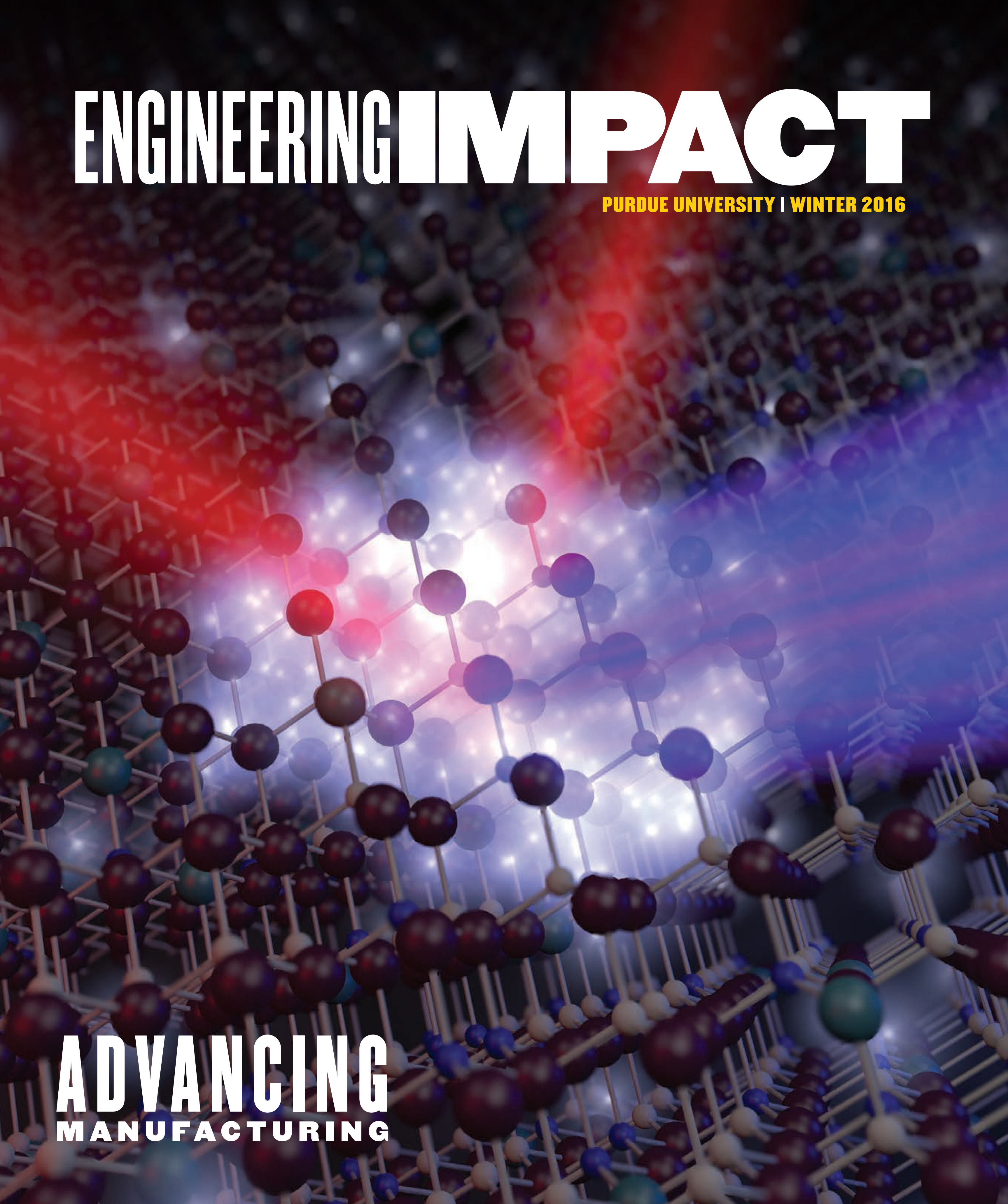
ENGINEERING IMPACT

PURDUE UNIVERSITY | WINTER 2016



ADVANCING MANUFACTURING

LEAH H. JAMIESON

The John A. Edwardson Dean of Engineering

Ransburg Distinguished Professor of Electrical and Computer Engineering

ON THE COVER:

This rendering depicts a new "plasmonic oxide material" that could make possible devices for optical communications that are at least 10 times faster than conventional technologies. The research team is led by Alexandra Boltasseva, associate professor of electrical and computer engineering, and Vladimir M. Shalaev, scientific director of nanophotonics at Purdue's Birck Nanotechnology Center and a distinguished professor of electrical and computer engineering. (Purdue University image/ Nathaniel Kinsey)

DEAN'S MESSAGE

Advanced manufacturing has been called the New Industrial Revolution. While the earlier movement brought a change from hand labor to machines that enabled mass production, advanced manufacturing allows a rapid transfer of science and technology into the manufacturing process.

In 2011, the President's Council of Advisors on Science and Technology recommended an advanced manufacturing initiative. The initiative is driving innovation through applied research programs for promising new technologies, public–private partnerships, and shared technology infrastructure to support advances in existing manufacturing industries. Purdue Engineering has heeded the call for innovation in advanced manufacturing through industry partnerships, a multidisciplinary range of specialized research, and centers of excellence that promise to transform manufacturing technology.

The Institute for Advanced Composites Manufacturing Innovation will offer modeling and simulation tools to develop composites more quickly and at a lower cost while allowing more time for innovation throughout the entire supply chain. The Flexible Hybrid Electronics Manufacturing Innovation Institute will focus on the design, manufacturing and integration of electronics and sensors and examine assembly and test automation for using complex flexible hybrid electronics.

For all of its alumni astronauts — 23 to date — Purdue has many more working engineers who have helped put those men and women into space. Among those experts on the ground during NASA's successful Orion spacecraft launch last December were three Boilermakers with degrees from the School of Aeronautics and Astronautics. Their work could help spur a future Orion flight, eventually leading to the first astronauts on Mars in the 2030s.

And in preparation for human habitation on the Red Plant, Jocelyn Dunn, an industrial engineering PhD candidate, had the opportunity to simulate living on Mars through the Hawaii Space Exploration Analog and Simulation (HI-SEAS) program. She spent eight months in isolation working as chief science officer.

On Oct. 9, the University announced "Ever True: The Campaign for Purdue University," with a record-setting $2.019 billion goal. As a College, we have benefited immensely from loyal alumni/ae and friends whose contributions have helped us achieve our strategic growth goals and those of the Purdue Moves initiative. With this campaign, the College of Engineering looks ahead to doing more by increasing our scholarships for deserving students, hiring and retaining premier faculty through endowed professorships, and modernizing and maximizing our space to accommodate our growth in both size and innovative teaching and research.

These are just a few of the exciting stories in this edition of *Engineering Impact*.

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. Read the Four Stories at https://engineering.purdue.edu/Eng/AboutUs/StrategicGrowthInitiative/pdf/strategy-for-impact.pdf*

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

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

AD VAN CING MANUFACTURING


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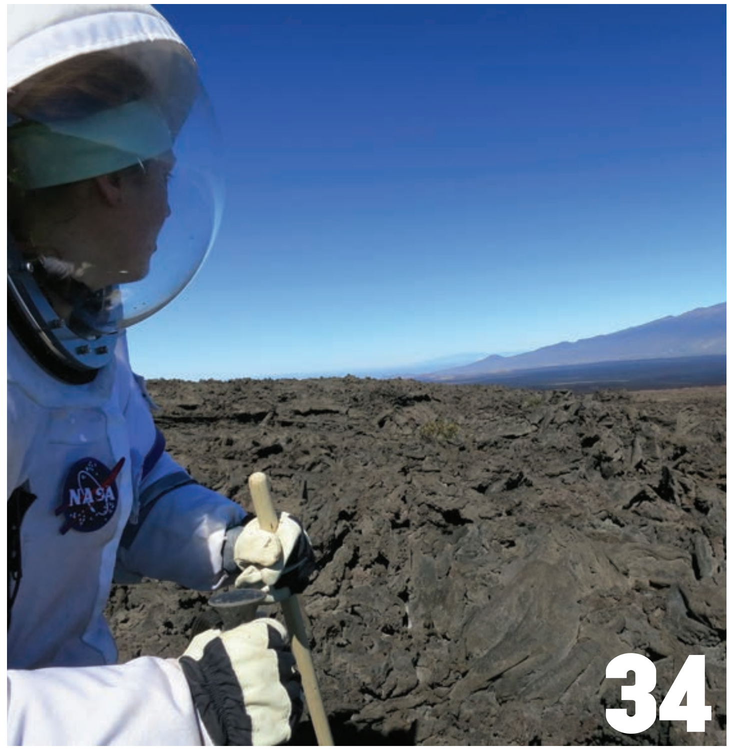
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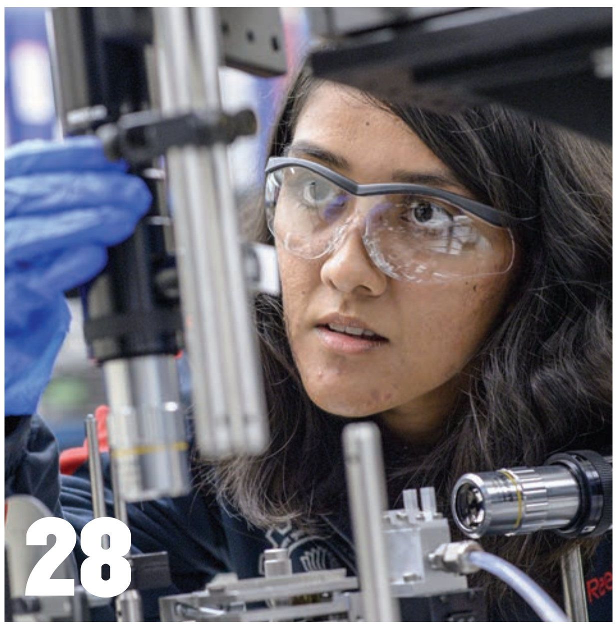
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43


40

AS OF FALL 2015, THE COLLEGE OF ENGINEERING HAS:

443 FACULTY
OF WHICH 77 ARE WOMEN
[A HIGH FOR THE COLLEGE]

11,509
STUDENTS THIS YEAR
[A RECORD HIGH]

UNDERGRAD ENROLLMENT
UP 14%
IN THE COLLEGE
OVER THE LAST FIVE YEARS

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

YEARLY RESEARCH EXPENDITURES UP
52%
SINCE THE BEGINNING OF THE STRATEGIC PLAN IN 2007

GRADUATE ENROLLMENT UP
19.1%
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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We may edit letters for length and clarity.

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ADVANCING MANUFACTURING

Purdue Engineering is driving innovation that moves discovery to delivery

■ BY PHILLIP FIORINI AND EMIL VENERE

PURDUE ENGINEERING IS heeding a national call for innovation in advanced manufacturing through industry partnerships, a multidisciplinary range of specialized research, and centers of excellence that promise to transform manufacturing technology.

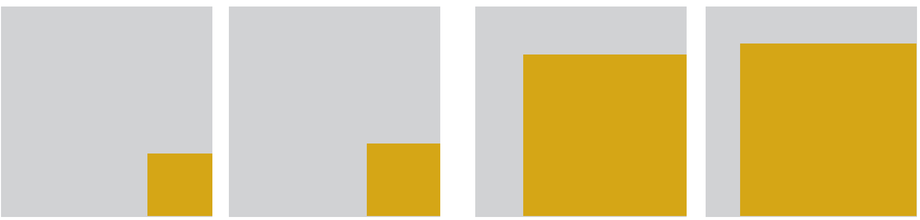
While an economic mainstay, manufacturing in the USA has for decades been declining as a share of GDP and employment, according to a 2011 report from the President's Council of Advisors on Science and Technology, which has recommended an advanced manufacturing initiative.

The initiative is driving innovation in advanced manufacturing through applied research programs for promising new technologies, public-private partnerships, the creation and dissemination of design methodologies for manufacturing, and shared technology infrastructure to support advances in existing manufacturing industries.

A FEW FACTS ABOUT
MANUFACTURING

Although manufacturing has become a smaller share of the nation's economy over time, it remains a crucial engine for job creation and economic growth.

MANUFACTURING IS RESPONSIBLE FOR ...



9% OF EMPLOYMENT

12% OF GROSS DOMESTIC PRODUCT

60% OF EXPORTS*

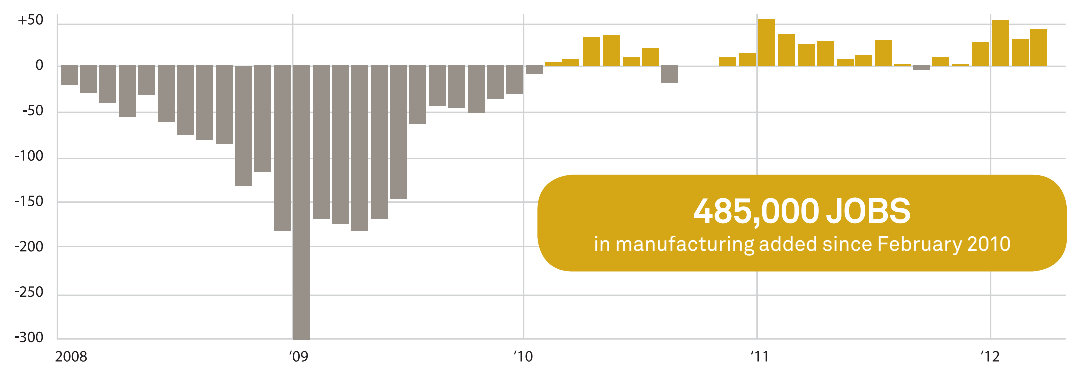
69% OF PRIVATE R&D SPENDING*

*Exports data from 2010, R&D data from 2009, the latest year available, all other data from 2011.

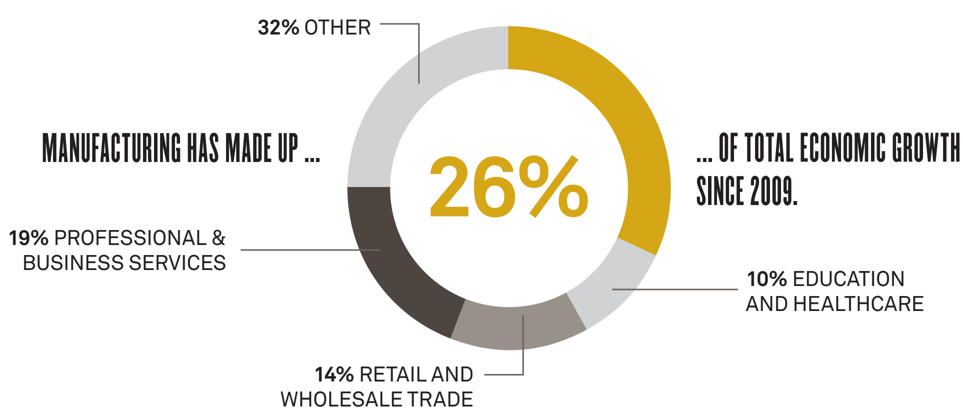
MANUFACTURING IS THE
LARGEST SECTOR
OF INDIANA'S ECONOMY,
ACCOUNTING FOR APPROXIMATELY
20%
OF INDIANA'S JOBS.

PURDUE UNIVERSITY CENTER FOR ADVANCED MANUFACTURING

MONTHLY NET JOB GROWTH IN THE MANUFACTURING SECTOR, THOUSANDS



RECENT TRENDS IN MANUFACTURING



Growth in manufacturing sector nominal GDP since 2009 as a percentage of growth in total nominal GDP since 2009

SOURCE: BLS, BEA, Census, National Science Foundation, U.S. Department of Commerce, U.S. Department of the Treasury, Purdue University Center for Advanced Manufacturing.

EQUIPPING A SKILLED WORKFORCE OF THE FUTURE

At the heart of Purdue's research and education efforts is the role the University plays in equipping the future leaders and skilled workforce in advanced manufacturing.

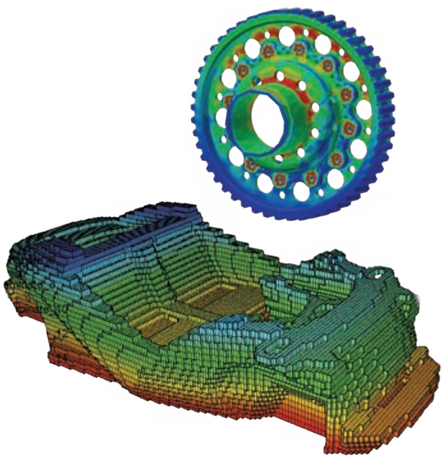
"If you want to have a significant impact as a land-grant university, you need a vision to translate the discoveries in the research laboratory to the marketplace, particularly in manufacturing," says R. Byron Pipes, the John Leighton Bray Distinguished Professor of Engineering. He will lead Purdue's Institute for Advanced Composites Manufacturing Innovation (IACMI), which includes the Design, Modeling & Simulation Enabling Technology Center. The center will offer modeling and simulation tools to help address the need to shorten the development cycle and decrease the cost of composites manufacturing while allowing more time for innovation throughout the entire supply chain, Pipes says.

"The USA's success in being competitive in the global economy forces research universities to impact value-added, labor-efficient processes that lead to higher paying jobs and a stronger manufacturing economy," Pipes says.

More than two-thirds of Indiana workers lack a college degree at a time when the state faces a serious shortage of skilled production workers, according to Brian Burton, president and CEO of the Indiana Manufacturers Association. And over half of job applicants who are rejected for manufacturing positions in Indiana lack basic technical training and problem-solving skills and have inadequate reading, writing and communication abilities.

A key provision within IACMI is workforce development and a strategy to include five major research centers located primarily in the Midwest since nearly 70 percent of U.S. auto production and more than 700 composite companies currently reside there, Pipes says.

Purdue will develop and launch the Composites Virtual Factory HUB (cvfHUB) to deploy and integrate simulation tools that capture the manufacturing phenomena under development in the other IACMI



Modeling and simulation tools on the Composites Virtual Factory HUB (cvfHUB) will help address the need to shorten the development cycle and decrease the cost of composites manufacturing while allowing more time for innovation throughout the entire supply chain. (Purdue image provided)

centers of excellence. The Indiana center will develop streams of valued-added products that can be manufactured from fibers and "prepreg" materials reclaimed from the factory floor.

In partnership with Oak Ridge National Laboratory, Purdue will develop simulation of composites additive manufacturing, stand up additive manufacturing facilities, and examine fundamental science and engineering of additive manufacturing. Indiana is providing $15 million in new funds to support this portion of the initiative.

Over the next 10 years, the IACMI estimates, more than 30,000 U.S. manufacturing jobs could be created in the fiber-reinforced polymer industry. During that same period, private capital investment also is expected for boosting production capacity for the carbon fiber and carbon fiber-reinforced polymer sectors.

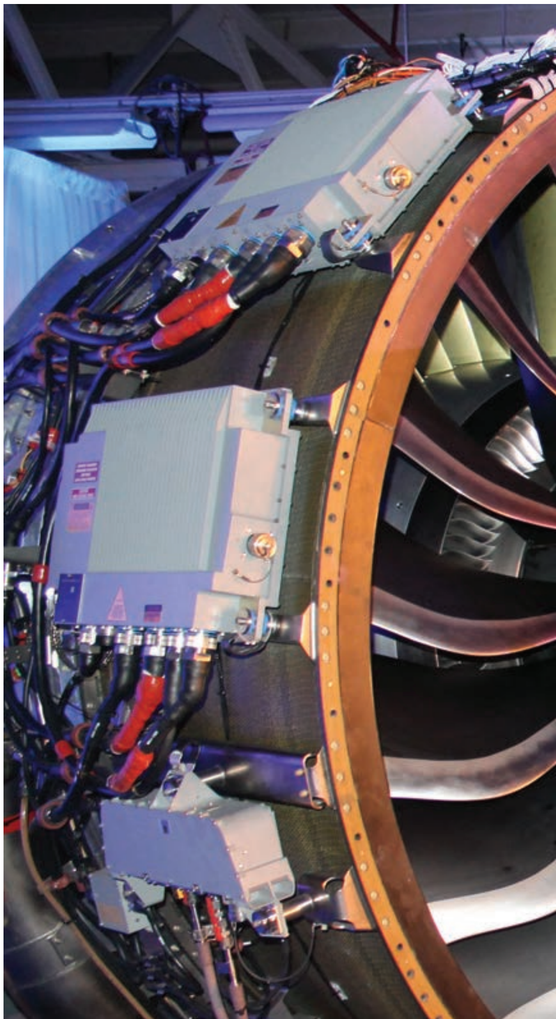
"This initiative offers an unparalleled approach to technical education and workforce development by bringing together community colleges and universities, state economic development organizations, and the National Institute of Standards and Technology's Manufacturing Extension Partnerships to address the challenges of developing a highly skilled manufacturing workforce for supporting the anticipated growth in advanced composites across the U.S.," Pipes says.

PARTNERING WITH GE ON 'BRILLIANT FACTORIES'

Purdue is working with GE on several projects related to advanced manufacturing. They are partners in the federal Digital Manufacturing Design Innovation Institute (DMDII), one of five manufacturing innovation institutes that have been established by the Obama administration to date to bolster America's leadership and competitiveness in manufacturing.

The focus of DMDII is to develop technologies to build a digital thread that connects all parts of the manufacturing supply chain from product design to operations on the factory floor. Such a thread will enable faster, more real-time decision making and provide feedback loops that allow for continuous improvements in manufacturing processes and product designs.

Purdue and GE in 2014 announced a GE/Purdue Partnership in Research and Innovation in Advanced Manufacturing



(PRIAM). It reflects a new era in manufacturing, promoting technologies that enable the digitization, decentralization and democratization of manufacturing to reduce cost, improve speed and drive innovation. All three trends are being driven by the increasing convergence of software and hardware that is turning today's factories into "brilliant factories" more capable, connected and productive.

"When GE CEO Jeff Immelt spoke at Purdue, digitization, decentralization and democratization were the three words he used in describing advanced manufacturing and where GE is going," says Abhijit Deshmukh, the James J. Solberg Head and professor of industrial engineering. "The brilliant factory involves the integration of information throughout the lifecycle of products starting from design to manufacturing to distribution to usage, with the goal of optimizing factories to produce the best possible product."

GE Global Research will invest up to $10 million in the five-year partnership. For manufacturing operations the size of GE's, just a 1 percent improvement in productivity would save $500 million, GE said in announcing PRIAM.

The brilliant factory concept includes the idea of creating a "digital twin" for every individual product rolling off the assembly line, an innovation made possible using a collection of models and simulations that are based on the hard physics of materials and designs.

"This is the concept of a living model," Deshmukh says. "What if, as somebody was born, there was a digital twin of you that actually went through the same life cycle as you, grew like you, and so on? So if at some point we wanted to figure out what would happen if we put you in certain situations, we actually could run simulations to show the results without touching the physical person."

Such an advance would make it possible to predict how individual products would perform over time. "We could figure out how long an individual engine is going to survive. Not the generic engine, but each engine being manufactured," Deshmukh says. "To actually map its life cycle."

Decentralization concerns development of manufacturing systems that are distributed and capable of servicing small regions and individual clients. "One example is personalized medicine, where medications are printed in the local pharmacy to your physical specifications," he says.

In democratization, manufacturing decisions are based on contributions from many entities.

"This includes smaller entities and suppliers participating in the process, mom-and-pop-type suppliers being part of this entire big supply chain helping you manufacture products," Deshmukh says. "Democratization generates more ideas, taps people across the entire community, even reaching out through social media."

Through PRIAM, Purdue is working with GE Global Research on several new projects, including those focused on model-based engineering.

"This is where we look at how to extend the current product models to include information such as materials, processing, manufacturing, product life cycle, and so on," Deshmukh says.

Researchers will work to model how a product's final characteristics and performance are modified by different manufacturing processes.

"This is being able to predict many aspects of the product using first principle-based physics models," Deshmukh says. "These models require heavy computations, but what we are looking at is creating surrogate models using the simulation experiments to reduce the overall computational requirement for the end user. The vision is

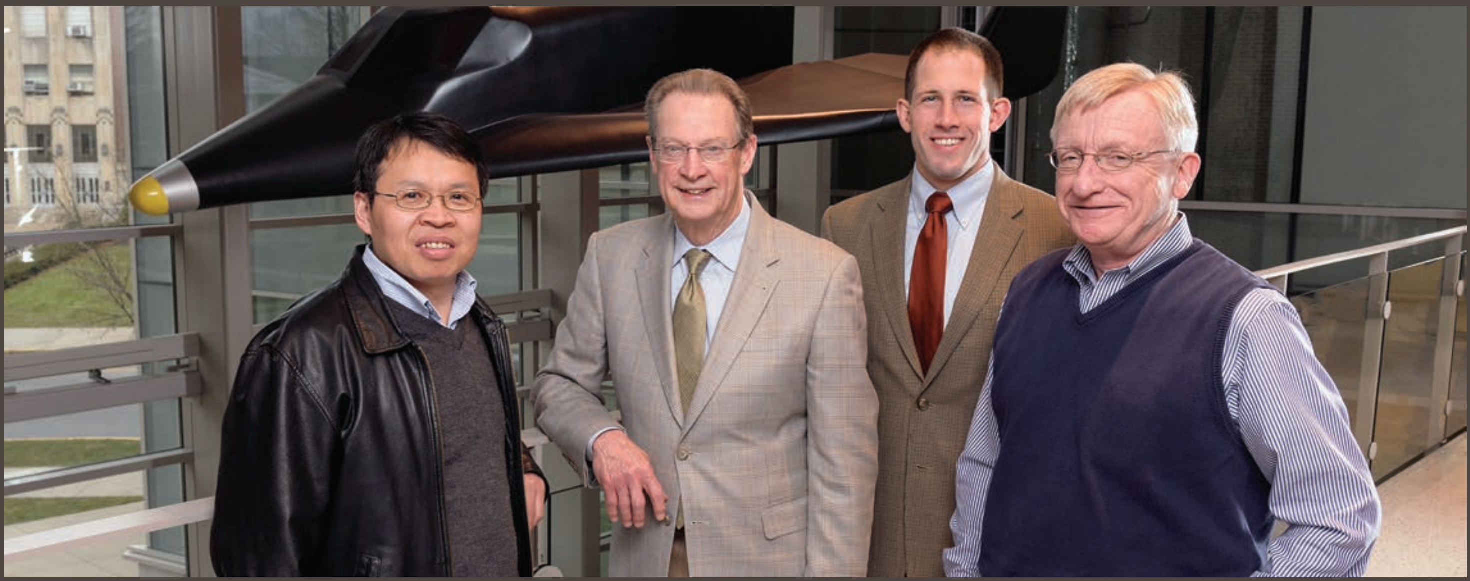
>> *continued on page 11*

GE Aviation's Vice President and General Manager, Assembly, Test and Overhaul Anthony Aiello and Purdue's Executive Vice President for Research and Partnerships Suresh Garimella, the R. Eugene and Susie E. Goodson Distinguished Professor. (Purdue University photo/Mark Simons)

INSTITUTE ADVANCES COMPOSITE MATERIALS MANUFACTURING

Purdue team ready to tackle innovative energy-saving initiative

■ BY PHILLIP FIORINI



The multistate Institute for Advanced Composites Manufacturing Innovation includes the Indiana-based Design, Modeling & Simulation Enabling Technology Center, which is led by R. Byron Pipes, the John Leighton Bray Distinguished Professor of Engineering at Purdue, along with a consortium of university researchers, manufacturers, national laboratories, and state and local government agencies. Team leaders at Purdue, from left, are Wenbin Yu, associate professor of aeronautics and astronautics; Pipes; Johnathan Goodsell, visiting assistant professor of aeronautics and astronautics; and Ronald Steuterman, the center's managing director. (Purdue University photo/ John Underwood)

R. Byron Pipes knew of the need and potential impact of the Institute for Advanced Composites Manufacturing Innovation (IACMI). And the longtime engineer, researcher and university administrator understood what it would take for a massive national research initiative focused on composite materials manufacturing to move toward reality.

The goal was to help draft a comprehensive proposal that included all the stakeholders in this advanced manufacturing initiative — industry, universities, state and federal government agencies, and others. Those team members also pledged $189 million, a key factor in the U.S. Department of Energy's decision to select the team that included Purdue for the $259 million IACMI.

"The U.S. has a strong historical strength in composites through many decades of investment for aerospace uses," says Pipes, the John Leighton Bray Distinguished Professor of Engineering at Purdue and chairman of IACMI's Technology Advisory Committee. "IACMI is bringing together an impressive lineup of research universities, major U.S. manufacturers and industry players, and six state economic development agencies, helping create an entirely new industry for advanced composite materials, with their proven applications because of their lightweight properties and unusually high stiffness and strength."

The objective of this five-year effort that is a part of President Barack Obama's National Network for Manufacturing Innovation (NNMI) is to develop the manufacturing technology for more energy efficient vehicles, compressed-gas storage and wind energy systems. Industry analysts think the global composite market will nearly double by 2020.

For Purdue's role in IACMI, construction is underway on the $50 million, 62,000-square-foot Indiana Manufacturing Institute facility at the Purdue Research Park in West Lafayette, Indiana. Purdue faculty, including about 10 engineers and a number of graduate students, will occupy 30,000 square feet in the IMI facility for advancing research on composite materials that could have a significant impact in many industries such as aerospace, aviation, automotive, energy and sporting equipment.

"Purdue is a recognized leader in composite materials, and the research that will be carried out in this new facility will advance this important technology for the new industries developing in Indiana," says Pipes, who served as the 17th president of the Rensselaer Polytechnic Institute before coming to Purdue in 2004.

Advanced composite materials are used in everything from skateboards to airplanes. These materials have broad possibilities because of their lightweight properties and unusually high stiffness while also remaining elastic. The Boeing 787 commercial airplane is a wonderful example of what this technology can achieve.

"The ability for U.S. manufacturers to compete in this market through innovative solutions can help enable economic growth and help lead to job growth," Pipes says. "The focus of IACMI to increase energy productivity will help manufacturers reduce the amount of energy used to make these products."

The Indiana Manufacturing Institute will lease space in the new building, as will industries that wish to locate near the center. In partnership with the Indiana Economic Development Corporation, an expenditure of almost $35 million in research equipment and materials in the institute is expected over the next five years, funded through the cooperative agreement with the DOE. Purdue Research Foundation will invest $11 million in the building's construction.

"The construction of the new facility expands the park's role even more because of the collaborative opportunity it provides for Purdue innovators," says Dan Hasler, president of the foundation. "We believe this institute will be a magnet for private manufacturers that wish to locate near this unique facility," Hasler says.

The IACMI estimates that over the next 10 years, more than 30,000 U.S. manufacturing jobs could be created in the fiber-reinforced polymer industry. During that same period, capital investment is expected to boost production capacity for the carbon fiber and carbon fiber-reinforced polymer sectors.

Research shows that a 10 percent drop in vehicle mass can yield a 6 to 8 percent reduction in fuel consumption. Using highly engineered carbon fiber composites can yield mass reductions of 60 to 70 percent in optimized vehicle structures. Wind turbines also will operate more efficiently at a lower cost to displace non-renewable energy sources. Compressed gas tanks will allow economic use of natural gas and, ultimately, hydrogen as fuels with lower environmental impact than petroleum-derived fuels.

"As the national leader in manufacturing job growth last year, Hoosiers were already well-positioned to take the lead in advancing this technology," says Indiana Secretary of Commerce Victor Smith. "With this added bolt of support, composite material technology will help lift the future of advanced manufacturing in Indiana in partnership with our universities, national labs and neighboring states.

"This important public–private partnership has a strong research, development and deployment mission, establishing a major sector of our manufacturing economy focused on advancing the use of composite materials such as carbon fiber to make lighter-weight cars, wind turbines, natural gas storage tanks and other products."

BUILDING ON MIDWEST'S STRENGTH IN MANUFACTURING

Purdue is involved in two of the five major research centers that comprise IACMI. Most of the centers are primarily located in the Midwest because nearly 70 percent of U.S. auto production and over 700 composite companies currently reside there:

- Purdue will develop and launch the Composites Virtual Factory HUB (cvfHUB) to deploy and integrate simulation tools that capture the manufacturing phenomena under development in the other IACMI centers of excellence. The Indiana center will develop streams of valued-added products that can be manufactured from fibers and "prepreg" materials reclaimed from the factory floor. In partnership with Oak Ridge National Laboratory, Purdue will develop simulation of composites additive manufacturing, stand up additive manufacturing and lab scale composite-part production facilities, and examine fundamental science and engineering of additive manufacturing. Indiana is providing $15 million in new funds to support this portion of the initiative.

- The Vehicles Application Center, which is organized around core partner Michigan State University. Manufacturing support is from the University of Dayton Research Institute (UDRI) and Oak Ridge National Laboratory (ORNL), with computer modeling and simulation support from Purdue. The University of Michigan, Michigan Tech and Interlaken are supporting partners. The state of Michigan is contributing $15 million. ■

>> *continued from page 9*

that eventually we will create an app that will be in the hands of an end user who could be a machine operator or a designer that will give them predictive capability about the product."

'SMART FACTORIES'

Another project concerns development of "smart factories" where models could be created automatically — with little need for human input — to analyze manufacturing systems.

"You have a shop floor with lots of machines, and it takes a long time to create models," Deshmukh says. "This could be scheduling models or models that will be used to predict and simulate the facility's performance. What we are looking at is how to rapidly and automatically create models from data describing the system."

Also providing opportunities is a new GE jet engine assembly facility near Veterans Memorial Parkway and U.S. 52 southeast of Lafayette, Indiana, where the company will make its new LEAP engine. Production is expected to begin in 2016. The facility will incorporate the latest technologies and innovations in engineering and workflow processes to enhance efficiency and productivity.

A Purdue student and a postdoctoral research associate created a detailed "discrete event simulation model" of the facility.

"It's a way to simulate the operation of factories and manufacturing systems," Deshmukh says. "They did this in a very short period of time and figured out that the design needed some modifications to meet the high production demand. The changes could actually be done before construction began on the factory because of this modeling effort, so that was important."

GE and Purdue have been working together for more than 120 years, and the company is the largest employer of Purdue graduates.

DRIVING INDIANA, MIDWEST COMPETITIVENESS

As home to the Indiana Next Generation Manufacturing Competitiveness Center (IN-MaC), Purdue also is working in partnership with Ivy Tech Community College and

Vincennes University on ways to rebuild America's manufacturing capacity.

Many U.S.-based companies face a shortage of trained workers capable of filling open positions. Technology is moving quickly and must be transferred to industry quickly in order to remain competitive. Investment in new knowledge creation today will ensure future competitiveness for U.S. industry.

IN-MaC, involving researchers from across the Purdue campus, including John Sutherland, the Fehsenfeld Family Head of Environmental and Ecological Engineering, and Deshmukh, answers these needs with an integrated partnership among industry, academia and government that addresses education, workforce, new technology adoption and research for future competitiveness.

Leah H. Jamieson, the John A. Edwardson Dean of the College of Engineering and the Ransburg Distinguished Professor of Electrical and Computer Engineering, serves on IN-MaC's executive committee.

"How can we take the expertise that resides at the universities and bring that to bear on specific problems and challenges being faced by companies?" Jamieson says. "Through IN-MaC and our other engagement efforts across campus, Purdue is committed to be the leader in facilitating partnerships with manufacturers in Indiana and across the globe."

Thirty-four Indiana companies have launched technology-adoption projects with IN-MaC. Initial education projects at Purdue and partners Ivy Tech Community College and Vincennes University range from orthopedic and advanced manufacturing training to mechatronics and advanced manufacturing leadership development.

Led by Purdue and partnered with Vincennes University and Ivy Tech Community College, IN-MaC works to attract, retain and grow high-value manufacturing industries by creating a seamless pathway from leading-edge research labs to the market in Indiana and beyond, says Ronald J. Steuterman, managing director of IN-MaC and the Purdue-led Institute for Advanced Composites Manufacturing Innovation (IACMI).

"... PURDUE IS COMMITTED TO BE THE LEADER IN FACILITATING PARTNERSHIPS WITH MANUFACTURERS IN INDIANA AND ACROSS THE GLOBE."

— LEAH H. JAMIESON

The John A. Edwardson
Dean of Engineering

The Technology Adoption Program was IN-MaC's first initiative. IN-MaC also has education and workforce development programs underway with Ivy Tech, Vincennes and Purdue Calumet. In addition, research programs have been started in three areas: digital manufacturing enterprise, personalization and market viable manufacturing processes.

"IN-MaC's goal is to help Indiana companies grow by adding employees and strengthening competitiveness nationally and globally," Steuterman says. "Making use of the latest technology available is vital to helping companies meet this goal."

One of the first companies that signed on with IN-MaC was Jeco Plastic Products of Plainfield, Indiana. CEO Craig S. Carson says an immediate result of IN-MaC support was an initial order of more than $110,000 in tooling and $150,000 in parts that once had been outsourced to China.

"IN-MaC provided us with technological tools of which we formerly knew nothing," he says. "As a result of our collaboration with Purdue through IN-MaC, we developed completely novel improvements on existing process technology. The growth prospects within 12 months are for three to five times that amount."

A key connector for programs like IN-MaC is the Purdue Technical Assistance Program (TAP), which is focused on advancing Indiana's economic prosperity, health and quality of life by supporting performance improvement in Indiana companies and organizations. TAP programs include Manufacturing Extension Partnership, a Hollings NIST MEP Center with programs and services that utilize professional staff, subcontractors, faculty and students in eight statewide offices.

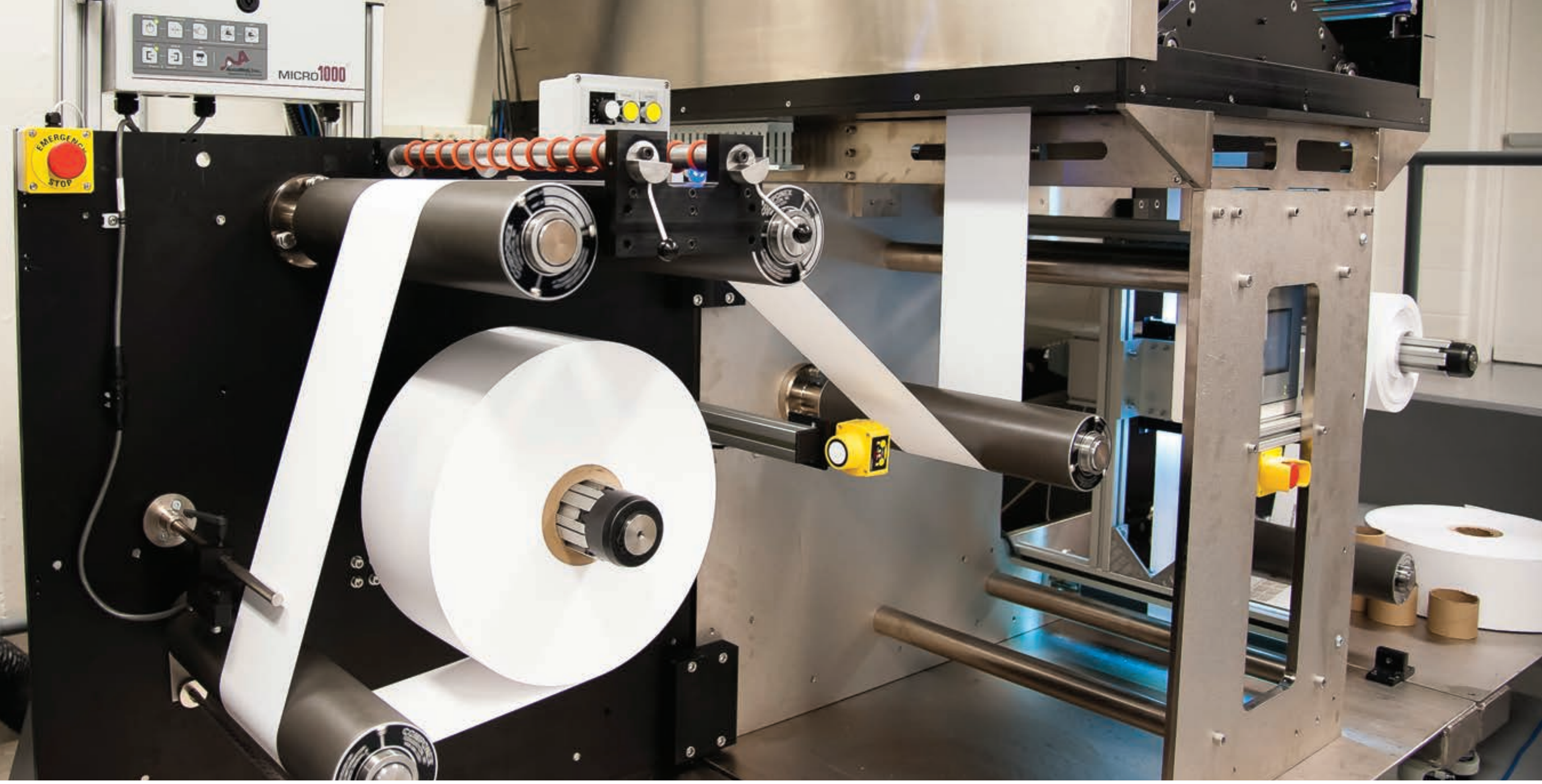
TAP serves more than 500 companies annually by implementing continuous improvement principles in the areas of productivity, growth and technology, says Steven Abel, associate vice president for engagement at Purdue. Since 2005, TAP has helped Indiana companies collectively achieve more than $1 billion of economic impact.

Recently, engineers at Alcoa Inc.'s Global Hard Alloy Extrusions facility in Lafayette, Indiana, discovered that an H-13 tool steel component used to manufacture aluminum extrusions for the aerospace industry was cracking. An Alcoa team wanted to understand the cause of the failure before installing new material into the container housing and repeating the problem, preventing losses that could reach $50,000.

A research team led by Purdue materials engineering professor John Blendell used scanning electron microscopy and hardness measurements in their analysis.
Their finding: The faulty tool steel had an excessive hardness, causing it to behave in a brittle manner and fail prematurely.

"In response, Alcoa decided to approach another company to complete the relining

This is a photo of the microgravure/slot die coating machine in Discovery Park's Birck Nanotechnology Center. It will be used in conjunction with other printing tools such as roll-to-roll inkjet-laser processing and roll-to-roll plasma chemical vapor deposition to create SMART films. (Purdue University photo/ Rebecca Wilcox)



Roll-to-roll systems at Discovery Park's Birck Nanotechnology Center are creating smart thin films for multiple applications. (Purdue University photo/Rebecca Wilcox)

of the tool steel so the global manufacturer could restart production on that assembly line," Blendell says.

GOING WHERE NO ONE HAS GONE BEFORE

Nanomanufacturing, a sector of manufacturing led by research and development advancements in this country, is still struggling to find its true identity or potential. Currently, more than 800 commercial products rely on nanomaterials, according to the U.S. National Nanotechnology Initiative.

The key challenge, experts say, is the question of scale. Techniques in nanomanufacturing do not support mass-scale production because of the difficulty in fabricating a large number of nanodevices repeatedly and under precisely controlled conditions. Moreover, nanomanufacturing involves several processes and a high level of supervision.

Those very challenges are motivating many Purdue researchers:

- Teams in Birck Nanotechnology Center in Discovery Park are advancing research aimed at creating "aware-responsive" films — known as SMART films — with applications in pharmacy, agriculture, food packaging and functional non-woven materials for uses including wound dressings and diapers.
- Researchers are developing a method to mass-produce a new type of nanomaterial for advanced sensors and batteries, with an eye toward growing the Midwest economy.
- Another team is focused on nanomanufacturing plasmonic metamaterials for different applications by using patented processes in material fabrication and development.

The Printing SMART Film Initiative, led by Ali Shakouri, professor of electrical and computer engineering and the Mary Jo and Robert L. Kirk Director at Birck, is taking up that challenge to develop more economical printing and manufacturing methods for these aware-responsive films, which can record data and provide real-time feedback.

The initiative tapped 24 faculty members across 10 Purdue schools who have received grants of more than $3 million from the National Science Foundation. Using a new Birck laboratory for roll-to-roll manufacturing completed in early 2015, the SMART film manufacturing techniques include custom-designed roll-to-roll systems and functional printing.

"This builds on Purdue's engineering strengths as we pursue advances as part of a broader nanomanufacturing initiative at Birck where we focus on roll-to-roll production of smart thin films for applications in pharmacy and food packaging," Shakouri says.

SMART FILM APPLICATIONS COULD BE REVOLUTIONARY

Advanced nanotechnology films on food packaging could track food contamination, bacterial growth and provide detailed information on a product's shelf life, providing the consumer with information and allowing manufacturers to track a product throughout the supply chain.

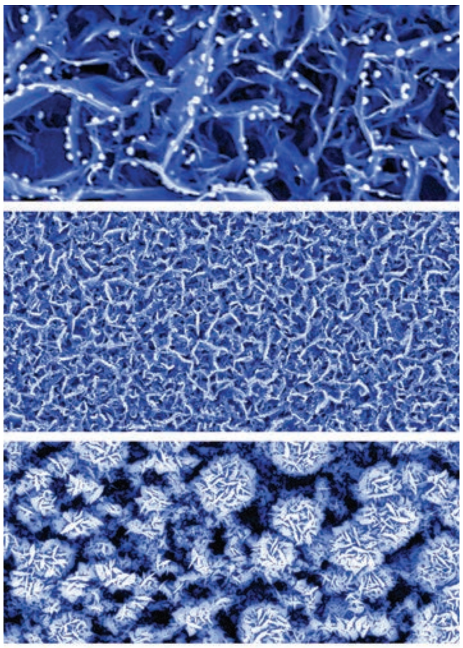
Other applications include bandages that track physiological information and SMART pills that release medicine in response to changes within the body.

The researchers are trying to link small, medium and large enterprises in diverse sectors with original equipment manufacturers and university researchers, Shakouri says. In June 2015, Purdue hosted a Midwest workshop on roll-to-roll nanomanufacturing for that purpose.

Arvind Raman, the Robert V. Adams Professor of Mechanical Engineering, has expertise in roll-to-roll manufacturing, a mainstay of many industrial operations including paper and sheet metal production. He models the mechanics of the process of creating flexible materials in sheets at high speed and under tension.

"A key factor is going to be industry partners," Raman says. "There are many industries that have roll-to-roll operations. So focusing on roll-to-roll as a platform for doing nanomaterials production is very strategic for the Midwest."

A slew of new device and material concepts based on graphene nanopetals are emerging in applications as diverse as carbon fiber composites and new thermal-interface materials, Raman says. "Commercial interest is extremely high for this recent carbon nanomaterial."



These color-enhanced scanning electron microscope images show nanosheets resembling tiny rose petals. The nanosheets are key components of a new type of biosensor that can detect minute concentrations of glucose in saliva, tears and urine. (Purdue University photo/Jeff Goecker)

Nate Kinsey, PhD candidate, and his advisor, Alexandra Boltasseva, associate professor of electrical and computer engineering, in the nanophotonics lab. (Purdue University photo/Phillip Fiorini)

The nanopetals are created in a vacuum by exposing a cloth of carbon fiber to high-energy plasma that contains hydrogen ions and other ingredients, a process known as plasma-enhanced chemical vapor deposition.

A research group led by Timothy S. Fisher, the James G. Dwyer Professor of Mechanical Engineering, developed the underlying technology, which consists of vertical nanostructures resembling tiny rose petals made of a material called graphene, which is a single-atom-thick film of carbon, and his group has now demonstrated a new scaled-up roll-to-roll manufacturing process.

"Using these graphene nanopetals, we have realized exceptional performance in a wide range of devices at laboratory scales, and our new roll-to-roll process increases throughput by a factor of 100 or more," Fisher says.

Alina Alexeenko, associate professor of aeronautics and astronautics, leads the work to model the plasma reactor and to optimize its conditions for fast and environmentally friendly conversion of raw materials, such as methane and hydrogen, into carbon nanopetals.

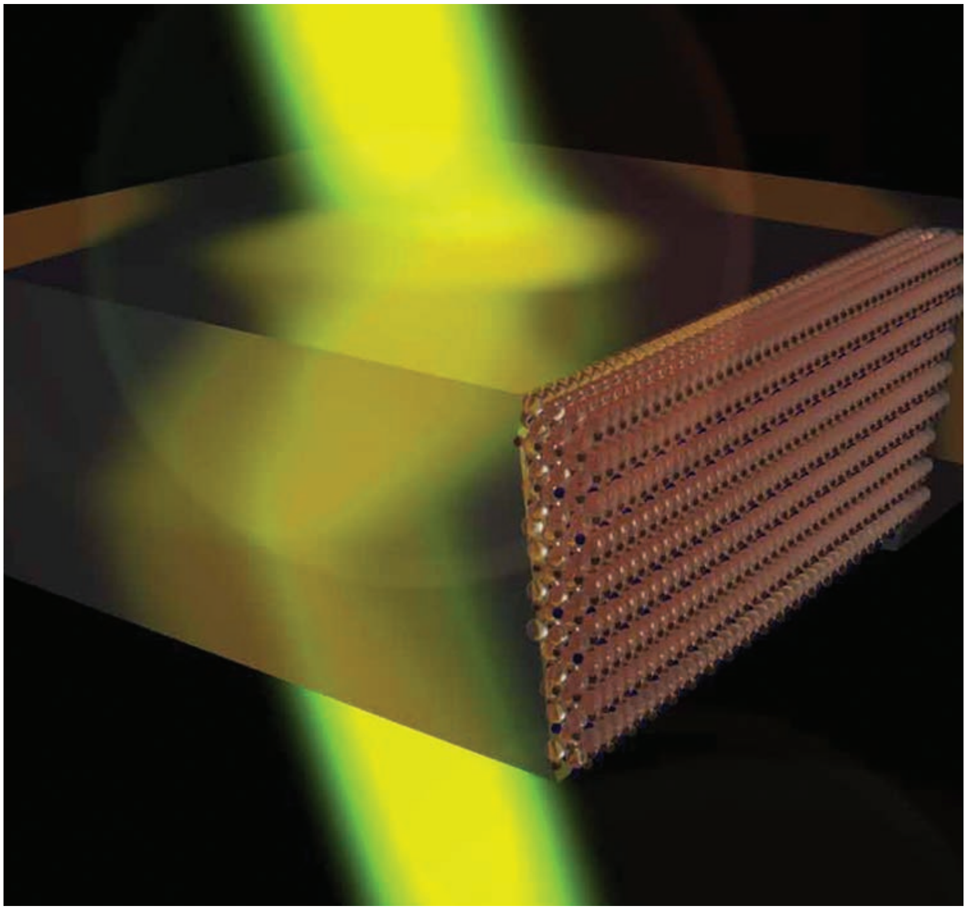
The new technology also could be of particular interest to battery makers in Indiana.

"Many results from this research are not just applicable to graphene nanopetal technology, but rather to a wide variety of nanomaterials manufactured in low-pressure and ambient roll-to-roll nanomanufacturing processes," Raman says.

MYRIAD USES FOR PLASMONIC METAMATERIALS

Alexandra Boltasseva and Vladimir Shalaev, the Robert and Anne Burnett Distinguished Professor of Electrical and Computer Engineering, have an eye focused on nanomanufacturing plasmonic metamaterials for different applications by using their patented processes in material fabrication and development.

Based on their research, they launched Nano-Meta Technologies Inc. to advance efforts not only to control light but also to manipulate it. As the light is guided or routed at the nanoscale level, the technology can be used to develop more powerful microscopes, more efficient thermo-



This graphic depicts a device created using "negatively refracting metamaterials" that could bring advances in applications including sensing, imaging, data storage, solar energy and optics. Purdue researchers are working on a range of options to overcome a fundamental obstacle in commercializing the materials. The small spheres represent a lattice of "meta-atoms" carefully designed and fabricated to produce a high-performance device. (Birck Nanotechnology Center/Purdue University)

photovoltaic solar cells, increase data storage and improve medical treatments.

"We are doing this by tailoring the materials to optimize their properties and making nanoscale unit cells," says Boltasseva, associate professor of electrical and computer engineering. "For example, to increase data-storage densities, we are developing new materials for heat-assisted magnetic recording capability, which uses heat to record data on a magnetic disk."

ADVANCING SUSTAINABILITY

Researchers at Purdue are developing solutions to the shortages of rare earth metals used in a variety of clean-energy applications. This includes how remanufacturing and recycling techniques can recover rare earths from end-of-life products. Such an approach helps address the shortages and may have significant economic and environmental advantages.

Carol Handwerker, the Reinhardt Schuhmann Jr. Professor of Materials Engineering, leads Purdue's partnership with the Critical Materials Institute (CMI), an Energy Innovation Hub funded by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy Advanced Manufacturing Office, focused on developing solutions to the shortages of rare earth metals and other materials critical for U.S energy security.

Established through a five-year, $120 million award from DOE, the hub is led by the Ames Laboratory in Iowa and is one of four Energy Innovation hubs. Purdue CMI researchers are receiving up to $2.5 million through 2018 for their part of the initiative.

"Purdue is contributing its expertise in manufacturing, design and lifecycle engineering," Handwerker says. "Purdue also is a leader in research surrounding sustainable manufacturing and remanufacturing, and had one of the first national courses on critical elements."

Working with Handwerker on CMI are Ananth Iyer, the Susan Bulkeley Butler Chair in Operations Management at Krannert; John Sutherland, the Fehsenfeld Family Head of Environmental and Ecological Engineering; and Fu Zhao, an associate professor of mechanical engineering and environmental and ecological engineering.

Handwerker is developing a technology roadmap in collaboration with the entire CMI enterprise for applying a systems view of the opportunities and risks to diversify sources for rare earth elements, develop substitutes for rare earth materials for high-energy-impact applications, and reduce waste in manufacturing. The systems opportunities and risks are both economic and environmental, as analyzed by Iyer and Idaho National Lab researchers, and Zhao and Colorado School of Mines researchers, respectively.

Sutherland is focused on closed-loop material cycles for rare earth elements (REE), which are used in making magnets for lighter and more efficient generators that power wind turbines. These materials also are in hybrid vehicles and hard disks.

John Sutherland, the Fehsenfeld Family Head of Environmental and Ecological Engineering. (Purdue University photo/Mark Simons)

Carol Handwerker, the Reinhardt Schuhmann Jr. Professor of Materials Engineering, discusses materials sustainability issues in electronics with Purdue students. From left: Gamini Mendis, Shane Peng and Milea Kammer. Handwerker will play a key part in Purdue's partnership with the Critical Materials Institute, developing a technology roadmap for applying a systems view of the risks to pursue new materials and energy technologies instead of relying on rare earth materials. (Purdue University photo/ Vincent Walter)

Through closed-loop materials cycles, REEs are recovered and reused instead of being discarded to a landfill or treated as a waste.

A conventional gear drive train system for a wind turbine may require about 100 kilograms of REEs per megawatt capacity, while a direct-drive system may require 600 kilograms of REEs per megawatt capacity. The U.S. is projected to increase the number of wind turbine installations to meet approximately 20 percent of the domestic electricity demand with wind power by 2030, requiring about 30,000 to 180,000 tonnes of REEs.

"Like other industrial sectors, manufacturing has an important role to play in terms of ensuring that we achieve a long-term balance among the environmental, societal and economic dimensions of sustainability," says Sutherland, one of the world's leading authorities on the application of sustainability principles to design, manufacturing and other industrial issues.

Sutherland is collaborating with researchers at the Oak Ridge National Laboratory and industry partners to identify opportunities for improving manufacturing and recycling.

For his pioneering efforts related to sustainable manufacturing and the creation of methodologies to promote the remanufacturing and recycling of end-of-life products, Sutherland received the American Society of Mechanical Engineer's William T. Ennor Manufacturing Technology Award in 2013.

"Our mission at Purdue is to help companies innovate and become more competitive, while simultaneously reducing their environmental footprint," Sutherland says.

REENGINEERING FREEZE-DRYING FOR FOOD, PHARMACEUTICALS

Food manufacturing is the single-largest manufacturing sector in the United States, generating $812 billion annually and supporting 2 million jobs. At the same time, the nation's pharmaceutical industry generates $375 billion in creating 800,000 jobs.

Put together researchers from those two industry segments and the impact could be substantial. That's the goal of the Purdue-led Advanced Lyophilization Technology Consortium (LyoHUB), which was launched this summer with $453,623 in funding from the National Institute of Standards and Technology (NIST).

Lyophilization, known commercially as freeze-drying, removes water by

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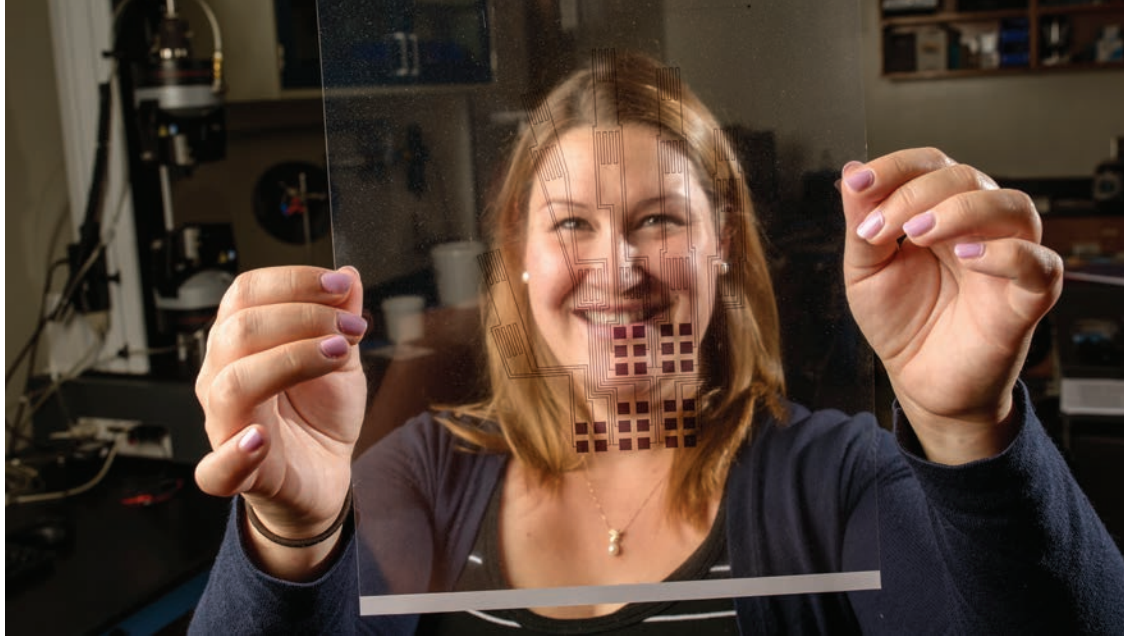
REBECCA KRAMER



Digital fabrication lab developing new methodologies that embed control at the material level

Rebecca Kramer, assistant professor of mechanical engineering, is one of seven U.S. researchers selected for a NASA Early Career Faculty Space Tech Research grant. The NASA award recognizes the potential of young faculty who are conducting transformative research applicable to space technology.

Kramer and her research team are developing a robotic fabric that moves and contracts and is embedded with sensors — an approach that could bring active clothing and a new class of soft robots. Such an elastic technology could enable development of robots that have sensory skin, stretchable robotic garments that people might wear for added strength and endurance, g-suits for pilots or astronauts to counteract the effects of acceleration, and lightweight, versatile robots to roam alien landscapes during space missions.

The robotic fabric is a cotton material containing sensors made of a flexible polymer and threadlike strands of a shape-memory alloy that return to a coiled shape when heated, causing the fabric to move.

"We have integrated actuation and sensing, whereas most robotic fabrics currently in development feature only sensing or other electronic components that utilize conductive thread," Kramer says. "We also use standard sewing techniques to introduce the thread-like actuators and sensors into the fabric, so they could conceivably be integrated into the existing textile manufacturing infrastructure."

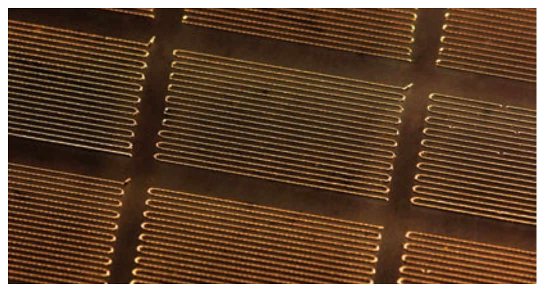
The robotic fabric can be wrapped around a block of foam or an inflated balloon. Orienting the fabric in one direction causes the robot to bend, producing locomotion similar to that of an inchworm. Orienting the fabric in a different direction causes it to compress — producing a peristaltic, or slithering, locomotion.

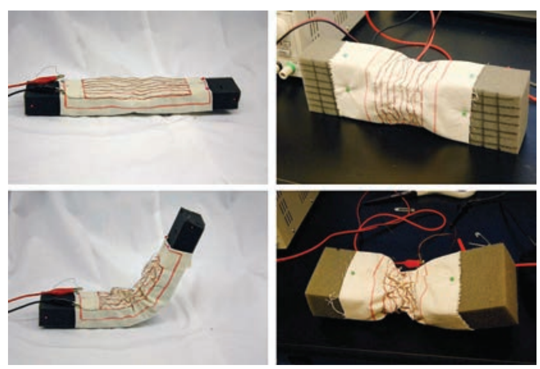
APPLICATIONS FOR SPACE AND BEYOND

Kramer is leading development of active elastic skins for soft robotics, where all the functional elements are embedded in a stretchable skin. This skin will include flexible electronics that are less sensitive to vibration than conventional hardware, making them rugged enough for space missions. Such a technology could allow space travelers to ship lightweight, easy-to-store sheets of robotic skin for assembly once they reach their destination. Like the robotic fabric, the skin might be wrapped around a deformable object, creating robots capable of exploring alien terrains.

"We will be able to design robots on-the-fly," Kramer says. "Anything can be a robot because all of the robotic technology is in the fabric or skin."

Kramer is also collaborating internationally with researchers on "variable stiffness" fabric, where integrated fibers including a shape-memory polymer allow the fabric to have changing stiffness. When heated, the polymer softens; when cooled, the polymer stiffens. This variable stiffness polymer is coated onto thin heating wires in order to precisely control the stiffness of the overall fiber. Such a fabric could be used in medical braces that lock in place for support. The approach represents a potential energy-efficient technology for robotics. "Ordinarily, if we are moving a hinge joint and want to maintain a particular position, we would have to maintain a high energy input to keep the joint from relaxing," Kramer says. "Here, we could just lock it in place." ■





TOP: Purdue researchers have developed a technique to embed a liquid-alloy pattern inside a rubber-like polymer to form a network of sensors. The approach might be used to produce "soft machines" made of elastic materials and liquid metals for potential applications in robotics, medical devices and consumer electronics. **BOTTOM:** Orienting the robotic fabric in two different directions causes a block of foam to either bend or compress, a principle that could be used to create robots that inch forward or slither. (Purdue University photos/ Rebecca Kramer)

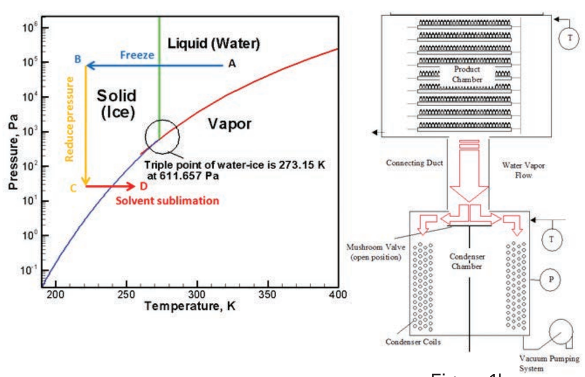
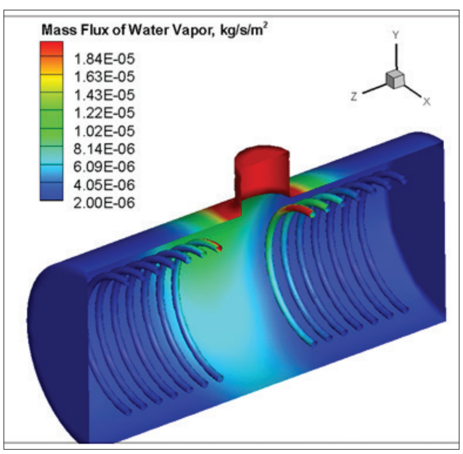
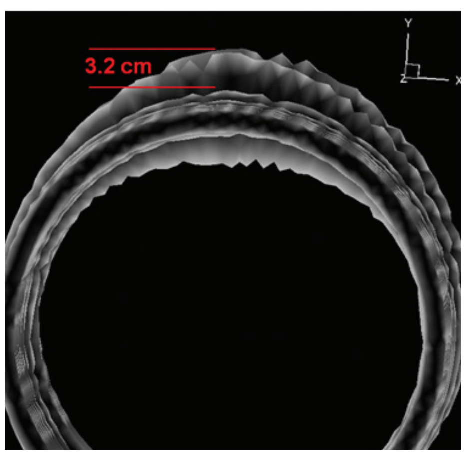


Figure 1b

ABOVE: Purdue University has created a new lyophilization consortium, LyoHUB, to improve freeze-drying technology. Elizabeth Topp, head of Purdue's Department of Industrial and Physical Pharmacy, and Alina Alexeenko, an associate professor of aeronautics and astronautics, co-lead the consortium. (Purdue University photo/Mark Simons) **RIGHT:** Water Vapor Phase Diagram superimposed indicating the vapor flow path on the schematic of a typical Freeze Drying Cycle. Figure 1b: Schematic of a freeze-dryer.





Water vapor mass flux and streamline in a section of the condenser of a Lyostar II freeze-dryer with the predicted steady non-uniform ice buildup shown on the right after 24 hours. The simulation parameters correspond to m= 55 g/hr, Duct pressure: 115 mTorr. The large non-uniformity in the ice growth between the coils close to the duct exit (center) and those away from the exit is purely a result of the non-uniform mass flux of the water vapor exiting from the duct.

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sublimation at low temperature and pressure and is used in the food and pharmaceutical industries to preserve sensitive materials such as protein drugs, vaccines, fruits and probiotic cultures.

This interdisciplinary research effort is led by Elizabeth Topp, industrial/physical pharmacy professor and department head; Alina Alexeenko, aeronautics and astronautics engineering professor; Kevin Keener, professor of food science and agricultural and biological engineering; and Steve Shade, managing director of the Center for Advanced Manufacturing. Joining them are researchers at the University of Connecticut and Baxter BioPharma Solutions.

The team looks to advance the way freeze-drying is done to reduce costs and make it more commercially viable, particularly for food and pharmaceutical products. Worldwide, the annual market for lyophilized foods and pharmaceuticals is $15.7 billion and is equaled by the market for lyophilization equipment and services.

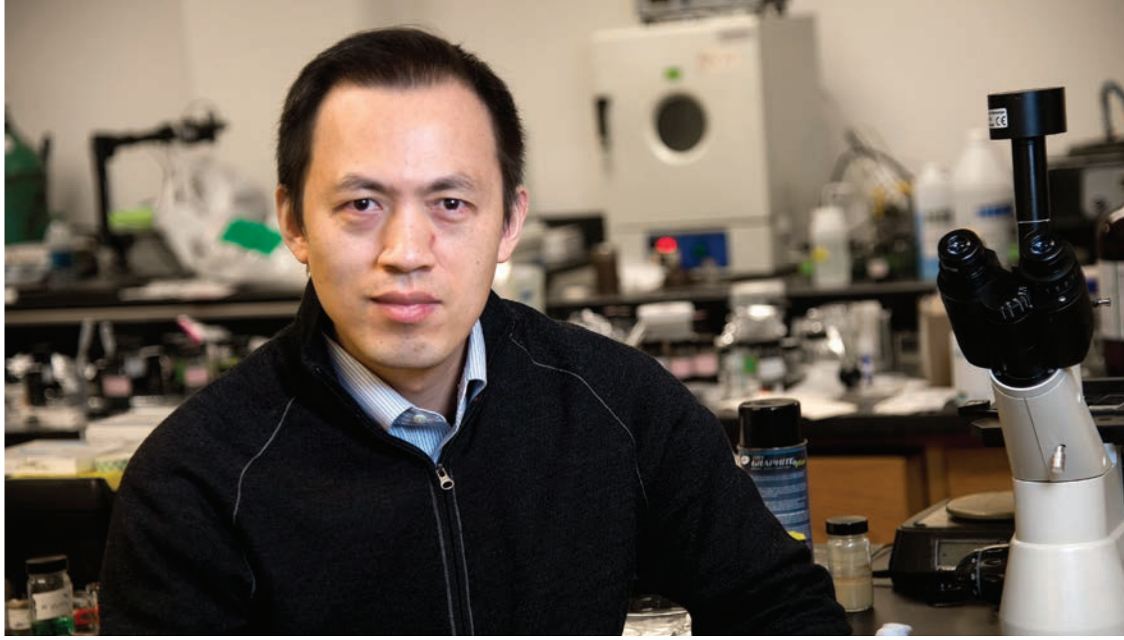
The goal is to develop innovative strategies for using lyophilization to improve the safety, quality and profitability of the U.S. food and pharmaceutical industries, says Topp, head of the Department of Industrial and Physical Pharmacy and the Dane O. Kildsig Chair in Industrial and Physical Pharmacy.

Alexeenko is passionate about the project, knowing the impact lyophilization technology can have on those with chronic and debilitating diseases.

"I am familiar with how long, difficult and expensive the lyophilization step is in manufacturing of those drugs and how it contributes to hundreds of dollars per dose," she says. "For biologics — many of which can only be produced in lyophilized form — there are no low-cost generic alternatives.

"Applying some of the rocket science tools, hopefully we can engineer better lyophilization equipment, which happen to operate in a vacuum environment similar to spacecraft."

GARY CHENG



Research advances large-scale nanoshaping of ultrasmooth 3D crystalline metallic structures

Research led by Gary Cheng, associate professor of industrial engineering, is breaking new ground in nanomanufacturing. Central to his work is the use of a pulsing laser to induce a shockwave inside a multilayered film topped with a glass sheet. In the latest results, researchers showed how to create large patterns of three-dimensional nanoshapes from metal sheets. The concept represents a potential manufacturing approach to inexpensively mass producing of plasmonic metamaterials for advanced technologies.

"Traditionally, it has been really difficult to deform a crystalline material into a nanoscale mold because at these small sizes materials are super hard," Cheng says. Whereas other researchers have created nanoshapes out of relatively soft materials, the new work shows how to create shapes out of hard metals. "These nanoshapes have extremely smooth surfaces, which is potentially very advantageous for commercial applications," Cheng says. Moreover, the new method, called laser shock-induced shaping, creates shapes out of crystalline metals, potentially giving them ideal mechanical and optical properties using a bench-top system capable of mass producing the shapes inexpensively.

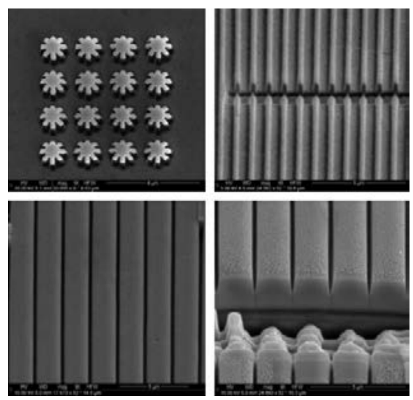
To overcome the limitation of formability at nanoscale, this transformative approach realizes a high strain rate deformation in nanoscale. The multilayered sandwich structure has a nanomold at the bottom. Exposing this layered film to a pulsing laser causes the ablative layers to generate an ionized gas and a shockwave that exerts a downward pressure, forcing the metal film into the mold. The 3D crystalline metallic structures, some as small as 10 nanometers, include pyramids, gears, bars, grooves and a fishnet pattern stamped out of titanium, aluminum, copper, gold and silver.

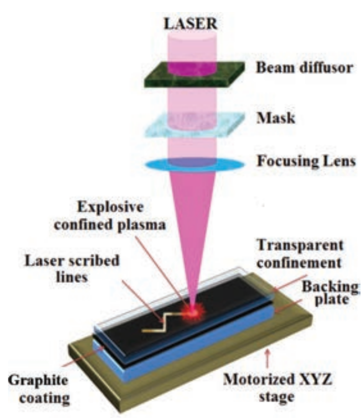
HYBRID STRUCTURES COULD EXPAND APPLICATIONS

The researchers also created hybrid structures that combine metal with graphene, an ultrathin sheet of carbon that is promising for various technologies. Such hybrid structures could enhance plasmonic effects and bring metamaterial perfect absorbers, or MPAs, which have potential applications in optoelectronics and wireless communications. Plasmonic metamaterials could harness clouds of electrons called surface plasmons to manipulate and control light. They have engineered surfaces that contain features, patterns or elements on the scale of nanometers that enable unprecedented control of light and could bring advances such as high-speed electronics, advanced sensors and solar cells.

IN OTHER RESEARCH

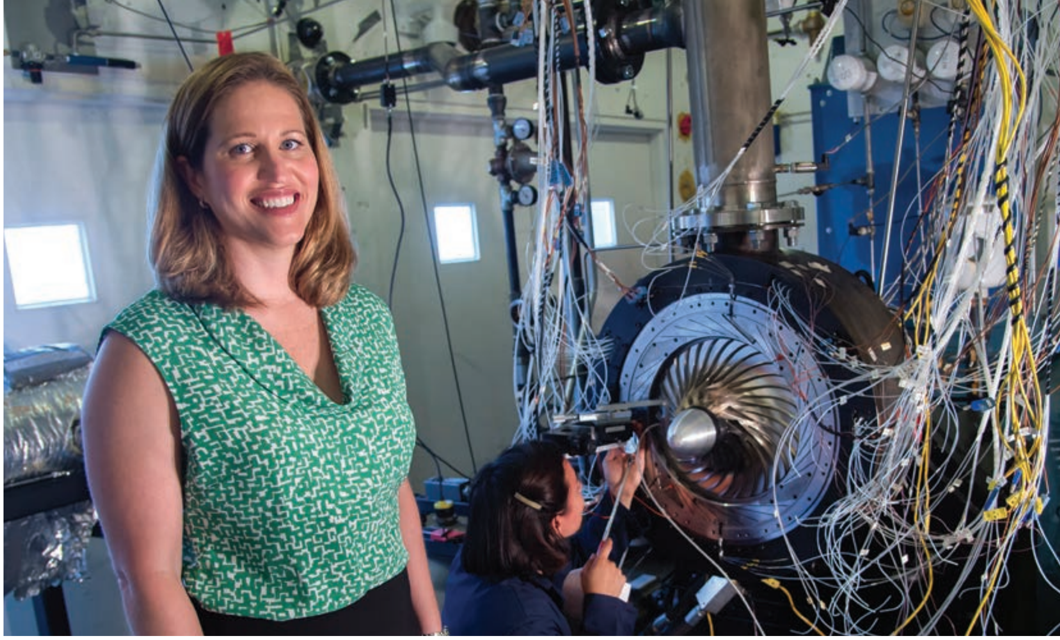
In related work, Cheng's group has shown how to create synthetic nanodiamond films and patterns from graphite, with potential applications ranging from biosensors to computer chips. "The biggest advantage is that you can selectively deposit nanodiamond on rigid surfaces without the high temperatures and pressures normally needed to produce synthetic diamond," he says. "We do this at room temperature and without a high temperature and pressure chamber, so this process could significantly lower the cost of making diamond. In addition, we realize a direct writing technique that could selectively write nanodiamond in designed patterns." The researchers have named the process confined pulse laser deposition (CPLD).





This illustration depicts a new technique that uses a pulsing laser to create synthetic nanodiamond films and patterns from graphite, with potential applications from biosensors to computer chips. (Purdue University image/Gary Cheng)

NICOLE KEY



Research advancing next-generation compressor technologies

Rolls-Royce is developing high-performance compressor technologies for next-generation jet engines, and much of the research to develop the enabling technology is based at Purdue's Maurice J. Zucrow Laboratories.

"This work will immediately impact the industry because the data are getting folded into design methods and future engine concepts currently being developed at Rolls-Royce," says Nicole Key, associate professor of mechanical engineering. "We have a good team in place."

Her group has two grants from Rolls-Royce — one each for axial and radial compressor research — totaling several million dollars. The team includes four graduate students, a postdoctoral researcher and a research scientist. Because of a tight timetable, the researchers will have the test rigs fabricated by a vendor. "It's a really aggressive program but an amazing opportunity," Key says. "The good thing is we've already been running similar kinds of rigs for Rolls-Royce, and we have an excellent capability as far as taking measurements with high accuracy and good resolution."

An important challenge facing engine manufacturers is how to design the rear stages of a "small core" compressor. "The rear stages become physically small, and this makes the losses associated with endwall regions more significant," Key says.

She and her group have been studying the effects of relatively large rotor tip clearances for NASA the past four years.

"Through the NASA project, we invested in hardware and instrumentation that allows us to better understand the development of these flows and how they affect the losses in the downstream stages," Key says. "I'm excited to extend this work to a current state-of-the-art compressor design."

The current three-stage axial compressor utilized in the laboratory has been operating for about 15 years with the majority of its funding from Rolls-Royce. The compressor is being redesigned to match Mach numbers and Reynolds numbers and blading styles consistent with next-generation engines. This is possible because of a lab renovation led by Key in 2009, where 1,400-horsepower electric motors were installed in the test cells, allowing operation of compressor research vehicles with higher pressure ratios and higher speeds.

The compressor lab at Purdue has been working on centrifugal compressors with Rolls-Royce since 2009. More recently, researchers in the lab have been studying the effect of tip clearance size and diffuser design on the overall compressor performance.

The new centrifugal compressor facility will incorporate inlet flow features that mimic the engine transition duct between the axial stages and the centrifugal stage providing an opportunity to understand the impact of these nonuniform inlet flows on impeller performance.

"The new centrifugal compressor facility is a researcher's dream — it is always challenging to get flow-field measurements in these machines, but a close collaboration between Purdue, Rolls-Royce, and the rig supplier ensures that instrumentation access will be excellent," Key says.

The team utilizes standard probes to measure temperature and pressure, but fast-response transducers that can track the passing of the individual blades are also used in the lab. Additionally, plans for laser-based velocimetry measurements ensure that the team will understand the flow field without the effect of probe interference.

"This research is satisfying on many levels. We know we are impacting the future of engine design, and yet we are able to simultaneously investigate many fundamental questions associated with these complicated flow fields."

The ultimate goal of this research is to advance the state of the art in performance and operability for next-generation axial and centrifugal compressors.

"The test and measurement capabilities being developed by Dr. Key at Zucrow and implemented on our compressor rigs will be the cornerstone of future compressor design methods and have far-reaching impact across Rolls-Royce business units and future products," says Nate Cooper, chief of Compressor Sub-System, AES Tech Demo at Roll-Royce.

YUNG SHIN

Research could improve laser manufacturing technique

Yung Shin, the Donald A. and Nancy G. Roach Professor of Advanced Manufacturing, has pioneered laser-assisted machining techniques and recently was awarded the Frederick W. Taylor Research Medal from SME, formerly the Society of Manufacturing Engineers. He was among six people from industry and academia who were honored by the organization, receiving the award during SME's 2015 International Honor Award & Scholarship Presentations Ceremony in Detroit. The awards recognize the recipients' influence in various specialties, including automation, lasers, machining, welding, microscale process modeling and other areas of manufacturing.

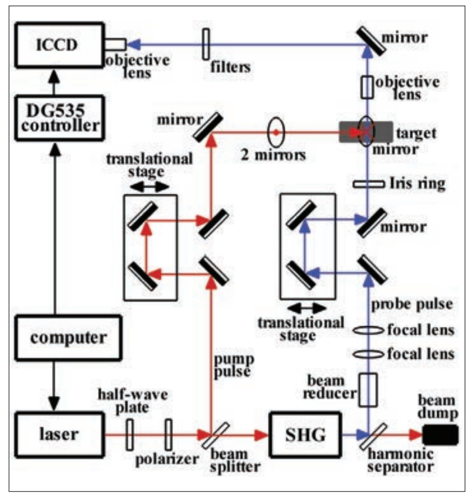
He has led work to discover details about the behavior of ultrafast laser pulses that may lead to new applications in manufacturing, diagnostics and other research.

Shin uses ultrafast laser pulses to create features and surface textures in metals, ceramics and other materials for applications including the manufacture of solar cells and biosensors. The lasers pulse at durations of 100 femtoseconds, or quadrillionths of a second, and cause electrons to reach temperatures greater than 60,000 degrees Celsius during the pulse duration. The pulses create precise patterns in a process called "cold ablation," which turns material into a plasma of charged particles.

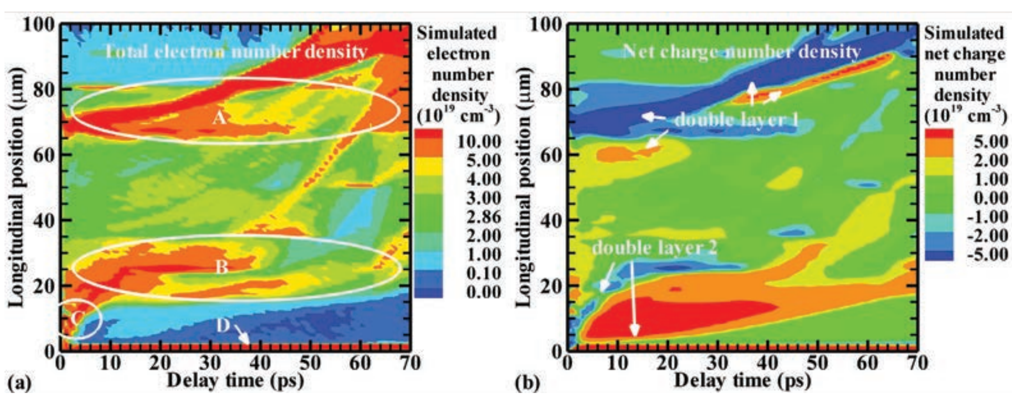
Images taken with a high-speed camera show tiny mushroom clouds eerily similar in appearance to those created in a nuclear explosion. The tiny clouds expand outward at speeds of 100 to 1,000 times the speed of sound within less than one nanosecond. However, findings reveal that an earlier cloud forms immediately before the mushroom cloud, and this early plasma interferes with the laser pulses, hindering performance.

Finding a way to eliminate the interference caused by the early plasma could open up new applications in manufacturing, materials and chemical processing, machining and advanced sensors to monitor composition, chemical and atomic reactions on an unprecedented scale, he says.

Shin directs Purdue's Center for Laser-Based Manufacturing. ■



Schematic of the pump-probe shadowgraph measurement.



Simulated spatial-temporal evolution of charged particle number density within the delay time of 70 ps for case I. (a) Total electron; (b) net charge. Laser wavelength: 800 nm; pulse duration: 100 fs; power density: 4.2×10^{14} W/cm^2; target: Cu.

ON A ROLL

Purdue to lead key part of $171 million flexible hybrid electronics manufacturing initiative

■ BY PHILLIP FIORINI

Ali Shakouri, left, the Mary Jo and Robert L. Kirk Director of the Birck Nanotechnology Center in Discovery Park and a professor of electrical and computer engineering, discusses the goal of the new roll-to-roll nanomanufacturing laboratory in Birck with Willard “Chuck” Raymond, president of Prototype & Production Systems Inc. in Plymouth, Minnesota. (Purdue University photos/Rebecca Wilcox)

Purdue engineers will be at the forefront of an effort that fosters U.S. leadership in flexible hybrid electronics, particularly in technologies for smart pills, sensors in food packaging or agriculture, and smart wound dressings.

Researchers at Purdue are partnering with Indiana University-Purdue University, Indianapolis (IUPUI), global industry leaders in the Midwest and the state of Indiana through a $171 million White House initiative focused on the field of flexible hybrid electronics.

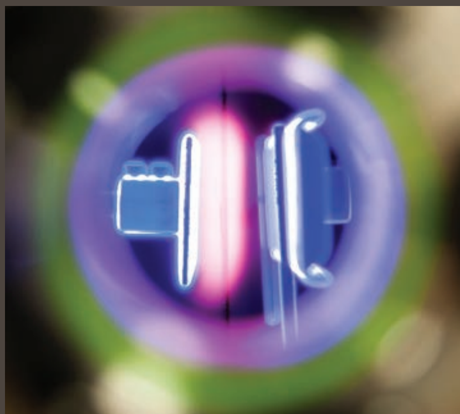
The Purdue team, led by Purdue electrical and computer engineering professor Ali Shakouri, will direct a $13 million component of the U.S. Department of Defense effort to launch the Flexible Hybrid Electronics Manufacturing Innovation Institute (FHE MII).

Through the five-year initiative, researchers across the country will focus on the design, manufacturing and integration of electronics and sensors and examine assembly and test automation for using complex flexible hybrid electronics on non-traditional conformal, bendable, stretchable and foldable substrates.

“This national effort builds on Purdue’s engineering strengths as we pursue advances as part of a broader nanomanufacturing initiative at Birck where we focus on roll-to-roll production of smart thin films for applications in pharmacy and agriculture,” says Shakouri, the Mary Jo and Robert L. Kirk Director of the Birck Nanotechnology Center in Discovery Park.

Partnering with Purdue and IUPUI are industry leaders Eli Lilly & Co., Roche Diagnostics USA, Molex Inc., IMA Life, Landauer, Smith & Nephew, Kimball Electronics and Samsung. Another key partner is the Battery Innovation Center, adjacent to the Naval Surface Warfare Center in Crane, Indiana.

Flexible hybrid electronics have the power to unleash wearable devices to improve medical health monitoring and personal fitness; soft robotics to care for the elderly or assist wounded soldiers; and lightweight sensors embedded into the very trellises and fibers of roads, bridges and other structures across the globe.



ABOVE: Pictured is a radio-frequency plasma glow between two electrodes, with a web material moving downward between them. The plasma breaks down gases such as argon, hydrogen and methane to produce species that contribute to the deposition of carbon nanomaterials on the web. (Purdue University photo/Rebecca Wilcox) **RIGHT:** Timothy S. Fisher, the James G. Dwyer Professor of Mechanical Engineering, is part of a Purdue research team that advances research and manufacturing in the field of flexible hybrid electronics. His research in scalable graphene production to meet large-scale manufacturing needs has led to new discoveries in biosensors and energy storage devices that are being developed in collaboration with both large companies and small startups. (Purdue Research Park photo)

Through Purdue's strengths in roll-to-roll nanomanufacturing, the team will examine how to enable low-cost fabrication for those applications. In addition, research will focus on inkjet/pulsed laser processing and printable nano-ink synthesis, flash light curing and sintering systems. It also will study low frequency RF plasma chemical vapor deposition for graphitic materials such as flexible connectors, super-capacitors and glucose sensors.

The Indiana effort will focus on advancing new nano-inks synthesized at IUPUI that will be used in roll-to-roll manufacturing systems at Purdue.

"While hundreds of commercial products rely on smart sensors, there remains a question of scale and cost," Shakouri says. "Nanomanufacturing techniques don't support mass-scale production because of the difficulty in fabricating a large number of smart devices repeatedly and under precisely controlled conditions. Moreover, nanomanufacturing involves several processes and a high level of integration."

U.S. Defense Secretary Ash Carter on Aug. 28 announced the selection of the FlexTech Alliance for Flexible, Hybrid and Printed Electronics team during a ceremony in San Jose, California, where the national institute will be based.

The FlexTech consortium unites companies like Applied Materials, Apple, United Technologies, Hewlett Packard and Qualcomm with end users like Boeing, General Motors, the Cleveland Clinic, Corning and Motorola that can embed these flexible, bendable electronics into everything from medical devices to supersonic jets while also building on the cutting-edge research underway at partner universities such as Purdue, Stanford, UC Berkeley, Harvard and MIT.

The project, which is receiving $75 million from the Department of Defense and $96 million in cost-sharing from private companies, universities and many state economic development agencies, joins five other federal institutes launched through President Barack Obama's National Network for Manufacturing Innovation (NNMI).

Joining Purdue on the FHE MII project are 96 companies, 11 laboratories and nonprofits, 41 other universities, and 14 state and regional organizations.

"This public-private partnership represents the ideal mix of industry and university researchers working together to create jobs, strengthen the economy and potentially benefit a wide array of markets," says Purdue President Mitch Daniels. "The spinoff benefits to students also will be substantial by providing research opportunities to prepare them for careers in the increasingly competitive global marketplace that demand highly skilled people." ■

ON THE CUTTING EDGE

M4 Sciences CEO and founder James Mann works on a computer numerically controlled lathe machine used for the company's TriboMAM ultra precision drilling technology. M4 Sciences received the 2011 Tibbetts Award for the innovation. The design provides greater precision and increases the speed of mechanical machining processes. The device can be used in the electronics, health-care and manufacturing industries. (Photo provided by the Purdue Research Park)

With modulation-assisted machining, James Mann and M4 Sciences aim to change the landscape of industrial drilling

■ BY ERIC BENDER

FACED WITH MATERIALS that are increasingly difficult to machine such as titanium alloys and stainless steels, conventional drilling often backs off. Literally — the drilling process is extremely slow, and in some cases the drill tool is repeatedly withdrawn to remove drilled material. The conventional drilling process leads to increased cost and production time, as well as quality issues.

With modulation-assisted machining (MAM), however, the drill tool steadily cycles in and out of the material with rapid and precise "modulated" timing — up to 1,000 times per second. The technique enables a series of smaller cuts and enhanced lubrication. The result is faster, better-controlled drilling with increased drill life.

"MAM is a totally new approach to a very old problem that really changes the physics of what's happening in metal cutting," says James Mann, chief executive of M4 Sciences. "This is the way metal drilling will be done, regardless of the application, the size of the hole or the material."

The concept was originally developed in the 1990s by W. Dale Compton and Srinivasan Chandrasekar, professors of industrial engineering at Purdue. But MAM's commercial history began in 2004, when Mann, who had gathered bachelor and master's degrees in aeronautics at the university, returned after a 15-year career in industry. As he pursued a PhD in industrial engineering, Mann both advanced MAM research and began to build a company around the technology.

The result was M4 Sciences, which he launched with Brian Gootee in 2005 to provide MAM enhancements for industrial drilling systems (the technology also has other applications related to machining).

"OUR BIGGEST CHALLENGE TODAY IS NOT TECHNOLOGY — BUT ADOPTION, MARKETING AND THE SALES PROCESS."

— JAMES MANN

Located at the Purdue Research Park in West Lafayette, M4 Sciences shipped its first product in 2009. The TriboMAM drilling systems now sell in 15 countries and are protected by a series of patents by Purdue and M4 Sciences. The company is profitable, with revenue soaring and annual growth exceeding 50 percent. M4 Sciences' customers range from small manufacturers to some of the biggest names in orthopedic, fuel systems, and the oil and gas sector.

Mann's industry experience and the MBA he previously earned at Indiana University helped in boot-strapping the business. "We did not take a lot of investment — we focused first on profitability and second on growth," he says. Much of M4 Sciences' research and product development funding came from the National Science Foundation, other federal agencies and the Indiana 21st Century Fund. In 2007, the startup gathered a welcome $30,000, plus considerable attention, by winning Purdue's 20th annual Burton D. Morgan Business Plan Competition. The following year M4 Sciences raised capital through private investment.

But commercializing MAM was no walk in the park. "We are talking about a product that operates in an extremely aggressive industrial environment," Mann points out. "The TriboMAM system has to work, and it has to operate continuously — for years. That is not necessarily easily accomplished. There were about 10 years of research before we started M4 Sciences, and it took five more years to develop to a commercial product."

In the startup's early years, the struggle was relentless, he says. "We were trying to find the money, trying to find the people, and trying to get through every hurdle of technology, engineering and business." Figuring out how to manufacture the TriboMAM system was a major part of the struggle. There were also plenty of first-time puzzles, like how to deliver the first product M4 Sciences shipped, which was delivered to a customer in Switzerland. "We were not even sure how to ship the system or how it would pass through customs," he recalls.

In the beginning, "a lot of challenges were related to accessing the market," Mann says. "They still are. Our biggest challenge today is not technology — but adoption, marketing and the sales process. We still often talk with customers who say they have never heard of MAM technology." Fortunately, M4 Sciences has built strategic relationships with a number of customers, one being Belgium-based NV Bekaert SA, which has licensed the technology.

Mann, who also continues to engage in academic research at the Purdue Center for Materials Processing and Tribology, points out that MAM offers a rare example of manufacturing technology successfully moving from academic research to real application. "The evolution of MAM technology and M4 Sciences are great examples of what Purdue engineering is really all about," he says. ■

Installation of two TriboMAM-LIVE rotating TriboMAM systems installed on a dual spindle gun-drilling machine.

BEYOND THE LABORATORY

Three Purdue researchers find success with startup companies

■ BY WILLIAM MEINERS

IF ENGINEERING IS about improving the human condition, any research brought to market can expedite that process. Three Purdue women, all with connections to biomedical engineering, have turned cutting-edge research into commercialized products. Their success, in turn, is helping pave the way for future faculty and student innovators.

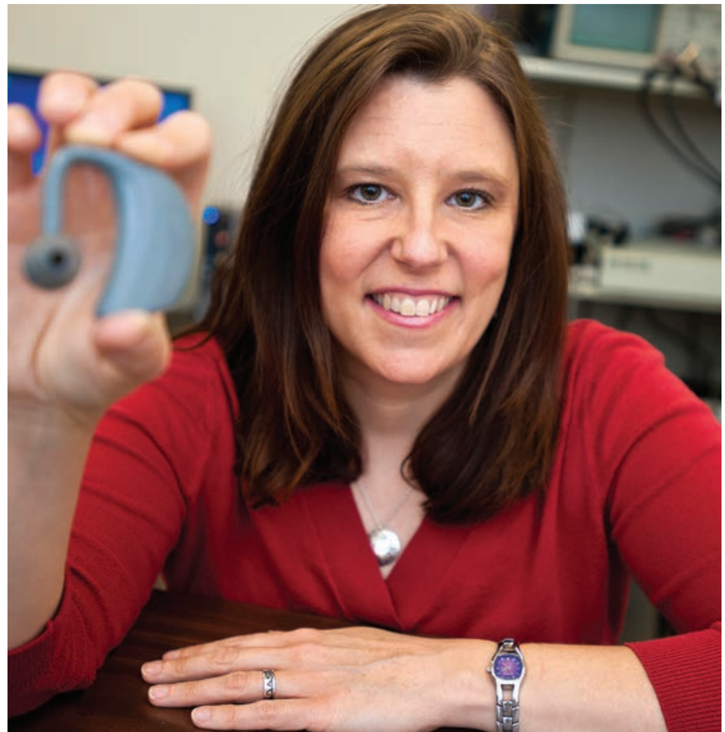
Jessica Huber, professor of speech, language, and hearing sciences, collaborated with engineers on a device that helps people with Parkinson's disease speak more loudly and clearly. Her startup, SpeechVive, helped her earn the 2015 Outstanding Commercialization Award for Purdue University Faculty. Alyssa Panitch, the Leslie E. Geddes Professor of Biomedical Engineering, has launched three startups, including Symic Biomedical, which secured more than $15 million in Series A financing this year. And Sherry Harbin, professor of biomedical engineering, founded GeniPhys in 2014. Her licensed research in collagen and engineering matrix technologies could revolutionize the way certain biomaterials are standardized and developed for research and medical purposes.

ENGINEERING INNOVATION

The idea came first, says Huber, who began working in 2006 with biomedical engineering researchers Kirk Foster, senior research engineer, and Jim Jones, engineering resources manager, both from the Weldon School of Biomedical Engineering, on a prototype that resembles a hearing aid. People with Parkinson's disease often suffer from a diminished voice. Huber's device creates background noise, forcing people to speak louder.

For the better part of a decade Huber strived to perfect the technology while investigating the ways to build a business. And from component parts to batteries and molding, she learned a lot about engineering along the way. "That's part of being a faculty member," she says. "Anyone excited about learning who earns a PhD and finds a faculty position doesn't just turn that off. The desire to learn never goes away."

Today Huber's invention is available in over 25 states and through some 70 different speech pathology clinics. A current Series B fundraising round, along with a software update, could help them penetrate the market for veterans as SpeechVive is the sole provider for the U.S. Department of Veteran Affairs.



Jessica Huber, associate professor of speech, language and hearing sciences, has invented SpeechViveTM, which helps Parkinson's disease patients overcome the tendency to speak too quietly. (Purdue University photo/Andrew Hancock)

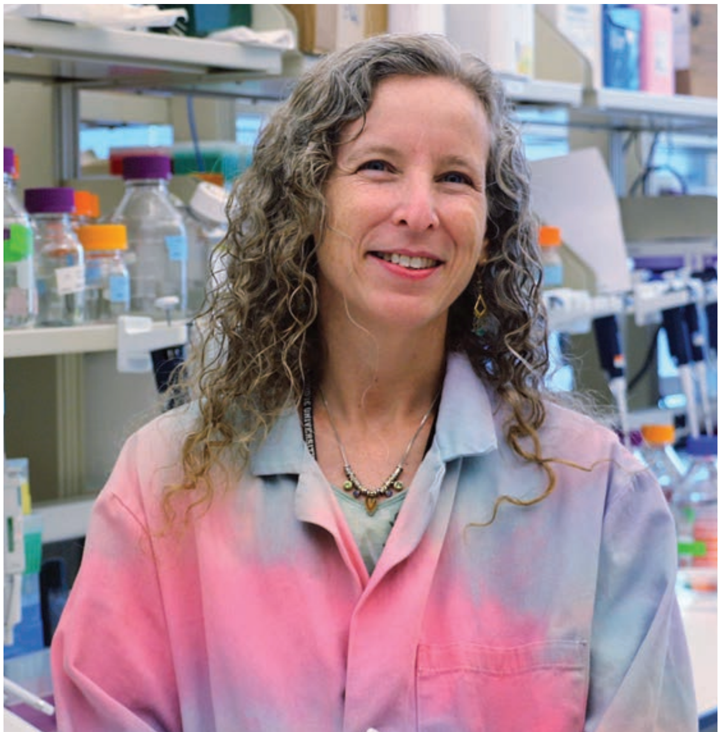
Huber's journey from idea to startup made her a good resource to help others on the same path. She was named the Faculty Fellow in Entrepreneurship in 2014, a position that allows her to meet with faculty and students regularly to provide direction on maneuvering the commercialization process. One group she started, the Entrepreneurial Ambassadors, gathers faculty who've started companies with faculty looking to do the same. "It's really helpful to have people who've had startup success share their stories," she says.

An evolving University culture that focuses on entrepreneurship is also paying dividends in the area of translational research. Huber says the Purdue Research Foundation, under the leadership of Dan Hasler, has helped make her multifaceted job easier — as both a faculty fellow and faculty entrepreneur.

SOLVING UNMET NEEDS

Panitch arrived at Purdue in 2006 with startup experience under her belt, having helped launch one as a faculty member at Arizona State University. In addition to Symic Biomedical, which offers an innovative approach to treating disease through a new category of therapeutics, Panitch took Moerae Matrix, a peptide development company that treats diseases that involve inflammation and fibrosis, to current human clinical trials.

Like Huber, Panitch is now helping others realize their own startup dreams. In 2014, she was named the inaugural director of Deliberate



Alyssa Panitch, the Leslie A. Geddes Professor of Biomedical Engineering, is a cofounder and an inventor of Symic Biomedical's proteoglycan technology. She has over 20 years experience in biopolymer and biomaterials research. She has cofounded three biotechnology companies based on this research. (Purdue Research Foundation photo)

Sherry Harbin, professor of biomedical engineering, in her laboratory in Purdue's Weldon School of Biomedical Engineering. A tissue engineer with about 90 patents, Harbin founded GeniPhys, a startup based on her research in collagen and engineering matrix technologies. (Purdue Research Foundation photo)

Innovation for Faculty in life sciences and medical technologies. Her first piece of advice: Try solving unmet needs. "It's better to have a technology that knows what its home is rather than have a technology searching for an application," she says.

She also advises researchers to play to their particular strengths and make the most of on-campus resources like the Purdue Foundry, a center dedicated to getting startups off the ground. "Most of us are really smart people and we think we can do just about anything," Panitch says. "But having a good business team is really important."

As a named professor that honors the memory of Leslie Geddes, the iconic Purdue biomedical engineering inventor and innovator with whom she worked, Panitch remains passionate about carrying that translational research torch. "I like working with graduate students, seeing the lightbulbs go off and helping them get to the point where they are really strong researchers," she says.

ENHANCING HUMAN MEDICINE

Harbin has been at Purdue since her graduate school days in 1987, where she also worked with Geddes and others at the Hillenbrand Biomedical Engineering Center developing and translating tissue engineering technologies. Though her original plan was to attend medical school, her philosophy never altered even as she followed a research path. "My goal has always been to have a positive impact on human medicine," Harbin says. "I realized I could do that best by working behind the scenes in developing new products."

Harbin's technology represents the first standardized self-assembling collagen that forms fibril networks similar to those found in our body's tissues. These polymer building blocks support design customization of bioinstructive collagen-based materials as well as cell encapsulation. This customization, along with versatile formatting, makes them broadly useful for medical and research applications including 3D cell culture, medical implants, engineered tissue constructs and vehicles for localized delivery of therapeutic agents and/or cells. Harbin says one highlight of developing this technology was working through ASTM International to draft standard guidelines for manufacturing and characterizing these new collagen formulations.

GeniPhys is currently selling research grade materials online that can be used in modernized 3D cell cultures. "We are generating a small stream of revenue and that's important as we move forward into the planning stages of medical grade products," says Harbin.

As for pushing the limits of her own research and development expertise, Harbin enjoys thinking about the broader aspects of commercialization. "When you go out and vet the technology and people say, 'Wow, this is really going to be impactful,' that's really the motivation. There's a significant gap in getting it from research grade on the lab bench to where it's something that's rigorously quality controlled and standardized. I've been trying to put those pieces into place."

For Harbin and any researcher working along an engineering path marked by trial and error, the opportunity for commercialized success could have rippling effects throughout campus and society.

REPLACING THE

GOLD STANDARD

New materials begin to bring plasmonics technology out of the lab and into nanophotonic devices for harsh environments

■ BY ERIC BENDER

Krishnakali Chaudhuri

NEW PLASMONIC METAMATERIALS that operate at high temperatures could radically improve solar cell performance and bring advanced computer data storage technology that uses heat to record information on a magnetic disk.

In plasmonics research, far too often what happens in the lab stays in the lab. But a startup firm founded by Purdue researchers aims to change that.

Surface plasmons are waves that move along the surface of a conductor and involve resonating clouds of free electrons on the conductor's surface. Researchers build plasmonic devices that can act as tiny nanometer-scale antennas for visible or infrared light, and manipulate light at a smaller scale than is possible with more conventional approaches.

In fact, "plasmonics seems to be the only way to bring light down to the sub-100nm scale," says Vladimir Shalaev, the Bob and Anne Burnett Distinguished Professorship in Electrical and Computer Engineering. And plasmonic nanophotonic devices hold high promise for applications ranging from optical computing to thermovoltaic energy production and from industrial sensing to biomedical imaging. But in many potential roles the promise of plasmonics has been difficult to keep, largely because of durability problems.

Until recently, the two materials most often used to create these devices were gold and silver, Shalaev explains. The noble metals generally are not compatible with existing CMOS semiconductor materials. Gold and silver also are very soft and cannot sustain high temperatures, which rules them out for many uses.

"We realized that this was a fundamental problem, and unless we came forward with realistic materials, plasmonics would not lead to practical devices," Shalaev says. Shalaev and Alexandra Boltasseva, associate professor of electrical and computer engineering, are developing a new class of plasmonic ceramic materials based on compounds known as transition metal nitrides that take harsh environments in stride.

"We have optimized these plasmonic ceramic materials, finding the right ways to prepare them," he says. "Their optical properties are as good or better as those offered by noble metals, but they can operate in very high temperatures and aggressive chemical environments."

MAKING PLASMONICS MORE PRACTICAL

In 2011, Shalaev, Boltasseva and colleagues founded Nano-Meta Technologies to bring these new materials out of the lab. Ernesto Marinero, professor of engineering practice and of materials engineering, is now interim chief executive officer for the startup, which is focusing primarily on a few applications whose path to commercialization seems quickest. These applications typically employ plasmonic titanium nitride combined with other components to withstand degradation or meet other needs.

Nano-Meta's leading commercial target is recovering energy from the heat lost in certain manufacturing processes. In glass and steel manufacturing, for example, "there's no real way to isolate furnaces perfectly, and you lose a lot of energy in terms of heat," says Urcan Guller, Nano-Meta chief scientist and a former postdoc in the Shalaev and Boltasseva labs. "We are designing materials that capture heat energy on their surface, so that we can use the excess heat out of the furnaces to generate electricity from photovoltaic cells."

In a related application, plasmonic devices could collect solar energy and convert it into infrared energy optimized for collection via photovoltaics. This technology is highly efficient and scalable on a range from handheld power generators to energy for apartments or houses, Shalaev says.

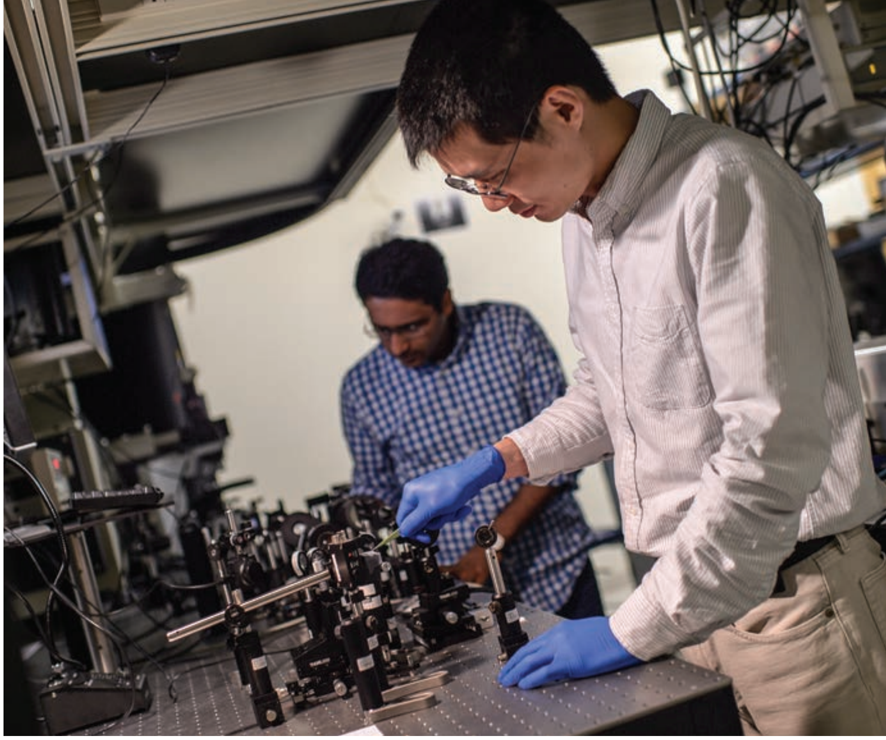
Among other projects that may pay off in the longer run, Nano-Meta has been working to enhance a next-generation hard drive storage technology known as heat-assisted magnetic recording (HAMR). In HAMR, a tiny area of magnetic recording material is heated by laser before data is written or read. A plasmonic antenna potentially could focus the laser beam in a smaller area, thus helping to boost the density of data storage. Nano-Meta is investigating commercial opportunities for this technology under a small business research grant from the National Science Foundation.

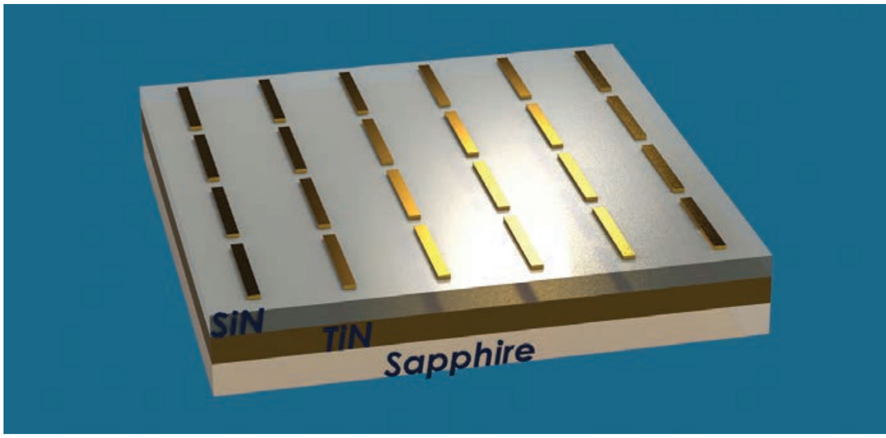
In additional early-stage efforts, the company is pursuing medical applications. For years, investigators have experimented with gold nanoparticles that might aid in medical imaging and sensing, drug delivery and even the destruction of tumors via heat. Plasmonic nanoparticles could handle these jobs while being smaller and cheaper to manufacture than the current gold alternatives, Shalaev says.

"These optical surfaces with special functions can be applied to many environments," he says. "This is a very general breakthrough. I believe that we have developed here the materials that enable all these beautiful applications."

Key to the development, Boltasseva emphasizes, is Purdue's strength in interdisciplinary research collaboration.

"The research and our startup company have their roots in cooperation and expertise exchange between materials science, optical technologies, computational physics and nanotechnology," she says. "It's crucial to bring together different disciplines to find solutions for the challenges the current technologies face. That's what makes Purdue a unique place, and that's why this was successful." ■





TOP: Doctoral students Rohith Chandrasekar and Jieran Fang (foreground).
MIDDLE: Vladimir Shalaev, the Robert and Anne Burnett Distinguished Professor of Electrical and Computer Engineering. (Purdue University photos/Charles Jischke)
BOTTOM: In solar thermophotovoltaics, an extremely thin layer of "metamaterial" depicted here uses plasmonic nanoantennas to absorb and emit light, potentially resulting in high-efficiency solar cells. (Birck Nanotechnology Center/Purdue University)

SCALING THE
SOLAR SYSTEM

Student-led team designs interactive exhibit that honors Purdue alumna Janice Voss

■ BY JAMISON STOIKE

TUCKED NEATLY AWAY in an acre and a half of Purdue's Discovery Park, the Visiting Our Solar System (VOSS) interactive exhibit can seem effortless at first sight. The spiraling network of planets and the vibrant metal arcs of the sun belie the challenges of designing this scaled model of the solar system, as well as the creativity of the student-driven solutions that made its construction possible.

Named in honor of the late Purdue alumna and NASA astronaut Janice Voss, the project was intended to create a field trip destination for elementary and middle school students. This made EPICS (Engineering Projects in Community Service) a natural home for the development of the model over its six-year gestation.

Bill Oakes, director of EPICS, says, "We had seen other solar system models and we thought that we could do one in a Purdue way, one that better engages with local students."

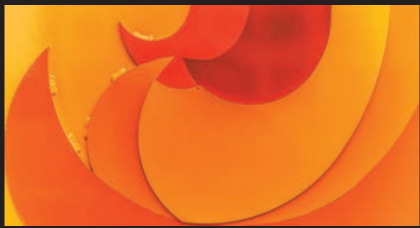
"The model's purpose is to inspire," says Anna Tatara, industrial engineering student and design lead for the VOSS website. "Students are entranced by walking through the solar system and physically wrapping their arms around the planets." Diego Martinez, a sophomore engineering student and co-leader of the EPICS team, says, "It is really a stepping stone to learn more science."

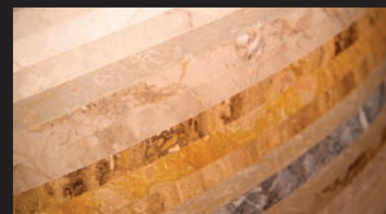
Supported by the Indiana Space Grant Consortium and its director, Barrett Caldwell, professor of industrial engineering, the creativity of more than 50 students made the $1.5 million project possible.

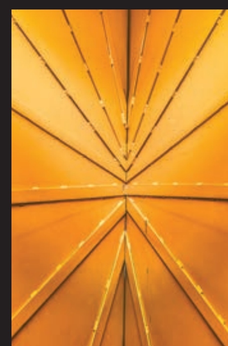
At the dedication ceremony in April, Leah Jamieson, the John A. Edwardson Dean of Engineering, said, "Thanks to these students and their many team advisors, Purdue has a unique interactive learning tool for our young space enthusiasts that also serves as a reminder of Purdue's deep and storied connection to space exploration."

Oakes concurs, saying that he and Caldwell believe that the students' design was far better than anything they envisioned.

"Initially we had ideas like putting it on top of campus buildings," Oakes says, expressing amusement with the unusual idea. The







Diego Martinez, left, and Anna Tatara — both EPICS students who worked on the VOSS Model. Tatara, an industrial engineering student, designed the plaques containing educational and inspiring information about the planets. Martinez worked on the Virtual Fly Through Tour available on the website. The model is designed for students to learn more about the solar system and for educators to inspire their students to learn about space. It is a fitting tribute to Purdue alumna Janice Voss. (Purdue University photos/Mark Simons, Charles Jischke, John Underwood)

“THE MODEL’S PURPOSE IS TO INSPIRE”

— ANNA TATARA

EPICS team left no stone unturned in solving the project’s greatest challenges: scale and location.

Scaling down the more than 7.4 billion kilometers from the sun to the edge of the Kuiper Belt was no small task. The team had to reconcile not only how to scale the distances between the planets, but also the sizes of the planets to each other and their sizes relative to the sun. One design had the model running linearly through Discovery Park, but to keep the size of the planets proportional to the sun, “the inner planets would actually be inside the sun,” says Tim Strueh, a Purdue Engineering alum and EPICS advisor.

To solve the scale issue, the students created a spiraling design that compactly coils the planets around the sun. “Ultimately we used the Fibonacci spiral, in part because it’s an architectural feature throughout Discovery Park,” Strueh says.

With the scale issue solved, the question of where to put the expansive outdoor installation became easier to answer. Its compactness is ultimately what made the VOSS exhibit viable as a field-trip destination for local teachers. “We had to make the planets close enough together that kids wouldn’t lose interest,” Oakes says.

Though the model on campus has always been the central focus of the project, the desire to augment the experience and further interact with the community has led to the development of additional projects and two small-scale models.

“We knew that not every student will be able to come here, especially with reductions in funding for field trips, so we asked what else could we do for those students,” Strueh says. Now the project features a website with games, a social media presence and a tabletop model that can be expanded for outdoor use.

The EPICS team is developing a focused curriculum for teachers using the website, the portable model and the VOSS exhibit itself. Project lead TJ Herron, a senior in nuclear engineering, says the team is working to ensure that the curriculum doesn’t lose sight of the model’s mystery and wonder: “We want to keep the experience from becoming so rigid that it loses the freedom that comes with discovery.” ■

SPACE HUNTERS

Purdue aeronautics and astronautics graduates play critical roles in the historic Orion space launch

■ BY WILLIAM MEINERS

FOR ALL OF its alumni/alumnae astronauts — 23 to date — Purdue has many more working engineers who have helped put those men and women into space. Among those experts on the ground during NASA's successful Orion spacecraft launch last December were three Boilermakers with degrees from the School of Aeronautics and Astronautics. Their work could help spur future Orion flights, eventually leading to the first astronauts on Mars in the 2030s.

Orion flew deeper into space on a test flight mission than any crewed vehicle since the Apollo missions more than 40 years ago. William Gerstenmaier (BSAAE '77, OAE '03, DEA '07), associate administrator for Human Exploration and Operations Mission Directorate; Mark Geyer (BSAAE '82, MSAAE '83), recently named deputy director of the Johnson Space Center; and Julie Kramer White (BSAAE '90), Orion program chief engineer, are a trio of high-ranking NASA officials who helped ensure Orion's success from launch to landing.

OVERSEEING COMPLEX ENGINEERING ACTIVITIES

As head of the human spaceflight directorate, Gerstenmaier helps balance the needs of Orion against NASA's other spaceflight programs. He also represents the program to the legislative and executive branches of the U.S. government and oversees the barter with the European Space Agency for the service module being developed for Orion.

"The engineering background I received at Purdue helped provide me with the knowledge needed to oversee a highly complex engineering activity," Gerstenmaier says. "I have an engineering understanding of the trade-offs being discussed and represent the program to a less technical community. My Purdue education was well rounded and trained me to balance many competing priorities."

Dan Dumbacher (BSME '81), professor of engineering practice in aeronautics and astronautics, returned to his alma mater in 2014 after a 33-year career at NASA. He knows something about balancing competing priorities. In his most recent post as deputy associate administrator in the Exploration Systems Development Division, Dumbacher led teams throughout Orion's history, which dates back some 10 years. Through policy shifts and a spaceflight hiatus, Orion still fit the bill for taking people deep into space and returning them home.

Back at Purdue, Dumbacher is helping establish the Purdue Systems Collaboratory. "From my perspective, particularly in my last five or six years at NASA," he says, "I know that as much as we need the technical experts to understand all the fine intricate details of the technical theory and application, we also need people who can work across multiple disciplines. The Purdue Systems Collaboratory is intended to move that forward."

SUCCEEDING IN STRESSFUL ENVIRONMENTS

All told, there are more than 60 Purdue graduates directly involved in the Orion program through work at NASA, Lockheed Martin and Honeywell. Alums hold various positions ranging from avionics to control systems to propulsion and beyond. Engineers will take all the data from the test flight and put it into an Orion spacecraft that will fly on the first test flight of NASA's new Space Launch System rocket. That next mission, paving

the way for deeper and deeper flights, also will be a test flight without astronauts, Dumbacher says.

Dumbacher believes working with fellow Purdue alums at NASA provided some common ground in building successful teams. “Even though it’s technical work, all of it is fully dependent on personal relationships,” he says. “With a Purdue engineering degree, you end up with a certain language and understanding in common and that helps with the communication side of it.”

Since 2007, Geyer was responsible for the day-to-day management of the Orion program, which has included the development and integration of the system. Like Dumbacher, Geyer believes that a Purdue program that focused on applications with high expectations prepared him for his work at NASA’s Johnson Space Center.

“I learned how to solve difficult engineering problems in the courses we had at Purdue,” says Geyer, who believes simply having the chance to make mistakes and mature in college helped guide him to adulthood. “I also learned how to succeed in a stressful environment, how to build collaborative relationships with fellow engineers and how to interact and work with people in authority.”

EXCEEDING EXPECTATIONS

For many NASA employees, whether they’re working behind the scenes at the ground controls or flying aboard a spacecraft, the idea of working on space challenges has been a lifelong dream. That was the case with Dumbacher, whose mother tells him he never missed watching a launch on television.

“Certainly you have to have the engineering education to get in the game,” says Dumbacher, who is now even more impressed with the quality of students since his days on campus 34 years ago. “I was lucky enough to have a couple of NASA internships before I graduated, and all I ever wanted to do was work at NASA.”

White combined her mechanical aptitude with a love of science fiction. That call to the frontiers of space resounded early in her childhood. Though she attended Purdue because it was the state school close to home, she admits to later learning about its far-reaching reputation as she began her work at NASA.

As a senior engineering official at the Johnson Space Center, White works as a liaison between engineering and program functions, serves as an advocate for engineering staff and is the overall technical advisor to the program manager. President Barack Obama recognized her specifically for her leadership role in Orion’s test flight. A future Mars landing, the president says, with the Americans first on the planet, would also be indebted to White.

Even with high praise from the Commander-in-Chief, White remains humble, perhaps reflective of her Midwestern roots. “My education at Purdue taught me a lot of great fundamental engineering,” White says. “However, the skills I value most are general leadership and problem-solving skills.”

White also stresses perseverance, along with learning how to prioritize, manage stress and work in teams — both good ones and not-so-good ones — as keys to success in a demanding, revitalized field seeking to find the farthest reaches of space. ■

Photo courtesy of NASA

LIFE ON 'MARS'

Doctoral student spent eight months in simulated Red Planet environment

■ BY ANGELA PETRIE

Not just anyone would jump at the chance to spend eight months away from their family and friends — let alone in an isolated, confined and extreme environment.

For Jocelyn Dunn, an industrial engineering PhD candidate, the opportunity to simulate life on Mars through the Hawaii Space Exploration Analog and Simulation (HI-SEAS) program was a dream come true.

“As an aerospace and biomedical engineer, I always found myself wondering about how the extreme environment of space impacts astronauts and how we can develop biomedical devices to keep them safe and healthy,” she says. “This was my opportunity to learn more about the human side by experiencing a long-duration mission, and to give back to the space program to help future travelers to Mars.”

To send a real mission to Mars, there are still a few hurdles to jump. Besides the obvious struggles of getting a crew there safely and achieving a livable habitat, there are many other biological, psychological and social factors to be studied. HI-SEAS missions study these factors to learn how crews adapt and evolve over time.

HI-SEAS Mission 3 ran from Oct. 15, 2014 to June 16, 2015 with a crew including Dunn, Martha Lenio (Commander), Sophie Milam, Allen Mirkadyrov, Neil Scheibelhut and Zak Wilson. During this eight-month mission, Dunn and her fellow crew members facilitated research studies of biological samples, social interactions, as well as psychological and cognitive testing with the goal of learning how health and performance change throughout their time in an isolated, confined and extreme environment.

CREATING MARS LIFE ON EARTH

The dome habitat was situated on the slopes of Mauna Loa where there is little evidence of plant or animal life. Due to the length of time it takes messages to travel from Earth to Mars, there was a 20-minute delay on all communications incoming and outgoing from the HI-SEAS habitat. To support a mission to deep space, the HI-SEAS program has adopted a model of “mission support” rather than “mission control” in order to promote an autonomous crew that works collaboratively with the support team that is millions of miles away.

Keeping the goal of crew autonomy in mind, Dunn and her crewmates found ways to bond and enjoy many of the comforts of home while on their mission — whether it was cooking Thanksgiving dinner using mainly freeze-dried foods, working out to P90x (a 90-day workout program) or watching the sci-fi television series “Firefly” on DVD.

“When envisioning life in a dome, my research ambition was inspired by the valuable data to collect and analyze from this experience, and a big part of me was excited to leave distractions of the real world behind,” Dunn wrote in her blog on Nov. 20, 2014. “I looked forward to reading a long list of books and imagined these eight months of living in a dome as an intellectual and spiritual retreat.” She goes on to inform readers that one month into the mission, she’s read only one book, and it was a short one at that.

> “MY RESEARCH AMBITION WAS INSPIRED BY THE VALUABLE DATA TO COLLECT AND ANALYZE FROM THIS EXPERIENCE”

Days in the dome were spent with many different responsibilities to the mission and lingering commitments to her life outside of the dome. Between checking email, working out, extravehicular activities (EVAs), taking about 40 surveys per week, doing K-12 outreach and scientific presentations, journaling, having crew socials, cooking, eating, cleaning, on top of coding, collecting data, writing for her dissertation, and savoring a few small blocks dedicated to personal time, Dunn found time passing more quickly in the dome than in her normal life.

However busy they seemed, Dunn wrote, overall she felt amazing.

“I'm tackling projects that would have been overwhelming previously,” she recorded on Dec. 16, 2014. “This big move to ‘Mars’ has been a powerful transition for my personality as well, feeling stronger, happier and more determined.”

As the mission came to an end, Dunn reminisced about what returning to her normal life would be like. She would miss having unlimited food, cooking only once a week, sharing inside jokes with the crew, wearing slippers to work every day and feeling the sense of belonging with her crew and mission.

With one month to go, the crew was ecstatic when plans were finalized for the U.S. Army Golden Knights jump team to take them tandem skydiving as a simulated re-entry to Earth. And if that wasn’t exciting enough, they also learned that Tony Horton, creator of P90x, whom the crew lovingly dubbed their “seventh crew member,” and his fiancée were going to join them on the jump. Looking forward to going home and meeting their hero, the crew began playing “Final Countdown” by Europe on repeat.

Before re-entry, Dunn expressed a sense of being beyond excited to reunite with her Boilermakers at Purdue. ■

Jocelyn Dunn, a PhD candidate in Purdue’s School of Industrial Engineering, spent eight months simulating life on Mars through the Hawaii Space Exploration Analog and Simulation (HI-SEAS) program. She served as chief scientist during the simulation. (Photos provided by Jocelyn Dunn)

ENGINEERING

A BETTER 'DO'

Purdue researchers finally figure out how much heat hair can withstand

■ BY LINDA THOMAS TERHUNE

HAIR DAMAGE FROM repeated use of straightening chemicals and hot irons has left many curly-haired people looking for a better solution for hair care. Tahira Reid and Amy Marconnet are using engineering to solve the problem. Their focus is on the end-user and includes social context, an approach that runs counter to the conventional engineering focus on functionality.

Reid, an assistant professor of mechanical engineering who studies interdisciplinary design, has long been fascinated by hair. It is a central part of her African-American culture and comes with challenges she knows well, because she made her own choice to leave chemicals behind and go the natural hair route. In college, she helped a hairstylist friend prepare a patent application for a grooming tool for dreadlocks. Her graduate studies included design optimization of hair beauty in African-American women. And a few years ago, her own experience with hair care got her thinking about the $700 million-plus black hair care industry, a huge portion of which is devoted to natural hair products and cosmetics. Like a good researcher, she immersed herself in the topic and attended a national hair convention in Atlanta.

Are consumers being well-served by hair product design? Are their needs being taken into account? As Reid pursued these questions, she began to wonder about the mechanics of hot irons, which led her to ponder technical questions about heat transfer — the process that makes straightening irons hot. She approached her colleague Marconnet, also an assistant professor of mechanical engineering and specialist in heat transfer and energy conversion processes. The two recognized a collaborative, interdisciplinary challenge — the kind of work they both love.

Believing that "an engineering perspective on mathematical correlation between heat and hair can help yield more practical and customer-relevant knowledge in the field," they undertook an interdisciplinary approach to integrating customer needs — one that considers design methodology and thermal sciences for application to the hair care industry. They named their study "The Beauty of Mechanical Engineering."

"Heat transfer is everywhere we look. It has an impact on what we can see, touch, feel," Marconnet says. She is particularly interested in energy efficiency and clean water issues, and uses her expertise to help people who develop materials understand the physics of how energy moves. This could be energy from cellphone batteries that heat up the device or, in the case of thermal hair appliances, energy that fries hair.

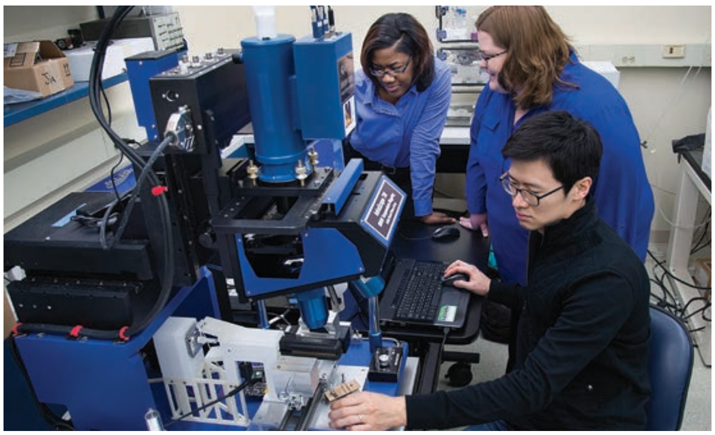
Working with Reid and Marconnet, graduate student Jaesik Hahn designed an automated flat ironing mechanism and process that mimics the hair straightening process and measured temperature distribution on hair samples with a high-resolution infrared microscope. Measured temperature maps combined with predictive models allow the researchers to understand at what point the physics of heat transfer affects hair strands.

The study focused on how people and heat transfer — consumers and straightening irons — interact. Using this information, the team is aiming to develop a model for how often and how long consumers can use straightening irons before causing irreparable damage.

Reid and Marconnet are going about this engineering challenge by targeting the user — hair care professionals and consumers who use straightening irons. It is an example of the type of work undertaken in an area of the R.E.I.D. Lab (Research in Engineering and Interdisciplinary Design) that focuses on socially and culturally relevant engineering design. In this area, researchers develop frameworks, methods and models that help engineers think critically about nontechnical issues and their effect on engineered design solutions. Other work in the lab includes collaboration with anthropology professor Sherylyn Briller, mapping best practices in compassionate design, such as radiation oncology masks that respect user dignity and sensitivities.

For Marconnet, who envisioned mechanical engineering as focusing on nanotechnology, fast cars and robots — but never on hair care —the hair project poses a good mechanical engineering problem. "The research complements work done on manmade and natural fibers for other industries such as textiles. The same types of testing and analysis that we use for yarns and textile fibers applies also to individual hair strands and bundles of hair," she says.

Reid agrees that the seemingly nonconventional mechanical engineering research challenge has merit beyond the beauty industry. "This is a good topic for mechanical engineers, because it helps them see the impact of their knowledge on problems beyond those that are obvious or typical," she says. ■



Tahira Reid, at left, and Amy Marconnet, both assistant professors of mechanical engineering, work with graduate student Jaesik Hahn in using an infrared microscope to study how heat affects hair while heat is applied with a flat iron. The goal is to learn precisely how much heat to apply in hair styling and how frequently to use heat treatment for a given hair type without destroying it. (Purdue University image/Mark Simons)

'SYSTEMS COLLABORATORY'

Utilizing a multidisciplinary approach to solve complex issues

■ BY EMIL VENERE

IN SEPTEMBER, NASA administrator Charles Bolden kicked off the Purdue Systems Collaboratory aimed at integrating multidisciplinary teaching and research stressing the "convergence of knowledge" in problem solving. The Collaboratory's approach leverages Purdue's strengths in the area of complex systems.

"We are building a community from a research perspective that's looking at cross-disciplinary problems and also thinking about how we educate all of our students including the next generation of political science majors, English majors, business majors and engineering majors, to think about these kinds of problems," says Purdue Provost Deba Dutta, executive vice president for academic affairs and diversity and a professor of mechanical engineering. "Because complex systems span many disciplines and domains, finding solutions requires a convergence of knowledge from all relevant areas."

For example, properly managing a range of projects and situations requires professionals capable of understanding and dealing with more than their own specialties.

"To take care of disaster relief after a hurricane or a tornado, you need to consider how people are going to react, what they will do, what they will need the most and when they will need it," says Abhijit Deshmukh, the James J. Solberg Head of Industrial Engineering. "We've built power grids, launch vehicles and rockets and other complex systems, but the hardest part is how to account for the human interaction. Our ability to create complex systems has far exceeded the capability to understand and manage them. What's most important is that the Systems Collaboratory drives home the concept of the convergence of knowledge — physical sciences, social sciences, arts, life sciences — which is different from what other universities are doing."

The approach is needed to both better prepare students and also tackle research projects.

"In the corporate world the engineering community has a hard time working with the marketing people, the financial people and others crucial to the success of a project, and so you are always trying to bridge that gap," says Dan Dumbacher, professor of professional practice and a retired NASA engineer. "In my own world I spent a lot of time bridging the gap between the engineering world and the policymakers in Washington. Humans are invariably an essential, and often least understood, element of these systems. So understanding and integrating the human dimension is a central element of any solution."

Purdue created an honors course last fall titled "It's A Complex World" to address the problem. It was co-taught by faculty members from political science, computer science, industrial engineering and mechanical engineering.

"We had students from many different degree tracts. And the idea was to mix those, encourage interaction and get them working with each other on a problem no one person could solve by themselves," Deshmukh says. We are trying to figure out how we can scale that one course up to a broader audience."

Through the Collaboratory, Purdue is working to create a concentration of courses, first at the graduate level, promoting the science of systems and systems thinking.

"We are also going to take advantage of courses that already exist," Dumbacher says. "Purdue is thinking about this differently than other universities. We are thinking about this from a holistic perspective."

Purdue has the ideal portfolio to attack the problem, says Deshmukh. "We are skilled at interdisciplinary research and are well-established in global collaboration networks. And we have a well-developed high performance computing capability and broad interest and expertise in systems domains. In addition, Purdue has external partners who share our passion and interest in our broader definition of systems thinking and integration." ■

GirlSPARC

SOME GIRLS DANCE after school. Some girls play soccer. In California, a group of girls gather once a week to crack codes, outsmart earthquakes and explore circuitry and chemical engineering by building lava lamps.

The young engineers are students in girlSPARC®, a non-profit that offers an after-school program for girls in grades 2 through 6. Founded by two Purdue graduates, Anita Mathew (BSChE '93) and Tracy Stone (BSECE '97), the extracurricular program is designed to take away the mystery of the STEM disciplines and encourage girls to study engineering.

Similar to the grade school programs offered by Purdue's Women in Engineering Program (WIEP), girlSPARC is focused on introducing engineering concepts to girls before they hit the age at which studies show they walk away from STEM disciplines. Research indicates that girls begin to lose interest in math and science as early as fourth grade for many reasons, such as negative stereotypes surrounding science and engineering and unconscious bias about who can be an engineer, says Jennifer Groh, WIEP associate director. Stone says the desire to offer positive and inspiring STEM experiences to girls at that at-risk age is what led to the creation of girlSPARC.

"Studies show that, at a young age, girls shut down on math and science. They don't see how their creativity can make a difference," Stone says. "Girls have a need to know that in what they are doing, they are impacting others, but we don't articulate engineering that way in schools. We need to say, 'Look at engineering and how it's so important in the world, and here's how you can use your creativity to build something that could impact the world.' "

Mathew and Stone say it was a combination of their Boilermaker Pride and a mission that aligns with WIEP that led to their collaboration with Purdue. To drill down on how girls learn, and then offer a curriculum that suits that style, they work with WIEP, which provides consultation around best practices, including sample curricula and lessons learned. WIEP has also helped to introduce and develop funding collaborations for girlSPARC, such as the GoogleRISE partnership, a three-way collaboration among WIEP, girlSPARC and Science Buddies. GirlSPARC will use the Science Buddies Raspberry Pi curricula, which was originally developed for at-home use, in a coding lesson. Science Buddies is a nonprofit dedicated to helping K-12 students build their literacy in science and technology.

Two Purdue Engineering alumnae founded girlSPARC, a non-profit that promotes STEM disciplines and encourages girls to studying engineering. (Photos provided)

SPARKING CREATIVITY THROUGH ENGINEERING

Offered in the Los Altos School District of Silicon Valley, girlSPARC has so far drawn some 200 participants whose families pay $275 for the eight-week session. Mathew and Stone develop and write the 90-minute lessons that sometimes leverage material from WIEP's I2D2 program. The curriculum is hands-on and plays to creativity and solving real-world problems.

"Programs like girlSPARC show young girls that they can be engineers and make a difference and that their imagination and creativity can be used for the betterment of society, because dreams need doing," says Beth Holloway, WIEP director and assistant dean of undergraduate education in the College of Engineering.

The girls-only environment offers a safe haven for girls to make mistakes — and learn from them — which is a fear they commonly have when around boys, Mathew explains. It is also customized to learning style.

"Girls like to be collaborative and creative and solve things in a different manner from boys, so let's have them solve things in that order, rather than doing the equation first. Girls want an understanding of the end goal or purpose," Mathew says.

A zip line carrier activity, for example, starts with the target and then introduces engineering concepts of forces, such as friction and gravity and how that affects speed. Traditional presentations would teach science and math equations first and then explain the relevance, Mathew says. "We flip things on their head — this way girls see the purpose and it doesn't seem pointless," she says.

Other lessons include introductions to electrical engineering via squishy Play-Doh circuits and lava lamp construction; structural engineering design to withstand earthquakes; a look at bike helmet materials fashioned by materials engineers; and computer engineering's use of password cryptography. Guest speakers include a female bioengineer, who visits to discuss prosthetic legs and introduce yet another approach to problem solving.

Mathew says the message that engineering can help others is key to getting girls into engineering. The biomedical engineering activity, for example, approaches the topic by showing how an engineer can help people with torn anterior cruciate ligaments (ACLs). The girls are shown how ACLs work, then how engineering can be used to fix them. This is counter to the traditional engineering approach of considering a material and then figuring out how to use it, Mathew says.


Co-founders Anita Mathew, right, and Tracy Stone with their daughters.

FROM INDUSTRY TO ENTREPRENEURSHIP

Mathew and Stone credit influential high school math and science teachers with inspiring their love of STEM studies and pointing them toward engineering. Stone, who wanted to be a doctor, says a high school physics teacher in her native Pittsburgh got her involved in a program with Carnegie Mellon University's supercomputing center. She attended a summer program at Carnegie Mellon following her junior year in high school and continued working on coding problems during study halls and free time her senior year. The experience opened her eyes to engineering and the possibility that it, too, could be used to help people.

The two women did not cross paths while at Purdue. After graduating from Purdue, Stone spent more than 15 years as a manager and engineer in both computer hardware and software organizations at Hewlett-Packard, Intel and Adobe. She then left the working world to spend time with her son and two daughters.

Mathew worked in product development at General Mills for three years, and then earned an MBA from the University of Pennsylvania's Wharton School of Business. This was followed by a decade at Johnson & Johnson and then an exit into the world of startups while raising two girls.

Mathew and Stone, whose daughters attend the same elementary school and are now in fifth grade, met at a New Year's Eve party in 2012. Their conversation that night included a discussion of math and science programs in the local schools and a shared interest in getting girls to pursue STEM studies. Married to an engineer, Mathew was personally inspired by her daughters to change the way that girls think about engineering. Her oldest daughter — the progeny of two engineers — insisted she wasn't good at math and didn't like science. Mathew didn't agree and wanted to change that kind of thinking, or what she terms a bias by girls that they can't do math and science. Six months after meeting Stone, Mathew left the startup world, but continued to use her business-building skills to help create girlSPARC.

Women make up less than 25 percent of the STEM workforce, and the number of female engineering students and professionals remains low. Stone and Mathew hope their program can help girls understand the breadth of engineering beyond mere math and science, show its possibilities and opportunities for creativity and change the numbers of women in engineering. Mathew says she would like for girls to realize the breadth of what engineering is and has to offer, and consider it as an occupation or a path to their future before closing the door to it early on. Stone is like-minded.

"I would love for girlSPARC to inspire girls and spark an interest in engineering, build their confidence and expose them to what engineering can be. I'd love for it to influence how many women choose engineering as a degree and as a career," Stone says. ■

■ BY LINDA THOMAS TERHUNE

GETTING BIGGER
IS NOT ENOUGH

Strategic growth: Much more than growth

■ BY AMY RALEY

MANAGING ACCELERATED GROWTH in a college whose size already matches that of many universities is an immense, multifaceted challenge. That is true even when all that's planned is expansion; but when the intent is also to transform how the college functions to better enable precedent-setting advances in discovery, and to revolutionize teaching methodology by continually putting research advances to use, the difficulty level increases exponentially.

That sort of difficulty, for the best and brightest engineers, is intriguing — even thrilling — because of the great reward in conquering it. And that sort of transformation, with its inherent difficulty, is underway in the College of Engineering under Dean Leah Jamieson's Strategic Growth Initiative.

As the college marks annual milestones in the 2011-16 initiative, Jamieson is leading the charge to think and act differently to affect transformation in the college as it grows.

With a record 8,209 undergraduate students and 3,300 graduate students this fall, Purdue Engineering has already exceeded the 2016 target of enrolling 7,778 undergrads, and has seen a 34 percent increase in total enrollment over the past 10 years. With a 2015-16 faculty count at 444, faculty growth is on pace to increase by an historic 30 percent, from 358 to 465, during the same period.

"We are achieving our goals to educate more Purdue engineers, but also to simultaneously improve our undergrad-to-faculty ratio from 21.2 to 17.6, to increase opportunities for our undergraduates to conduct research and study abroad, and to reinvent instructional spaces so they better reflect how top engineers function today and into the future," Jamieson says.

At a time when the University has frozen tuition for four consecutive years as part of its thrust to increase affordability, the college's need to generate novel efficiencies is central to its strategic growth agenda. The reinvented interior of Grissom Hall exemplifies the commitment to link new efficiency to innovation.

"I hope that all our alums will visit Grissom Hall to see how we are rethinking — and will continue to rethink —the college's space," Jamieson says. "Grissom's interior is entirely redesigned for the ways that today's students learn and work — individually and in teams — and for how collaborative work is done. We are converting space to be far more versatile, and we are setting much higher expectations than we used to for the role space plays in supporting how we teach, learn, collaborate and innovate."

The Peter Wang Student Excellence Center, named for its chief benefactor, has several desktop workstations that facilitate independent work as well as team meetings. The co-location of the student space and Industrial Engineering's administrative offices is creating new interactions between students and the school's leadership. (Purdue University photo/Mark Simons)

The interior of Grissom, which began as the civil engineering building early in Purdue's history and now is home to the fast-growing School of Industrial Engineering, had become obsolete. Its former long, narrow, dimly lit hallways are now difficult to picture when standing in the new, wide-open, colorful student excellence center inside the building's front entrance. The new space is filled with comfortable furniture in conversational groupings. Plenty of high-top counter space is equipped with high-speed Internet connections and electrical outlets that invite either individual or collaborative productivity.

Collaborative work is facilitated throughout the building. "We have added functionality and more computational tools that meet our students' needs for collaboration," says Abhijit Deshmukh, the James J. Solberg Head of Industrial Engineering, about all three stories of the building. "Grissom is really the result of the college's guiding principles and vision of affordability, efficiency and enhanced capability."

Given the building's age, its former outmoded design, and the novel efficiencies made possible by adapting to how digital-age work gets done, there have been ample opportunities for new efficiencies. An initial expectation of a 50 percent increase in space efficiency has

TOP: There is no chalk dust to sweep up in this classroom. Two large flat screens display the instructor's computer screen, sites online, or a guest speaker at a remote location. All student desks are on rollers, enabling easy reconfiguration for group discussions and team projects. **MIDDLE:** IE Professor Juan Wachs has a student meeting in his new office on Grissom's second floor. Faculty offices, which are situated in the center of the floor, feature glass walls that let in natural light from large nearby windows. The windows are next to mobile and residential workstations for graduate students. (Purdue University photos/Charles Jischke)

been exceeded significantly, according to Robert Frosch, professor of civil engineering and associate dean of resource planning and management.

"We have more than doubled the space efficiency," Frosch says. "We have increased the capacity of the building to support faculty, staff, and students. More importantly, however, we have improved the work environment to support our academic mission in the 21st century. And in true Purdue spirit, the re-invented Grissom Hall preserves Engineering's history while enabling Engineering's future — at an estimated $7 million in savings, or 30 percent, compared to the cost of raising a comparable new building on the Grissom site."

The college's strategic growth is helping to accomplish the objectives of the Purdue trustees and President Mitch Daniels in the Purdue Moves emphases on STEM leadership and transformative education.

For this reason, the college announced in early October its goal to raise $700 million as part of the University's new capital campaign to raise $2.019 billion by 2019. The new campaign, called "Ever True: The Campaign for Purdue University," seeks philanthropic funding for student scholarships and other student support; endowed professorships; new facilities and renovations for existing facilities; and unrestricted support for opportunities that emerge.

"We are accomplishing our agenda for our growth and transformation," Jamieson says. "We are eager for our alums and friends to visit and get to see our transformation in action. These are historic times for Purdue Engineering and all of Purdue." ■

AT YOUR SERVICE

Concierge program provides resources to recruit and retain faculty

■ BY PAIGE POPE

STARTING A NEW chapter in your life can be an exciting time, but often a major move causes major stress — something that the College of Engineering is addressing as it fulfills its goal of increasing faculty by 30 percent. In order to provide that helping hand and overcome the hurdles that come with relocation, the Concierge Faculty Recruitment and Retention Program was established in April 2014.

“The program assists in the College’s ability to attract and retain talented, innovative and diverse faculty,” says program director Michelle Jansen.

The College recognizes that part of successful recruitment and retention of faculty not only comes from the resources within the University, but also from life outside of office hours. Currently the program has worked with 61 dual career partners of new or current faculty, and has assisted 65 prospective or new faculty members with their relocation needs.

“When we recruit faculty and they build successful careers at Purdue, they do it with people in their lives who are important to them,” says Klod Kokini, associate dean for academic affairs. “We want our faculty and their loved ones to be successful and happy. The Concierge program helps us achieve these important goals by providing expert support for dual career needs, relocation assistance and visa services for international faculty. It also gives us a competitive advantage both in recruiting and retaining outstanding faculty.”

One of the most lauded aspects of the program is the dual career service. Many incoming Purdue faculty have a talented spouse or partner who is also going through the complications of relocation without the comfort of having a new job lined up. The concierge works with these partners to find a suitable career fit through many partnerships with both hiring units on campus and with local employers.

Andrew Whelton, assistant professor of civil engineering and environmental and ecological engineering, says the program made a difference for him and his family. “With a fast approaching employment start date and moving with two children under two years old, our family had many questions about relocating. Purdue’s Concierge program sets them apart from other universities and made our transition so much easier.”

Rao S. Govindaraju, the Bowen Engineering Head of Civil Engineering, sums up the positive impact of the Concierge program: “ I hear many good things about the program from people within and outside Purdue,” he says. “It is a strong testament to our value system.” ■

EVER 150 YEARS TRUE

THE CAMPAIGN FOR PURDUE UNIVERSITY

Purdue sets its largest fundraising goal

WITH A GOAL to further advance the University's Purdue Moves objectives, Purdue President Mitchell E. Daniels announced on Oct. 9, "Ever True: The Campaign for Purdue University," with a record-setting $2.019 billion goal.

The comprehensive campaign encompasses the initiatives Affordability and Accessibility, STEM Leadership, World-Changing Research, and Transformative Education.

In asking for support from the entire Purdue family, Daniels said the campaign "will elevate our University's reputation for research excellence and intellectual achievement in a new era of accountability in higher education."

As part of the campaign's efforts to raise support for all Purdue colleges, it seeks to help the College of Engineering achieve its strategic growth goals, all of which advance the campaign's three key priorities:

PLACE STUDENTS FIRST

Students are the heart of the University, and fostering their talent is our highest calling. Our students will grow as leaders and global citizens who enjoy a lifelong relationship with Purdue that equips them for the future's broad, ever-changing challenges and opportunities.

BUILD ON OUR STRENGTHS

Intersecting with the arts, humanities, social sciences, and business disciplines, we will increase our investment in areas that have the greatest potential for impact and explore innovative ways to leverage our historic strengths.

CHAMPION RESEARCH AND INNOVATION

Faculty research requires a nimble, state-of-the-art ecosystem that attracts and celebrates creative minds — a fusion of people, resources, facilities, and environment that spurs collaboration across disciplines, expands the boundaries of knowledge, and positions faculty for success.

"President Daniels and the Purdue Board of Trustees have invested a great deal in the enrollment growth and research expansion in the College of Engineering," says Leah H. Jamieson, the John A. Edwardson Dean of Engineering. "As a college, we have benefited immensely from loyal alumni/ae and friends whose contributions have helped us achieve our strategic growth goals and those of the Purdue Moves initiative. With this campaign, we look ahead to doing more by increasing our scholarships for deserving students, hiring and retaining premier faculty through endowed professorships, and modernizing and maximizing our space to accommodate our growth in both size and innovative teaching and research."

NEWS SPOTLIGHTS

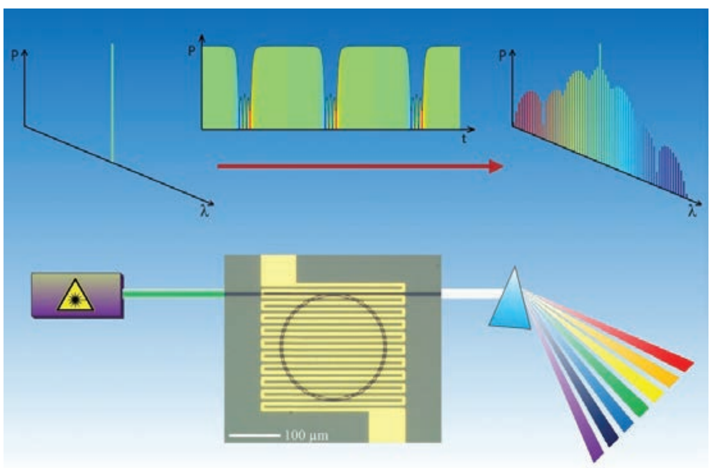
01

Microresonators could bring optical sensors, communications

RESEARCHERS HAVE SOLVED a key obstacle in creating the underlying technology for miniature optical sensors to detect chemicals and biological compounds, high-precision spectroscopy, ultra-stable microwave sources, and optical communications systems that transmit greater volumes of information with better quality.

The technology is based on the reliable generation and control of laser pulses containing a number of equally spaced frequencies called “comb lines.” By precisely controlling the frequency combs, including their initiation, “coherence” and spacing, researchers hope to create miniature optical devices using ring-shaped “microresonators.”

A research team at Purdue has demonstrated prototypes, and new findings were described in a paper in the journal *Nature Photonics*. The findings, together with those in another paper in the journal *Laser and Photonics Reviews*, detail an optical phenomenon called “dark pulses” and show how to precisely control the comb generation.



Researchers are developing "microresonators" for miniature optical sensors and other potential applications. This graphic depicts the optical spectrum of a “pump laser” used in the technology and an intriguing optical phenomenon called “dark pulses,” which might be harnessed to precisely control comb lines. (Birck Nanotechnology Center, Purdue University)

Whereas conventional optical communication requires many lasers to transmit various frequencies, the new devices might require only a single light source, which is then transformed to emit light at multiple wavelengths. Such an innovation would reduce cost and make possible more compact optical systems small enough to fit on electronic chips, says Minghao Qi, associate professor of electrical and computer engineering.

“Say you have 40 channels. If we have 40 individual lasers, together with their individual control circuitry on a single telecommunication chip, then your cost is high. If one of the lasers goes down you have to replace the entire chip. You could achieve significant cost reduction if you were able to use just one laser to create multiple wavelengths to drive different channels,” he says.

The microresonators accumulate optical power, and enhance an otherwise weak effect of “optical nonlinear interaction,” which allows for the generation of numerous frequencies, says Xiaoxiao Xue, postdoctoral research associate. The ring-shaped device has a radius of about 100 micrometers, or the thickness of a sheet of paper, and is fabricated from silicon nitride, a material compatible with silicon material widely used for electronics.

Researchers had previously created bulk optics systems, which use mirrors, lenses and other optical components arranged on a vibration-dampened table several feet long to convert and transmit the pulsed signals. However, these systems are far too large to be practical, and the Purdue researchers miniaturized the technology, creating microresonators small enough to fit on a computer chip. However, miniaturizing the apparatus poses challenges because it is difficult to retain a property of optical fiber called “anomalous dispersion,” which makes the high frequency components of a pulse travel faster than the lower ones, and which was previously considered necessary to generate the frequency combs.

“To achieve anomalous dispersion in silicon nitride microresonators ordinarily requires very thick film, which is susceptible to cracking and not practical to manufacture,” says Andrew M. Weiner, the Scifres Family Distinguished Professor of Electrical and Computer Engineering. “Here, we show how to generate the combs without anomalous dispersion, so we potentially no longer need the thick films.”

Dark pulses can be envisioned as a shutter that is normally open to allow light to pass through, but can quickly close to block the light and then open again to turn the light back on. The entire process can be as fast as 1-2 picoseconds, almost 100 times faster than the switching speed of the fastest computer microprocessor now available.

The technology could bring miniature optical sensors to detect and measure chemicals, ultra-precise spectroscopy for laboratory research, and optical communications systems that transmit greater volumes of information with better quality and at lower cost. ■

02

Lunabotics student organization places second in NASA competition

PURDUE LUNABOTICS, A student organization focused on the advancement of robotics for space exploration, placed second in the on-site mining category at the 2015 NASA Robotic Mining Competition at the Kennedy Space Center in Florida.

The competition challenges university student teams to find solutions to real-life issues faced by NASA when developing robots to operate in harsh extraterrestrial environments.

"We spend the majority of our time during the school year preparing for this competition, and as part of that we create a functioning prototype robot that could be used in space exploration," says Bobby Rolley, president of Purdue Lunabotics and a senior in the School of Mechanical Engineering.

Rolley said the skills gained from involvement in Purdue Lunabotics will transfer to any field.

"Classes can teach you a lot, but they can't teach you all of the skills needed for a very team-based engineering setting," he says. "Purdue Lunabotics helps you apply the knowledge that you have learned and face issues that you don't find in class."

Branden Elkins, a senior and director of business operations for the organization, says that in addition to the technical skills gained from Purdue Lunabotics, the organization stresses the importance of community involvement through outreach events and finding a perfect fit for each of its team members.

"One of our goals is to create opportunities for our members, connecting them with companies and getting them involved in student organizations, the community and professors to broaden their experience," he says. "When students join our group we evaluate their strengths, interests and experience so they can get the most out of the organization, gain new skills and, most importantly, have fun."

Currently, there are more than 30 members in Purdue Lunabotics, whose primary workspace is located at the Anvil, a student and community co-working space and business incubator located at 320 North St. in West Lafayette. ■

03

Alumna Jill Hruby is first woman to lead Sandia Laboratories

JILL M. HRUBY became president and director of Sandia National Laboratories, the country's largest national lab in July. She is the first woman to lead a national security laboratory.

A Sandia staff member and manager for the past 32 years, Hruby most recently served as a vice president overseeing Sandia efforts in nuclear, biological and chemical security; homeland security; counterterrorism; and energy security.

Hruby is the first woman to lead any of the three national security labs — Sandia, Los Alamos and Lawrence Livermore national laboratories — under the Department of Energy's National Nuclear Security Administration (NNSA).

"Leading Sandia is a tremendous responsibility because of its importance to the security of our nation and the phenomenal engineering and scientific talent here," Hruby says. "I embrace the opportunity to maintain the U.S. nuclear deterrent and lead Sandia in solving the difficult security challenges we face as a nation. I'm proud to be the first woman to lead an NNSA laboratory, but mostly I'm proud to represent the people and work of this great lab."

Hruby came to Sandia's New Mexico site in 2010 as vice president of the Energy, Nonproliferation and High Consequence Security Division and of the International, Homeland Security and Nuclear Security Program Management Unit. She was responsible for more than 1,300 Sandia employees in such diverse areas as nuclear security and nonproliferation technologies; chemical and biological defense and security; homeland security and counterterrorism; and energy technologies.

Hruby earned a bachelor's degree from Purdue University and her master's from the University of California at Berkeley, both in mechanical engineering. She has authored numerous technical publications, holds three patents in microfabrication and won an R&D 100 Award in solid-state radiation detection. ■

04

Laboratory research mimics blast-induced brain trauma in soldiers

RESEARCHERS HAVE DEVELOPED a procedure to mimic in laboratory experiments a form of brain trauma commonly seen in combat veterans, and findings suggest a new diagnostic tool for early detection and a potential treatment.

About one in five wounded soldiers suffers from traumatic brain injury and an estimated 52 percent of those injuries are blast-induced neurotrauma. A subclass called mild blast-induced neurotrauma is particularly difficult to diagnose because people who have it often display no obvious motor impairment or other neurological symptoms, says Riyi Shi, professor in Purdue's Department of Basic Medical Sciences, College of Veterinary Medicine and Weldon School of Biomedical Engineering.

“Many times they don’t even realize they’ve been injured, and this is particularly alarming because these injuries have been linked to severe long-term psychiatric and degenerative neurological dysfunction,” he says. “The underlying mechanisms of injury remain poorly understood, impeding development of diagnostic and treatment strategies.”

The initial injury is caused by the shock wave from explosions. However, researchers believe secondary damage takes place in the days and weeks that follow the initial injury, and this secondary damage might be treatable.

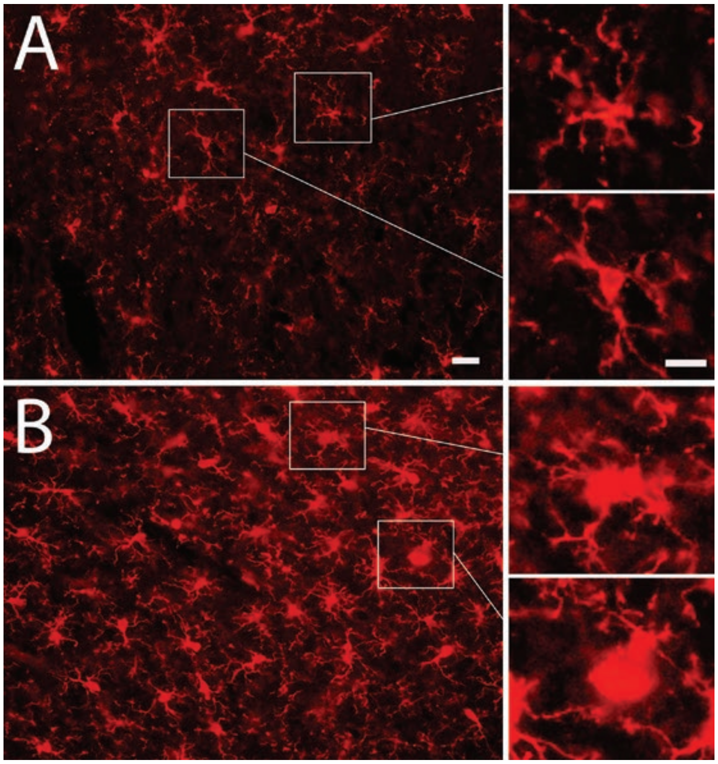
The researchers have developed a method to mimic mild blast-induced neurotrauma in laboratory rats, representing a new strategy to establish a clinically relevant “animal model” that recreates typical human symptom profiles. This model can be used to study the effects and pinpoint mechanisms responsible for ongoing damage that occurs following the initial injury, Shi says.

Findings suggest a simple urine test could be used to diagnose the injury, and damaging effects might be alleviated through drug therapy that reduces the concentration of a toxic compound produced by traumatized cells.

“Early detection and intervention could potentially mitigate or prevent delayed onset development of significant neurological dysfunction,” Shi says.

The research shows evidence of brain inflammation that may indicate ongoing damage, potentially leading to altered brain function and degenerative diseases.

“We detected structural and biochemical brain damage without obvious motor or cognitive deficits,” Shi says. “These findings highlight the difficulty and importance of early detection, indicating missed early diagnosis and subsequent lack of intervention could lead to serious long-term consequences.”



These microscope images show undamaged (A) and damaged (B) microglial cells in the brains of laboratory rats in research that mimics a form of brain trauma commonly seen in combat veterans. Findings suggest a new diagnostic tool for early detection and a potential treatment. (Purdue University image/Riyi Shi)

A neurotoxin called acrolein is produced within the body after nerve cells are damaged and has been shown to lead to continued damage. However, the concentration of acrolein could be reduced using the drug hydralazine, which has been approved by the U.S. Food and Drug Administration for hypertension, he says.

The drug has been shown to be effective in reducing acrolein levels in previous research led by Shi, who is working to develop a low-dose version for that purpose in humans.

New findings indicate elevated levels of acrolein in brain tissue and in urine from research animals lacking neurological signs of damage. Acrolein concentrations were three times the normal level the first day of the experiment and remained elevated five days later. The findings suggest urine tests showing elevated acrolein might indicate trauma despite the lack of symptoms following mild blast injury.

Treatment at this point could reduce the risk of developing chronic neurological diseases, said Shi, who is a member of the International Brain Mechanics and Trauma Lab, a newly established initiative aiming to gather multidisciplinary expertise for the study of brain mechanics in trauma and diseases. ■

Purdue civil engineering professor Monica Prezzi, at left, works with doctoral student Fei Han to operate a new test chamber that allows engineers to simulate precisely what happens to soil underground during the installation of piles and other structural elements. (Purdue University photo/Mark Simons)

05

Test chamber allows study of challenging 'geotechnical' problems

A TEST CHAMBER developed at Purdue allows engineers to simulate precisely what happens to soil underground during the installation of piles and other structural elements, a research tool for improving construction of everything from buildings and bridges to offshore wind turbines.

The system can be used to study many types of geotechnical structures during both their construction and service life, says Rodrigo Salgado, professor of civil engineering. Geotechnical research involves aspects of geological science, mechanics and civil and structural engineering.

"The nice thing about the chamber is that it can be used to study many geotechnical problems for which there are neither experimental data nor theoretical solutions," he says.

The researchers have demonstrated the system with cone penetration testing, which can reach depths in excess of 100 feet and is often used to estimate the properties of soil before installing structures both offshore and on land.

"You need to know how strong the soil is to determine how much load you can put on it or whether you need to do something to improve it before building on it," says Monica Prezzi, professor of civil engineering.

The system consists of a half-circle-shaped chamber 1.2 meters tall and 1.6 meters wide with a transparent window in the side. A series of images is taken with cameras and a digital microscope as the cone penetrometer probe is pushed into the sand. The sand contains colored particles that allow researchers to track the movement of soil particles with a technique called digital image correlation (DIC).

The researchers also developed a mechanism that precisely controls the density of the soil by uniformly "raining" the sand into the chamber through holes in a disc-shaped "pluviator."

A paper about the new chamber was awarded a Geotechnical Research Medal from the Institution of Civil Engineers in the UK, meaning it was the best paper of the year in ICE journals with geotechnical content.

One limitation of current methods of interpreting cone penetration is that there is "no rigorous theoretical solution of the penetration problem," Salgado says. The problem is complicated by the fact that soil sometimes behaves as a solid — when stresses are below certain limits — and sometimes as a fluid, when those limits are exceeded, Salgado says.

Experiments using the chamber will provide data for development of models and also to validate new models. Images were shown to precisely track the displacement of soil in the cone penetration experiments.

It took about five years to design and build the chamber, which was challenging because elements of the system must remain perfectly aligned while objects are forced at high pressure into the soil sample. Another challenge was integrating the transparent window, which is made of 3-inch-thick Plexiglas.

Research findings reveal new details about how the cone penetration tip displaces soil differently at specific depths.

"Until now, nobody has been able to measure the displacement and deformation field around the cone," Salgado says. "So this is the first time we can actually visualize that."

The chamber is the first such large-scale system for geotechnical research, enabling the study of problems with axial symmetry, "or symmetry with respect to plane" that would not otherwise be possible, Prezzi says. It is housed in Purdue's Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research and has been used to study problems of interest to the Center for Offshore, Foundation and Energy Engineering (COFFEE) at Purdue. ■

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The majesty of the solar system is captured in a fitting tribute to alumna Janice Voss. See more about the Visiting Our Solar System (VOSS) model on page 30.
(Purdue University photo/Charles Jischke)