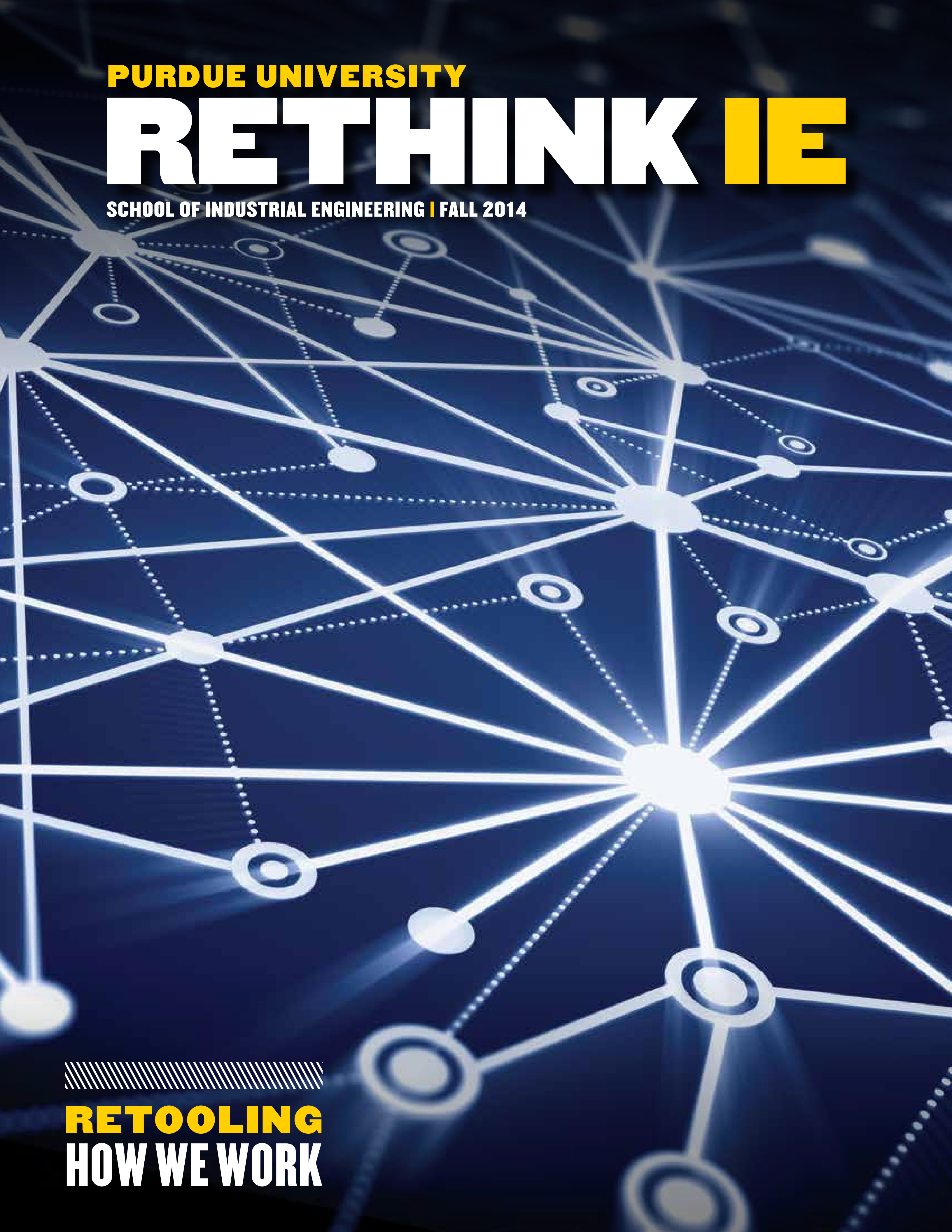
PURDUE UNIVERSITY

RETHINK IE

SCHOOL OF INDUSTRIAL ENGINEERING | FALL 2014



RETOOLING HOW WE WORK

ON POSSIBILITIES


Photo by Mark Simons

Welcome to *ReThink IE* magazine. I am delighted to share with you the excitement that is in the air at Purdue's School of Industrial Engineering!

These are historic times for IE and for the entire College of Engineering. We are ambitiously expanding to help answer the U.S. President's call for 10,000 more engineering graduates every year. This call, aimed at keeping our nation competitive in the world, is motivating our school, our college and the University. In his Purdue Moves initiatives, President Mitch Daniels has identified the effort to produce graduates who excel in STEM — science, technology, engineering and math — as a key priority. At the same time, Purdue is leading the national dialogue on making higher education affordable and accessible for all.

In this issue, I invite you to explore how our school is leading the way in "ReThinking IE" to address these national challenges. This issue highlights how Purdue IE innovators are ReThinking the very nature of work. Can we improve how we work, both individually and collaboratively as teams? How has ubiquitous connectivity and computation changed the future of work? Can we work better to personalize service? Answers to these questions will not only impact the academic enterprise, but will undoubtedly transform society as a whole.

As part of College of Engineering's strategic growth, IE is also growing significantly. This year we have added several trailblazing faculty to complement and augment our superb current faculty. I invite you to read about our new colleagues who are fostering new interdisciplinary collaborations and giving us opportunities to ReThink the frontiers of the IE profession.

And last, but surely not the least, we are ReThinking space. Grissom Hall, our home since the inception of the school, is being completely renovated. Actually, renovated is a rather tame word to describe the transformation. We hope to welcome you next year to a completely new experience. The new Grissom will revolutionize how our students work, collaborate, and play. In the meantime, please stop by our temporary home in the brand-new Wang Hall when you are on campus next.

I hope you sense the excitement and tremendous possibilities that are Purdue IE. I welcome you to join us on this journey!

Abhi Deshmukh
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A CH 46 Sea Knight helicopter (in the background) completes a landing near an MV 22 Osprey on the amphibious transport dock of the USS San Antonio in 2006. Wikimedia Commons photo.

TASKS RETOOLED

Purdue IE is ReThinking how we work in the air, on the ground, in an e-world and in health care to optimize safety, effective collaboration and personalization for all

■ **BY AMY RALEY**

IN THE AIR

An epiphany while showering coalesced years of study and preparation, and ultimately gave rise to three patents for David Rozovski, whose realization would become an invention that changes how pilots operate specific aircraft.

The story begins in 1995, 19 years before Rozovski would earn his PhD in IE at Purdue. During a flight test, an Air Force V-22 Osprey crashed. Moments before the crash, the Osprey — a hybrid aircraft that ascends and hovers like a helicopter but also offers the forward speed and fuel economy of an airplane — had surged to an unusually high altitude and then descended much faster than normal, crashing into the ground. The pilots survived.

Rozovski, who studied psychology as an undergrad at Ohio's Linfield College and got his master's in human factors specific to aviation from the University of Illinois, wanted to understand how the crash happened. "I asked myself, 'How could this happen; what caused this?'" says Rozovski, a commercial airplane and helicopter pilot himself, and now a U.S. Navy lieutenant and aerospace experimental psychologist.

David Rozovski's Rotational Throttle Interface (RTI). Photo provided.

Rozovski first wanted to understand the V-22's controller. He found that the V-22 hybrid was operated with an airplane throttle rather than a helicopter throttle after it had gone through many engineering changes. Many similar tiltrotor aircraft had gone through the same changes.

"In a helicopter, you pull up to add power and push down to reduce power," Rozovski says. "In an airplane, you push forward on the throttle to add power and pull back to reduce power. The pilot in the V-22 controlled it like a helicopter throttle when he shouldn't have. This is what we call a control reversal," Rozovski says. "A control reversal essentially is when an individual knows what the appropriate action is; however, they input the opposite control needed. Typically these are self-correcting, but in this case, due to the proximity to the ground, the pilot crashed."

Rozovski's deduction about the crash's cause would define the next six years of his life. "I spent my master's defining the cognitive elements of how an interface of this type should operate — how it should work based on how the operator thinks."

Later, during his doctoral thesis at Purdue, Rozovski built an operating prototype of what he calls the "Rotational Throttle Interface" (RTI).

Demonstrated in a YouTube video at **www.youtube.com/watch?v=Deenad8iHjY**, the animation first shows how lifting the device's lever brings the aircraft up and into a hover. It then demonstrates how tilting the lever forward causes the RTI to rotate to coordinate with the aircraft's thrust until the engines' nacelles are in forward position. At this point, the RTI converts to a fixed-wing throttle, like that of an airplane. Subsequently, as the pilot rotates the nacelles back for the landing, the RTI responds similarly, mapping both the magnitude and the direction of commanded thrust consistently, congruently, and compatibly.

"Nobody's ever been able to produce a controller that allowed the pilot to push or pull in the direction they wanted to go during all phases of flight without moving their hand off of the interface. This has been a problem since the early '50s with the first tiltrotor aircraft," he says. "It's not a throttle, as in a plane; and it's not a collective, as in a helicopter. It is a power-control interface."

Testing of Rozovski's RTI device began at the NASA Ames Vertical Motion Simulator, which is considered the highest fidelity facility for flight test simulation. It's now in flight test simulation trials at the Canadian National Research Council Flight Research Lab. Rozovski says that more than 18 months of testing has shown the RTI to be an effective interface in all its different modes.

Rozovski's next goal is to incorporate the unit into production aircraft. He already has designs for the Sikorsky X-2, Eurocopter X-3, Piasecki X-49A, and a variety of other tiltrotor and vectored thrust aircraft.

Steven Landry (right), associate head of IE, works on a flight simulator in his lab with two PhD students, Yul Kwon (standing) and Julian Archer. Purdue University photo/Mark Simons.

ON THE GROUND

As Rozovski built the first RTI for prospective use in the air, his work was overseen by Steven Landry, associate head of IE, who has done extensive research in ground-based systems for safe flight — air traffic control systems.

"Many of these systems fail because of poor integration with the human operators," Landry says. "I'm trying to develop theories of human-machine systems to help guide tomorrow's engineers in developing better integrated human-machine systems."

Part of Landry's research involves creating algorithms to enable automation of the air-traffic controller's conflict detection and resolution — automation he believes is needed in order to meet demands for increasing traffic in the skies.

"The aviation industry wants the system to handle several times the amount of traffic it currently handles," he says. "This is almost certainly impossible without automating the task of keeping the aircraft separate in flight." Landry says he has refined an algorithm that is more effective at keeping

Advanced air traffic control tools are used to conduct a study at NASA s Ames Research Center. Photo provided.

the aircraft separate while delineating the different roles that air traffic controllers and automation will play in such a system. This points the way toward a viable operational concept for automation.

Landry also is studying how engineers can predict human-machine interaction problems based on data that commercial aircraft collect during flight. The goal is to prevent the problems and the accidents associated with them.

IN AN E-WORLD

Words prefaced with a lowercase "e" permeate our vocabulary these days. Most of what we accomplish at work is at least facilitated by electronics or the Internet, and, therefore, is "e-work." *ReThink IE* magazine, for example, is written, edited and designed within various software applications; the layout is shared and approved by email; and files are transferred to and from the printing company via the Internet.

IE professor Shimon Nof works with graduate students in the Transitions Cyber Lab in Wang Hall. Purdue University photo/Mark Simons.

An authority on e-support systems that enable e-commerce of all kinds, IE professor Shimon Nof coauthored the book "Revolutionizing Collaboration Through e-Work, e-Business and e-Service" with current PhD candidate Mohsen Moghaddam; Wootae Jeong, now with the Korea Railroad Research Institute in Uiwang, Korea; and Jose A. Ceroni, dean of engineering at Catholic University, Valparaiso, Chile. "Any electronic device, such as a cell phone or computer that helps us interact with robots, software agents or other people to accomplish tasks or objectives," is e-work, Nof says.

Nof and the researchers in the PRISM (Production, Robotics, and Integration Software for Manufacturing and Management) Center develop protocols for task administration — workflow optimization algorithms — in collaborative e-work.

Today's inundation of digital information and processes has created a fundamental problem that Nof's work endeavors to solve.

"Due to information and task overloads," Nof says, "decision makers cannot tell in time when, where, and how errors and conflicts occur or opportunities arise, and how to best respond to them. To solve this fundamental problem, we rely on CCT — the collaborative control theory that we pioneered at the PRISM Center in collaboration with many other researchers globally."

Nof says CCT theory includes design principles with algorithms and techniques to optimize collaborative specific e-work. "Related to it are task administration protocols that are designed to enable seamless, dynamic integration of information flow among the diverse functions and participants." Nof says.

This dynamic integration is critically needed, as evidenced by the fact that the participants in Nof's research include IBM, the Indiana Department of Transportation and Kimberly-Clark.

"Once a business problem that motivates the research need is deeply understood, we as a research team provide the theoretical expertise, and our industry colleagues provide us with the live data for experimentation, validation, and plenty of critical questions," Nof says.

"We are blessed in Purdue IE with many colleagues and students who are aware of the challenges of collaborative e-work. The future of e-work is bright everywhere, because it will be designed for the best-augmented collaboration among people, computers and machines. When e-support is administered well and automatically, it will augment human abilities at work and organizations' abilities to accomplish their missions."

WITH OUR DOCTORS

No two humans are completely identical — not even "identical" twins, according to genetic research reported in *The American Journal of Human Genetics* in 2008. So how does an industrial engineer help health care professionals improve patient health when each human system is different? By enabling physicians to make better informed decisions, one human at a time.

Barrett Caldwell, IE professor and self-described systems engineer with an emphasis on humans, leads researchers in the GROUPER (Group Performance Environments Research) Laboratory. This human-factors research lab solves problems with information flow, knowledge sharing and task coordination.

Caldwell is now overseeing the work of PhD student Liang Wang as she develops new decision-assistance software for physicians that also helps doctors effectively discuss care options with patients.

"The tool we are working on would help physicians use a particular patient's history to understand the various forms of uncertainty," Caldwell says. "It recognizes the sources of uncertainty and presents them in a way that makes it easier for the physician to make a decision and easier for the physician to describe the reasons for the decision to the patient. It presents a probability around specific likelihoods, but it never says, 'You are here, and you must do this.'"

> *"YOU ARE NOT A POPULATION, AND YOU ARE NOT A PROBABILITY.* **YOU'RE AN INDIVIDUAL."**
>
> *— BARRETT CALDWELL*

Caldwell says the graphical tool shows a range of possible states of a patient's health along with a range of strategies for addressing each state. The physician and the patient can then discuss the strategy options in tandem with such things as cost and quality to make a final decision about next steps.

"The physician can tell the patient, 'Because we believe this, we would like to suggest this. Do you have any concerns? And how about these other strategies?'"

Caldwell says the tool is geared toward individualizing health care and moving away from health care strategies built on health-risk probabilities among populations. "You are not a population, and you are not a probability. You're an individual," he says, underscoring the rationale for the tool.

Discussions are underway now to put the tool's prototype into use in a hospital setting sometime in 2015.

IE professor Barrett Caldwell works with PhD student Liang Wang on developing decision-assistance software for health care professionals that will enhance communication with patients. Purdue University photo/Charles Jischke.

INTRODUCE YOUR SELF(IE)

Faculty growth enables exciting opportunities to ReThink IE frontiers and foster interdisciplinary collaborations

VANEET AGGARWAL

Assistant Professor
Industrial Engineering

Today's consumers are engaged in more social networking and e-commerce activities than ever before and are increasingly storing their documents and media in the online cloud. Businesses are relying on big-data analytics for business intelligence and are migrating their traditional IT infrastructure to the cloud. These trends cause the online data-storage demand to rise faster than the rate estimated in Moore's Law. I will explore novel storage solutions that make efficient use of server resources to meet the service-quality demands of the end user while minimizing costs for storage, bandwidth, electricity, etc., in a cloud system.

INFORMATION ENGINEERING

HARSHA HONNAPPA

Assistant Professor
Industrial Engineering

I study systems such as computer datacenters, hospitals, road networks and communication networks, all of which require resources to be shared among many users. A recurring problem across these systems is the queues that form when demand exceeds service capacity (think of rush hour on the freeway). My PhD dissertation focused on the development of new mathematical tools for analysis of queue models and the efficient management of queues. Resource-sharing systems are manifest in today's world, and operators' ability to control and manage these systems makes up a crucial part of the cost of doing business. Using and developing new theory in stochastic modeling, game theory, control theory and statistics, my research furthers our understanding of resource management.

DAN DUMBACHER

Professor of Practice
Systems

I will help establish the Purdue Systems Institute, bringing my NASA systems-engineering management and program management experience to students and the institute. During my 30-plus years with NASA — from the first flight of the Space Shuttle to the development of the rocket (Space Launch System) and the crew spacecraft (Orion) to take us to Mars — I have learned that thorough systems thinking is key. In addition to the important technical disciplines, complex systems require people who understand policy concerns and can communicate with all levels of stakeholders. Bringing these skills and lessons learned to students in IE, as well as in the other engineering schools in order to address the challenges of the 21st century, is my passion, and why I came to Purdue.

COMPLEX SYSTEMS

CHRISTOPHER QUINN

Assistant Professor
Industrial Engineering

DAVID JOHNSON

Assistant Professor
Industrial Engineering and Political Science

The extent of climate change and its global, regional and local impacts are deeply uncertain. This poses a great challenge to investments in infrastructure for risk mitigation, natural-resource management, urban planning and other long-range adaptation efforts. My research brings together insights and techniques from engineering, operations research, statistics and economics to produce risk assessments and decision-support tools for policymakers, with the goal of identifying climate-change strategies that are robust against a wide range of possible future outcomes. As a current example, I am working for the state of Louisiana to develop new methods for modeling flood risk, estimating the uncertainty associated with those estimates, and determining the effects of proposed structural protection systems and nonstructural risk-mitigation policies.

PUBLIC POLICY

C. ROBERT KENLEY

Associate Professor of Practice
Systems

Most engineers have very limited training in systems engineering and learn it on the job, which does not provide them the underlying theoretical foundation from mathematics, physical sciences, systems science, and the social sciences. In addition, models and methods suited to systems engineering in the past world of two superpowers are limited in their ability to capture the uncertainty, dynamics, and multiple stakeholders of the current environment. My role is to provide students with an expanded and robust set of processes and techniques along with the understanding of the foundations that underlie them — in essence, give them the right tools for the job and the wisdom to apply the tools to address the grand engineering challenges of the 21st century.

SERVICE SCIENCE

RAMSES MARTINEZ

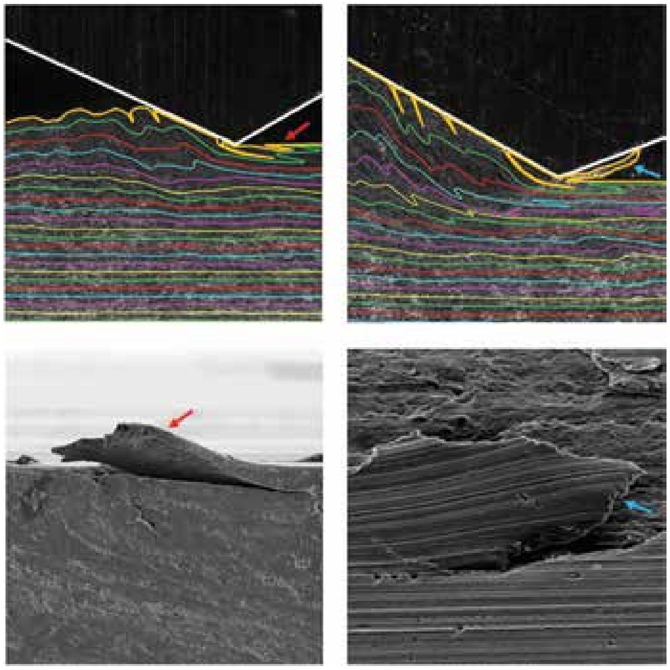
Assistant Professor
Industrial Engineering

Technological advances are leading to the development of personalized medicine, ubiquitous health monitoring and neuron-to-machine interfaces for prostheses. I will work on the development of tissue-like, wearable or implantable nanoelectronics that are compatible with tissue and skin, resistant to bodily fluids, flexible, and sufficiently stretchable to adapt to tissue and body motions.

Flexible nanoelectronic devices have the opportunity not only to revolutionize existing industry but also to create entirely new ones. The fabrication of multifunctional flexible devices presents unique scientific challenges and enormous research opportunities, particularly from the perspective of materials science. By combining principles of soft-matter physics, surface chemistry, and nonlinear optics with materials science, my goal is to conceptualize, develop, and implement new strategies for producing multifunctional flexible devices with advanced applications.

NANOMANUFACTURING

At Purdue, my research group will develop rigorous methods to characterize the structure and flow in real world networks. From gene regulatory systems and the human brain to the Internet and global financial infrastructure, networks play an increasingly important role in many facets of life. But for many large, complex networks, little is understood about the structure or how problems in one part of the network can spread to other areas. My group will create new computational and statistical approaches to analyze such large systems.



This sequence of images reveal surprising fluid-like behavior in a solid piece of metal sliding over another, forming defects leading to wear in metal parts. (Top) Two image frames of the material flow showing how defects are spawned in the wake of the contact. (Bottom) Scanning electron microscope pictures of the corresponding wear surfaces showing a tear and a crack. Wear particles are formed when the tears and cracks detach from the surfaces. (Purdue School of Industrial Engineering image/Anirban Mahato)

SURPRISING METAL WEAR DISCOVERED

Findings have important implications for component and metals manufacturing

■ BY EMIL VENERE

A previously unknown swirling, fluid-like microscopic behavior that one piece of metal induces as it slides over another could be key in reducing wear of metal in all sorts of applications, according to IE Professor Srinivasan Chandrasekar.

"Our findings have implications beyond wear itself, extending to manufacturing and materials processing," he says.

Researchers from Purdue; the Indian Institute of Science in Bangalore, India; and M4 Sciences, a West Lafayette, Ind. company, collaborated on the research, demonstrating how wear particles and surface defects can form. Their findings appear in the July 23 issue of *Proceedings of the Royal Society A*, a publication of the Royal Society in the United Kingdom.

Using a microscope, high-speed camera and other tools, the researchers had previously shown the formation of bumps, folds and vortex-like features on sliding metal surfaces. These findings were published in 2012 in *Physical Review Letters*. The present work, also using high-resolution imaging, shows how the swirly fluid-like behavior leads to cracks and wear particles.

The findings were counter-intuitive because the experiment, involving a wedge-shaped piece of steel sliding over a flat piece of aluminum or copper, was conducted at room temperature, and the sliding conditions did not generate enough heat to soften the metal. Yet, the swirling flow is more like behavior seen in fluids than in solids, Chandrasekar says.

The observations show how tiny bumps form in front of the wedge, followed by the swirling movement. When the wedge angle is shallow, the flow is laminar, or smooth. However, it changes to a swirly flow when the angle is less shallow, mimicking what happens in actual sliding metal parts. As the wedge slides across the metal specimen, folds form between the bumps, and then the folds transform into tears and cracks in the wake of the wedge, eventually splitting off as wear particles.

"A single sliding pass is sufficient to damage the surface, and subsequent passes result in the generation of platelet-like wear particles," Chandrasekar says.

The defects range in size from 5 to 25 microns and are similar to those found in sliding components such as parts in automotive engines, compressors and many common types of equipment and machinery.

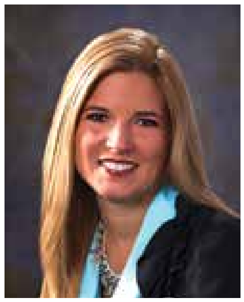
"In the past these features had only been seen after they had formed, and their formation was attributed to a variety of mechanisms," he says. "Here, we capture the formation of these features in real time and provide a mechanism for their occurrence. The defect features observed also occur in surfaces created by manufacturing processes like grinding, polishing, burnishing, drawing, extrusion, rolling, and so on, which are all commonly used in making structural and mechanical components in the ground transportation, aerospace, and energy systems sectors."

Ongoing research is exploring potential routes to reducing wear arising from this type of mechanism in metals, and how the findings may be applied to improve manufacturing quality.

"We want to show that the mechanism is more general and extends down to even finer-grained metals," Chandrasekar says.

Go online for more information and links to YouTube videos: **www.purdue.edu/newsroom/releases/2014/Q3/discovery-is-key-to-metal-wear-in-sliding-parts.html.**

AROUND IE



TWO IE ALUMS BECOME DISTINGUISHED ENGINEERING ALUMS

James Gibbons (BSIE ’85), president and CEO of Goodwill Industries International Inc.; and Kathy Kortte Kilmer (BSIE ’92), director of worldwide sales channel planning and analysis for Disney Destinations, were each recognized with a 2014 Distinguished Engineering Alumni/Alumnae Award.

James Gibbons was in third grade when he started to lose his eyesight to a degenerative disease that made him completely blind while he was a student at Purdue. He talks admiringly about the helpful people who surrounded him at Purdue. Betty Nelson, then dean of students, was one.

“At Goodwill we do a lot of work providing wrap-around services for people with disabilities — people for whom life ‘gets in the way.’ Betty was the person who provided me with navigating skills.” After becoming a Purdue industrial engineer he went on to be the first blind person to obtain a master’s degree in business administration from Harvard.

Kathy Kilmer is a proven team leader. She has spent 19 years within Disney Destinations industrial engineering department, and has directed a team of 110 Disney employees that supports all worldwide destinations.

“Our team has been so successful that I’ve been asked to share those lessons as a keynote speaker at many industry conferences,” she says, adding that the best part of her career has been using her Purdue industrial engineering education to be a part of innovations in her field. IE

Photo provided.

ALUMNA ENDOWS IE PROFESSORSHIP

With IE’s ambitious goals to build its faculty in order to grow enrollment and expand world-changing research, generous and helpful alumni/ae like Kathryn Stecke are invaluable.

Stecke (MS Math ’74, MSIE ’77, PhD ’81) is the Ashbel Smith Professor of Operations Management in the Naveen Jindal School of Management at the University of Texas at Dallas. She has given IE a gift creating an endowment that will fund the Professor Kathryn E. Stecke Scholar in Industrial Engineering at Purdue. It is a “Rising Star” faculty endowment, a program created to help fund midlevel professors whose exemplary work makes them deserving of a named chair. “I feel that recognition via a named chair will aid retention,” Stecke says.

Abhijit Deshmukh, the James J. Solberg Head and Professor of Industrial Engineering, says that such generosity speaks to the ongoing strength and significance that the Purdue IE experience has for alumni/ae. “They look back on their time here and say, ‘That changed me. I’m a different person today than I would have been without that experience,’” he says.

Stecke agrees: “Purdue was an important part of my life and did a lot for me.”

She earned a BS in mathematics from Boston State College before coming to Purdue. She launched her career at the University of Michigan business school, teaching there 21 years before going to Texas. IE

INDUSTRIAL ENGINEERING RECEIVES FIRST STUDY ABROAD INCENTIVE AWARD

IE has received the first incentive award to support the design and launch of its new program in China.

The Study Abroad Incentive Award was created in support of the University’s Purdue Moves’ goal to nearly double the number of students studying abroad by offering scholarships to make such opportunities as close to cost neutral as possible.

“Our long-term goal is to enable every industrial engineering student to participate in at least one international experience before graduation,” said Abhijit Deshmukh, the James J. Solberg Head and Professor of Industrial Engineering.

> *“WE WANT ALL STUDENTS TO HAVE A GLOBAL EXPERIENCE.”*
>
> *— ABHIJIT DESHMUKH*

This spring, industrial engineering students who are juniors can participate at Tsinghua University and Shanghai Jiao Tong University. There is no language requirement, and students can enroll in engineering and other courses that fit their plans of study.

More information about program options is available at ***www.studyabroad.purdue.edu.*** IE

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WANG HALL FORESHADOWS THE FUTURE GRISSOM HALL

Newly opened Wang Hall is providing modern temporary quarters for IE faculty and graduate students while Grissom Hall is reinvented and renovated to offer similar modernity. Architects and designers are ReThinking the office, conferencing, learning and research spaces in Grissom to accommodate the collaborative and electronically portable work styles of today and the future. The new Grissom Hall will be open for students, faculty and alums in the fall of 2015. Be sure to visit and see the new Grissom Hall!