EQuad News

Summer 2011
Volume 23, Number 1

CORPORATE CONNECTIONS

Collaborating with businesses enhances teaching while meeting critical societal needs

PRINCETON
School of Engineering
and Applied Science

CONNECTIONS

Business collaborations bridge theory and practice

Warren Powell BSE '77 has written the book on the fundamental mathematics of his field, but what's really captured his attention these days is wind and how it can become a practical part of our energy system. Mung Chiang is a leader in the field of network optimization theory, but recently he's opened a lab to test his ideas in real-world Internet and wireless communications systems.

The translation of deep mathematical and theoretical knowledge into innovations that improve the world is a defining quality of Princeton Engineering. This issue of *EQuad News* focuses on one of the key ingredients in making those connections: close collaboration with industrial and corporate partners. These are not simply transactions in which a company pays for research it needs. They are partnerships where the messiness and practical constraints of real-world applications infuse teaching and research with new ideas; and the academic work, in turn, provides more fundamental and long-term solutions than would otherwise be possible.

The increasing number of corporate collaborations is just one part of a broad campaign of growth and strengthening at Princeton Engineering. On pages 6 and 7, we take stock of the progress we've made in the last five years, much of it due to the tremendous generosity of alumni and friends who have given to Princeton as part of the Aspire campaign.

It's a personal moment of reflection for me because this year marks my fifth as dean. I could not be prouder of the faculty, students, staff and alumni with whom I have the privilege to work. I am endlessly inspired by their curiosity and perseverance as well as their dedication to putting their knowledge to use to benefit people around the world.

Photo by Frank Wojciechowski

H. Vincent Poor Ph.D. '77
Dean
Michael Henry Strater University
Professor of Electrical Engineering

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Poor (left) with David Crane '81, CEO of NRG Energy, and Princeton University President Shirley M. Tilghman at a recent workshop on energy research supported by the software company SAP (see page 16).

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In the Nation's Service and in the Service of All Nations

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Photo by Frank Wojciechowski

Freedom to tinkerers: Shostack endows Project X

Photo by Frank Wojciechowski; courtesy of Lynn Shostack

Lynn Shostack, a businesswoman and philanthropist, has given Princeton University $10 million to endow its Project X fund, which supports innovative projects in engineering. Among the funded projects is an effort to isolate microorganisms from soil samples (above right) that show an unusual ability to process unwanted ammonium that pollutes water due to agricultural fertilizers.

Seeking to provide "tinkerers" with freedom to explore hunches and passions, businesswoman and philanthropist Lynn Shostack has given $10 million to permanently endow the Project X innovation fund in Princeton University's School of Engineering and Applied Science.

Project X, which had been running as a pilot program for two years, provides small but critical amounts of money to engineers who wish to pursue projects that may be outside their formal area of expertise or are too speculative to attract conventional funding.

"I have an element of subversiveness in me," said Shostack, noting she wanted to bypass the often lengthy justifications and reporting requirements of typical sponsored research. "I know that great minds need freedom."

Shostack, whose late husband David Gardner was a member of Princeton's class of 1969, previously endowed the University's David A. Gardner Magic Project, which continues to fund creative endeavors in the humanities.

In its first years, Project X has supported research ranging from an exploration of techniques to sterilize hospital rooms to the development of an idea for playing highly realistic three-dimensional sound from conventional speakers. In the most recently funded project, environmental engineer Peter Jaffe is pursuing a hunch that an unexpected biological process discovered in some New Jersey soil may lead to a solution for a looming problem with fresh water around the world.

"With this visionary gift, Lynn Shostack is providing Princeton's engineering faculty with a unique opportunity to do what they do best—to explore, create and solve—while engaging students in the thrill of chasing down the boldest of ideas," said Princeton President Shirley M. Tilghman. "I have no doubt that Project X will yield some wonderful surprises and advances in the years ahead."

Shostack said her interest in open-ended, curiosity-driven exploration began with her father, who was a mechanical engineer and had a workshop in the garage. "He could tinker and play around with things that interested him and were outside of his job," she said. "We all need our own mental stimulation that comes from doing things that interest us, not necessarily what others want us to do."

Shostack carried that independent streak into her own career. Starting as an art major at the University of Cincinnati, she eventually

Project X, continued from page 1

Photo by Frank Wojciechowski

Peter Jaffe, a professor of civil and environmental engineering, received funding from Project X to pursue a hunch that microbial activity discovered in samples of New Jersey soil could be key to improved water treatment.

found her way to Harvard Business School. "I had no interest whatsoever in business, but I'm very risk-oriented, and later I discovered that business is very plastic and organic and you could mold it to pursue interesting things."

In the mid-1970s, Shostack joined Greenwich Associates to perform market research and consulting for financial services firms. This work led her to publish a series of influential articles and books on how to translate the marketing of products to the marketing of services, and her work remains an important reference in the field.

Shostack then served as a vice president at Citibank, where she was a pioneer in the field of private banking. She went on to senior positions at Bankers Trust Company and a manufacturing company before joining with her husband to run the Gardner Capital Corp. investing in real estate and other assets.

Since Gardner's death in 2001, Shostack has devoted considerable attention to philanthropy, including supporting medical research at Columbia University and serving as vice president of the Muscular Dystrophy Association.

In creating Project X, Shostack said she had in mind some of the most creative incubators in industry, from Bell Labs to the "skunk works" division of Lockheed Martin. "You don't need to justify; you don't need to report to anyone; you don't even need to succeed," Shostack said.

H. Vincent Poor, dean of the School of Engineering and Applied Science, said the response by Princeton faculty members to Project X grant opportunities in the first two years has been overwhelming. "These are engineers who are leaders in their fields, and they are brimming with ideas to build on their deep and fundamental knowledge in very creative ways," Poor said.

For Jaffe, whose work on water treatment was funded this year, Project X allowed him to pursue a lead that would have been nearly impossible otherwise. The idea began several years ago when Jaffe and his students were conducting research on nitrogen that washes off agricultural fields into New Jersey wetlands. One of his graduate students, Junu Shrestha, came back to the lab with data that showed something completely unexpected happening in the soil—the typically destructive ammonium from the run-off was being converted directly back to harmless nitrogen gas in a reaction that was driven by iron instead of oxygen, which normally would be required.

The unique qualities of this reaction suggested to Jaffe that if he could isolate the micro-organisms responsible for it, and understand their growth requirements, then they could be harnessed in a wide-scale cleanup of waterways. Much of the world's fresh water and coastal ocean waters are threatened by nitrogen compounds that come from fertilizer. Giant "dead zones"—areas where fish and plants have been killed—already have emerged.

Jaffe suspects that if the right mix of organisms could be incorporated into wastewater treatment facilities, then water could be cleaned up much more thoroughly while using much less energy. In addition, wetlands having the right geochemical conditions for these organisms to flourish, and possibly seeded with these organisms, might become self-cleaning systems.

"I was aching to move this forward, but there was no way I could go to the NSF (National Science Foundation), because we don't understand what's happening in that soil," said Jaffe, a professor of civil and environmental engineering. "So it's perfect that Project X came along. Something is going on, so let us play with it."

For Shostack, such projects are evidence that Project X will be needed for as long as there are researchers. "There will never come a day when you don't need freedom, or there's not something else you could discover," Shostack said. **–Steven Schultz**

Breakthroughs in sensor technologies offer new tools for health, security, environment

Two independent breakthroughs in laser sensing emerged from Princeton Engineering labs earlier this year, offering the promise of better devices for monitoring health, sensing pollutants and detecting explosives.

'Air laser'

In one finding, published in the journal *Science*, the researchers found a way to turn nothing but air into a laser—at a distance.

"We are able to send a laser pulse out and get another pulse back from the air itself," said Richard Miles, a professor of mechanical and aerospace engineering at Princeton. "The returning beam interacts with the molecules in the air and carries their fingerprints."

Miles collaborated with three other researchers from Princeton's Department of Mechanical and Aerospace Engineering: Arthur Dogariu, a research scholar and the lead author on the paper, and James Michael, a doctoral student; and Marlan Scully, a lecturer with the rank of professor who also is a professor of physics at Texas A&M University.

The new technique differs from previous remote laser-sensing methods in that the returning beam of light is not just a reflection or scattering of the outgoing beam. It is an entirely new laser beam generated by oxygen atoms whose electrons have been "excited" to high energy levels. This "air laser" provides a signal 1,000 times stronger than previously possible for remote measurements of trace amounts of chemicals in the air.

The strong signal should allow for detection of much smaller concentrations of airborne contaminants, a particular concern when trying to detect trace amounts of explosive vapors. It also should allow researchers to determine not just how many contaminants are in the air but also the identity and location of those contaminants.

Super sensitivity

In a separate discovery, a new nanoscale architecture and fabrication technique developed in the lab of Stephen Chou, a professor of electrical engineering, has yielded a laser detector that is the most sensitive of its kind to date.

The device boosts faint signals generated by the scattering of laser light from a material placed on it, allowing the identification of various substances based on the color of light they reflect. The sample could be as small as a single molecule.

The technology dramatically advances a decades-long search to identify materials using Raman scattering, a phenomenon discovered in the 1920s where light reflecting off an object carries a signature of its molecular composition and structure.

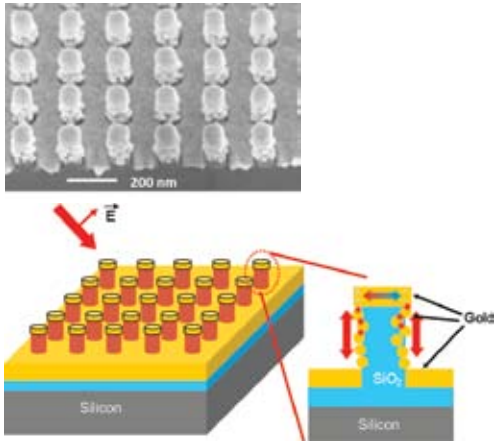
"Raman scattering has enormous potential in biological and chemical sensing, and could have many applications in industry, medicine, the military and other fields," Chou said. "But current Raman sensors are so weak that their use has been very limited outside of research. We've developed a way to significantly enhance the signal over the entire sensor, and that could change the landscape of how Raman scattering can be used."

So far, the chip is a billion times more sensitive than was previously possible, and the sensor is uniformly sensitive, making it more reliable for use in practical devices.

Researchers at the U.S. Naval Research Laboratory in Washington, D.C., are experimenting with a chip based on the Princeton method to explore whether the military could use the technology for detecting chemicals, biological agents and explosives. **–Chris Emery**

Photo by Frank Wojciechowski

The research team that developed an "air laser" technology includes James Michael (left), a doctoral student, and Arthur Dogariu, a research scholar, both in the Department of Mechanical and Aerospace Engineering.



Above, an electron microscope image and drawing show the structure of a highly sensitive laser developed in the lab of electrical engineer Steve Chou.

Math method may help find new drugs for HIV, other diseases

Photo by Frank Wojciechowski

Christodoulos Floudas (right) and Meghan Bellows-Peterson of the Department of Chemical and Biological Engineering developed mathematical models to reduce guesswork in discovering new drugs. Using the technique, they identified several potential new drugs for fighting HIV. The image on the screen shows a graphic of a promising drug candidate (red) attached to HIV (blue).

Princeton researchers have developed a mathematical method of discovering new drugs for a range of diseases by calculating which physical properties of biological molecules may predict their effectiveness as medicines.

The technique already has identified several potential new drugs that were shown to be effective for fighting strains of HIV by researchers at Johns Hopkins University.

"The power of this is that it's a general method," said Christodoulos Floudas, a professor of chemical and biological engineering who led the work with doctoral student Meghan Bellows-Peterson.

The researchers' technique combines concepts from optimization theory, a field of mathematics that focuses on calculating the best option among a number of choices, with those of computational biology, which combines mathematics, statistics and computer science for biology research.

"The Princeton researchers have a very sophisticated way of selecting peptides that will fit a particular binding site on HIV," said collaborator Robert Siliciano, a professor of medicine at Johns Hopkins and a 1974 Princeton graduate who specializes in the treatment of HIV. "It narrows the possibilities, and may reduce the amount of time and resources it takes to find new drugs."

In validating the method, the researchers found potential alternatives to Fuzeon, which is commonly given to HIV patients for whom first-line HIV medications have not proven fully effective. Fuzeon costs nearly $20,000 per year, and patients must take it regularly due to its short period of effectiveness in the body.

Out of millions of candidates, the Princeton researchers used their formula to narrow their search to several promising molecules. The Johns Hopkins team found they were effective against HIV, and one was particularly potent without harming cells. **–CE**

Report: Direct removal of carbon dioxide from air likely not viable

A 90-page report presents a detailed analysis of "direct air capture" technologies for removing the greenhouse gas carbon dioxide from the atmosphere. Princeton engineer Robert Socolow led the committee that produced the report.

Technologies for removing carbon dioxide from the atmosphere are unlikely to offer an economically feasible way to slow human-driven climate change for several decades, according to a report issued by the American Physical Society and led by Princeton engineer Robert Socolow.

"We humans should not kid ourselves that we can pour all the carbon dioxide we wish into the atmosphere right now and pull it out later at little cost," said Socolow, a professor of mechanical and aerospace engineering and affiliated faculty member of the Andlinger Center for Energy and the Environment.

The report, issued by a committee of 13 experts, was co-chaired by Socolow and Michael Desmond, a chemist at BP. The group looked at technologies known as "Direct Air Capture," or DAC, which would involve using chemicals to absorb carbon dioxide from the open air, concentrating the carbon dioxide and then storing it safely underground.

In essence, the committee found that such a strategy would be far more expensive than simply preventing the emission of the carbon dioxide in the first place.

Making optimistic assumptions from available evidence, the committee estimated that building and operating a DAC system today would cost at least $600 per metric ton of carbon dioxide removed from the atmosphere. In comparison, removing carbon dioxide from the flue gas of a coal-fired power plant would cost about $80 per ton. The group concluded DAC is not likely to become worthwhile until nearly all the significant point sources of carbon dioxide are eliminated.

"We ought to be developing plans to bring to an end the carbon dioxide emissions at every coal and natural gas power plant on the planet," Socolow said. **–SS**

Vision for energy and environment center advances as construction begins

Even before construction begins on its state-of-the-art labs, the Andlinger Center for Energy and the Environment is moving forward rapidly with its vision for research and teaching about sustainable energy and environmental issues related to energy.

"The center already is going full bore in terms of research activities aimed at securing our energy future and solving environmental problems related to energy use," said Emily Carter, the center's founding director.

After starting as director in September 2010, Carter has focused on creating a vibrant intellectual community and fostering research collaborations. She met throughout the fall and spring with the leaders and members of 14 academic units on campus, including all the departments of engineering and natural sciences, as well as the Woodrow Wilson School of Public and International Affairs and the School of Architecture.

"All the problems that we're tackling are puzzles that won't be solved by one discipline, by one set of expertise alone," said Carter, who is Princeton's Gerhard R. Andlinger Professor in Energy and the Environment and a professor of mechanical and aerospace engineering and applied and computational mathematics.

"It's going to involve multiple disciplines and ideas from many perspectives," Carter added. "Therefore we really want to catalyze these intersections so we can bring new creative ideas to bear on overcoming the challenges we face to achieve sustainable fuel and electricity production, effective, large-scale energy storage, loss-free electricity transmission and efficient use—all these critical areas."

Carter's early outreach has resulted in an online directory of faculty members conducting research related to the center's mission. This listing is now informing plans to hire additional faculty to strengthen key areas. Carter said that by the time the building is completed in 2015, she expects to have hired nine new faculty members, each one with a joint appointment between the Andlinger Center and an academic department or school.

The center also is beginning to award research funds to "nucleate interdisciplinary projects," Carter said. In June, Princeton faculty members received competitive Gerhard R. Andlinger Innovation Fund grants for novel interdisciplinary research ranging from technology to clean polluted groundwater to methods to make computing infastructure more efficient.

The center also recently awarded an inaugural set of summer internship grants for undergraduates through its Peter B. Lewis Fund for Student Innovation in Energy and the Environment.

In addition, the center will sponsor an increasing number of visitors and speakers, Carter said. In the spring, the center co-sponsored talks by auto executives William Ford '79 of Ford Motor Company and Carlos Ghosn of Nissan Motor Co. and Renault SA, who spoke about green vehicles and manufacturing in the automobile industry.

In the meantime, initial site preparation began this summer for the construction of the 127,000-square-foot Andlinger laboratories, which will be located next to the Engineering Quadrangle near the corner of Olden and Prospect streets. Full construction is set to begin in early 2012 and the building is expected to be completed in 2015. **–SS**

Rendering by TWBT Architects

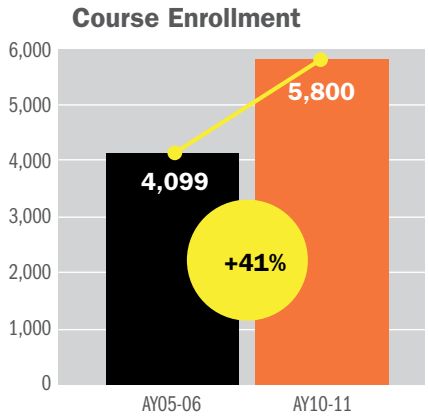
Video image by Seftel Productions

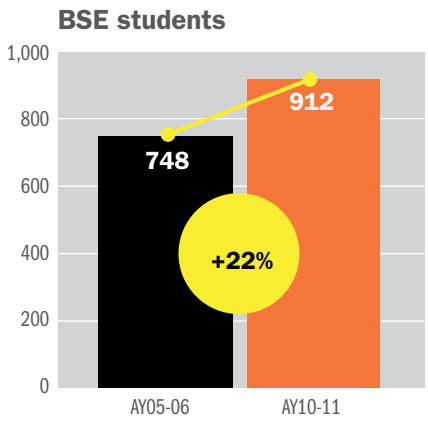
In a recent video, Andlinger Center director Emily Carter lays out her vision for the center and says that Princeton's track record for interdisciplinary work puts it in a unique position to solve the complex energy problems that society faces.

The artist's rendering above shows a partial view of the Andlinger labs, for which construction begins this summer.

CAMPAIGN PROGRESS

Growth in engineering helps meet critical societal needs





With one year left in a five-year campaign of fundraising, the School of Engineering and Applied Science has made substantial progress in all areas of its plans for growth, engineering dean H. Vincent Poor reported to the school's external advisory council.

The Aspire campaign, Princeton University's comprehensive fundraising effort, began in 2007 with an overall goal of $1.75 billion. Within that goal, the campaign seeks $325 million for "Engineering and a Sustainable Society." As of June 2011, the University had raised $284 million toward the engineering goal.

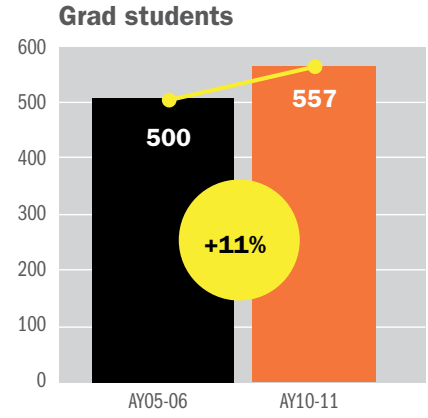
In April, Poor reported on the school's progress to the Leadership Council, a group of alumni and other leaders who advise the school. The report also marked Poor's fifth anniversary as dean. Having been appointed in 2006, Poor's five-year term ended June 30 and President Shirley M. Tilghman re-appointed him for a second term.

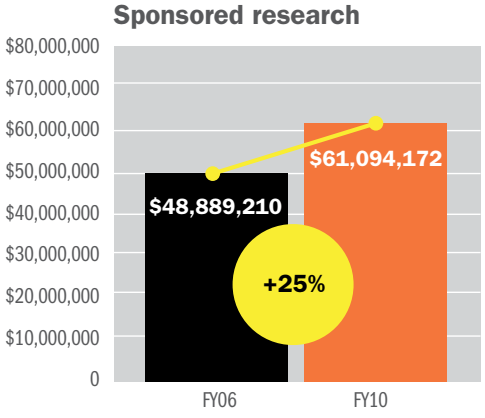
"The true measures of our progress are the impact of our research and the contributions of our people," Poor said. "New knowledge and innovations emerge from our labs to solve problems and improve lives. Students grow, graduate, become leaders and make untold contributions to society."

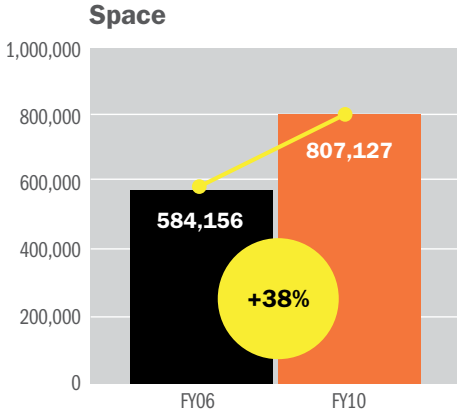
Poor noted that the growth in engineering during his leadership has focused on increasing the University's capacity to address four key areas of societal need: developing sustainable solutions to problems of energy and the environment; improving human health around the world; strengthening international security; and preparing leaders for a technology-driven society.

The milestones and graphs on these pages highlight progress in each of these areas. In the final year of the Aspire campaign, raising additional support for initiatives in human health will be a top priority, Poor said.

"The generosity of alumni and friends of Princeton has enabled extraordinary initiatives that already are paying dividends for our students and society," Poor said. "While each project is unique, the common thread is using science and technology to serve society. With each initiative, we create opportunities for the most talented and accomplished people to come together and achieve aspirations that would otherwise not be possible." –SS







A sitemap (right) shows the location of the new buildings that will house the Andlinger Center for Energy and the Environment at the corner of Olden and Prospect streets.

Energy and the Environment

In 2008, a transformative gift from 1952 alumnus Gerhard Andlinger established the Andlinger Center for Energy and the Environment. Construction of a major new laboratory complex is under way (see page 5), and founding director professor Emily Carter has embarked on an ambitious agenda of fostering research to fundamentally remake the way people produce and consume energy to ensure a sustainable future.

Innovation in Engineering Education

Addressing a global need for leaders who make wise use of technology to solve societal problems, 1963 alumnus Dennis Keller and his wife Constance endowed the Keller Center for Innovation in Engineering Education. The center brings together students from within and beyond the engineering school to work together in courses, entrepreneurial endeavors, service projects and other opportunities to bridge academic learning with hands-on experience. Leadership of the center passes on Sept. 1 from Sharad Malik to Sanjeev Kulkarni, both professors of electrical engineering.

Michael Gordin (at right), professor of history, teaches the core course in the new Program in Information Technology and Society, which draws students from all parts of the University. The program was created by the engineering school's Keller Center and the Center for Information Technology Policy.

Photo by Brian Wilson

Sherrerd Hall

The University completed construction in 2008 of Sherrerd Hall, which provides space for the Department of Operations Research and Financial Engineering and the Center for Information Technology Policy. Made possible by a gift from the late Jay Sherrerd, a 1952 alumnus, and his family, the building serves as a link between engineering and the social sciences, supporting teaching and research that applies deep technical expertise to better decision-making in business and public policy.

Photo by Frank Wojciechowski

Innovation Funds

Many gifts have provided open-ended support for innovative research that would be difficult or impossible to fund through conventional channels. The largest of these are the Eric and Wendy Schmidt Transformative Technology Fund and Project X. The Schmidt Fund, donated by 1976 engineering alumnus Eric Schmidt and his wife Wendy, is open to faculty members University-wide, while Project X, donated by Lynn Shostack in memory of her late husband David Gardener of the class of 1969, supports bold and unconventional projects within the School of Engineering (see page 1). –SS

Photo by Volker Steger

Professor Claire Gmachl (above center) won an inaugural grant from the Eric and Wendy Schmidt Transformative Technology Fund to develop clip-on medical sensors to enable non-invasive, continuous glucose monitoring for diabetes patients.

TEACHING SPOTLIGHT

Photo by Frank Wojciechowski

Michael Coulon MF '05 returned to Princeton as part of a federally funded program to increase the number of U.S. citizens and permanent residents who pursue careers in the mathematical sciences.

Engineering program seeks to boost graduate student involvement in the mathematical sciences

By Chris Emery

During a recent class, Michael Coulon scrawled mathematical formulas and diagrams all over the chalkboard while throwing out terms like "fixed income," "yield curves" and "options and forwards."

Through this parlance, he outlined the financial mathematics behind commodities markets, an area of research that's receiving much attention after the financial crisis upended assumptions about how such markets function.

Coulon, who received his master's degree in 2005 from the Bendheim Center for Finance and a doctorate in applied mathematics from the University of Oxford, has returned to Princeton as part of a federally funded program to increase the number of well-prepared citizens, nationals and permanent residents in the United States who pursue careers in the mathematical sciences.

The program, known as the Research Training Group in Stochastic Analysis and Applications, is part of the Department of Operations Research and Financial Engineering. Funded by the National Science Foundation, it supports teaching and research by U.S. graduate students and post-doctoral fellows, and summer research opportunities for undergraduates.

"This helps us attract the best American graduate students and gives them time to pursue their studies and research," said Ronnie Sircar, one of the four professors of operations research and financial engineering who manage the program. "It also helps us to bring in distinguished scholars and fund activities for undergraduates interested in math-intensive fields like economics, finance, science and engineering."

The Research Training Group receives $4.4 million in funding over five years, half from the National Science Foundation and half in matching funds from Princeton. In addition to Sircar, the program is led by professors Rene Carmona and William Massey '77 and assistant professor Birgit Rudloff.

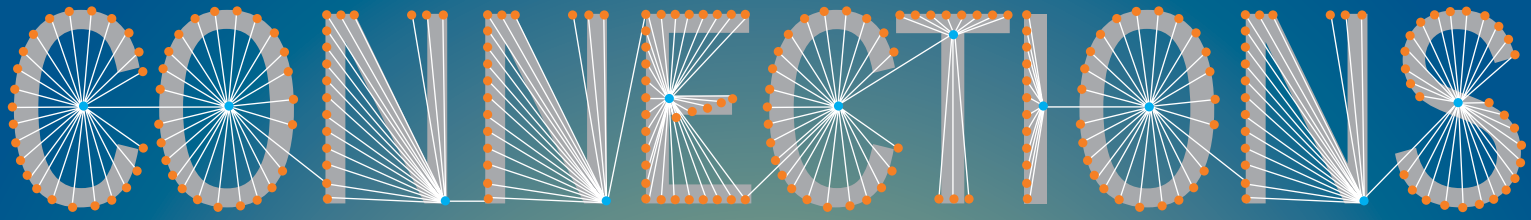
The research and teaching focuses on stochastic analysis, a field of mathematics that attempts to account for seemingly random behavior, uncertainty and risk in a wide range of phenomena, including financial markets, telecommunications networks and environmental pollution.

Another goal of the program is to engage groups that are underrepresented in math-heavy fields and to involve those students in high-level research.

The program has supported undergraduate research projects by women and minority students and organized guest speakers and seminars. In February, Rudloff organized an information seminar for female students considering graduate school. The program also supported meetings of the Conference for African-American Researchers in the Mathematical Sciences, organized by Massey.

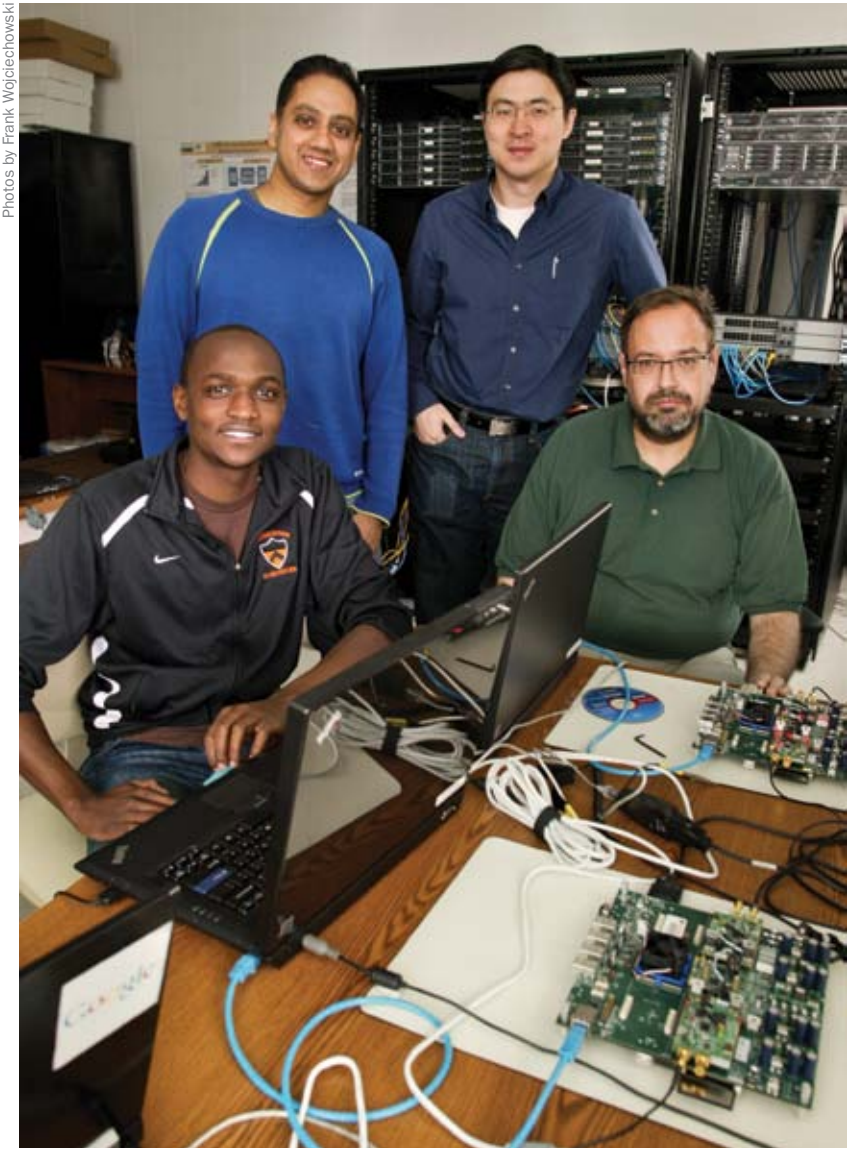
The federal funding allows the department to offer graduate students a lighter teaching load, freeing them to focus more on their research interests. Andrew Ledvina, the first graduate student supported by the program, received his doctorate this spring and will begin a postdoctoral fellowship in mathematical finance at the California Institute of Technology in September.

"By providing new resources, the Research Training Group has infused the department with new energy and talent," said Carmona. "Michael was the first postdoc in the program and we'll have the fifth starting in this coming fall. It's a great first academic job for them, and it's given us the freedom to establish a vibrant postdoctoral teaching program." **E**



Princeton engineers straddle the divide between fundamental research and real-world problem solving, testing new ideas and technologies while giving students hands-on experience and helping industry meet consumer demand. Here, *EQuad News* highlights collaborations between Princeton academics and industry researchers, from delivering Internet video to mobile phones to pricing the wind energy that powers homes and businesses. These are stories of how faculty and students work with industry to develop new knowledge and make a difference in people's lives.

Photos by Frank Wojciechowski



KEEPING THE DATA FLOWING AS OUR APPETITE FOR VIDEO GROWS

Mung Chiang (third from left) with three members of his research team, from left: electrical engineering senior Josphat Magutt and postdoctoral researchers Amitabha Ghosh and Haris Kremo.

By Chris Emery

If you adore Netflix, YouTube, Hulu, Skype or any other wellspring of Internet video goodness, you're not alone.

Demand is soaring for movies, television shows and amateur videos delivered via the Internet and mobile networks. According to the networking Company Cisco, Internet consumption on mobile devices alone—smartphones, tablet computers such as the iPad and devices yet to be invented—will grow by 65 times over the next five years, and video will represent 70 percent of that traffic by 2015.

What most people don't know is that our enormous thirst for moving pixels is fast outpacing the capacity to deliver video to viewers' screens.

"People take the Internet for granted, but Internet usage has exploded," said Mung Chiang, a Princeton professor of electrical engineering. "Our success at building and using these incredible networks may collapse under its own weight if we don't keep innovating."

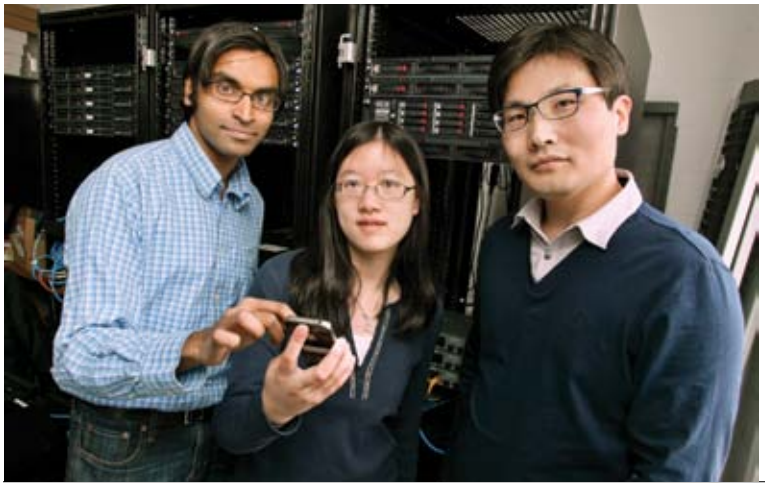
Fortunately, Chiang and his team are on the case. Over the past two years, they have methodically pieced together a replica of the global Internet and mobile networks, squeezing the scaled-down components into a Princeton laboratory.

Now they are using this miniaturized version of the global communications network, dubbed the EDGE Lab, to develop new ideas and systems that will help ensure that the networking infrastructure of the future will meet consumer demand.

To build the laboratory, he and his team worked with manufacturers of the equipment that runs various aspects of these networks. The devices are often proprietary, with their inner workings inaccessible to end users, but the Chiang lab negotiated to buy devices that were realistic yet flexible enough to examine and modify for experiments.

Among Chiang's corporate collaborators are AT&T, Hewlett-Packard, Intel, Telcordia, Qualcomm, Google, and Microsoft.

"In EDGE Lab, we're trying to make a difference in the actual networking world, and to make a fundamental difference based on analytic rigor," he said. "It's also important



Three members of Chiang's research group with a mobile phone they use for testing an application to help customers pinpoint when to download data at lower prices. Pictured (from left) are Soumya Sen, a postdoctoral researcher; Carlee Joe-Wong '11, a mathematics major; and Sangtae Ha, a postdoctoral researcher.

that we do this here, in academia, because we need to develop long-term solutions that aren't always tied to the product cycle."

At the same time, a benefit of having a laboratory that's working closely with industry, Chiang said, is that students get hands-on experience translating what they're learning to practical problems. "They learn network theory and then get to apply it to real networks," he said. "They can actually see the difference made by the theory they are working on, so it's more intuitive and engaging."

Carlee Joe-Wong, a mathematics major who graduated in May and who has worked in Chiang's lab since the fall of 2009, said the experience changed her perceptions of how research is conducted. "I always had this impression that academia and industry are completely separate," she said. "It's been eye-opening to see that companies are in interested in these very abstract models and want to put them to use."

Chiang's research focuses on so-called "edge networks," technologies within about two miles of the end user, including familiar services such as 4G, WiFi, U-Verse and FiOS. The name of the lab stems from this focus, and also serves as a metaphor for an edge connecting academic theory and real-world applications, a rarity in the field of networking research.

The EDGE Lab is filled with racks and tables of black boxes, covered in blinking lights and connected to one another by wireless antennas and the bundles of networking cables snaking around the room.

Most of the boxes are servers, routers, radios and other computers that are the workhorses of our modern digital networks. Others are machines Chiang and his students use to experiment on their mock Internet.

The lab is also littered with devices more familiar to the average person: laptops, tablet computers, smartphones and a high-definition television mounted to one wall. The researchers use these devices to understand how altering the way the network operates changes the end user's experience.

One problem is that Internet servers can often become inefficient at delivering content from one place to another, sometimes routing the data through long, convoluted paths. Along with Professor Jennifer Rexford '91 and their joint graduate student, Joe Jiang, of the computer science department, Chiang is experimenting with new ways to store and deliver content that could reduce Internet bottlenecks, such as intelligent ways to spread traffic among the available paths and to distribute files from the right servers or other user's computers on the network, called "peers."

Another major thrust of Chiang's research is helping service providers develop new pricing methods as consumer demand for bandwidth continues to surge. "Imagine that you go to a buffet but your appetite doubles every year," Chiang said. "Starting last year, service providers in the U.S. are saying they can't keep serving a buffet because customers are starting to eat too much relative to the cost of making the food. Either they have to double the price of the buffet or find a cheaper, more efficient way to dish up the food."

To address this, Chiang and his collaborators developed the mathematics and a prototype for TUBE, short for "Time-dependent Usage-based Broadband price Engineering," that gives consumers more information and thus control over when they use the Internet and how much they pay.

He is working with AT&T on a trial that began April 27 with 40 customers at Princeton—faculty, staff, and students—to test the system.

H. Vincent Poor, dean of the engineering school and an expert in communications networks himself, said Chiang's research offers a unique combination of mathematical rigor and practical impact.

"Netflix streaming an HD movie to the TV in our family rooms, watching YouTube on our iPhones or laptops, talking on our cell phones—these are just a few examples of times when we rely on edge networks," Poor said. "Mung's research on networks, especially edge networks, has been at the forefront of improving the quality of these experiences and in creating seamlessness among them." E

Photo by Frank Wojciechowski

PHOTONIC NEURON COMPUTES A BILLION TIMES FASTER THAN BRAIN CIRCUITS

Paul Prucnal speaks with Nicole Rafidi '12, one of several undergraduates who have been involved in the "photonic neuron" project sponsored by Lockheed Martin and Princeton's Stuart Essig '83 and Erin Enright '82 Fund for Innovation in Engineering and Neuroscience.

By Chris Emery

The name of the project—"photonic neuron"—was catchy enough, but what really caught Mitchell Nahmias' attention was the opportunity to combine his interests in engineering and neuroscience.

Nahmias became one of seven Princeton undergraduate students to participate in a research collaboration between the University and Lockheed Martin, the aerospace and defense technology corporation, to produce fiber-optic-based computational devices that work similarly to neurons, but are a billion times faster.

"I'm an electrical engineering major, but I really like biology and cognitive science," said Nahmias, a member of the class of 2012. "This is a cool project, a really interesting confluence of a bunch of fields."

If the project is successful, the new technology could allow for computer circuits that are capable of making nearly instantaneous calculations in life-or-death situations, such as locating a terrorist from a radio signal or deciding whether to eject a fighter pilot from a jet. It might also allow speedy processing of huge amounts of data, such as the video signals that currently guide the movements of robotic cars or scans of genetic data for clues to fighting diseases.

The research is led by Paul Prucnal, a Princeton professor of electrical engineering, and David Rosenbluth, a neuroscientist and principle engineer at Lockheed Martin's Advance Technology Laboratory, in Cherry Hill, N.J. It is funded by Lockheed Martin and Princeton's Stuart M. Essig '83 and Erin S. Enright '82 Fund for Innovation in Engineering and Neuroscience.

The project, which started in 2008, seeks to overcome the inherent speed constraints of electrical circuits, which are ultimately limited by the time it takes electricity to flow through wires. Instead of electrical wires, the team is using clear fiber-optic cables, through which information travels at nearly the speed of light. The "photonic" half of the project's name derives from photons, which are the fundamental unit of light, just as electrons are the fundamental unit of electricity. In conventional fiber-optic communications, photons speed information along great distances but are converted back to electrons once they reach a destination and the information needs to be processed. In Prucnal's lab, the processing occurs while the information is still encoded in light.

In addition to harnessing the ultimate speediness of light, the researchers are borrowing computational concepts used by the neural circuits that help humans and other organisms make ultrafast decisions. Each neuron, whether in the brain or peripheral circuits of the nervous system, is connected to other neurons, which communicate through electrochemical pulses known as action potentials, or, colloquially, as "spikes." Based on the pattern of incoming spikes, a neuron decides whether to send out its own signal to convey information to the rest of the network. This function is the basis for neural computing.

The ability to make such decisions rapidly comes in handy in many situations. A gazelle being pursued by a cheetah, for instance, has to decide extremely quickly – and correctly – whether to dart left or right. A baseball player at bat has to decide to swing or not swing based on a number of cues that arrive a fraction of a second before the decision must be made.

The way that neural networks compute in do-or-die situations offers clues as to how computational devices based on light could function. "We are transposing learning, inhibition and other behaviors typical of neural processing onto fiber-optic circuits," Rosenbluth said. "But I don't think of it as trying to reproduce something in the brain. It's a hybrid between the analog computing done in the brain and the purely digital systems used by most computers."

When Prucnal and Rosenbluth first began talking about the possibility of studying blending fiber-optic signal processing and neuroscience, they noticed that although the mathematical equations used to model neural and fiber-optic networks used different variables, they were very similar in their overall formulation.

"We put the equations side-by-side and it was really an 'aha!' moment for us," Prucnal said. "It was pretty exciting that it might actually work."

In addition to Nahmias, undergraduates who have worked on the project include Vinayak Venkataraman, '11, Will Herlands '12, Nicole Rafidi '12, Alex Tait '12, Abdulrahman Mahmoud '13 and Dolly Xu '13, all electrical engineering students. Yue Tian, a graduate student in electrical engineering, is focusing on the project as part of his doctoral research.

Prucnal said the students have played a central role in directing the course of the research and have worked on a range of related independent research projects.

One major thrust, lead by postdoctoral researcher Mable Fok, is to use an optical processing device to model the tail-flip escape response of a crayfish, the fastest known escape behavior of any animal. Fok and Tian are working on techniques to train the photonic neuron to learn, allowing them to adapt to external signals in a way similar to how human brains strengthen connections between neurons based on experience.

Another project, led by Nahmias, seeks to make an entire computer chip using photonic neurons, based on densely packed arrays of lasers called vertical cavity surface emitting lasers.

In May, four of the undergraduate students presented papers on their work at a workshop on high- speed digital systems organized by the IEEE Photonic Society in Santa Fe, N.M. This summer, funding from the Essig Enright Fund is allowing six more undergraduates and several high school students to work on the project.

Tait said Prucnal has encouraged him and the other students to follow their interests in developing their independent research. Every week the students meet with Prucnal to report on their progress and brainstorm new ideas, often leaving the white board in their meeting room covered in multicolored renderings of a mix of brain anatomy and signal-processing circuit diagrams.

"Computation with spiking systems is a new frontier in signal processing, and that's really intriguing," Tait said. "But it's also important that Professor Prucnal lets us come up with ideas and helps us pursue them. That's what keeps it so interesting." E

INDUSTRY COLLABORATIONS

A number of companies collaborate on research projects with Princeton engineers, use the school's laboratories and other facilities, or provide funding for research programs. These partnerships help industry solve problems and develop new technologies and offer academic researchers real-world test beds for their ideas and innovations.

CITP WORKS WITH INDUSTRY TO ADDRESS ONLINE PRIVACY ISSUES

Personal privacy is a growing concern as people spend more and more time online, sharing personal information and having their Internet and mobile device use tracked by the services they use.

With that in mind, Princeton's Center for Information Technology Policy (CITP) has participated in a number of projects intended to protect people's data and help industry develop guidelines for how corporations access and use personal information.

Last fall, CITP arranged for a group of computer science graduate students to work with engineers at Google to develop software that allows Google's Internet browser, Chrome, to protect users' private data better.

In May, the center and the World Wide Web Consortium, an international organization that develops Web standards, convened a conference on user privacy and online tracking. Representatives from a number of Internet companies attended the event, which was sponsored by Microsoft, Google, Mozilla and Adobe.

"It was a forum to discuss how academic theory could foster the development of privacy guidelines that match the practicalities of industry," said Stephen Schultze, CITP's associate director. "Privacy is increasingly an area of technology policy where academia and industry have something to talk about."

Photo by Wendy Seltzer

From left, John Morris of the Center for Democracy and Technology, Adrian Bateman of Microsoft and Jonathan Mayer '09 of the Stanford Center for Internet and Society speak at a conference this spring on user privacy and online tracking organized by the Center for Information Technology Policy and the World Wide Web Consortium.

PARTNERING WITH MERCK TO BETTER DELIVER DRUGS IN THE BODY

Varun Kumar, a Princeton engineering doctoral student, has worked with researchers at the pharmaceutical company Merck to develop new ways to deliver drugs in the human body.

Kumar and Robert Prud'homme, a professor of chemical and biological engineering, developed a way to encapsulate a drug in tiny spheres made of water-resistant particles. The drug is based on short interfering RNA, genetic material that holds potential for treating a wide range of diseases, including cancer, hepatitis and high cholesterol.

The Princeton researchers have been working with Merck for about two years to test whether their delivery system can effectively target disease in mice and cell cultures. "It helped me to gain a broader exposure of the drug delivery field and taught me to work as a team to achieve a bigger goal," Kumar said.

GLOWING INK COULD MAKE SENSITIVE INFORMATION MORE SECURE

Princeton engineers have teamed up with researchers at Honeywell Corp. to protect sensitive information by printing with glowing inks.

Led by professors Yiguang Ju, of mechanical and aerospace engineering, and Robert Prud'homme, of chemical and biological engineering, the team is exploring a method of inkjet printing that uses ink made of tiny particles that emit a certain color of light, but only when exposed to light of another color. Only people using scanners keyed to these colors of light could verify the authenticity of documents printed with such ink.

The collaboration was initiated through the Princeton Institute for the Science and Technology of Materials (PRISM), based on preliminary research funded by the Princeton Center for Complex Materials, a National Science Foundation-supported materials science program at PRISM.

Photo by Chris Emery

Professor Robert Prud'homme (right) and Sherif Soliman, a postdoctoral researcher, have developed an ink that glows when exposed to certain colors of light.

DEVICE COULD ALLOW AMPUTEES TO CONTROL ARTIFICIAL LIMBS WITH THOUGHT

Princeton electrical engineering faculty Naveen Verma and Sigurd Wagner are working with scientists at the medical device maker Integra LifeSciences to develop reliable electrical devices that allow people to control the movement of artificial limbs with their mind.

The Princeton researchers are collaborating with Simon Archibald, Integra's chief scientific officer, to develop electrical devices that can be implanted in the brain and relay signals to prosthetic devices such as artificial arms and legs. The goal is to produce a technology that allows amputees to control robotic limbs with their thoughts and that can remain in the brain for a long time without harming nerves and other tissues.

"Working with Integra has permitted a new research direction that goes beyond electronics," Verma said. "To take advantage of the devices we can build, we need to understand and resolve the interfaces between our familiar and powerful electronic devices and the physical systems we are interested in interacting with."

Photo courtesy of Naveen Verma

Princeton electrical engineers Naveen Verma and Sigurd Wagner have connected this prototype device to neurons with the help of Lynn Enquist, a Princeton professor of molecular biology.

Photo by Steven Schultz

Princeton Engineering recently joined CTIF, an industry-academia partnership to promote wireless communication research. Participating in an opening symposium at Princeton in April were (from left) Parag Pruthi, chairman and CEO of Niksun Inc., a Princeton-based network security firm; Finn Kjærsdam, rector of Aalborg University in Denmark; H. Vincent Poor, dean of engineering at Princeton; and Ramjee Prasad, director of the CTIF center at Aalborg.

COLLABORATION ACCELERATES NETWORK RESEARCH

Strengthening the global reach and impact of its research on computer networks, Princeton University entered a partnership in May with the Denmark-based Center for Tele-Infrastructure (CTIF) and the Princeton-based network security firm Niksun.

In addition to giving Princeton researchers greater access to European network projects and funding, the three-way partnership will involve student internships and workshops at Niksun, whose clients include many major financial firms and telecommunications companies.

"The connection with Niksun is really appealing because of the access to real problems and the technical constraints of solving them," said Jennifer Rexford '91, a Princeton professor of computer science who already has partnerships with companies such as Google, Intel, Cisco, Microsoft and NEC. "It's nice to have that perspective locally, rather than getting on a teleconference or a flight."

For Niksun, the collaboration offers a deeper look at the fundamentals of networks. "There's a good chemistry between the people here and at Princeton," said Ashutosh Dutta, a senior scientist at Niksun. "We need to look into the future to optimize a system so we can give ultimate performance to the end user."

Photo by Steven Schultz

Rajesh Talpade, vice president for product management at Niksun Inc., discusses his company's specialty in "network forensics" at the April conference launching a partnership with Princeton's engineering school.

Photos by Frank Wojciechowski

A Feb. 15 workshop at Princeton brought together academic researchers with industry leaders to discuss new optimization methods for the energy industry. Professor Warren Powell (left) led the research. Also participating in the event were (upper right, from left) Dean of Engineering H. Vincent Poor, David Crane, CEO of NRG Energy; Princeton University President Shirley M. Tilghman; and (lower right, from left) Bill McDermott, co-CEO of SAP; Paul Hofmann, vice president of research at SAP; A.J. Stewart Smith, dean for research at Princeton; and Powell.

FROM WIND POWER TO ELECTRIC CARS, ENGINEER POWELL HELPS INDUSTRY CHART ENERGY RESOURCES

By Chris Emery

The realization that wind turbines and freight trains have a lot in common changed the trajectory of Warren Powell's career.

For decades, Powell, a professor of operations research and financial engineering and 1977 alumnus, has used his expertise in applied mathematics to help the U.S. freight industry streamline the movement of goods and services around the country, making American companies more competitive and environmentally friendly.

In recent years, as concerns about the environmental impacts of fossil fuel use have grown and new technologies have emerged, Powell has shifted his focus to study problems related to energy.

"It turns out that the mathematical concepts and computer algorithms we use for trucks and trains work for the energy industry as well," Powell said. "It's all about resource allocation, whether you need to assign trains better or need to decide how many wind turbines to keep running."

With businesses and utilities exploring new ways to generate, store and use electricity, Powell has started a number of energy-related research projects in collaboration with industry. The most mature of these efforts analyzed whether industrial-sized batteries could be used to offset the volatile nature of energy demand and pricing. The success of the batteries project led to Powell receiving $3.5 million in funding for his energy systems research over the next five years.

The support comes from SAP, a major provider of business software, and is intended to help its clients in the energy industry operate more effectively—including NRG Energy, a Princeton-based company that provides solar, wind and nuclear power as well as fossil fuel-based power to various regions around the United States.

"Energy is the one basic commodity that can't be stored in bulk," said David Crane '81, CEO of NRG. "Solving this issue is becoming increasingly important as society looks for more resources."

At a February event at Princeton to announce SAP's commitment to fund Powell's work, Crane said unusual weather and power circumstances that converged earlier in the month had illustrated the problem at hand. Uncommonly cold weather in Texas caused homeowners to crank their thermostats up, which exceeded the capacity of electricity providers and resulted in rolling blackouts around the state.

Although NRG maintained its service throughout the incident, the company faces uncertainty on two fronts when generating electricity from solar arrays and wind farms: fluky weather and fickle electricity markets. If the wind isn't blowing and energy demand soars, demand can outpace the wind power supply, causing energy prices to spike and potentially overburdening the electrical grid. To take some of the guesswork out of the equation, NRG wanted to know if they could use new generation batteries to store electricity from wind turbines and solar panels on windy and sunny days so the energy could be used later when demand is high.

To help NRG answer this question, Powell began looking into the problem, supported by $500,000 in initial funding provided by SAP in 2010. Although he was studying the energy industry, Powell drew from his experience applying his academic research in math to operational challenges faced by the trucking industry, railroads and business jets.

Previously, Powell helped one of the largest U.S. truckload carriers, Schneider National, develop an algorithm that simulates the collective decision-making of the company's dispatchers, who must manage more than 15,000 drivers in complex circumstances made uncertain by the vicissitudes of weather, traffic, customers and drivers. The method combines concepts from various areas of mathematics and computer science to solve complex problems by breaking them down into simpler problems.

Having honed his method in the transportation industry, Powell is excited about applying optimization concepts to the field of energy.

"I just love wind because it's stochastic—and that randomness makes things difficult and interesting to model," Powell said.

To help NRG decide if batteries could be used to store energy from wind turbines, Powell and Jae Ho Kim, a Princeton doctoral student in electrical engineering, set out to model how energy prices fluctuated in Texas, one of the major markets in which NRG operates.

With Powell's guidance, Kim developed a formula that described the wildly volatile prices, laying the groundwork for understanding whether battery storage could help stabilize and better predict energy prices.

Paul Hofmann, vice president of research at SAP, and Bill McDermott, co-CEO of SAP, described their company's initiative to form partnerships with academic researchers to bring greater value to their customers while advancing broad areas of research.

Powell's research agenda also includes working with materials scientist Craig Arnold, a professor of mechanical and aerospace engineering affiliated with the Andlinger Center for Energy and the Environment, to help develop the battery-based systems to store wind and solar energy.

Powell also is helping New York City officials who are concerned that the city's burgeoning numbers of electric cars, trucks and buses could outpace the electric grid's ability to keep them charged. Three Princeton undergraduates in Powell's lab are exploring whether cutting power to large buildings during times of peak demand for electricity might help offset the demand from electric vehicles.

At the February event with SAP, Princeton President Shirley M. Tilghman said the project serves as a model for collaborations between the University and industry.

"The best collaborations are always those where there are mutual benefits," she said. "It has really touched the twin missions of the University—the generation of new knowledge and education."

Bill McDermott, co-chief executive officer of SAP, said this type of partnership can go beyond creating real benefits for SAP customers. "Our work with Professor Powell demonstrates how academic research can solve challenging technical and business problems, as well as open new fields of inquiry and train students," he said.

The work also is a model for Princeton's Andlinger Center, a recently formed research and teaching program aimed at combining the University's strengths—from engineering to policy—in developing sustainable energy solutions.

Whatever new energy-related projects Powell takes on in the future, he plans to keep working on problems that force him and his students to test their ideas and models in real-world situations.

"Life is not as neat as we academics sometimes assume," he said. "When you get out and talk with a company, you discover there's a lot going on that you didn't realize." E

INNOVATION FORUM HELPS RESEARCHERS TURN INVENTIONS INTO BUSINESSES

By Chris Emery

It took three tries, but Christian Theriault '07 MSE '08 finally won the top prize at the Innovation Forum, a competition organized by the Keller Center that showcases Princeton research with potential to be commercialized.

Theriault, who competed at the event twice before, wowed the judges with his pitch about the TAG Lens, a new kind of optical device made of fluid instead of glass that might one day be used for applications ranging from medical imaging to detection of environmental pollution.

"It uses sound to shape light … it's a revolutionary technology," said Theriault as he extolled for the judges the virtues of the lens developed by Craig Arnold, a professor of mechanical and aerospace engineering.

Theriault and Arnold, who won $25,000 in funding, were one of five finalist teams that competed for $40,000 in prize money on April 7 in the Friend Center Auditorium.

During the event, now in its sixth year, a member of each team delivered a three-minute pitch to a panel of judges that included angel investors, technology company executives and scientists.

SuryaTech, a manufacturing method that may reduce the cost of producing solar cells, won the $10,000 second prize. A team led by James Sturm '79, a professor of electrical engineering, developed the technology, and Yifie Huang, an electrical engineering graduate student, presented it to the judges.

An invention called Multifunctional Targeted Imaging Nanoparticles, which uses ultrasmall particles to deliver medical imaging dyes during biomedical research, won the $5,000 third-place prize. In his pitch, Vikram Pansare, a chemical and biological engineering doctoral student, said the nanoparticles could reduce the cost of conducting medical trials. The team that developed the technology was led by Robert Prud'homme, a professor of chemical and biological engineering.

In addition to the Keller Center, the event was sponsored by the Jumpstart New Jersey Angel Network and the law firm Drinker, Biddle and Reath in conjunction with Princeton's Office of Technology Licensing.

The format of the competition was altered this year so that participants had more interaction with the judges prior to the final pitching event, according to Cornelia Huellstrunk, the Keller Center's associate director for external affairs.

Early on, the competing teams provided written drafts of their pitches and recorded videos of their presentation at the University Broadcast Center. "This has been wonderful, because the judges have used the materials to provide some valuable input for the participants," Huellstrunk said.

Howard Stone, a professor of mechanical and aerospace engineering who participated in the event for the first time, said he found the process helpful in thinking about how to turn a concept into a business. Stone's entry in the competition was a system that would allow scientists to gather data, access safety information and manage other laboratory functions by using voice-activated software.

"It was great," Stone said of the process at a poster session held after the pitch event. "I've never started a business, so I really valued talking to people who could tell me whether I had a decent idea and how to take it to the next step."

Mario Casabono, one of the event judges and founder of Casabono Ventures, a New Jersey angel investing firm, said the forum is valuable for the investing community as well.

"It gives investors like myself a glimpse of what is in store for the future," he said. "We can start tracking potential new products, and we may actually find a technology we can commercialize in the near term."

For Theriault, who earned an A.B. in molecular biology in 2007 and an MSE in mechanical aerospace engineering, the event was an opportunity to hone his sales pitch for a new company he and Arnold launched earlier this year.

The startup, called TAG Optics, plans to sell the lenses that Arnold developed and will work with customers to match the devices to their needs. The devices work by applying sound waves to the fluid lens, which changes how light refracts as it passes through the fluid. This allows the lens to change its depth of focus much faster than a traditional glass lens. TAG is short for Tunable Acoustic Gradient Index of Refraction Lens.

Theriault said the new company has one customer already and that the lens could be customized for a wide range of uses, such as laser manufacturing, research, and in environmental and medical devices.

Having competed at the Innovation Forum twice before, with teams headed by other Princeton professors, Theriault said he appreciated the ongoing feedback provided this year.

"It was a lot more structured, and the judges really spent time providing comments and going back and forth with us," he said. "It was really about getting us ready to present our business idea in the best way possible."

Carmina Mancenon, a Class of 2014 engineering major, attended the event for a class she was taking with Ely Dahan, the James Wei Visiting Professor of Entrepreneurship.

"It encapsulated the exciting potential of the intersection between technology and entrepreneurship perfectly," Mancenon said. "I understand the importance of being able to deliver good speeches and know that I will need to make many such pitches in the future, so it was a valuable event to attend." E

Photos by Bentley Drezner

At the 2011 Keller Center Innovation Forum (clockwise from top left): Graduate student Peter Qiang Liu (left) pitches his work on a low-cost mid-infrared laser for use in environmental monitoring and medical diagnostics; Professor Vivek Pai deliveres a keynote address on his experiences as an entrepreneur; Professor Howard Stone pitches a plan to develop a lab-management and safety tool; Edgar Choueiri discusses his invention of a system for delivering highly realistic 3D sound through two speakers; From left, third-place winner Vikram Pansare, second-place winner Yifei Huang and professors James Sturm and Ed Zschau share a moment of discussion; From left, Professor Craig Arnold and Christian Theriault '07 MSE '08 won first place for a lens that can be tuned very quickly with sound waves, which could be very useful in many areas of manufacturing and research.

LESSONS FROM A COMPUTER SCIENTIST TURNED SERIAL ENTREPRENEUR

Photo by Frank Wojciechowski

Vivek Pai, next to a stack of powerful research computers in the computer science building at Princeton, has developed several Internet technologies he spun off into businesses.

Vivek Pai has some advice for the budding technology entrepreneurs: Be humble, get help.

"You may be technically good but you need someone who's been there before, who understands business," said Pai, a professor of computer science who's started and sold two companies based on technologies he developed during his academic research.

Pai, a past winner of the Innovation Forum business pitch competition, which showcases Princeton research with commercial potential, said he's been fortunate to experience people saving his skin during his entrepreneurial adventures.

When he started his first company in 1999, iMimic Networking, which sold technology for faster loading of Web pages by storing copies of them on local computers, he learned that assessing business contracts is fraught with pitfalls for newbies.

"I looked over a contract that one of our early customers proposed, and thought it looked fine," he recalled. "But one of our business partners knew a lot about contract law and she said we were about to give away far too many rights. It was highway robbery basically, but that's often the way business-people start negotiating, by seeing just how much they can get."

After Pai sold iMimic in 2004, he and Larry Peterson, another Princeton computer science professor, launched his second company, CoBlitz, which helps companies deliver video faster through the Internet.

CoBlitz technology allows Internet service providers to better manage content delivery networks, or CDNs, systems for hosting multiple copies of the same video on Internet servers in various geographical locations. A CDN allows the end user to access a video file from the closest server, speeding the download and reducing data traffic through the backbone of the Internet.

Pai said his earlier business experience convinced him to pursue CDN research instead of his original interest in peer-to-peer models, which use end-user computers to store and deliver content to one another. "It was working with industry that told us they wanted to use 1,000 powerful machines and big server centers, rather than a million smaller machines," Pai said.

Pai incorporates his hard-won experience working with industry into his teaching at Princeton, fortifying his lectures on theory with a healthy measure of practicality.

"A lot of times, students learn something that's interesting, but it needs context," he said. "A programming technique that saves some memory or tries to be precise is interesting. But in a real situation the cost savings of optimizing the program has to be weighed against the cost of having a developer make the change."

Last October, Pai and Peterson sold CoBlitz to Verivue, a digital content delivery company based in Westford, Mass. Pai is taking a two-year teaching sabbatical to help Verivue integrate the technology he and Peterson developed into their CDN products.

"The demand for online video is growing quickly and it's a huge emerging market," Pai said. "The lesson here was to have a good technology—and have it at the right time." **–CE**

Faculty awards

Photo by Frank Wojciechowski

Chemical and Biological Engineering

Ilhan Aksay
Member, Turkish Academy of Sciences

Rodney Priestley
National Science Foundation CAREER Award

Civil and Environmental Engineering

Elie Bou-Zeid
E. Lawrence Keyes Jr./Emerson Electric Company Faculty Advancement Award, Princeton University

Photo by Frank Wojciechowski

Ignacio Rodriguez-Iturbe
(left) Prince Sultan Abdulaziz Prize in Water Research

James Smith
2011 Robert E. Horton Lecturer in Hydrology, American Meteorological Society

Erik Vanmarcke
Kwang-hua Chair Professor, Tongji University, China

Eric Wood
Honorary Doctorate, Ghent University, Belgium; Fellow, Australian Academy of Technological Sciences and Engineering

Computer Science

David Blei
Young Investigator Award, Office of Naval Research

Michael Freedman
Alfred P. Sloan Foundation Research Fellowship

Kai Li
Fellow, IEEE

Larry Peterson
Kobayashi Award, IEEE

Jennifer Rexford '91 (above, center)
Graduate Mentoring Award, Princeton University McGraw Center for Teaching and Learning

Robert Tarjan
Fellow, Society for Industrial and Applied Mathematics
Edelman Award, Institute for Operations Research and Management Sciences

Olga Troyanskaya
(right) Overton Prize, International Society for Computational Biology; Finalist, 2011 Blavatnik Awards for Young Scientists

Photo by Frank Wojciechowski

Kevin Wayne
Distinguished Teaching Award, Princeton University School of Engineering and Applied Science

Electrical Engineering

Stephen Chou
Einstein Professor of Chinese Academy of Sciences

Andrew Houck '00
Presidential Early Career Award for Scientists and Engineers, White House; Young Faculty Award Defense Advanced Research Projects Agency; E. Lawrence Keyes Jr./Emerson Electric Company Faculty Advancement Award

H. Vincent Poor Ph.D.'77
Honorary Degree, University of Edinburgh; Eric Sumner Award, IEEE

Sigurd Wagner
IBM Faculty Award

Gerard Wysocki
Finalist, 2011 Blavatnik Awards for Young Scientists

Mechanical and Aerospace Engineering

Frederick Dryer
Fellow, American Society of Mechanical Engineers

Marlan Scully
Herbert Walther Award, German Physical Society & the Optical Society

Photo courtesy of P. Rigollet

Operations Research and Financial Engineering

Philippe Rigollet
(left) National Science Foundation CAREER Award

Faculty members elected to national academies

Photo by Jaime Rose

Edward Felten, professor of computer science and public affairs (left), and **Howard Stone**, the Dixon Professor of Mechanical and Aerospace Engineering (below), were elected to the American Academy of Arts and Sciences, one of the nation's most prestigious honorary societies. Members of the academy span all areas of academia, business, public affairs, the humanities and the arts. Felten, who directs Princeton's Center for Information Technology Policy, is currently on leave serving as the chief technologist of the Federal Trade Commission. Stone is a leader in the field of microfluidics, the flow of fluids at extremely small scales.

Photo by Frank Wojciechowski

Photo by Frank Wojciechowski

H. Vincent Poor Ph.D. '77, dean of engineering (above), and **Loren Pfeiffer**, senior research scholar in electrical engineering (below), were elected to the National Academy of Sciences, one of the highest honors across all scientific disciplines. Poor, who also is Princeton's Michael Henry Strater University Professor of Electrical Engineering, is a leader in the fields of statistical signal processing, stochastic analysis and information theory, particularly as applied to wireless networks. Pfeiffer is an expert in a technique called molecular beam epitaxy, which he uses to make ultrapure semiconductor crystals that are essential for many leading areas of physics and materials science research.

Photo by Volker Steger

Christodoulos Floudas, Richard Miles and **Alexander Smits** were elected to the National Academy of Engineering, the highest honor across all the engineering disciplines. Floudas, the Macaleer Professor in Engineering and Applied Science in the Department of Chemical and Biological Engineering (above right), works on mathematical modeling of chemical processes and using optimization techniques in areas such as biology and pharmaceuticals. Miles, a professor of mechanical and aerospace engineering (left), conducts research in the areas of hypersonic flight as well as advanced laser diagnostics and sensing. Smits, chair of the Department of Mechanical and Aerospace Engineering (below), pursues fundamental experimental research in turbulence and fluid mechanics, which has included subjects ranging from biomechanics to techniques for laser eye surgery.

Photo by Frank Wojciechowski

Photo by Frank Wojciechowski

Photo by Frank Wojciechowski

New members of the engineering faculty in 2010-11

Chemical and Biological Engineering

Photo courtesy of B. Koel

Bruce Koel, a specialist in catalysis and surface science, joined the Department of Chemical and Biological Engineering as a full professor as of Jan. 1, 2011.

Koel came to Princeton from Lehigh University, where he had been a professor of chemistry since 2005 and served for two years as interim vice president and associate provost for research and graduate studies.

He previously spent 15 years as a faculty member at the University of Southern California and six years at the University of Colorado-Boulder.

Koel's work in catalysis and surface science are at the heart of technologies associated with the chemical and petroleum industries, functioning of batteries and fuel cells, production of microelectronic devices, and design and fabrication of sensors and diagnostic devices. The author of some 250 published articles, Koel is a fellow of the American Association for the Advancement of Science and the American Physical Society and a member of the American Chemical Society.

He holds bachelor's and master's degrees from Emporia State University and a Ph.D. from the University of Texas-Austin.

Photo courtesy of Amac Garbe

Clifford Brangwynne, Assistant Professor
Start: Jan. 1, 2011
Previous position: Postdoctoral fellow at the Max Planck Institute for Molecular Cell Biology and Genetics and the Institute for the Physics of Complex Systems in Germany
Education: Ph.D. from Harvard University; bachelor's degree from Carnegie Mellon University
Research: Bioengineering, particularly investigating the physical principles underlying self-assembly of biological materials, such as tissues, cells and sub-cellular components

Photo courtesy of M. Brynildsen

Mark Brynildsen, Assistant Professor
Start: Sept. 1, 2010
Previous Position: Postdoctoral fellow at Boston University
Education: Ph.D. from University of California-Los Angeles; bachelor's degree from Rutgers University
Research: Biogengineering, particularly computational and experimental techniques in systems biology, synthetic biology and metabolic engineering to understand and combat infectious disease

Computer Science

Photo courtesy of Z. Dvir

Zeev Dvir, Assistant Professor appointed jointly with the Department of Mathematics
Start: Sept. 1, 2011
Previous position: Senior postdoctoral fellow at Princeton University; postdoctoral fellow at the Institute for Advanced Study
Education: Ph.D. from the Weizmann Institute of Science in Isreal; bachelor's degree from Tel Aviv University
Research: Theoretical computer science and mathematics

Photo by Brian Wilson

Rebecca Fiebrink Ph.D.'10,
Assistant Professor
Start: July 1, 2011
Previous position: Graduate student in computer science at Princeton University
Education: Ph.D. from Princeton; master's degree from McGill University; bachelor's degree rom Ohio State University
Research: Music and human-computer interface

Michael Gordin, professor of history (standing), teaches "Technology and Society," the foundational course of the new Information Technology and Society certificate program.

Photo by Frank Wojciechowski

Certificate program explores information technology and society links

By Chris Emery

When computer science major **Jennifer King** looks around at her field she doesn't see a niche specialty; she sees one of the most powerful influences in society today, from the instant communication of Facebook and Twitter to the complexities of computer-driven financial markets.

So when the University created a new certificate program that explores the links between information technology and society, she was among the first to sign up.

"Coming from the perspective of a CS major, the certificate really underscores how interdisciplinary computer science is, and has to be, in our society today," said King who graduated in May.

The Program in Information Technology and Society began enrollment during the 2010-11 school year and immediately had 13 students in majors ranging from computer science and electrical engineering to history and politics. The program is sponsored jointly by the Center for Information Technology Policy and the Keller Center.

Sharad Malik, outgoing director of the Keller Center, said the new program brings extra attention to a set of courses and faculty expertise that have been building for a long time. "The Wireless Revolution," which is one of the courses that satisfy requirements of the certificate, has been popular since the Department of Electrical Engineering began offering it in 2000.

In addition to helping students, the program also facilitates cross-disciplinary conversations between faculty members as they push into new research areas, Malik said.

"It's a reflection of what's happened in society today," said Malik, who is Princeton's George Van Ness Lothrop Professor in Engineering. "Technology is an important part of our lives and we need to keep looking at its interactions with society."

In pulling together the list of courses that would satisfy requirements of the program, Ed Felten, who directs the Center for Information Technology Policy and is currently on leave to serve as chief technologist for the Federal Trade Commission, said he was pleased to see how many already existed. "As always, there are lots of courses I wish I could take," Felten said.

One new course that was developed specifically as an anchor for the certificate program is "Technology and Society," taught by Professor of History Michael Gordin. This course was developed by professors Gordin, Angela Creager, Elizabeth Armstrong and Malik in collaboration between engineering, history, sociology and the Woodrow Wilson School of Public and International Affairs. The course, which enrolled more than 80 students in the fall, examines the interaction of technology, politics, economics and culture, as well as themes such as innovation, regulation, risk and ethics.

The course exemplifies a wider theme in at Princeton, where fundamental research in science and technology can interact in interesting ways with the social sciences and humanities, said Malik. "Engineering is an integral part of a liberal arts education, and its importance will only increase."

SERVICE AND ENTREPRENEURSHIP

Engineering students lead in business plan competitions

Teams including engineering students won first place in both tracks of the 2011 Tiger-Launch Business Plan Competition, garnering support for a business that helps people buy clothes online and another that boosts the test scores of students in remote parts of Kenya.

Nick DeVeaux, a Class of 2011 computer science major, joined with Class of 2012 philosophy major **Woody Hines** in pitching Madi, a company developing a 3-D camera that will allow users to try on clothing virtually, seeing how they would look in clothes before buying them online.

Electrical engineering major **Josphat Magutt** and computer science major **Eric Kuto** joined with molecular biology major **Richard She**—all rising seniors—in presenting M-Profesa, a system for using cell-phone text massaging to prepare Kenyan students for a critical national academic exam.

The competition, run by the Princeton Entrepreneurship Club, provides both teams with $5,000 and free office space in Palo Alto, Calif. For DeVeaux, success in the competition provided an important boost. "For us, this really provides validation," De Veaux told the *Princeton Alumni Weekly.* "That's probably much higher value than the actual cash prize."

Photo by David Heinz

Rising seniors (from left) Eric Kuto, Richard She and Josphat Magutt won an entrepreneurship contest for M-Profesa, a business to help Kenyan students prepare for a national exam.

Service work provides launching pad after rocky freshman start

After her first semester at Princeton, **Jane Yang** was not sure she belonged. In a recent video produced by the Office of Development, Yang explains how her perception changed as she became involved in a series of community and international service projects.

Photo by Brian Wilson

Scan the QR code at the right to watch a video in which Jane Yang '11 discusses her passion for service.

Yang, who graduated in May with a degree in chemical and biological engineering, first volunteered with Princeton Engineering Education for Kids (PEEK), a group that uses Legos to teach basic engineering techniques to school-age children. She went on to work in Ghana as co-president of the Princeton chapter of Engineers Without Borders.

Yang, who earned certificates in engineering biology and in sustainable energy, was named one of the winners of the Spirit of Princeton Award, which honors undergraduate students for their positive contributions to campus life. She also won the School of Engineering Joseph Clifton Elgin Prize, awarded annually to the student who "has done the most to advance the interests of the school in the community at large."

Photo by David Heinz

From left, business leaders Jason Glickman and Brion Feinberg '80 served as judges of the Entrepreneurship Club's 2011 Tiger-Launch Business Plan Competition. Nick DeVeaux '11 (second from right) and Woody Hines '12 (far right) won the technology, products and services track.

School of Engineering 2011 Class Day Awards

Steven Baldassano,
chemical and biological engineering
Calvin Dodd MacCracken Senior Thesis/Project Award

Bayard Gardineer IV,
mechanical and aerospace engineering
Jeffrey O. Kephart '80 Prize in Engineering Physics

Chelsea Graf,
mechanical and aerospace engineering
J. Rich Steers Award

Michael Keaton,
chemical and biological engineering
J. Rich Steers Award

Jennifer King,
computer science
Tau Beta Pi Prize

Andrew Mills,
chemistry
Global Photonics Energy Corporation Solar Energy Innovation Award

Chetan Narain,
operations research and financial engineering
Lore von Jaskowsky Memorial Prize

Kunal Nayyar,
mechanical and aerospace engineering
Lore von Jaskowsky Memorial Prize

Jakub Rajniak,
chemical and biological engineering
James Hayes-Edgar Palmer Prize in Engineering

Cameron Ritchie,
civil and environmental engineering
George J. Mueller Award

Katherine Song,
electrical engineering
Tau Beta Pi Prize

Mary Catherine Wen,
electrical engineering
PRISM Newport Award of Excellence

Patrick Wendell,
computer science
Calvin Dodd MacCracken Senior Thesis/Project Award

Jane Yang,
chemical and biological engineering
Joseph Clifton Elgin Prize

Han (Tony) Zhu,
electrical engineering
Calvin Dodd MacCracken Senior Thesis/Project Award

Class Day, which takes place the day before Commencement, includes recognition of graduating seniors for their contributions.

Photos by Frank Wojciechowski

Clockwise from top: Morgan Fowler shakes hands with Dean H. Vincent Poor; Poor congratulates Bayard Gardineer; Jakub Rajniak; Katherine Song; Patrick Wendell and Steven Baldassano; Mary Catherine Wen; Michael Keaton and Chelsea Graf.

Undergraduates win national honors, fellowships

Five 2011 graduates—four in computer science and one in civil and environmental engineering, all from the class of 2012—recently won national competitions and fellowships, recognizing work ranging from improving water quality in India to designing a more efficient Internet.

Hijung (Valentina) Shin and **Patrick Wendell**, both majors in computer science, received the Outstanding Undergraduate Researcher Awards 2011 from the Computing Research Association, the highest recognition in that field for exceptional undergraduate research.

Two other Princeton computer science students, **Kay Ousterhout** and **Michael Ty**, received honorable mentions in the competition.

Shin was recognized for her work with professors **Thomas Funkhouser** and **Szymon Rusinkiewicz** to develop a computer program that helps archeologists in Greece reconstruct ancient frescos on the Aegean island of Santorini. Her system, which analyzes shards and suggests matches, has already produced 50 matches, an accomplishment that could represent years of conventional work.

Wendell worked with computer science professors **Jennifer Rexford** and **Michael Freedman** to develop a system for routing online traffic more efficiently over the Internet. Wendell developed a system called DONAR that computes the most efficient way to deliver Internet content, such as video, to users without overwhelming servers that are geographically close to the user. His system is being used by a commercial company and in research labs.

Kay Ousterhout, a computer science major, was one of 15 students nationwide to receive a fellowship from the Fannie and John Hertz Foundation, which provides $250,000 in support of graduate research. Ousterhout plans to pursue research relating to the flow of data across the Internet by focusing on distributed systems and networking, work that also relates to her senior thesis research with Professor Jennifer Rexford.

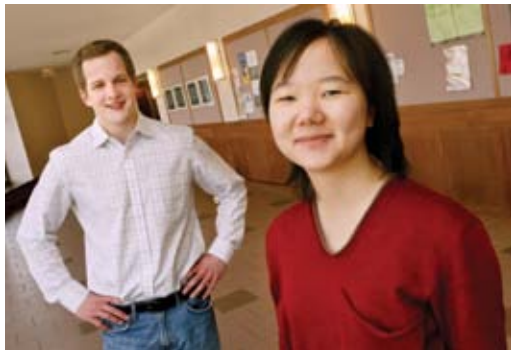
In addition to her academic work, Ousterhout and classmate **Jennifer King** co-founded Princeton Women in Computer Science, an organization dedicated to providing support and mentoring to women interested in computer science.

Jarett Schwartz, also a computer science major, and **Victoria Hewitt**, who majored in civil and environmental engineering, won Fulbright Fellowships, one of the most prestigious awards to support international study.

Schwartz plans to pursue research at the intersection of mathematics and theoretical computer science at Charles University in Prague, Czech Republic. His plans were inspired in part by summer trips to Prague to present a paper at an academic conference and to participate in a Research Experience for Undergraduates program.

Hewitt plans to join a research group at the Indian Institute of Technology at Kanpur and help develop plans to update a wastewater treatment plant. Her work grew out of her senior thesis research with professor **Peter Jaffe** on a new technique to treat industrial wastewater.

Photo by Frank Wojciechowski



Patrick Wendell (left) and Valentina Shin won the 2011 Outstanding Undergraduate Researcher Awards from the Computing Research Association.

Photo courtesy of K. Ousterhout, other photos by Frank Wojciechowski

Clockwise from top left, Kay Ousterhout, Jennifer King, Jarett Schwartz and Victoria Hewitt.

The School of Engineering and Applied Science recently created a series of posters and an online gallery profiling more than 30 students from the school's six departments. Six of the graduate students profiled are featured on these pages; to see the full project, visit **www.princeton.edu/engineering/departments**.

Photo by Denise Applewhite

Stephanie Lee

CHEMICAL AND BIOLOGICAL ENGINEERING

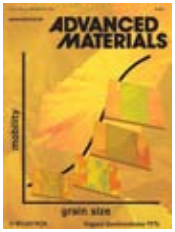
BEFORE PRINCETON

Massachusetts Institute of Technology

RESEARCH

Incorporating organic semiconductors as the active materials in low-cost, flexible electronic devices and solar cells. Controlling the morphology in these materials to influence device performance. Lee's work in this area was featured in the journal *Advanced Materials*.

WHY



"I am interested in using technology to address problems of sustainability and quality of life in developing countries. I traveled to Haiti twice during college, and these experiences strongly influenced my career goals and aspirations. Organic electronics have the potential to be used in disposable biosensors for disease detection, as well as for water quality control. Additionally, organic solar cells have the potential to provide low-cost, renewable energy."

All other photos courtesy of those pictured

Matthew Reid

CIVIL AND ENVIRONMENTAL ENGINEERING

BEFORE PRINCETON

University of Chicago, Peace Corps and a research assistantship at Columbia University

RESEARCH

"I'm interested in wetland biogeochemistry, and my research focuses on how wetland vegetation mediates the transfer of gases and other volatile compounds between saturated wetland soils and the atmosphere. The research may help to predict the behavior of methane, a powerful greenhouse gas, in different wetlands and to design wetlands that minimize methane emissions. Another application is phytoremediation, which is the use of plants to remediate contaminated soils."

WHY

"I'm interested in international development, and one of my reasons for studying engineering in graduate school was to do research in science and technology that can be applied to sustainable development. This became a big interest of mine when I was a Peace Corps volunteer in Tanzania."

HONORS

National Science Foundation Fellowship and a Wu Fellowship.

Mohammad Hossein Bateni

COMPUTER SCIENCE

BEFORE PRINCETON

Sharif University of Technology in Tehran, Iran. Participated in international programming competitions, winning the gold medal in the International Olympiad in Informatics in South Korea and the bronze medal in the Central European Olympiad in Informatics in Slovakia. ACM-ICPC World finalist in the Czech Republic and China.

RESEARCH

Algorithm design, especially in approximation algorithms and online algorithms. Worked on theoretical and practical problems in network design, algorithmic game theory and database management. Work has led to more than a dozen papers in top journals and at conferences, as well as three patent applications filed by AT&T.

HONORS

Gordon Wu Fellow and Charlotte Elizabeth Procter Fellow. Served as a referee for more than a dozen conferences and journals, and gave more than 10 invited talks in research labs or universities.

INTERNSHIPS

AT&T Labs–Research, Toyota Technological Institute and Microsoft Research.

Pierre Bouzi

ELECTRICAL ENGINEERING

BEFORE PRINCETON

After growing up in Jacmel, Haiti, came to New York City and earned an associate degree in computer science and then bachelor and master's degrees in electrical engineering at City College of New York.

RESEARCH

Working with Professor Claire Gmachl on the design of quantum cascade lasers for use in detecting and quantifying trace levels of gas. The work is part of Mid-Infrared Technologies for Health and the Environment (MIRTHE), a major National Science Foundation-funded research consortium based at Princeton.

WHY

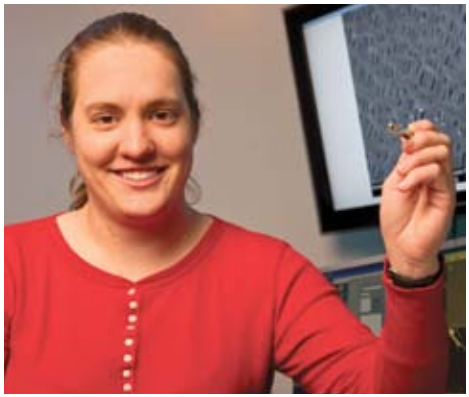
"I chose this field of study because of its wide range of applications—the huge impact this type of research can have on the environment, health care and security systems. I see myself working in a government lab or private industry down the road, pursuing similar research, whether identifying greenhouse gases released in the atmosphere or analyzing breath for pathological traits."

INTERNSHIPS

Two summers at Corning Inc.

EXTRACURRICULAR

Participating in MIRTHE outreach events to spur excitement in research among young students.



Christina Peabody

MECAHNICAL AND AEROSPACE ENGINEERING

BEFORE PRINCETON

Vanderbilt University

RESEARCH

"I study the mechanical properties of lithium-ion batteries and battery materials to improve their performance and lifetime. In my work, I'm looking at how the effects of stress on the polymer separators used in these batteries causes pores in the separator to close, which results in decreased energy storage capability."

HONORS

National Science Foundation Graduate Student Fellowship and Princeton University Upton Fellowship. Best presentation award at the Tokyo Institute of Technology's Global Center of Excellence Conference in Ishigaki, Japan.

FOR FUN

"I enjoy training for triathlons, and for the past three years I've been a little league softball coach here in Princeton, which has been a great way to connect with the community outside of the University. I also enjoy playing softball for the department's team in the University's summer intramural league."

Ilya Ryzhov

OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

BEFORE PRINCETON

Bachelor's degree from Cornell University and a master's degree from Stanford University.

RESEARCH

"I study the problem of efficient information collection, which arises when we have several alternatives to choose from, but don't know which is best. One example is in energy storage, where a utility company could choose to charge a large battery when the price of electricity is low and sell it back when the price goes up. However, energy prices are notoriously volatile and unpredictable, so we do not know which prices are 'low' and which are 'high.' Our decision-making will involve learning and experimentation. The same issue arises in finance: A mutual fund has to decide how much cash to have on hand to satisfy demand for withdrawals while investing as much money as possible in various portfolios."

HONORS

More than 10 publications in journals and conference proceedings. Two Excellence in Teaching Awards from the University's undergraduate Engineering Council and the Graduate Engineering Council. Association of Princeton Graduate Alumni Teaching Award.

–SS

All photos courtesy of those pictured except where noted

Abriola and Gast recognized as notable women in science

Two Princeton engineering alumnae, **Linda Abriola** Ph.D. '83 and **Alice Gast** Ph.D. '84, were featured in American Women of Science Since 1900, an encyclopedia of the 20th century's most notable American female scientists.

Abriola's research focuses on water pollution and ways of removing pollutants from the underground aquifers that supply drinking water. She received her Ph.D. in civil engineering from Princeton.

Abriola was a professor of environmental engineering at the University of Michigan and then moved to Tufts University, where she served as a professor of civil and environmental engineering before becoming dean of the engineering school.

Gast, who is president of Lehigh University, is an expert in the chemistry of complex liquids and surfaces and co-wrote a popular textbook in that field. After receiving her Ph.D. in chemical engineering from Princeton, she joined the faculty of Stanford University and then served as vice president for research and associate provost at the Massachusetts Institute of Technology. She was named the first female president of Lehigh in 2006.

Alumni elected to National Academy of Engineering

Three engineering alumni, **Stuart Cooper** Ph.D. '67, **Cato Laurencin** '80 and **Mihalis Yannakakis** Ph.D. '75, were elected in 2011 to the National Academy of Engineering.

Cooper, who received his doctorate in chemical engineering from Princeton, was recognized for his contributions to polymer chemistry, biomedical polyurethanes, blood compatibility and academic administration. He is the chair of the Department of Chemical and Biomolecular Engineering at Ohio State University.

Laurencin, who earned his bachelor's degree in chemical engineering from Princeton, was recognized for his contributions to biomaterial science, drug delivery, tissue engineering involving musculoskeletal systems and academic leadership. He is the director of the Institute for Regenerative Engineering and the Van Dusen Chair in Orthopedic Surgery at the University of Connecticut.

Yannakakis, who received his doctorate in computer science from Princeton, was elected to membership in the academy for his contributions to research on algorithms and computational complexity. He is a professor of computer science at Columbia University.

Alumni honored for innovation and leadership

Norman Augustine '57 MSE '59, retired chairman and chief executive of Lockheed Martin Corp., will be presented with The Wings Club 2011 Distinguished Achievement Award at its 69th annual dinner in October. The award recognizes his contributions to the aviation industry.

Daniel Warmenhoven '72, executive chair of the board of directors of NetApp and its chief executive from 1994 to 2009, was presented with the 2010 Visionary Award by the Entrepreneurs Foundation. He was acknowledged for his continuing leadership in the funding, development and staffing of the community relations and philanthropy function at NetApp.

Sir Gordon Wu '58, chairman of Hopewell Holdings LTD of Hong Kong, one of the largest civil construction companies in Asia, was presented with a Lifetime Achievement Award by CNBC Asia. Wu was among those honored for epitomizing "core values of a successful leader—strength, innovation, ingenuity, knowledge and foresight."

Photo by Denise Applewhite

Kathleen Chesmel '85, a chemistry teacher at New Egypt High School in New Jersey, won Princeton University's award for exceptional secondary school teaching and was honored at the University's Commencement ceremony on May 31. Recognized for bringing a research scientist's spirit of inquiry into the classroom, Chesmel also is known for incorporating theater, dance, music and multimedia to explain complex material and engage students. One student commented that "Dr. Chesmel did not spoon-feed the answers to me. Rather, she taught me the importance of self-sufficiency and researching the answers on my own—something that I will be expected to do in college, in the workplace and in life."

Engineering alumni take the helm

James Curtis '86 was promoted to president of Cooperstown Environmental LLC, an environmental engineering consulting firm that specializes in the Massachusetts Brownfields Tax Credit program, which encourages the cleanup of contaminated sites. Curtis will lead business development and growth efforts and oversee strategic planning.

Paul Johnson Ph.D. '88 was named dean of the Fulton Schools of Engineering at Arizona State University, where he has been a faculty member since 1994. More than 7,000 undergraduate and graduate students are enrolled in Fulton's seven engineering departments. An expert in soil and groundwater remediation and risk assessment, Johnson is a professor in the School of Sustainable Engineering and the Built Environment.

Greg M. Smith '94, co-founder of Lyfe Communications, was appointed the company's CEO. Lyfe developes next-generation media services, integrating television, high-speed Internet and enhanced voice services.

Carl Sparks '89 was named the CEO of Travelocity, an online discount travel site. He was formerly the president of Gilt Groupe, an online fashion retailer. Earlier in his career, Sparks held positions at Expedia and Hotels.com.

Philip Hammarskjold '87 was appointed to a four-year term on Princeton University's Board of Trustees as well as to the chairmanship of the board of the Princeton University Investment Company. Hammarskjold, who earned a degree in mechanical and aerospace engineering from Princeton and an MBA from Harvard University, is CEO of Hellman & Friedman, a private equity investment firm.

Frank Moss '71, who recently stepped down from his post as director of Massachusetts Institute of Technology's Media Lab, wrote about the work of the lab in a new book titled "The Sorcerers and Their Apprentices." Moss serves on the leadership council of Princeton University's school of engineering and recently completed a term as a University trustee.

Princeton engineers provide organizational guidance

Sumir Chadha '93 was elected chair of the Indian Venture Capital Association, a member-based organization that represents venture capital and private equity firms, in its first-ever election. Chadha is the co-founder and managing director of WestBridge Capital Fund, a public-markets fund.

Laura Forese '83 was appointed to the new working group established by the National Institutes of Health to study the future of the biomedical research workforce in the United States and develop a plan to guide workforce development. Forese is chief operating officer, chief medical officer and senior vice president at New York Presbyterian Hospital/Weill Cornell Medical Center in New York City and is a Princeton University trustee.

Paul Maeder '75, co-founder and general partner of Highland Capital Partners, a firm that has made investments in over 225 seed, early and growth stage companies, was elected to serve as chair of the board of directors of the National Venture Capital Association. The organization advocates for policies supporting innovation and entrepreneurship.

"Engineering is a fabulous foundation for virtually any kind of career, from medicine to public policy."

– Lisa Jackson MSE '86, administrator, U.S. EPA

Photos on this page by Sameer Khan

Photo by Denise Applewhite

She Roared

Nearly 1,300 alumnae of Princeton University gathered on campus April 28 through May 1 for a historic conference titled "She Roars: Celebrating Women at Princeton." In the 40 years since coeducation began at Princeton, the School of Engineering and Applied Science has undergone a transformation along with the overall University. Today, 36 percent of undergraduate engineering students are women. In two departments—civil and environmental engineering and chemical and biological engineering—at least half the undergraduates are women.

"The major problems facing society today—energy, environment, health, security—are complex and urgent, and we must engage all the available talent and perspectives to solve them," said H. Vincent Poor Ph.D. '77, dean of engineering. "Striving for gender balance in engineering is a critical part of that goal."

During the conference, engineering alumna Lisa Jackson MSE '86, administrator of the U.S. Environmental Protection Agency, delivered a keynote address and also met with the student group Graduate Women in Science and Engineering (GWISE).

"Engineering is a fabulous foundation for virtually any kind of career, from medicine to public policy," Jackson told the students.

In other engineering related events at the conference:

- Naomi Leonard '85, a Princeton professor of mechanical and aerospace engineering, discussed her collaboration with Susan Marshall, director of Princeton's Program in Dance, to translate the flocking behavior of birds and fish into a piece of performance art called "Flock Logic";
- Emily Carter, founding director of Princeton's Andlinger Center for Energy and the Environment, gave an overview of the center's mission to secure a sustainable energy future for the planet;
- Laura Forese '83 and Akira Bell Johnson '95 participated in a panel discussion titled "Careers in Science and Technology: Where are the Women?"

Lisa Jackson MSE '86 (opposite, top) delivered a keynote talk during the She Roars conference. Scan the QR code below to watch her talk. The conference also featured a talk by Emily Carter, director of the Andlinger Center for Energy and the Environment (opposite, bottom right); a discussion of women in leadership including Jane Yang '11 and alumna and professor Naomi Leonard '85 (opposite, middle row center); and a talk by Leonard on her collaboration with the Program in Dance (opposite, middle row right). Engineering alumni Catherine Toppin '02 and Kenneth Bruce '83 (second and first from right in the photo above) were among the attendees at She Roars.

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