdotal evidence," García says. "While we have applied this theory to lithium-ion batteries, it was formulated so that it could

be readily applied to other emerging battery chemistries, such as magnesium-ion and lithium-sulfur."

Findings were in the February 2013 edition of the *Journal of the Electrochemical Society*. The paper was written by postdoctoral researcher David Ely and García. Their work was funded by Toyota Motor Engineering & Manufacturing North America Inc.

The dendrite lithium formations grow like tumors while batteries are being recharged. Some of them add layers that when cut in half reveal an internal structure like tree rings, each representing a single recharge. Because they grow faster when exposed to the high voltages needed for fast recharging, the dendrites limit recharging speed.

"You want your battery to recharge as fast as possible, in a matter of 10 minutes or so," García says. "This would be possible if we could better control or eliminate dendrite growth."

Each battery's anodes and cathodes are separated by an insulating polymer that keeps the electrodes from touching. When the battery is recharged, lithium-ions are shuttled from the cathode to the anode through a liquid or gel called an electrolyte, from which the dendrites draw material to build up on the anode's surface. The dendrites may grow large enough to penetrate the separating barrier and touch the cathode.

"The moment these touch, the battery is dead," García says. "Or worse, if you have too much current going through the dendrites while the battery is being charged, the battery can catch fire."

The researchers used their analytical model to identify behavior associated with dendrite formation and have proposed methods to suppress or control them.

One solution might be to engineer the anode's surface chemistry to inhibit the lithium's beading at the surface so that it wets the surface instead of nucleating into a dendrite.

Another potential approach is to induce lithium deposits to grow uniformly, instead of heterogeneously. The heterogeneous growth means the dendrites sprout unevenly at various locations on the electrode's surface. Some of the formations grow in needlelike spikes that quickly breach the barrier to the cathode. High voltage is required for fast charging, but heterogeneous dendrite formation restricts this process. Having uniformly distributed lithium deposits with a uniform size could make fast charging possible by allowing higher voltage.

Another method might be to charge the batteries using rapid pulses of electricity instead of a constant current.

"We have developed an analytical theory that identifies the different ways in which lithium-ion batteries can fail during recharge," García says. "Fundamentally, we proposed a universal road map that allows experimentalists and theoreticians to explore the different regimes of behavior during battery recharging. The proposed analytical road map enables researchers to identify the charging conditions that will completely suppress or at least minimize the formation of lithium dendrites."

Findings showed how to keep a dendrite from growing beyond its "critical kinetic radius," the size at which it will either shrink or continue to grow, depending on how much current is applied.

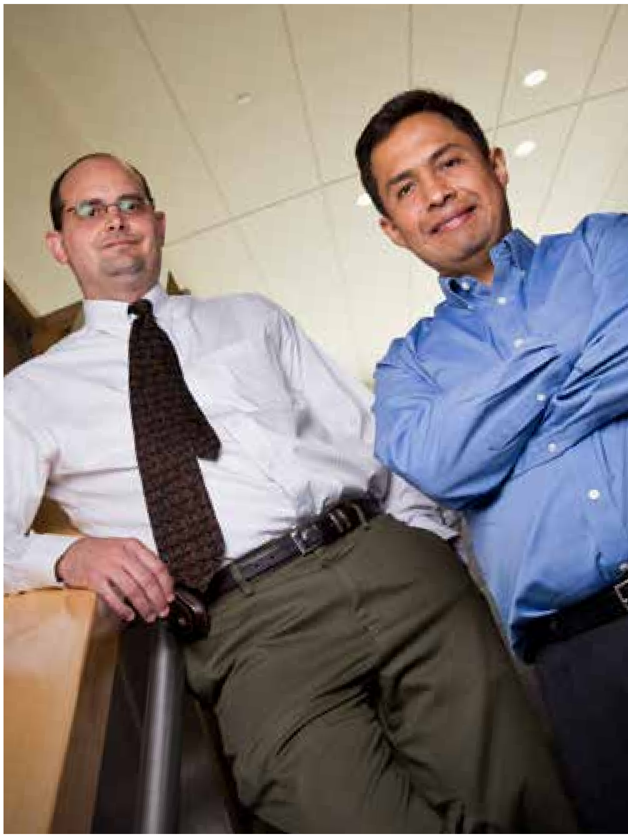
Researcher Stephen J. Harris at Lawrence Berkeley National Laboratory has recorded dendrite growth in movies that the Purdue researchers studied for their simulation.

The Purdue researchers have found that the smaller dendrites may transfer their mass to larger ones, causing the larger dendrites to grow faster and more stably. The work was validated against available experimental data in the scientific literature.

"We also unified conflicting existing theories as they were reported in the 1990s and early 2000s," García says.

As their work continues, future research is likely to aim at learning more detail about dendrite behavior.

"The dendrites don't grow just everywhere, but at very specific locations on the anode," García says. "We want to model that. Such a comprehensive model would lead to advanced battery designs of improved performance and reliability." ■



R. Edwin Garcia, associate professor of materials engineering, right, with former postdoctoral researcher David Ely to find ways to control dentrite formation on lithium-ion batteries. (Purdue University photo/Mark Simons).

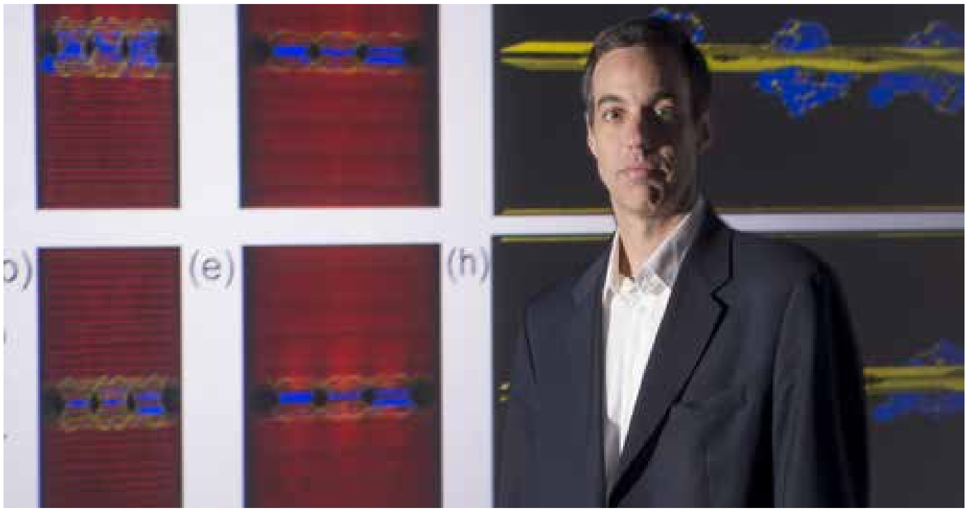
MATERIALS WORLD

Faculty couple shares research and personal bond

■ BY LINDA THOMAS TERHUNE

Two physicists with an interest in materials. One marriage. Infinite contributions to microsystems and nanostructure.

Purdue University photo/Mark Simons



MARISOL KOSLOWSKI, associate professor of mechanical engineering, and **ALEJANDRO STRACHAN**, professor of materials engineering, met at the University of Buenos Aires in Argentina. Strachan was completing graduate studies in physics, with an interest in molecular modeling of advanced materials. Koslowski was wrapping up undergraduate studies in physics.

The two married and, as a pair, joined the California Institute of Technology, where Strachan was a postdoctoral associate in the Materials Process Simulation Center and Koslowski completed a doctorate in aeronautics and the behavior of metals related to explosives.

The years in California were followed by three more at Los Alamos National Laboratories. Strachan worked in the theoretical division and Koslowski focused on the computational side of material behavior in a chemistry group. They joined the Purdue engineering faculty in 2005.

Koslowski and Strachan have forged a career in computational modeling of materials. Both were coming of age as the field exploded. The applications of the research range from polymer composites for the aerospace industry, nanomaterials for microelectronics that are only a few atoms thick and composites for pharmaceuticals.

They often work as a team in the research world and partner as parents raising a son and a daughter. Though they say they try to separate work life from that at home, the two naturally intersect.

Strachan points out that other couples might benefit from hearing about a partner's day at work, which "takes you to a different world." Not for them. "We talk about research at work and at home," Koslowski says, "but the kids keep us very busy." This includes soccer — Strachan coaches one of the teams. The researchers take turns attending conferences so that one parent can stay home with the children. Sometimes the whole family travels together.

NUTS AND BOLTS

Determined from an early age to be a scientist, Koslowski was drawn from pure science into engineering through her undergraduate thesis. In 2006, she received the Leon Heller award for a postdoctoral publication in Theoretical Physics from Los Alamos National Laboratory.

Her research has explored materials behavior at the intersection of physics and engineering. She now works in microsystems, examining materials on the computational level to learn how material breaks or fails.

"Being able to predict material failure is important in microsystems and in many other applications from polymer composites to pharmaceutical materials and microelectronics." Koslowski says. "Many systems do not make it to the market because of poor reliability. Understanding failure will help us design future materials with improved properties and high reliability."

For example, the behavior of crystalline materials is not only determined by the structure. Defects play an important role in defining the physical and chemical response, Koslowski says. Manipulating these defects facilitates the development of improved materials with unique properties. She points out that nanocrystalline materials exhibit high yield and fracture strengths, superior wear and radiation damage resistance.

She and her research team conduct their work at the Center for Prediction of Reliability, Integrity and Survivability of Microsystems (PRISM) at Purdue's Discovery Park in West Lafayette, Indiana.

Strachan develops methods to predict how materials behave using computational modeling. His group examines materials on the atomic scale, doing simulations to study each atom individually. He focuses on modeling of condensed-phase chemistry, active materials and nanotechnology, as well as mechanical properties of structural materials.

His work has applications in electronic, thermal and mechanical properties of nano and micro-electromechanical systems and electronic and energy conversion devices; thermo-mechanical response of polymer composites and molecular solids; and the physics and chemistry of active materials including shape memory and energetic materials. Strachan is also involved with Purdue's nanoHUB — created by the National Science Foundation-funded Network for Computational Nanotechnology. A research software code that he developed allows users to perform molecular dynamics simulations of materials using a Web browser. It is a rare resource that gives researchers and students the ability to do industrial and research-grade simulations with complex calculations. Sophomores, for example, can perform electronic structure calculations via cloud scientific computing, using simulations previously restricted to researchers.

"Students have access to tools that would have been unthinkable when I joined Purdue seven years ago," Strachan says. "It will bring more kids to engineering, lower the barriers to access and give people tools to develop knowledge." ■

PREEMINENT TEAMS

■ BY EMIL VENERE

The College of Engineering has named four preeminent teams to focus on research ranging from drug delivery to nanomanufacturing. The effort is part of the college's strategic growth plan, which will add as many as 107 faculty over five years.

"The preeminent teams process helps us make informed faculty hiring decisions based on research strengths and with a focus on the potential for impact," says Leah Jamieson, the John A. Edwardson Dean of Engineering. "This approach emphasizes the power of team-based research."

It is the second annual competition, which brings the total number of teams to eight. To learn more about the 2013-14 preeminent teams, visit the College of Engineering's website.

The teams are building on strengths that are already part of the college. To become preeminent teams, they went through a process similar to a pitch entrepreneurs would give to venture capitalists. This year 27 teams, comprising more than 150 faculty members, participated in the competition.

The strategic growth plan is part of Purdue Moves, a range of initiatives designed to broaden the University's global impact and enhance educational opportunities for its students.

DESIGNER PARTICULATE PRODUCTS

A research center for the manufacture of particulate products including foods and feed, consumer goods, specialty chemicals, agricultural chemicals, pharmaceuticals and energetic materials. The work will focus on a model-based process design to produce engineered particles and structured particulate products, develop the understanding of process-structure-function relationships for these products and build capacity through a highly qualified workforce in particulate science and engineering. The research could affect applications in areas including drug delivery and agriculture. Particle products contribute more than $1 trillion to the U.S. economy annually, and a number of companies are headquartered in the Midwest.

TEAM LEADER

JIM LITSTER, professor of chemical engineering and professor of industrial and physical pharmacy

TEAM MEMBERS

KLEIN ILELEJI, associate professor of agricultural and biological engineering
ZOLTAN NAGY, professor of chemical engineering
LYNNE TAYLOR, professor of industrial and physical pharmacy
CARL WASSGREN, professor of mechanical engineering and professor of industrial and physical pharmacy

COLD PLASMAS

Extreme density, low-temperature plasmas for electronics, aerospace, food science and biotechnology applications. Low-temperature plasmas (LTP) are weakly ionized gases that are being extensively used in fluorescent lights and in microchip fabrication. New ways of generating and controlling LTP could lead to new applications ranging from medicine and food processing to enhancing aerodynamics and propulsion performance of existing and future airplanes. The ability of plasmas to interact with electromagnetic waves, combined with controllability and "tenability" of plasma characteristics, could enable novel radio-frequency devices.

TEAM LEADER

SERGEY MACHERET, professor of aeronautics and astronautics

TEAM MEMBERS

ALINA ALEXEENKO, associate professor of aeronautics and astronautics
SALLY BANE, assistant professor of aeronautics and astronautics
TIMOTHY FISHER, the James G. Dwyer Professor of Mechanical Engineering
ALLEN GARNER, assistant professor of nuclear engineering
AHMED HASSANEIN, the Paul L. Wattelet Professor of Nuclear Engineering and head, School of Nuclear Engineering
KEVIN KEENER, professor of food science
ROBERT LUCHT, the Ralph and Bettye Bailey Professor of Combustion in Mechanical Engineering
DIMITRIOS PEROULIS, professor of electrical and computer engineering

NANOMANUFACTURING

Nanomanufacturing research aimed at creating "aware-responsive" films with applications in pharmacy, agriculture, food packaging and functional non-woven materials for uses including wound dressings and diapers. Nanomanufacturing can bring advances such as smart pharmaceuticals that release medications differently for specific patients, food packaging that contains sensors to monitor food quality and cheap sensors for health monitoring.

TEAM LEADER

ALI SHAKOURI, professor of electrical and computer engineering and the Mary Jo and Robert L. Kirk Director of Birck Nanotechnology Center

TEAM MEMBERS

JAN ALLEBACH, the Hewlett Packard Distinguished Professor of Electrical and Computer Engineering
GARY CHENG, associate professor of industrial engineering
GEORGE CHIU, professor of mechanical engineering
TIMOTHY FISHER, the James G. Dwyer Professor of Mechanical Engineering
JOE KOKINI, professor of food science
KINAM PARK, the Showalter Distinguished Professor of Biomedical Engineering
RODO PINAL, associate professor of industrial and physical pharmacy
ARVIND RAMAN, associate dean of the college's Global Engineering Programs and the Robert V. Adams Professor of Mechanical Engineering
ALEX WEI, professor of chemistry
JEFF YOUNGBLOOD, associate professor of materials engineering
BABAK ZIAIE, professor of electrical and computer engineering

SPINTRONICS: ATOMS TO SYSTEMS

Research into development of new types of computer memory and electronic devices based on "spintronics." In 2006, the semiconductor industry and the National Science Foundation launched the Nanoelectronics Research Initiative (NRI) to look for "the next transistor." Purdue researchers, led by the Network for Computational Nanotechnology and Birck Nanotechnology Center, have been a visible and active part of the NRI since its inception. Conventional computers use the presence and absence of an electric charge to represent ones and zeros in a binary code needed to carry out computations. Spintronics, however, uses the "spin state" of electrons to represent ones and zeros. Purdue could play a leading role in this new field emerging from the confluence of spintronics and nanomagnetics.

TEAM LEADER

SUPRIYO DATTA, the Thomas Duncan Distinguished Professor of Electrical and Computer Engineering

TEAM MEMBERS

JOERG APPENZELLER, the Barry M. and Patricia L. Epstein Professor of Electrical and Computer Engineering and scientific director of nanoelectronics in Birck Nanotechnology Center
YONG CHEN, associate professor of physics and astronomy and associate professor of electrical and computer engineering
ZHIHONG CHEN, associate professor of electrical and computer engineering
ERNESTO MARINERO, professor of engineering practice of materials engineering
ANAND RAGHUNATHAN, professor of electrical and computer engineering
KAUSHIK ROY, the Edward G. Tiedemann Jr. Distinguished Professor of Electrical and Computer Engineering

Wang Hall, top right, is providing "swing space" to allow occupants of older buildings like Grissom Hall, top left, temporary space while renovations are completed. The renovated Grissom Hall will provide more collaborative and open space, sunlight and energy efficiency. (Purdue University photos/Matt Thomas and Charles Jischke. Rendering provided by MSKTD & Associates Inc.)

FLEXIBILITY

STATE-OF-THE-ART SPACE KEY TO GROWTH

Wang Hall is part of the College of Engineering's strategic plan to grow the faculty 30 percent and increase undergraduate enrollment by 10 percent and graduate enrollment by 25 percent.

The School of Electrical and Computer Engineering is using 40 percent of the building for laboratories and offices, forming the third leg of the "ECE triangle" with the Electrical Engineering Building and the Materials and Electrical Engineering Building across the street.

Professional online programs for engineering and technology are sharing an area on the second floor while Engineering Education will house their research labs on the third floor. Finally, the fourth floor is "swing space," now temporarily occupied by the Industrial Engineering faculty and staff from Grissom Hall.

Leah Jamieson, the John A. Edwardson Dean of Engineering, says, "This swing space is a lifesaver for engineering. As we add 107 new faculty members, we need more space for faculty, staff, students and labs. Rather than build everything new, we are aggressively re-envisioning and reinventing space in our core older buildings. As we renovate facilities — such as Grissom Hall — the occupants of these older buildings will move temporarily to Wang, allowing us to work faster and improve space utilization efficiency in our existing buildings by 50 percent."

Like Wang Hall, the renovated buildings will provide more collaborative and open space, sunlight, and energy efficiency.

■ DELLA PACHECO

Photo by Mark Simons

GOING FOR THE GREEN

For Boilermaker brothers Tyler and Trevor Back, a passion for golf and entrepreneurship combine for startup success.

Tyler (BSME '03) and Trevor (BSMET '01) are the co-inventors of **Gimme Charge**, a charger for cell phones and other USB-powered devices that plugs into the existing charging port on electric golf carts.

"I was on the golf course with Tyler and had a dying phone when I realized I was sitting on a huge source of electrical power," Trevor says. "Why can't you just plug it into the cart like you would a car?"

Though it seemed like a simple question, the Back brothers quickly learned that the answer was a bit more complex.

"Electric golf carts don't have outlets for car or wall chargers, and their charging ports are all different sizes, shapes and voltages," Tyler says. "So, we decided to focus on the three leading cart manufacturers — Yamaha, Club Car and E-Z-GO — and create custom versions for each."

Working from the Tech Shop, a communal workshop for entrepreneurs in San Francisco, Tyler designed, tested and refined the prototypes and mechanics. Back home in Indiana, Trevor assembled the electronic components, developed supply and distribution channels, and built the Gimme Charge website.

BUT THEY WEREN'T ON THE GREEN JUST YET.

"Once we got to market, we realized we had to qualify each sale by determining which type of cart the buyer used," Trevor says. "So, we lowered our price point and introduced a one-size-fits-all design with interchangeable components that would work with all of them."

Today, less than three years after that fateful golf game, Gimme Charge is selling briskly in retail locations on the West Coast and direct to consumers via the company website. "The market is there," Trevor says. "It's just a matter of keeping enough inventory to meet demand."

Toward that end, the enterprising siblings now devote themselves full-time to Gimme Charge.

"My background is in mechanical design, and Trevor's background is in electronics manufacturing, so our skill sets are very complementary," Tyler says. "And we both do a little bit of everything. When your company is only two people, you have to wear a lot of different hats."

Trevor, who previously worked for Siemens, operates from his Indianapolis home. "The entrepreneurial spirit is alive and well in my basement," he says.

Tyler, who previously worked for BAE Systems in Silicon Valley, maintains an office at the Tech Shop and travels to Indiana for about a week each month on business — and, if time permits, for a couple rounds of golf with his older brother.

"It's amazing how much less golf we play since launching the company," Tyler says. "We used to be able to leave work around 6 p.m. and get in nine holes before it turned dark. Now we're up until 2 a.m. working on Gimme Charge. But that's fine with us — it's a different kind of fun."

■ ERIC NELSON

SOCIAL RESPONSIBILITY DRIVES THIS

'FATHER' OF INVENTION

STEPHEN KATSAROS' career has been centered on innovation — ranging from product development to intellectual property. A 1996 BSME alumnus, he has invented products ranging from Dynastar Skis to a RevoPower motorized bicycle wheel that gets 200 mpg at 20 mph.

In 2011, Katsaros founded Nokero (short for No Kerosene), a company formed with a mission to bring solar-powered light bulbs to the 20 percent of humanity without access to power. Those without power collectively burn 77 billion liters of kerosene a year in order to see at night. Burning kerosene for light emits 190 million metric tons of carbon dioxide, causes respiratory illness and increases the risk of accidental fires.

Additionally, for those with an income of $2 or less a day, the cost of kerosene to fuel the lamps consumes up to 20 percent of their wages.

To date, more than 600,000 light bulbs have been sold to people in 120 different countries, no small feat given the challenges of distributing to the most geographically and economically isolated parts of the world.

Katsaros shares his motivation for entrepreneurship, the challenges he addresses and offers advice for would-be innovators.

Q&A

Why did you decide to attend Purdue and major in mechanical engineering?

I have always been tinkering with technology. When I was in high school, I invented a product used for alpine ski racing. Traveling around to various ski resorts, I would sell this tool to the shops. That was the start of my entrepreneurial projects. I applied to Purdue early and was accepted, but did not go directly after graduation. Instead, I took a post-graduate year to continue ski racing. I knew, however, that I wanted to major in mechanical engineering.

Your career is centered on innovation, ranging from product development to intellectual property. What are some of your inventions and products and why did you develop them?

I have had so many ideas across so many industries. I can't explain why these have been so broad, other than the "spark" just comes at different times, and you never know which one will become the main pursuit. Overall, I just love creating products, and it is much better when they make it to market!

You received a BFGoodrich Collegiate Inventors Award in 1995. How did this come about?

It is now called the Collegiate Inventor's Competition.
My invention was a suspended pivotal bike storage rack that uses the overhead space in a house or apartment without sacrificing living space. As a senior, I was working closely with the late Purdue Professor Alan McDonald, and we decided to send in an application. It was a special event as it was the opening of the National Inventors Hall of Fame in Akron, Ohio. Fast-forward to today, and after receiving the United States Patent Office's "Patents for Humanity" award, it has been fun to come full circle. I was asked to become a judge for this very program.

What inspires you?

Seeing my products in the hands of customers.

What are you working on right now?

Figuring out distribution routes for our solar lights. In particular, we work closely with our staff and partners in Kenya.

You have said that so many ideas die in a boardroom, in endless meetings, or on dry erase boards. That once a decision is made you've got to be fearless and move it forward. Can you give an example of a mistake you made and what you learned from it?

I have made lots of mistakes. In some ways the entire RevoPower project was a total loss of $2.3 million of investors' money. We tried very hard for five years to make it a success.

Nokero is all about social responsibility and "doing well by doing good." What made you move toward this path in your career?

It wasn't a calculated transition, it just happened. But it has been the best thing in my career. I have really enjoyed meeting great people throughout the world who are driven by things other than money. I highly recommend social entrepreneurship to those who are looking for a career change.

What is your definition of social entrepreneurship? What are the challenges? What are the rewards?

To me, social entrepreneurship is solving social problems with a key approach being a for-profit model. The rewards range from doing the "right thing" to having an organization that can scale up based on its earnings.

Describe a typical day.

Up at 5 a.m. to hold Skype calls with our partners in Asia, help the kids get ready for the day and then I'm off to work around 8 a.m. There, I hop from meeting to meeting, finding little time to do larger projects.

After heading home and spending time with the family, I usually work for a few hours between 9 p.m. and midnight.

What is your role with the Center for Combatting Global Poverty?

We have a new home in Denver called the Posner Center for International Development. I worked with its visionary, Andrew Romanoff, while he pulled together 25 organizations and convinced all of us to share office space. I was an early advocate and Andrew asked me and two others to take key roles in pushing the project forward. This has been a large effort by a lot of people.

What is the toughest thing about being an entrepreneur? What is most rewarding?

It is hard faking skills that you don't have. In the early points, you have to do your best to be everything to everyone at every time. Being outside your comfort zone is hard. What has been most rewarding are the stories, letters and emails I receive about how the Nokero light has changed so many lives. Three million people have benefited from our products, and we are just getting started.

What is your best advice for current engineering students who want to become entrepreneurs?

Make a mistake. Today. Do it.

■ DELLA PACHECO

THE GREENING OF ALCATRAZ

As branch chief for design and construction in the National Park Service, Paul Cloyd has taken on some pretty high-profile projects. Working out of the Denver Service Center — the NPS's central planning, design and construction management project office — this 1976 IDE alumnus (architectural engineering) and 2001 recipient of Purdue's Outstanding Interdisciplinary Engineering Alumni Award oversaw the relocation of the historic Cape Hatteras Lighthouse. He also was a team member on the restoration of the Russian Bishop's House in Sitka, Alaska, and the restoration of the St. Philomena Catholic Church in Hawaii's Kalaupapa Leprosy Settlement.

Alcatraz Island is now outfitted with a solar-powered microgrid. The 305-kW photovoltaic array installed atop the cellhouse building displaces diesel-fueled electricity. (Photo courtesy of National Park Service.)

His latest project concerned one of the most notorious sites in the United States: Alcatraz Island, home from 1934 to 1963 of the maximum-security Alcatraz Federal Penitentiary and now an NPS landmark that receives 1.4 million visitors a year. The island is part of the Golden Gate National Recreation Area.

"Alcatraz ran off diesel generators since the 1970s," Cloyd says, "and that meant the fuel had to be shipped in. The National Park Service was concerned about the possibility of oil spills in the San Francisco Bay, along with the cost of the fuel." Indeed, the 1,200-gallon-a-week supply of diesel-generated electricity costs about 76 cents per kilowatt-hour, or about six times the national average.

In 2010, with funding from the American Recovery and Reinvestment Act, Cloyd's team began coordinating work on a plan to install a solar-powered microgrid on the prison's three-story cellhouse to serve as the island's primary power source.

In partnership with the Department of Energy's National Renewable Energy Lab, the National Park Service designed a 305-kilowatt photovoltaic (PV) system consisting of 959 crystalline-silicon solar panels to power computers, phones, appliances, pumps, indoor and outdoor lighting, and a few large peaking loads, such as an elevator in the cellhouse and a lift at the dock. The PV array is attached to two 2,000 amp-hour battery strings, housed in the historic Quartermaster Warehouse, and an inverter plant, located in the powerhouse.

"We worked closely with the park's cultural resources staff and the state historic preservation officer to make sure that we weren't doing anything detrimental, either culturally or environmentally," Cloyd says. To protect the island's bird sanctuary and hatchery, the NPS installed temporary screens along the cellhouse so that the birds couldn't see, and thus be disrupted by, work on the installation.

An earlier plan for a solar-powered system on the island was scotched, in part, because the PV system, if placed where intended, would have been visible from the prison exercise yard — a jarring anachronism for a site that famously incarcerated Prohibition-era gangsters like Al Capone and Machine Gun Kelly.

Fully implemented in 2012, the 959 PV panels generate nearly 400,000 kilowatt-hours of electricity a year. It has reduced greenhouse gas emissions by about 700,000 kilograms of carbon dioxide a year and has reduced the time the diesel generators run by about 60 percent. The drastic reduction in diesel use has meant much less corrosion of pipes and smokestacks and less pollution in the bay, although the new panels did attract more bird droppings than expected.

"The project was very gratifying," Cloyd says. "It's great to say that diesel generators — which used to run 24/7 — are only needed as a backup now. That was our goal."

■ LISA TALLY

“ALCATRAZ HAS RUN OFF **DIESEL GENERATORS** SINCE THE 1970s.”

– PAUL CLOYD

NEWS SPOTLIGHTS

01

Drinking water odors, chemicals above health standards caused by 'green building' plumbing

Several types of plastic pipes in eco-friendly green buildings in the United States have been found to leach chemicals into drinking water that can cause odors and sometimes exist at levels that may exceed health standards.

Buildings are being plumbed with many types of plastic drinking water pipes. These include crosslinked polyethylene (PEX), high-density polyethylene (HDPE), polyvinylchloride (PVC), chlorinated PVC (cPVC) and polypropylene (PP) pipes, says Andrew Whelton, assistant professor of civil engineering and environmental and ecological engineering.

Plastic pipes are generally less expensive, lighter and easier to install than metal pipes. A 2012 comparison showed PEX pipe was the least expensive among plastic pipes, costing 43 cents per foot compared with the most expensive metal, copper pipe, at $2.55 per foot.

Thousands of dollars can be saved during construction by installing plastic instead of metal plumbing systems, and proponents assert plastic pipes require less energy to manufacture — generating less carbon dioxide than metal pipes — ostensibly making them a good fit for green buildings.

"Little is known about the degree to which plastic pipes sold in the U.S. affect drinking water quality," Whelton says.

He detailed his research findings during the October 2014 U.S. Green Building Council's Greenbuild International Conference & Exposition in New Orleans with Rebecca Bryant, managing principal of Watershed LLC of Fairhope, Alabama. Some testing results were published online in September in the journal *Water Research*.

The researchers describe drinking water effects caused by six brands of PEX pipes available in the United States.

In the September 2014 study, drinking water was tested from a PEX plumbing system in a "net-zero energy" building in Maryland six months after the system had been installed. The testing revealed the presence of 11 chemicals that were PEX pipe ingredients and ingredient degradation products. Research with PEX pipes in the laboratory also showed that six brands caused drinking water to exceed the U.S. Environmental Protection Agency's maximum recommended drinking water odor limit, Whelton says. The maximum drinking water odor limit is a "threshold odor number" of 3, or 3 TON. Compliance is voluntary because the standard is based on aesthetic — not health — considerations.

Odor and chemical levels were monitored with and without chlorine treatment over a 30-day period for the six pipe brands.

Chlorine, the most popular disinfectant chemical used in the United States, protects drinking water from disease-causing organisms as it travels to the tap. When chlorine reacted with chemicals leached by the plastic pipes, odor levels for one brand of PEX pipe tripled. Though the total mass of chemicals leached by PEX pipes was found to decline after 30 days of testing, odors generally continued as the pipes aged, Whelton says.

The research also is showing that there are differences in the quality of PEX products on the market, and different brands cause different odor and chemical-leaching impacts.

The team plans to continue the work and release additional results from the study over the next several months. Findings show some chemicals released by plumbing pipes can be transformed into carcinogenic chemicals regulated by the EPA; chemicals leached by certain plastics are conducive to bacterial growth; and plumbing system cleaning practices described in some, but not all, plumbing codes can cause PEX pipe chemical leaching to worsen.

The work is funded by a National Science Foundation grant titled "Towards a Safer and Greener Indoor Environment: Chemical Liberation from Polyethylene Plumbing Pipe."

02

New process efficiently converts biomass to liquid fuel

Purdue researchers have demonstrated a new process to convert all biomass into liquid fuel, and the method could make possible mobile processing plants.

They filed a patent application on the concept in 2008 and have now demonstrated that it works in laboratory experiments, says Rakesh Agrawal, the Winthrop E. Stone Distinguished Professor of Chemical Engineering.

"The demonstration is a step toward commercialization," he says. "Because the process can produce hydrocarbons in a single tandem step, it clearly has a potential to have a positive impact on the biofuels sector."

The new method, called fast-hydropyrolysis-hydrodeoxygenation, works by adding hydrogen into the biomass-processing reactor and is made possible by development of a new catalyst and innovative reactor design. The method has the shortened moniker of H2Bioil (pronounced H Two Bio Oil). Researchers tested the process with cellulose and poplar wood, showing that it represents a potentially practical new biofuels technology.

Findings are described in a research paper published online in October 2014 in the journal *Green Chemistry*.

"The successful lab-scale demonstration of the H2Bioil concept paves the way for rapid conversion of biomass species to liquid fuel and chemicals," Agrawal says. "Furthermore, we envision that the process can be built on a distributed scale for widespread use. Ultimately, with proper design, this concept is amenable to providing mobile plants that could be transported from one biomass-available site to another."

The work is led by Agrawal; Fabio H. Ribeiro, the R. Norris and Eleanor Shreve Professor of Chemical Engineering; and W. Nicholas Delgass, the Maxine Spencer Nichols Emeritus Professor of Chemical Engineering, all at Purdue. The research paper was authored by doctoral student Vinod Kumar Venkatakrishnan, Delgass, Ribeiro and Agrawal.

03

Student team wins Ford grant to further work on a hybrid renewable energy system

A team of Purdue students working on a hybrid renewable power system for use in remote communities in need of electricity has won a 2014 Ford College Community Challenge (Ford C3) grant.

The grant is one of 16 from the Ford Motor Company Fund, the philanthropic arm of the automaker. The grants support student sustainability projects. The Purdue Micro-Hydropower (MHP) team received $25,000 to support its continuing effort in the village of Bangang, Cameroon.

The team, working in collaboration with Purdue's Global Engineering Program and the African Centre for Renewable Energy and Sustainable Technology, already has helped establish and upgrade a locally sourced and fabricated micro-hydropower facility to generate electricity in Bangang.

However, the plant alone cannot meet the village's electricity demand during the dry season. Now the MHP team is working on a hybrid, renewable energy system that, combined with the hydropower plant, will provide reliable electricity throughout the year.

Objectives of the ongoing project are to design the hybrid renewable energy system; locally fabricate, implement and evaluate the system; and then create an open-source online and physical database to support other rural communities interested in replicating the system.

The faculty advisors to the team are Konstantina Gkritza, associate professor of civil engineering and agricultural and biological engineering, and Jun Chen, associate professor of mechanical engineering. The students currently on the team are Eleni Bardaka and Rebekah Miller, civil engineering; Hamzah Alahmadi, electrical and computer engineering; Yousef Alkoblan, mechanical engineering; and Larisa Barannikova, psychological sciences.

Ford C3 recognizes colleges and universities for using school resources and student participation to address an urgent community need under the theme "Building Sustainable Communities."

Eleni Bardaka, doctoral student in civil engineering and student leader of the Purdue Micro-Hydropower team, works during a field trip to Bangang, Cameroon, in August 2013. (Photo provided)

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