PURDUE INDUSTRIAL ENGINEERING | FALL 2013

IMPACT

TAKING A SYSTEMS APPROACH TO HEALTH CARE

RETHINK IE

ON POSSIBILITIES

Welcome to the 2013 issue of the Purdue IE Impact magazine. As we begin another school year, it's an exciting time to connect with our alumni, industry partners, academic colleagues and friends and share our news.

Now is a truly transformational time for industrial engineers. On one hand, the world is recognizing the importance of what we do — from big-data analytics to systemic risk mitigation; from additive manufacturing to service science. At the same time, we are facing challenges that are hard to tackle with our current toolkit — from stopping pandemics to protecting global infrastructure; from creating incentives for individuals to designing social networks. The grand challenges facing society today inspire and drive our students and faculty to once again envision new perspectives and invent novel ways to improve the world they live in.

In our classrooms and laboratories at Purdue, in collaboration with our sponsors and industry partners, we are ReThinking IE and setting the pace for advances in industrial engineering that will move society forward.

In this issue of IE Impact magazine, focusing on health care, we explore ways in which Purdue industrial engineers are serving society by drawing on fundamental mathematical, physical and social sciences, creative partnerships with industry collaborators and 360-degree educational approaches to solve challenges in our increasingly complex world.

Photo by Mark Simons

Health care, a vast and complicated enterprise that begins with patients and (hopefully) ends with happy, healthy citizens, is among the most complex systems in the world. Health care is at the critical intersection of human life, technology and economy, a fascinating juncture and a world of opportunity for our enterprising thinkers.

We invite you to read how Purdue IE researchers are touching all areas of the system, from communication among health care team members to reducing errors in surgical procedures; from effective monitoring of patients with chronic diseases to enabling access to students with disabilities.

Purdue IE is constantly growing, evolving and reinventing. Ours is a world of excitement, passion for learning and energy fueled by discovery. We welcome you to join us on this journey!

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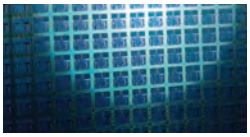
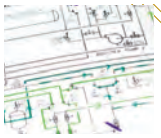
FEATURES

















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HAPPINESS FACTORY

Taking a systems approach to health care

In 1912, scientific management pioneer Frank Gilbreth observed that health care posed a unique challenge to industrial engineers. While demanding the efficiency and tight process control of manufacturing, its product — human welfare — was vastly different. Reaction of the product to the process was less predictable, and the product had an impact on how the process was delivered. From an engineering standpoint, health care required a unique approach.

Sara McComb (left) is introducing nursing students to systems engineering. (Photo by Mark Simons)

"I have always thought of hospitals as a happiness factory," Gilbreth wrote. "Would not standardization help you to be more efficient in that line?" he asked an audience of nursing school superintendents when speaking at their annual convention. Those words are ever more relevant a century later, as efficiency and cost control have become major players in the health care delivery system.

Drawing on its interdisciplinary strengths — and the legacy of its ties with scientific management pioneers Frank and Lillian Gilbreth — researchers in Purdue's School of Industrial Engineering are exploring ways to optimize health care for the benefit of provider and patient.

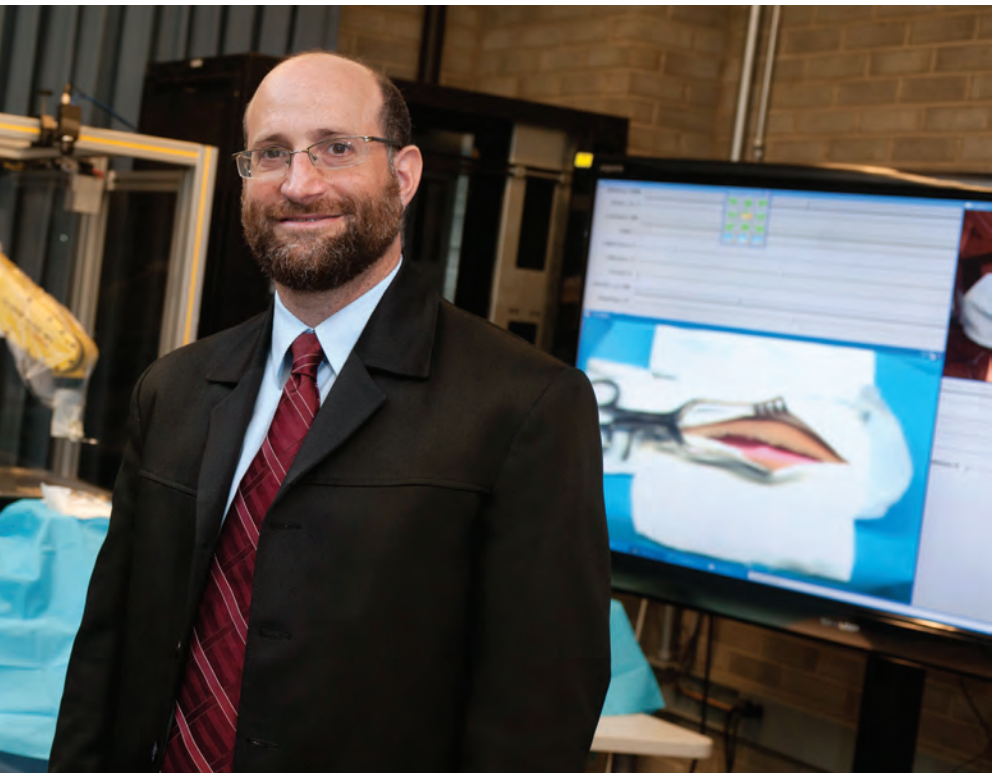
NURSING HELPS LEAD THE WAY

During his address to nursing supervisors, Gilbreth proposed that nurses could help blaze the trail for changes in health care using sound management principles and standards, and eliminating waste as determined through scientific measurement. "The entire hospital system must be studied and systematically," he wrote, "but if you desire it, why should not the nurses lead the way?"

According to the American Association of Colleges of Nursing, nurses now comprise the largest single component of hospital staff, are the primary providers of hospital patient care and deliver most of the nation's long-term care. And Purdue researchers like Sara McComb, who holds joint faculty appointments in the schools of Nursing and Industrial Engineering, are focused on extending Gilbreth's pioneering work.

In a study on teamwork and communication in a health care setting that explored ways to improve training and facilitate team activities, McComb found that shared mental models among team members can facilitate better outcomes. Her study indicated that teamwork transpires differently depending on the team's proximity, team behaviors and the mode of communication. The collaborative possibilities across time and space in health care are extensive, she wrote.

McComb is introducing IE systems approaches to Doctor of Nursing



Juan Wachs is developing robots for use in surgery. (Photo by Mark Simons)

Practice students through a course she teaches in the School of Nursing's Summer Healthcare Systems Institute, held in June at Purdue. The institute introduced students to basic skills in taking a systematic view of improvement by applying analysis tools such as process mapping, bottleneck analysis, queuing, lean engineering, simulation, optimization, dealing with uncertainty, "what if" analysis, quality control and performance monitoring techniques.

"Purdue is moving into teaching basic systems engineering principles and a systems perspective to Doctor of Nursing Practice students so that they can think more holistically when they get into management positions," McComb says.

As a doctoral student at Purdue in the mid-1990s, McComb looked at the processes and performance of teams in industry by, for instance, examining the ways in which leadership dynamics affect teams and how communication frequency among members is related to team performance. Currently, she is particularly interested in team communication and collaborative cognition, or how people in teams develop and apply similar worldviews.

Purdue industrial engineers take a unique approach to health care relative to their peers at large universities, observes McComb, who came to Purdue's faculty in 2011. Purdue researchers and students focus on "average" American health care by working with community hospitals and Purdue's nursing clinics in Delphi and Monon, Indiana.

The clinics were the subject of a 2012 *New York Times* article that looked at the increasingly important role of nurse practitioners — there are about 150,000 in the U.S. — and the shrinking number of primary care physicians, especially among populations similar to those served by Purdue's clinics: rural, uninsured, underserved. McComb's research on nursing systems, then, will inform a sector of health care that is becoming critical for a large portion of the nation's citizens. Her work at the intersection of nursing and engineering is representative of Purdue's advanced interdisciplinary approach to health care.

The classes McComb teaches — and a trip she led to Rome that introduced undergraduates to health care in Italy and included a visit to Europe's largest hospital — will help give industrial engineering and nursing students insights into each other's expertise. "Nurses may not be able to fix systems problems, but they will be able to recognize problems that can be fixed and can call for help. When engineers with an understanding of health care systems take those calls, they will be able to understand the issues and develop better solutions," she says.

STREAMLINING SURGERY

Equally critical to health care is communication in the surgical arena, an area of interest from a systems standpoint for Juan Wachs, assistant professor of industrial engineering. Ineffective team communication during surgeries contributes to some of the more than 98,000 deaths annually related to inpatient mortality and morbidity, according to data cited by Wachs in a 2013 paper published in the ACM titled "Collaboration with a Robotic Scrub Nurse."

For the last three years, Wachs has worked on developing multimodal robots that can serve as assistants to surgical teams, adding to a field dedicated to gestures for robotic control that began in the early 1980s. His Gestonurse, developed in consultation with a cardiovascular surgeon at the Indiana University School of Medicine, is able to deliver surgical instruments to the main surgeon communicating through hand gestures and speech recognition. This decreases cognitive load, time and effort for the surgeons, and it could ease staffing shortages.

Continued next page >

"Nurses are overworked, hospitals are understaffed, surgeries are delayed or not scheduled or take more time. This has implications on patient well-being," Wachs says.

The technology can also help prevent retention of surgical instruments — tools left inside patients — a considerable risk, given that 36 percent of communication errors in surgery are related to equipment use, Wachs writes. Robots could accurately pass and monitor instruments, sutures and sponges. Human surgical technicians, who are responsible for removing instruments surgeons might place around the operating area, could then concentrate on other tasks.

Gestonurse interprets hand gestures — a natural and existing communication form used by surgeons — through a video/depth stream acquired by a Microsoft Xbox 360 Kinect sensor. A robotic arm then delivers the requested instrument. This requires no special training by the surgical staff, says Wachs, whose dissertation at Ben-Gurion University of the Negev focused on pattern recognition, cognitive and physiological measures for hand gesture interfaces for robot control. Wachs was a postdoctoral fellow at the Naval Postgraduate School, where he worked on problems related to body posture recognition with surveillance applications. He hopes to continue his research in partnership with surgeons in a project funded by the Qatar National Research Foundation.

"Will robots replace nurses? No. The goal is not to replace them but to have them in places where robots aren't," Wachs says. "Eventually, I believe we can get them to do comparable tasks to what surgical technicians do. My motivation is to improve health care. There are a lot of good things happening, but humans don't know how to make the best use of technology. We have a long way to go."

IMPROVING CHRONIC DISEASE CARE

IE professor Yuehwern Yih and doctoral student Benjavan Upatising are teaming with Mayo Clinic to improve care for patients with chronic diseases, an increasingly important health care issue across the country.

"Chronic care is one of the biggest expenses health care is experiencing now," Yih says. "For instance, people with diabetes can't produce enough insulin. They have to be on medication for a lifetime, and they need to manage their diseases to prevent complications. They may develop other diseases and can't recover quickly because of the diabetes."

Yih says one of the goals is to use industrial engineering principles to design a process to help remotely monitor the patient's condition, alert nurses and physicians when the patient is off track and intervene as needed.

Benjavan Upatising (left) and Yuehwern Yih are streamlining processes. (Photo by Andrew Hancock)

Upatising recently completed a four-year Regenstrief Center for Healthcare Engineering fellowship with Mayo Clinic that centered on a home telemonitoring study of elderly patients with multiple chronic conditions. She is now a Regenstrief research scientist.

Upatising was part of a team of researchers analyzing data and developing predictive models from a controlled trial that involved 205 patients at four Mayo Clinic outpatient practice locations.

"Are there factors that can be used to predict when home telemonitoring, provided by the primary care practice, can reduce hospitalizations, emergency department visits and total health care cost for older adult patients with multiple chronic illnesses, high risk of worsening functional and medical status, and hospitalization?" Upatising says. "If so, then how can we use the knowledge to develop a decision-support tool that can assist physicians in deciding the appropriate level of care?"

MANUFACTURING HAPPINESS

Yih's and Upatising's activities focus on applying operations research methodologies to health care. These studies are part of a larger multidisciplinary effort coordinated by Purdue's Regenstrief Center.

Quality, safety, efficiency and economic viability are all essential to any sound manufacturing system. An additional focus on patient well-being, and, ultimately, happiness, is essential to a sound health care system. Established in 2005, the Regenstrief Center, which is located in Purdue's Discovery Park, conducts research to catalyze the transformation of health care delivery systems by applying the principles of engineering, management and science to health care system challenges.

IE professor Dale Compton pioneered the creation of such centers as co-author of a 2005 National Academies report that detailed a new engineering/health care partnership by transforming U.S. health care delivery from an underperforming conglomerate of independent entities (individual practitioners, small group practices, clinics, hospitals,

pharmacies, community health centers, et al.) into a high-performance "system."

Through partnerships with researchers and external partners across the University and beyond, Regenstrief is bridging the gap between discovery and delivery through a matrix that includes support services, funding, data repositories and project facilitation through HUBzero. In a 2009 conference, researchers affiliated with the center identified two core focus areas: care coordination and population health. The challenge? To maximize health care delivery with limited resources. The approach? Systems engineering; a challenge given health care's human component.

"Engineers aren't as adroit at being patient-centered, but they need to be," says Ken Musselman, a School of Industrial Engineering alumnus and strategic collaboration director of the Regenstrief Center. As a doctoral student in IE, Musselman worked with faculty member Alan Pritsker, father of the golden age of simulation. Pritsker, coincidentally, was also involved in transforming health care.

He developed large-scale simulation models to support policy analysis for organ transplantation by the United Network for Organ Sharing. In particular, his work was used to formulate more effective and equitable protocols for assigning liver transplants to waiting patients.

Regenstrief and its holistic view of health care and systems engineering offers a valuable perspective on health care, Musselman says.

BUILDING A HAPPINESS FACTORY

Similar to the manufacturing sector in its complexity, while radically different in its services, health care systems demand a unique outlook and approach. At Purdue, industrial engineers have long worked to adopt that approach and are continually working to improve the welfare of both the system and its users.

"Physicians focus on the patient to improve the health care system, whereas engineers focus on the system to improve patient care. We need both perspectives. It's the confluence of those two streams of thought that is going to improve health care," Musselman says, and lead to better outcomes for patients and the world's happiness factories.

■ LINDA THOMAS TERHUNE

Ken Musselman (Photo by Mark Simons)

FRANK AND LILLIAN GILBRETH

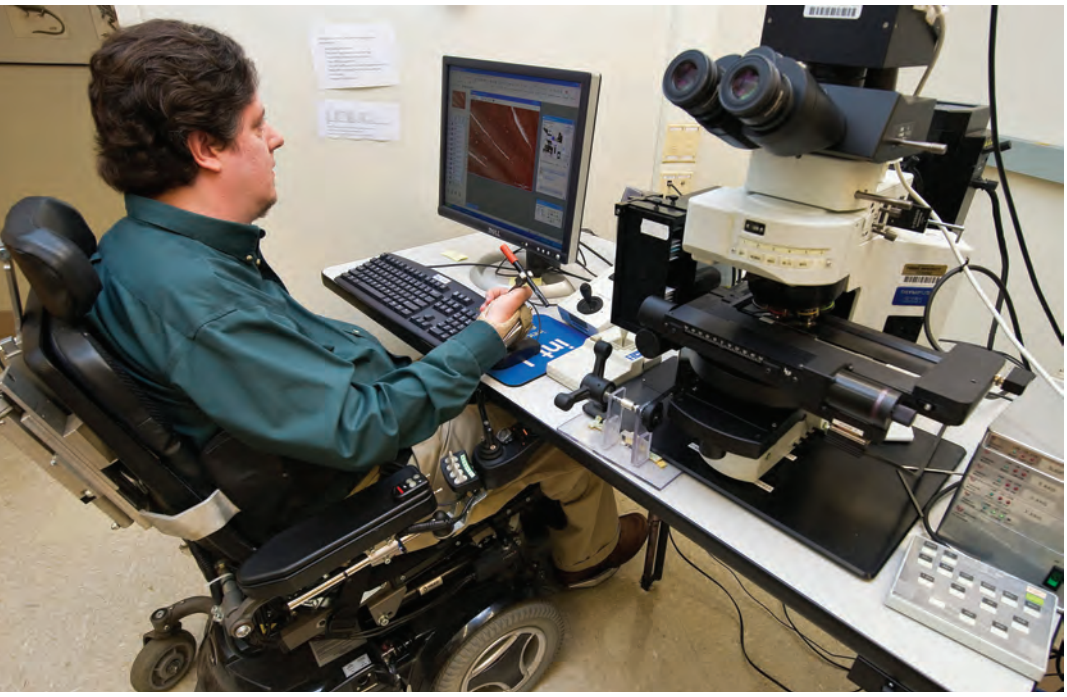
Purdue IE is proud of its historic ties with Frank and Lillian Gilbreth, who laid the foundation for scientific management and the academic discipline of industrial engineering.

Frank focused on the physiological aspects of work methods and measurement and Lillian concentrated on the psychological issues of worker participation in the operation and management of industrial enterprises. The researchers were friends of Purdue Engineering Dean A.A. Potter and were frequent lecturers at the University.

Following Frank's death in 1924, Lillian continued in the field and joined the Purdue faculty, teaching industrial engineering, industrial psychology and home economics from 1935 to 1947. Purdue Libraries' Archives and Special Collections unit now houses the Frank and Lillian Gilbreth Library of Management Research and Professional papers, 1845-1959.

ACCESSIBLE RESEARCH

Improving lab space and equipment for those with special needs



Brad Duerstock is developing new lab technologies for those with special needs. (Photo by Andrew Hancock)

Brad Duerstock once considered becoming a physician, but an accident when he was 18 damaged his spinal cord causing quadriplegia. The paralysis changed his plans, but he found ways to stick with science. Today, as director of the Institute for Accessible Science (IAS) at Purdue, he's a researcher inventing new technologies to help those with special needs in the lab.

Through the institute, Duerstock, associate professor of practice of industrial engineering and biomedical engineering, is working with other researchers to design laboratory space and equipment to accommodate physical disabilities.

Over the summer, six college students with disabilities were able to be active members of Purdue research teams by using laboratory equipment that is adapted (using assistive technologies) for their personal mobility and visual or hearing challenges. The institute is in its third year, and promotes resources through its IAS HUB (http://IASHub.org). Duerstock believes this initiative is the first to focus specifically on advancing the inclusion of students with physical disabilities in higher education and STEM careers. Other research groups have focused on kindergarten through 12th grade or entry into postsecondary education.

"The United States needs more students studying science and engineering, and many interested and qualified students are discouraged from the biomedical sciences because of physical challenges in traditional laboratory settings," Duerstock says. "There may not be room to maneuver or lab bench space may be inaccessible to wheelchair users; or people with limited vision can't use standard lab equipment, such as light microscopes and spectrophotometers. Through this program, we identify such challenges and then work with the research community to make adjustments so students can pursue an education and careers in science."

The IAS Summer Undergraduate Research Fellowship program matches undergraduate students, including two from Purdue, with a researcher and program of their interest. The participating areas of study are animal sciences, biological sciences, food science, biomedical engineering, and medicinal chemistry and molecular pharmacology. The institute provides financial support to the faculty member and assists with addressing any obstacles or providing assistive technologies specific to the students' disabilities. Among the accommodations used by Duerstock's students are machines labeled with Braille, printed tactile graph representations of data, a voice labeling system for equipment and weight measurement tools that don't just show measurements but also speak them.

The summer program gives the institute the opportunity to test assistive learning technology for student use. The Institute for Accessible Science is supported by a $2 million grant from the National Institutes of Health Director's Pathfinder Award. The grant awarded in 2011 made it possible

Brad Duerstock (right) confers with Susan Mendrysa (left), associate professor of biomedical sciences in the College of Veterinary Medicine and principal organizer for the IAS Summer Undergraduate Research Fellowship program. (Photo by Andrew Hancock)

for the research team to collect information and study laboratory and research challenges for science students with physical disabilities. This information is often collected through the institute's hub at http://IASHub.org.

"The goal is for the science community, especially at universities and colleges, to benefit from what we've learned so we can encourage more students with disabilities to pursue science careers," Duerstock says.

High school students' interest in STEM fields is comparable, at 18 percent, among the disabled and non-disabled. That interest drops, Duerstock says, for students with disabilities during their college years, because of few role models in STEM fields, lack of student research and internship opportunities, physical challenges to using wet-lab facilities and equipment, and lack of awareness of where to find more information regarding STEM accessibility.

In addition to the summer fellowship program, the Institute for Accessible Science also created the Accessible Biomedical Immersion Laboratory, known as AIBL, which is located in the Discovery Learning Research Center. Using information from people with disabilities, Duerstock and his team are redesigning the traditional lab space. In this lab, the wet-lab space and the emergency safety area are reconfigured for people in wheelchairs.

Other features include a motion-activated biohazard bin, adjustable-height lab table, and a talking scale and pitcher that can report data for those with visual impairments.

Duerstock uses a wheelchair and has limited mobility. His personal experiences have inspired him to develop new technologies such as the AccessScope, which is a remote-controlled research light microscope for people with limited use of their arms. He also is working on redesigning the micropipette, a high-precision instrument used for dispensing minute amounts of liquids. He and his students are also working with other Purdue researchers to assist students with disabilities in the lab using robotic systems.

"Our mission goes beyond just inclusion during education and while at universities. We want what we offer to carry over to the industry and professional practice," Duerstock says. "We are providing tools to help people seek employment in science and engineering fields, which is necessary for keeping people employed and increasing the number of those with disabilities working in STEM fields."

■ **AMY PATTERSON NEUBERT**

AROUND IE

Purdue IE is moving the world forward. Our faculty, students and alumni are rethinking and redefining the way that industrial engineering can improve life, and in doing so are making history. Here is a brief look at some of our trailblazers. For the latest news, visit us online at www.purdue.edu/IE.

GLOBAL EXPERIENCE IN ROME

Over spring break 2013, 20 Purdue undergraduate students teamed with 24 engineering students from University of Rome 'La Sapienza' to participate in an immersive, intercultural educational program focusing on engineering in the global service sector. The course was organized by professors Sara McComb and Pat Brunese, in collaboration with professor Lorenzo Fedele from La Sapienza and the Comitato Nazionale Italiano Manutenzione (CNIM, the Italian National Maintenance Committee). Educational activities were designed to help students apply a systems perspective to service activities and understand the commonalities in engineering challenges across different services. Combining classroom instruction with fascinating behind-the-scenes tours of industry, health care and cultural venues created a rich learning environment that expanded the students' views of how engineering can be applied in the service sector around the world. Topping off this amazing experience, the group was in Rome for the election of Pope Francis.

NEW FACULTY

SUSAN HUNTER

- Postdoctoral associate, Cornell University School of Operations Research and Information Engineering.
- PhD, Industrial and Systems Engineering, Virginia Tech. 2011.

Hunter's research interests are in Monte Carlo methods and simulation optimization. She is interested in providing simulation practitioners with efficient, implementable methods to enable decision making with less uncertainty.

Areas of focus include optimal sampling methods for "stochastically" constrained simulation optimization; simulation optimization algorithms for parallel and high-performance computing environments; detection of structure in functions from "noisy" function evaluations; applications in plant breeding.

MARIO VENTRESCA

- Postdoctoral fellow, mechanical and industrial engineering, University of Toronto.
- PhD, systems design engineering, University of Waterloo, Canada. 2009.

Ventresca's research focuses on the design, analysis and application of efficient algorithms for operations research, network science, machine learning and automated inference and design problems.

He is also interested in applying machine learning and pattern recognition methods for scientific discovery and proposing practical real-world policies from solutions to abstracted problems. Much of his current work is inspired by challenges in public health and biomedical informatics.


Theresa Carter


Mica Endsley

IE GRADUATES MAKE HISTORY

Purdue IE alumni are leading the world forward with a keen sense of the importance of fusing engineering and human performance, and have been internationally recognized for their contributions to the global good. Two alumna are playing a critical role in the U.S. Air Force; one as the first female engineering officer to be named major general and the other as the first female chief scientist.

Theresa Carter (BSIE '85, DEA '12) was promoted to Major General and assumed duties as the Air Force Civil Engineer, Deputy Chief of Staff for Logistics, Installations and Mission Support, Headquarters U.S. Air Force in June. She is responsible for installation support functions at 166 Air Force bases worldwide with an annual budget of more than $12 billion. She is also responsible for organizing, training and equipping the 60,000-person engineering force, and for planning, development, construction, maintenance, utilities and the environmental quality of Air Force bases worldwide valued at more than $251 billion. Additionally, she oversees the Air Force Civil Engineer Center with operating locations at Joint Base San Antonio, Texas, and Tyndall Air Force Base, Fla.

Prior to being named to her current position Carter was a brigadier general and commanded the 8,000-person 502nd Air Base Wing and Joint Base San Antonio, the largest joint base in the Department of Defense with nearly 90,000 personnel and over 200 mission partners from all services and multiple Department of Defense agencies. She's commanded at squadron, group and wing levels and served on staffs at the major command and air staff levels. General Carter deployed in support of the Gulf War in 1990; and in 1997 was named the Air Force Senior Civil Engineering Manager of the Year.

Carter believes in the importance of mentoring. "People don't always recognize mentoring when they see it. Throughout my career, I've had mentoring from bosses, peers — even subordinates. Today I have the honor of serving as the leader of my career field because I've been blessed to be at the right place at the right time with the right people and that's made all the difference."

She also adheres to author Leo Rosten's view that the purpose of life is to be useful, responsible and compassionate, and to have made some difference that you lived at all. "I think of that as a gauge to my success: Leave where you've been better than when you found it. Or in my case, leave the installation better able to support its missions," she says.

Mica Endsley (MSIE '85) is making history as the 34th Air Force chief scientist. She is the first human factors engineer and the first female to serve as chief scientist, the most senior science and technology representative in the U.S. Air Force.

Endsley began her IE studies as an undergraduate at Texas Tech University, then worked at Johnson Manufacturing and Southwestern Bell. After completing her master's degree at Purdue, she earned a doctorate in industrial and systems engineering from the University of Southern California. While completing her doctorate, she worked at Northrop Corp. on Air Force programs, and then taught at Texas Tech and at Massachusetts Institute of Technology in the Department of Aeronautics and Astronautics.

Endsley's academic and industry experience taught her that engineering has as much to do with machines as it does with people and human performance. Founder of SA Technologies, she is recognized internationally for her theory of "situation awareness," much of which is focused on aviaton.

UNDERGRAD RESEARCH LAYS FOUNDATION FOR CAREER FOCUS ON HEALTH CARE

Natalie Benda (BSIE '12) has been honing her research skills in health care since undergraduate days with human factors professor Barrett Caldwell's GROUPER (Group Performance Environments Research) lab. Next year, as a National Science Foundation Graduate Research Fellow, she will research potential patient safety solutions for non-native English speaking populations.

Benda is currently a research assistant at MedStar's National Center for Human Factors in Healthcare, in Washington, D.C., which is part of the MedStar Institute for Innovation. Her projects include employing a work systems approach to reducing health care associated infections in ambulatory care and validating the use of simulation-based games as a simulation tool.

As an undergraduate with GROUPER, she performed research in the health care fieldthat focused on medication adherence in chronic disease patients. She also spent a semester studying industrial engineering at the University of Carlos III in Madrid, Spain.

While at Purdue, Benda participated in a program called Ayuda y Aprende (help and learn), volunteering two hours a week helping a group of predominantly Spanish speaking adults in the Lafayette community to learn English.

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A NEW HOME BASE FOR STUDENTS

Peter Wang (BSIE '75) has made it possible for Purdue IE to move ahead with planning for a student excellence center — a cornerstone in the school's efforts to define the cutting edge of IE education.

This rendering shows the Peter Wang Student Excellence Center, to be located at the entry to Grissom Hall, which will serve as home base for Purdue's undergraduate IE students. It will support career guidance, facilitate global experience and provide an environment where entrepreneurial students can come together.