

# E

EQuad News

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# The EXTENDED CLASSROOM

*Teaching for  
the 21st century*



PRINCETON

School of Engineering  
and Applied Science





Photo by Denise Applewhite

## A tradition of change

An essential quality of the classroom at Princeton is change. Woodrow Wilson, former president of this university and the nation, transformed teaching in 1905 when he introduced the precept. To use the modern parlance, Wilson “flipped the classroom,” creating a student-centered discussion instead of a professor-driven lecture. More than 100 years later, the classroom experience continues to evolve and now is in another period of great transformation.

Perhaps the most dramatic example is the arrival of open online courses, which are reaching many tens of thousands of students around the world. Princeton Engineering faculty members have been early adopters, teaching seven of Princeton University’s 10 initial course offerings on the Coursera platform (see page 14). These courses not only amplify the dissemination of knowledge, they feed important insights back to the Princeton classroom, sharpening teaching skills and broadening discussions. Like Wilson’s precept, online courseware allows more in-person class time to be devoted to dialogue and inquiry.

Another change in the classroom is the subject matter itself, which constantly evolves. Here is where Princeton’s great strength in integrating research and teaching comes into play. When professors lead the research in their fields, their classes come alive with current, vital questions. Students, in turn, ask questions that drive new research (see pages 8 and 10). Visiting faculty members also inject ideas into the curriculum; gifts to the recently completed Aspire campaign have created several important new visiting positions (see page 20).

As a Princeton dean and alumnus, I also am keenly aware of the profound contributions that you – our alumni and partners – make in the education and lives of our students. Your participation, support and feedback are enormously valuable. Please find us on Facebook and Twitter, or follow the age-old tradition of stopping by to say hello.

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Photo by David Kelly Crow

## VALEDICTORIAN FINDS INSPIRATION IN QUESTIONS OF BALANCE

Programming a robot to perform like a plate spinner at a circus, making all the tiny adjustments needed to balance a thin stick perfectly upright, is part of what engineers call the inverted pendulum problem. For most students, the tricky balancing act can be quite a challenge. For Princeton senior Aman Sinha, it was an inspiration.

“You can push the pendulum, and it swings back as the computer compensates,” he said. “It almost seems like the computer is alive.”

The intricate merger of motion and reaction needed to balance the teetering pendulum brought to bear Sinha’s enthusiasm for engineering and mathematics. That desire to tackle difficult problems, to uncover the most elegant solution, helped propel him to the top of his class. A mechanical and aerospace engineering major from Ivyland, Pa., Sinha was the valedictorian of Princeton’s Class of 2013.

“The world is getting smaller, flatter and more connected,” Sinha said in his address at the University Commencement on June 4. “Our generation faces challenges, old and new, on all fronts. It is now our job to dedicate ourselves to the task at hand, that from our time here we take an increased devotion to

paving a better future, in this nation and in all nations. This is a daunting task, for sure, and one for which even Google doesn’t provide instructions. But perhaps we can start by asking ourselves a question: What if we strive to be more than we are told we can be?”

Sinha, who won numerous academic awards including the Shapiro Prize for Academic Excellence and the George B. Wood Legacy Sophomore Prize, will attend Cambridge on a Churchill Scholarship. After that, he plans to pursue a doctorate at Stanford as a Hertz Fellow.

Clarence Rowley (BSE '95), a professor of mechanical and aerospace engineering, said that Sinha has a great ability to work through complex problems and arrive at spare, forceful solutions. Although he has moved on to more difficult work, the pendulum problem was an early example.

“It is a case where there is a fairly involved amount of math that you have to do to arrive at a solution,” said Rowley. “But when you work through it, and see it actually work, it’s great. It’s really exciting to see it pan out. I think it really resonated with Aman.” ▶

Aman Sinha, a mechanical and aerospace engineering major, delivers the valedictory address at Princeton’s 2013 Commencement.

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**VALEDICTORIAN FINDS INSPIRATION IN QUESTIONS OF BALANCE**

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Professor of Mechanical and Aerospace Engineering Clarence Rowley, left, and Sinha demonstrate a low-tech version of the inverted pendulum experiment, a classic engineering problem that Rowley says “is like balancing a ruler on your hand.” For Sinha, the “pendulum problem” challenged and inspired his passion for engineering and mathematics.

Underlying Sinha’s friendly and easygoing manner – he describes the complicated math of control systems as “really cool” – is a formidable intellect. Sinha’s senior thesis adviser, Naomi Leonard (BSE ’85), recalled that he managed to solve every problem set in her course on modern control theory on a single sheet of paper. And when it came time to present his thesis to Leonard’s research group, Sinha sketched numerous equations and pictures on the board and spoke for nearly an hour — all from memory.

“The material that Aman presented on the board covered dozens of pages from his thesis work and was so carefully

explained,” said Leonard, the Edwin S. Wilsey Professor of Mechanical and Aerospace Engineering. “This kind of presentation without detailed notes is more typical of an accomplished graduate student.” —**John Sullivan**



Photo by Denise Applewhite



Left: Pablo Debenedetti; right: Claire Gmachl



**DEBENEDETTI PROMOTED TO DEAN FOR RESEARCH; GMACHL IS SUCCESSOR AS VICE DEAN**

Claire Gmachl, the Eugene Higgins Professor of Electrical Engineering, has been appointed vice dean of the School of Engineering and Applied Science, succeeding Pablo Debenedetti, who has been named the University’s new dean for research.

Debenedetti, the Class of 1950 Professor in Engineering and Applied Science and professor of chemical and biological engineering, succeeds Class of 1909 Professor of Physics A.J. Stewart Smith (Ph.D. ’66), who became

the University’s vice president for the U.S. Department of Energy’s Princeton Plasma Physics Laboratory.

As dean for research, Debenedetti will be responsible for encouraging innovation and collaboration across campus, promoting research at the University and ensuring that research meets ethical standards.

From 1996 to 2004, Debenedetti was chair of the chemical engineering department. In 2008, he was named vice dean of engineering. In that role, Debenedetti said, he

**NATURAL BACTERIAL BYPRODUCT OFFERS ROUTE TO NEW ANTIBIOTICS**

As public health officials sound the alarm about the global spread of drug-resistant bacteria, researchers are working to develop more effective antibiotics to counter this dangerous phenomenon. Now, results from a team including a Princeton University scientist offer a possible solution that uses the bacteria’s own byproducts to destroy them.

In a paper in the journal Nature Biotechnology, Mark Brynildsen, a Princeton assistant professor of chemical and biological engineering, reported that scientists can force bacteria to increase production of molecules called reactive oxygen species, which can either kill the bacteria or make them more vulnerable to antibiotics. Bacteria normally produce reactive oxygen species during growth. Small amounts don’t hurt them because of protective enzymes within the bacteria, but too much of the substances can lead to “oxidative stress.” The researchers decided to exploit this weakness.

“The question was, could we leverage this natural byproduct of growth?” Brynildsen said.

Brynildsen and fellow members of the research team led by Professor James Collins

at Boston University analyzed reactive-oxygen production from thousands of mathematical models and looked for trends. That analysis revealed that certain enzymes allowed bacteria to reduce the levels of reactive oxygen species they created.

The team chose a relatively benign strain of E. coli, a common bacteria whose variations can cause serious illness. Using a computer model, the team predicted which bacterial genes are likely involved in regulating reactive oxygen species production. They then deleted those genes in bacteria and confirmed that the bacteria experienced increased production of reactive oxygen and an increased sensitivity to oxidants. The researchers then treated these bacteria with antibiotics and found that the organisms were in fact more vulnerable. —**JS**

Photo by Denise Applewhite



Mark Brynildsen (left), an assistant professor of chemical and biological engineering at Princeton, meets with Ph.D. students Jonathan Robinson and Kirstin Adolfsen in the newly renovated Hoyt Lab. Brynildsen’s research team is one of four faculty groups that recently moved into the refurbished building, which supports biological engineering. The addition of Hoyt Lab adds more than 38,000 square feet of laboratory and conference space to the engineering school.

strove to use innovation funds to identify and promote “very new ideas,” which he described as work that has great potential and explores unfamiliar frontiers. He hopes to expand that vision University-wide.

As vice dean, Gmachl oversees the allocation of research resources, space and facilities. She also assumes responsibility for the promotion of new research initiatives and industrial collaboration, and for the facilitation of international initiatives.

Gmachl’s research focuses on quantum devices, particularly lasers, and their potential use in sensor systems for environmental monitoring and health care. She is the director of the University’s MIRTHE Center (Mid-InfraRed Technologies for Health and the Environment).

In addition to her academic role, Gmachl served as interim vice dean when Debenedetti was on sabbatical in 2012. —**John Sullivan and Morgan Kelly**

Graduate student Manu Mannoor, left, and Assistant Professor of Mechanical and Aerospace Engineering Michael McAlpine inspect the “bionic ear” developed in their lab.



Photo by Frank Wojciechowski

## PRINTED EAR MELTS BIOLOGY AND ELECTRONICS

Using 3-D printing tools, researchers have created a functional ear that can “hear” radio frequencies far beyond the range of normal human capability.

The researchers’ primary purpose was to explore an efficient and versatile method of merging electronics with tissue. The scientists used a standard 3-D printer to print cells – nanoparticles of silver and other structural materials – and then applied cell culturing procedures to grow the number of cells. The result was perfectly ear-shaped cartilage with a built-in antenna coil, creating what they call a bionic ear.

“There are mechanical and thermal challenges with interfacing electronic materials with biological materials,” said Michael McAlpine, an assistant professor of mechanical and aerospace engineering at Princeton and the project’s lead researcher. “Previously, researchers have suggested some strategies to tailor the electronics so that this merger is less awkward. That typically happens between a 2-D sheet of electronics and a surface of the tissue. However, our work suggests a new approach – to build and grow the biology up with the electronics synergistically and in a 3-D interwoven format.”

Photo by Frank Wojciechowski



Princeton engineers used 3-D printing to create an ear made up of a coil antenna and cartilage, demonstrating an efficient method of merging electronics with tissue.

McAlpine’s team has made several advances in recent years involving the use of small-scale medical sensors and antennas. Last year, a research effort led by McAlpine, Naveen Verma, an assistant professor of electrical engineering, and Fiorenza Omenetto of Tufts University resulted in the development of a “tattoo” made up from a biological sensor and antenna that can be affixed to the surface of a tooth.

This project is the team’s first effort to create a fully functional organ, one that not only replicates a human ability, but extends it using embedded electronics.

“The design and implementation of bionic organs and devices that enhance human capabilities, known as cybernetics, has been an area of increasing scientific interest,” the researchers wrote in an article published online May 1 in the journal *Nano Letters*. “This field has the potential to generate customized replacement parts for the human body, or even create organs containing capabilities beyond what human biology ordinarily provides.”

The researchers’ report received widespread media attention, including television interviews and many articles on websites and in newspapers and magazines around the world.

The 3-D printing technique uses a computer to control a nozzle that builds up the desired design in thin slices. In the case of the ear, the researchers combined a matrix of hydrogel and bovine cells with silver nanopar-

## PRINTED EAR MELTS BIOLOGY AND ELECTRONICS

(continued from page 4)

articles that form an antenna. The bovine cells later developed into cartilage.

Two wires lead from the base of the finished ear and wind around a helical “cochlea” – the part of the ear that senses sound – which can connect to electrodes. The current system receives radio waves, but McAlpine said the research team plans to incorporate other materials, such as pressure-sensitive electronic sensors, to enable the

ear to register acoustic sounds. Although McAlpine cautions that further work and extensive testing would need to be done before the technology could be used on a patient, he said the ear in principle could be used to restore or enhance human hearing. He said electrical signals produced by the ear could be connected to a patient’s nerve endings, similar to a hearing aid. –JS

## FBI ‘TRAPDOOR’ FOR CYBER-SLEUTHING POSES HIGH RISK, FELTEN SAYS

Responding this spring to an FBI proposal for new wiretapping technology, Edward Felten and a group of computer-security experts warned that the plan posed far more risks than benefits.

Felten, a professor of computer science and public affairs, said the FBI plan calls for “trapdoors” to be installed in the software of computers and phones that use certain communications technologies that law enforcement currently has difficulty monitoring. The trapdoors would allow law enforcement to secretly monitor communications in ways that are currently not available.

The proposal is distinct from recently disclosed surveillance programs such as PRISM. PRISM, run by the National Security Agency, primarily examines bulk data about standard electronic communications, while the FBI proposal would target encrypted communications that cannot be practically intercepted.

The FBI wants to prevent criminals from evading its oversight, but Felten, who is also the director of Princeton’s Center for Information Technology Policy, said the plan would

introduce dangerous security vulnerabilities into systems without adding much strength to federal agents’ surveillance capabilities.

In an argument delivered in a May 17 position paper, the security experts warned that creating a surveillance trapdoor would make phones and computers vulnerable to attack from hackers and other malicious groups. The stealthy design needed for a successful governmental trapdoor would also make it difficult for users to tell whether they had been hacked, and it would add to the complexity of the communications software.

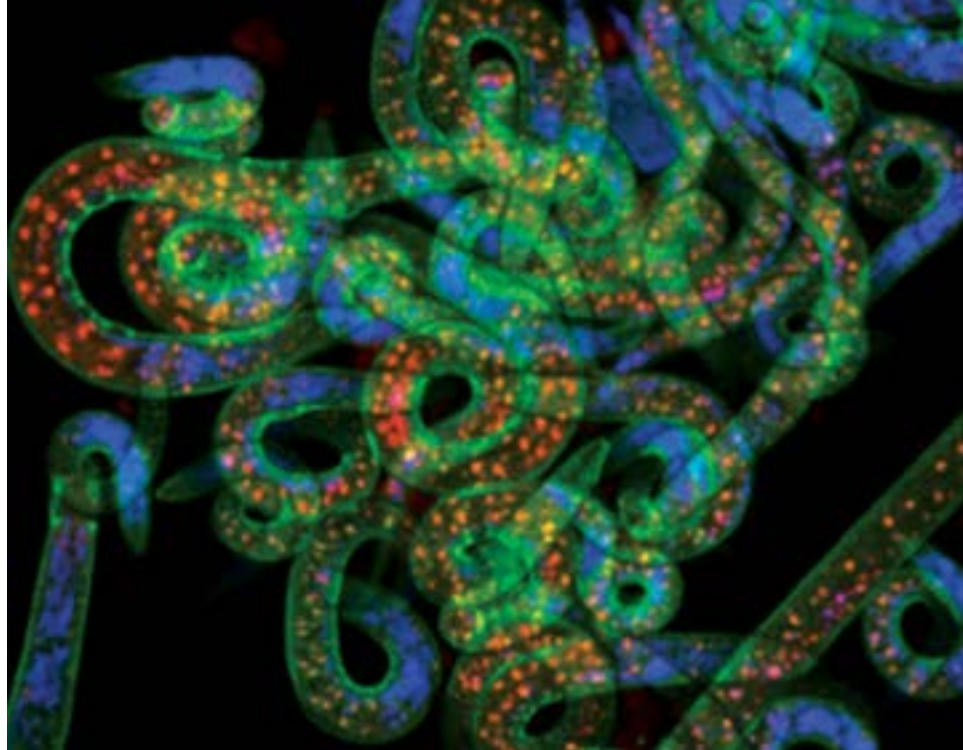
Felten also said the plan probably would not work as a surveillance tool. The group pointed out that users would be able to modify their systems’ software to remove any surveillance tools, thus defeating the intended purpose of the trapdoors.

“The bottom line is that harms that would result from the FBI’s plan vastly outweigh any benefits,” Felten wrote on his blog, *Freedom to Tinker*. “The cybersecurity problem is bad enough as it is. Let’s not make it any worse.” –JS



Edward Felten directs Princeton’s Center for Information Technology Policy.





**ART OF SCIENCE:  
CELEBRATING THE UNPREDICTABILITY OF CREATIVITY**

This image, titled “Medusa,” won third place in the People’s Choice category of Princeton’s Art of Science competition. Graduate student Jamie Barr and Clifford Brangwynne, assistant professor of chemical and biological engineering, wrote that the “bright clump of worms resembles the wild snakes that surrounded the head of the mythological monster Medusa. But unlike Medusa’s snakes, these worms became sticky and connected during an experiment designed to understand how molecules determine cell and organism size.”

Princeton University’s 2013 Art of Science exhibition opened May 10 with a display of 43 images of artistic merit created during the course of scientific research. The works were chosen from 170 images submitted from 24 departments across campus.

“Like art, science and engineering are deeply creative activities,” said Pablo Debenedetti, the former vice dean of engineering and now the University dean for research, who served as master of ceremonies at an opening reception that drew 200 people to Princeton’s Friend Center.

“Also like art, science and engineering at their very best are highly unpredictable in their outcomes,” Debenedetti said. “The Art of Science exhibit celebrates the beauty of unpredictability and the unpredictability of beauty.”

Adam Finkelstein, professor of computer science and one of the exhibition organizers, said that Art of Science spurs debate among artists about the nature of art while opening scientists to new ways of “seeing” their own research. “At the same time,” Finkelstein said,

“this striking imagery serves as a democratic window through which non-experts can appreciate the thrill of scientific discovery.”

The juried prize winners were selected by a distinguished panel of judges: David Dobkin, dean of the faculty; Emmet Gowin, professor emeritus of visual arts; Paul Muldoon, the Howard G.B. Clark ’21 University Professor in the Humanities; Shirley M. Tilghman, molecular biologist and now president emerita; and Katherine Bussard, the Peter C. Bunnell Curator of Photography at the Princeton University Art Museum. Attendees at the exhibit opening also selected People’s Choice winners.

To see the winning entries and all 43 images, visit [www.princeton.edu/artofscience](http://www.princeton.edu/artofscience).

Art of Science 2013 was sponsored by the David A. Gardner ’69 Fund in the Council of the Humanities, the Princeton Plasma Physics Laboratory and the School of Engineering and Applied Science. It also was supported by 15 other departments, centers and programs at Princeton. —Teresa Riordan

# The EXTENDED CLASSROOM

The timeless rite of professor and students gathering to pass along and debate knowledge remains at the core of the Princeton experience. Yet the classroom is far from static. The following pages offer a range of recent news illustrating the dynamic flow of ideas into and out of classes, and even the changing nature of the classroom itself, from virtual communities of learners across the Internet to projects rooted in communities that they serve.



# STUDENT WORK FUELS EFFORT to make smartphones SMARTER

by John Sullivan

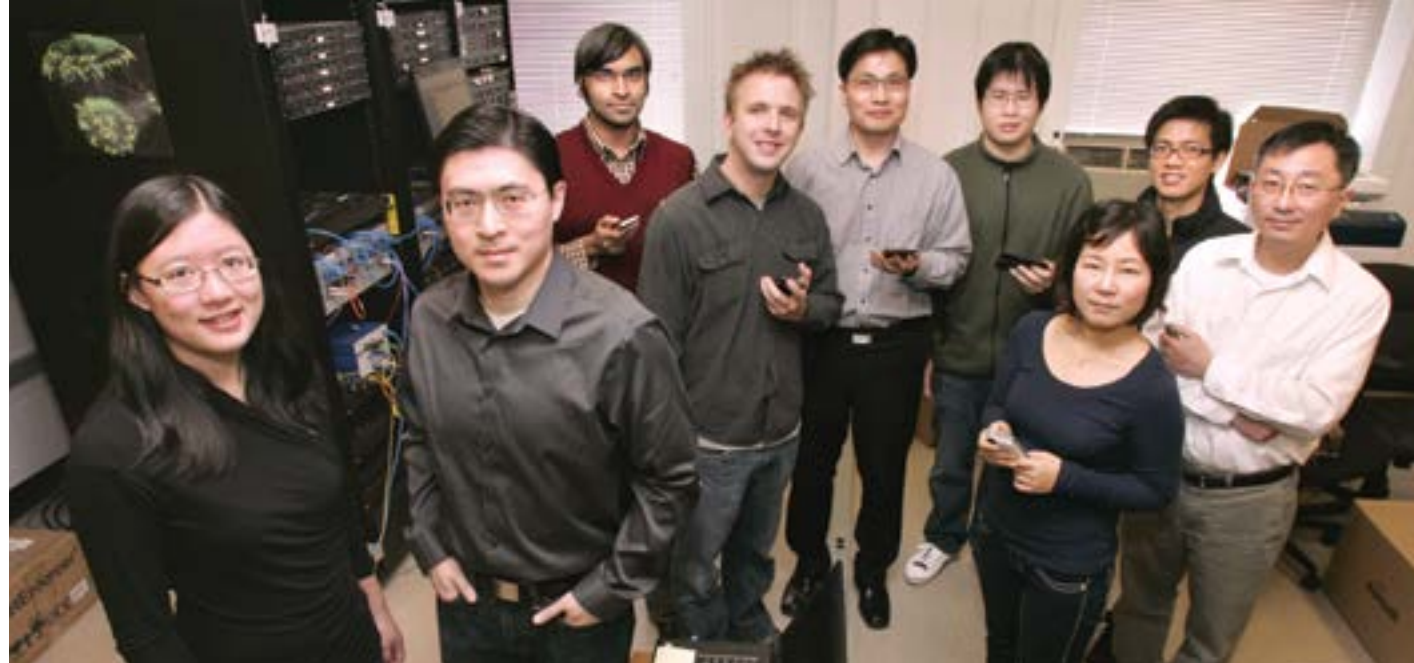


Photo by Frank Wojciechowski

## Most term papers are evaluated by one or two people, but Carlee Joe-Wong's will be checked by hundreds.

The paper, completed in 2010 as part of a junior-year independent project at Princeton University, has evolved into a research project involving wireless operators like AT&T and 1,000 participating wireless customers with mobile data plans. Along the way, it has also led to the development of a popular free app.

Titled "Time-Dependent Broadband Pricing: Mathematical Models and Optimization Solutions," Joe-Wong's work explored ways that wireless companies could reduce congestion by varying their prices depending on the time of day. The mathematics behind her analysis was so innovative that her professor, Mung Chiang, suggested that she continue to pursue the approach with his laboratory team.

"I had no idea it would turn into a real trial or anything of the sort," said Joe-Wong, who is now a doctoral student in applied and computational mathematics at Princeton. "I was hoping it could be published as a research paper, but I didn't expect it to go further than that."

It is the kind of project that Princeton's EDGE Laboratory was put together in 2009 to pursue. Chiang, the Arthur LeGrand Doty

Professor of Electrical Engineering and the lab's director, said the lab applies mathematical research to propose fundamental improvements in communication networks, bridging theory and practice.

The current problem the project is grappling with is driven by the increasing congestion on wireless networks caused by the proliferation of wireless data services. Wireless cloud services, video and apps are gobbling up bandwidth faster than wireless operators can expand their capacities, Chiang said.

Soon after Joe-Wong began working with the EDGE Lab in early 2010, Chiang suggested adapting the paper's thesis for a real-world trial. Sangtae Ha, a former associate research scholar in electrical engineering now an assistant professor at the University of Minnesota, began developing the trial plan and infrastructure for the work, and Soumya Sen, a former postdoctoral research associate who is now an assistant professor of information and decision science at the University of Minnesota, joined the team soon afterwards. The project's team and scope expanded further in the past year.

The original work focused on shifting traffic to off-peak times by using incentives to encourage consumers to access the network at low-congestion periods. To test this, Chiang's team recruited 50 members of the University community for a pricing experiment that began in the summer of 2011. Volunteers used the lab's time-dependent pricing system and the lab passed along the savings the participants achieved compared to their normal provider charges.

"We said we will pay your current Internet bills, and then we will charge you according to our time-dependent algorithm," Joe-Wong said.

### Tracking time and managing data

Time-dependent usage is not new in other sectors of society. In its simplest version, transit agencies charge riders less for travelling at off-peak hours and more during rush hour. When mobile voice was charged based on a quota, telephone companies used time-dependent pricing by charging callers less to make calls at night or on weekends.

Joe-Wong said that relatively simple techniques, such as creating low-cost "off-peak periods," do not work well for mobile data, because data consumption behavior is both more complex to track and easier to shift than commuting or phone-call patterns. The goal of

the effort is to minimize the stress on an overburdened system and allow wireless operators to reduce cost while providing choices to consumers. The trick is to balance the pricing to move just enough people to less congested times to smooth out the system.

This is where the mathematical sophistication comes into play. Chiang's team constructs approaches that can use data on consumers' past wireless usage to learn how time-dependent pricing affects customers' behavior. They use that analysis to evaluate and predict the most effective prices for balancing network use.

The team gained insights into how consumers use data through the Princeton trial. And they were able to create algorithms to learn changes in behavior and adjust pricing accordingly. The results were published at a major networking conference, ACM SIGCOMM, in 2012. The overall project has produced more than five publications at top-tier venues, and an edited volume contributed to by many research groups in academia and industry.

"We organized the first smart data pricing (SDP) industry forum at Princeton with about 20 leading U.S. companies in the wireless industry, both carriers and manufacturers, who talked about what the industry collectively could do," Chiang said. For this year, the EDGE Lab and companies such as Alcatel-Lucent, Cisco and Qualcomm are organizing a series of SDP industry forums around the world, designed to engage hundreds of industry engineers.

One of the outgrowths of that initial forum is the upcoming real-user trial between the EDGE Lab and AT&T in which 1,000 customers will be given data pricing that depends on the congestion condition. For the trial, scheduled to start this summer, the team will place a pricing indicator on the customers' phones next to the battery indicator that will allow participants to quickly monitor the cost of their data usage.

"The work at the lab has the ability to shape the industry," Chiang said. "We have smartphones. This is smart data." **E**

A project Carlee Joe-Wong (front left) pursued as a Princeton junior has grown into a major research initiative for Mung Chiang (at Joe-Wong's right), a professor of electrical engineering, and members of his Edge Lab.



## Study casts light on **DEADLY IMMUNE RESPONSE**

by Anna Azvolinsky



Photo by Frank Wojciechowski

### It was the near-death experiences of six men who volunteered to test an experimental drug that caught the attention of Hao Hong Yiu.

The chemical engineering major was taking a course on the other side of campus, in the Department of Ecology and Evolutionary Biology, where Assistant Professor Andrea Graham was teaching an immunology class. Graham told the class about a clinical trial gone bad – six healthy men checked into a London hospital to test the safety of a drug it was hoped would treat leukemia, but suffered near-fatal immune reactions after a single dose.

Yiu saw an opportunity to extend the classroom discussion of the incident to an independent research project. He sought out engineering faculty member Robert Stengel (Ph.D. '68), professor of mechanical and aerospace engineering, to help guide his mathematical analysis.

Stengel and Graham had not previously met, but Yiu and the two faculty members began a close collaboration that resulted in not only his senior thesis, but also a peer-reviewed paper published recently in the journal *PLoS One* with Yiu as the first author.

Using a database of measurements from the clinical trial the researchers created an unprecedentedly clear model for how immune signals called cytokines interact with each other. The work sheds light on a potentially deadly overreaction of the immune system known as a “cytokine storm.”

“We have developed tools that could ultimately reveal how and when clinicians might

intervene to prevent these dangerous inflammatory reactions,” Graham said.

The researchers said the collaboration highlights how an interdisciplinary approach by an ecologist and an engineer, bridged by a talented undergraduate, can result in a novel insight into a biological process — an insight that an immunologist working alone might have missed.

As an aerospace engineer, Stengel designed the manual controls for the Apollo moon missions, but became interested in applying his mathematical skills to biological problems 10 years ago. “The equations are just like those for planes and rockets, they just mean different things,” Stengel said. “What we do for calculating how much fuel it takes to put a satellite in orbit, we can use to understand the minimum amount of drug to use to kill a pathogen.”

Yiu, who graduated in 2010, said he found the intersection of engineering and biology exciting. “It was really interesting to see Professor Stengel’s and Professor Graham’s expertise come together to analyze this biological event,” Yiu said.

Graham said that beyond cytokines, the model also provides a general way to analyze biological data collected over time. “It seems to me that this is only the beginning,” Graham said. “With these quantitative tools applied to larger and better cytokines and other data sets, imagine the immunological insights that would emerge.” **E**



### Many classes involve field trips to museums; in this class, students created their own exhibit – with a field trip to Germany along the way.

Sigrid Adriaenssens and Branko Glišić, both assistant professors of civil and environmental engineering, co-taught a course on German thin-shell structures in the fall of 2012 that resulted in the exhibit, “Evolution of German Shells: Efficiency in Form,” now open to the public at Princeton’s Friend Center Engineering Library.

The undergraduate course, “A Social and Multi-Dimensional Exploration of Structures,” included a week-long visit to Germany, where students visited landmark shell structures and met architects and engineers involved in thin-shell construction. Germany was the birthplace of modern shell architecture in the 1920s and also where shell engineering is still the most advanced in the 21st century.



Watch the video at <http://www.princeton.edu/engineering/video/player/?id=10352> or scan the QR code on the right to watch on your smart device.



“In engineering, students usually don’t go on field trips but in other disciplines such as art and architecture, students are encouraged to go see the works of, for example, Monet or Le Corbusier,” Adriaenssens said.

Both Adriaenssens and Glišić consider the field trip to have been a cornerstone of the class. “The goal of the Germany trip was to expose the students to real-life settings,” Glišić said.

Adriaenssens said that another key goal of the trip was to meet with the people who designed many of the buildings they visited. “Actually going to offices and seeing what engineers and architects do during the course of a work day was very revealing for our students,” she said.

The original shell structures, inspired by forms found in nature such as eggshells, were made of concrete. However, engineers and architects today employ other materials such as wood and plastic or steel and glass.

Following their field trip to Germany, the students created models of the structures they studied using different techniques. The students also created short documentaries about five different structures: Balz House, Groetzingen Theater, Leipzig Markthalle, Mannheim Multihalle, and the Museum of Hamburg History. Those films can be viewed at <http://shells.princeton.edu/FGrotz.html>. **E**

## Class on **STRUCTURAL ART** AND ENGINEERING yields new **NEW EXHIBIT**

by Teresa Riordan

Branko Glišić (top left), assistant professor of civil and environmental engineering, and students take a break during a field trip to Germany for a recent class.



# STRONG VISION and WORD-OF- MOUTH DRIVE EXPONENTIAL GROWTH for CS COURSE

by John Sullivan

Photo of Vivek Pai and students by Frank Wojciechowski. All other photos by Bentley Drezner.



The course “General Computer Science” is known for the high level of support it offers students through precepts and study sessions led by faculty members such as Associate Professor Vivek Pai (at right in lower left photo) and Lecturer Donna Gabai (at right in lower right photo).

## Ryan McCarty is a music major, but after his roommate raved about Princeton’s introductory computer science class, he decided to try it himself. McCarty has now used the Java programming skills that he learned in class to create a musical composition program for his junior-year project.

“Now, my other roommate is taking it,” McCarty said. “He is a politics major.”

Computer science is not just for scientists anymore. In the past several years, the University’s basic computer course, “General Computer Science,” has seen its enrollment skyrocket from 131 in 2004 to the current level of 648. (Those numbers do not include students from Princeton’s Integrated Science course, who take “General Computer Science” for half a semester.) The course is now one of the most popular at Princeton. Much of that increase has come from students outside of the engineering school.

“When we started this, the idea was that there ought to be a course for any student at the University who wanted to learn some computer science,” said Robert Sedgewick, the William O. Baker \*39 Professor in Computer Science. “This is a course for everyone.”

When Sedgewick started the course nearly 20 years ago, the vast majority of computer science courses either focused on specific fields, such as physics or engineering, or they dealt with individual programming languages such as C. It was Sedgewick’s belief that there

were certain core principles of computer science and that beginning students could use a single programming language to obtain a strong foundation in these areas.

Kevin Wayne, the Phillip Y. Goldman ‘86 Senior Lecturer in Computer Science and Sedgewick’s colleague and co-author of the class’s textbook, said the idea was to teach students to view computer programming as a tool to solve problems rather than as an isolated topic.

“We teach a good amount of programming but the goal is not to learn a computer language, but to learn to solve problems and understand computation,” Wayne said.

The instructors use Java as the class language because it is a common program and shares features with other languages. But Wayne said the choice of language was really secondary; the course focuses on creating a general structure of a program and on learning how to conceptualize a program to solve a complex task.

Jean Wang, a sophomore, said the course, which is a requirement in the engineering school, convinced several of her friends to ma-

join in computer science. Although she originally thought to major in operations research and financial engineering, Wang said she is now considering computer science as well.

“The problem sets in the course were very challenging but they were manageable,” she said. “They made you realize the different ways you could implement the skills that you have learned.”

Sedgewick said he is pleased that the course leads many students to a greater interest in computer science, but he feels strongly that computers are so integral to modern society that a basic understanding of the field should be a part of any education. In the introduction to their textbook, “Introduction to Programming in Java,” Sedgewick and Wayne say that in the modern world computer science cannot be left to specialists.

“The basis for education in the last millennium was reading, writing and arithmetic; now it is reading, writing and computing,” they write.

Sedgewick’s approach in “General Computer Science” has proven so popular at Princeton that professors at other universities, including Yale and the University of Pennsylvania, have created similar classes.

Benedict Brown, who earned his doctorate in computer science from Princeton in 2008, now teaches the introductory computer science course at Penn using the Princeton model. Brown, a former teaching assistant in “General Computer Science,” said when he first arrived at Penn, he suggested taking the same approach to basic computer science.

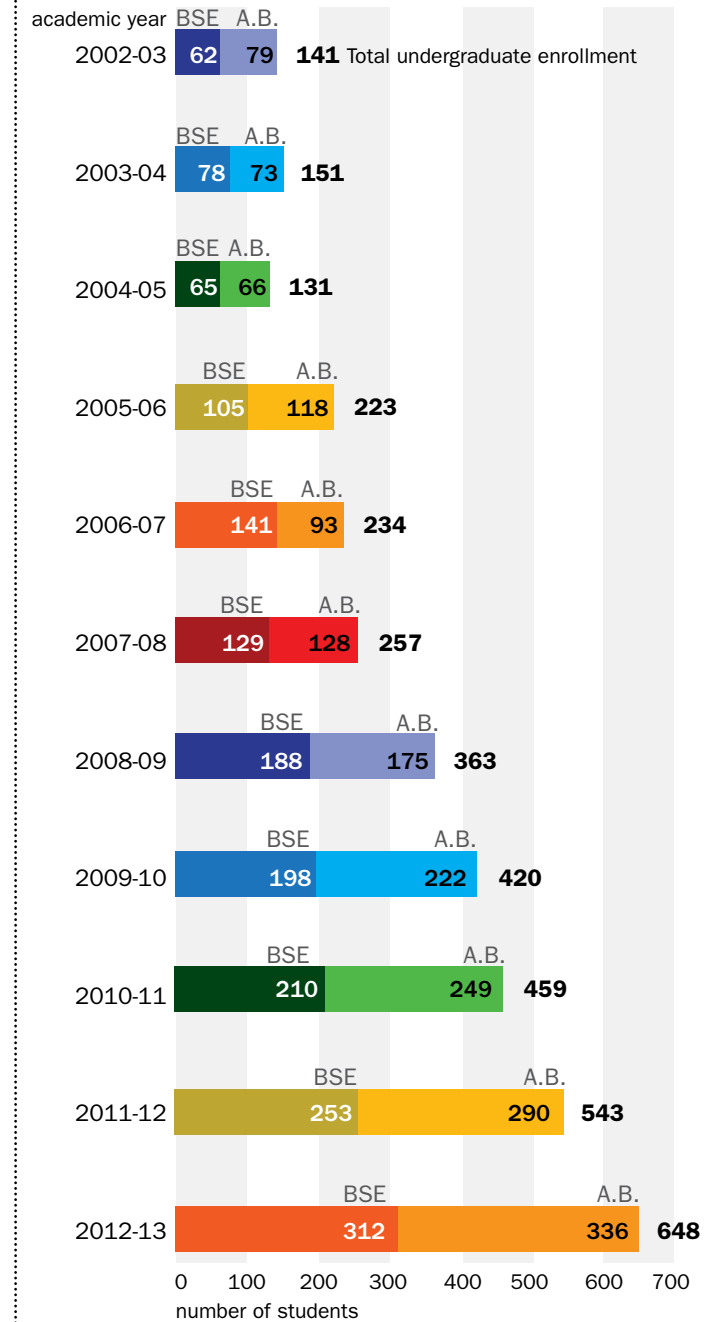
“They liked what they heard and thought it was a good model,” he said.

Brown said the course allows students to achieve a basic level of competence in programming and to reach a point at which “they know what they don’t know.”

“If they want to be computer scientists, they realize how much more there is to learn,” he said. “On the other hand, if they want to pursue it as a hobby or as an interest, they know enough to be successful.” **E**

## An algorithm for growth

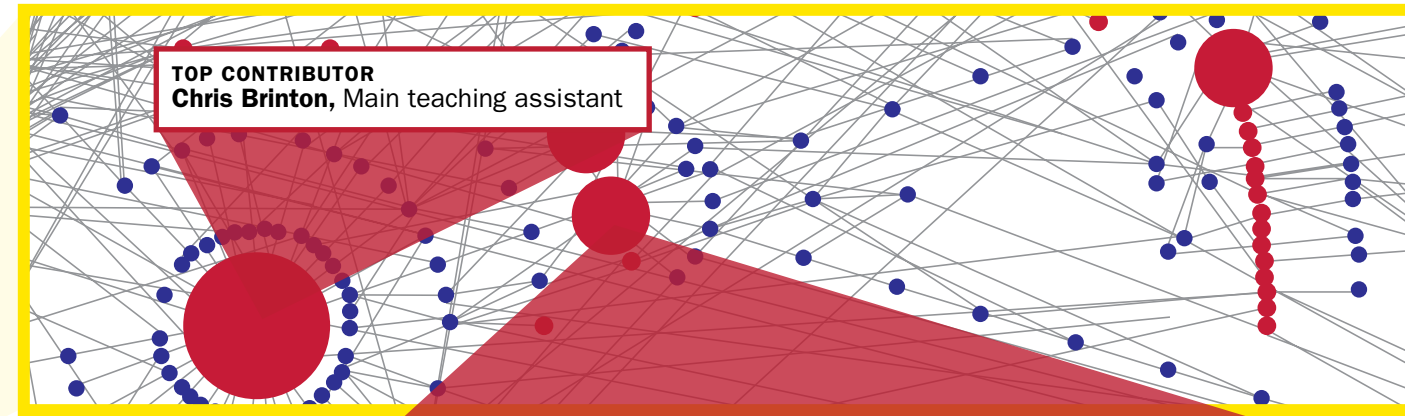
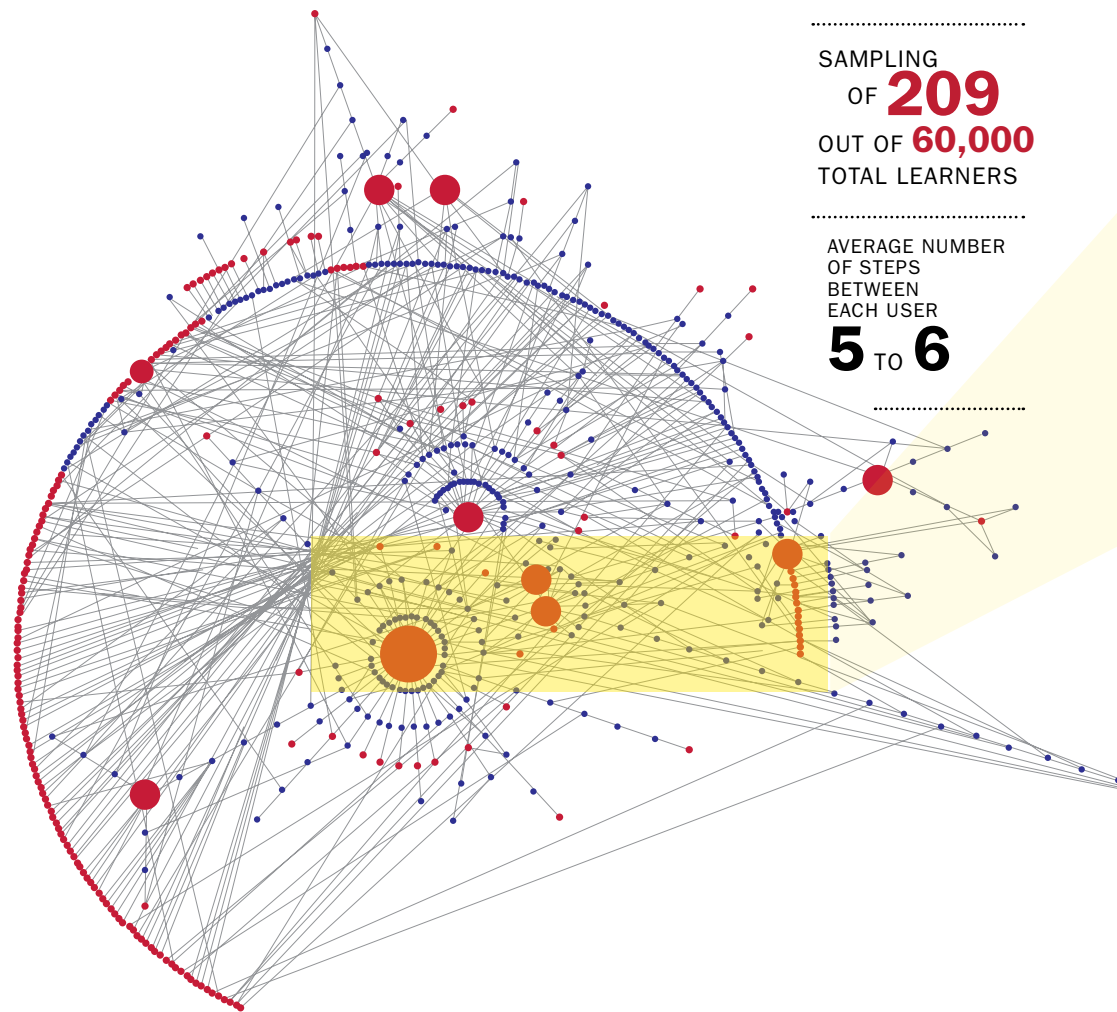
Undergraduate enrollment in “General Computer Science” has soared in recent years in engineering (BSE) and arts (A.B.) students. In addition to these enrollment numbers, about 40 students from the University’s Integrated Science curriculum take “General Computer Science” for half the fall semester.





# CLASSROOMS *without* BORDERS

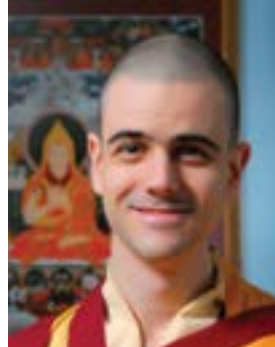
by Teresa Riordan



- TOP 10 CONCEPTS**
- Highest bidder
  - Uniform distribution
  - Best network topology
  - Baseline predictor
  - Target SIR (Signal-to-Interference Ratio)
  - Ad spaces
  - Power and speaking volume
  - Dominant strategy
  - Cell tower technology
  - Beta predictor

**THE MOST POPULAR POST**

**Kelsang Atisha** contributed the most popular post when he uploaded a spreadsheet that could calculate power levels needed when multiple users try to connect to a cell tower. A Buddhist monk at Manjushri Kadampa Meditation Centre in Ulverston, England, Atisha called the course a tour de force in education: "It helped me understand how the Internet is based on carefully conceived mathematical and computer science breakthroughs and to understand the role universities play in technological developments."



NUMBER OF VIEWS **48,000** NUMBER OF VOTES RECEIVED **59**

**Online learning is hot these days, and Princeton Engineering faculty are at the leading edge of the trend.**

Since the summer of 2012, Princeton University has been offering, on an experimental basis, free online classes through Coursera, an enterprise started by two Stanford professors. Massive online open courses (MOOCs) are a recent phenomenon but learners worldwide have had access to free content from Princeton Engineering lecture libraries and class websites for years. Some highlights and history:

**Mung Chiang**  
**Electrical Engineering**  
"Networks Illustrated: Principles Without Calculus" (Coursera)  
"Networks: Friends, Money and Bytes" (Coursera)

A well-known researcher in the field of networks and the Arthur LeGrand Doty Professor of Electrical Engineering, Mung Chiang attributes his passion for offering free online courses to the importance education played for him in the journey from poverty in his native

China to earning three degrees from Stanford. Chiang's take on Princeton's online education venture? "This is living out the motto of this University. Education is the main service we can provide to all nations. But this is an ongoing experiment. We've got much more work to do in the science of learning in an asynchronous and online environment before we can realize the full potential of this new model of teaching and learning. At the heart of the pedagogical challenge is this question: Can teaching be both in massive scale and individually effective at the same time?" ▶

## Connecting the dots

Juniors **Ankit Buddhiraju** and **Kevin Lin** analyzed conversation threads among a small subset of learners in Mung Chiang's Coursera class, "Friends, Money and Bytes," to develop an online recommendation system that helps instructors organize topics and match learners to other learners who have similar interests or who might be able to help with assignments. The blue dots here represent key concepts discussed during the online lectures (those closest to the middle are the most discussed). The red dots represent different online learners (the larger dots indicate those who posted most frequently). The large center red dot is the teaching assistant in charge of online discussions. This system is the subject of Buddhiraju and Lin's junior independent work as well as the focus of an academic paper they are writing in collaboration with graduate students from Chiang's EDGE Lab.



Continued from page 15

**Robert Stengel** (Ph.D. '68)  
**Mechanical and Aerospace Engineering**

*Optimal Control and Estimation  
Robotics and Intelligent Systems  
Aircraft Flight Dynamics  
Space System Design*

Robert Stengel, a professor of mechanical and aerospace engineering, and a leading figure in the field of flight and director of the Program in Robotics and Intelligent Systems, has been offering online lecture slides and links to virtual reference books from his Princeton courses since 2007. His website receives about 2.5 million hits a year from around the world, most of them to download lecture slides, which he updates every year.

**Robert Sedgewick and Kevin Wayne**  
**Computer Science**

*Algorithms (Coursera)  
Analytic Combinatorics (Coursera)*

Robert Sedgewick, the William O. Baker \*39 Professor in Computer Science, coauthor of best-selling introductory textbooks in computer science, notes that his classes have long had a global reach, thanks to innovative course-related materials he and Phillip Y. Goldman '86 Senior Lecturer Kevin Wayne maintain online. In 2012, their websites had 1.5 million unique visitors. More than 250,000 people signed up for their Coursera classes during the first year. Sedgewick says the online video lecture system is a boon to Princeton undergraduates, more than half of whom – regardless of major – take one of his and Wayne’s computer science courses. “It provides powerful tools for preceptors, who have more time for personal interaction with students,” Sedgewick said.

**David Wentzlaff**  
**Electrical Engineering**

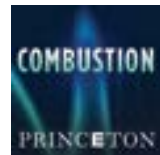
*Computer Architecture (Coursera)*

Assistant Professor of Electrical Engineering David Wentzlaff teaches an advanced course on computer architecture that unlike many Coursera classes, which appeal to the novice, requires a serious foundation in electrical engineering. During his first offering, 3,300 students watched all of the videos – more than 30 hours of lectures. Subsequently, Wentzlaff made the course content and lectures available outside of the actual class and now has about 30,000 active users. The Coursera class has benefited Princeton students in his on-campus Computer Architecture class, he said, by “battle-hardening” his teaching material and by making lecture videos available as supplementary material. **E**

**LECTURE LIBRARIES**

The School of Engineering has served up video lecture libraries on different topics for a half-dozen years.

Current libraries:



**Combustion**

A primer on the science of combustion from a summer

school lecture program organized by Princeton’s Combustion Energy Frontier Research Center (CEFR) and funded by the U.S. Department of Energy.



**Tall Buildings**

A collection of talks on skyscrapers sponsored by the

Department of Civil and Environmental Engineering. Includes interviews with three giants in the field of structural engineering as well as a lecture by legendary teacher David Billington (BSE '50).



**Engineering the Future**

A different faculty member explores a different

topic in each of these lectures. Topics range from cryptography to sustainable energy.

Watch these and other lectures: [www.princeton.edu/engineering/video](http://www.princeton.edu/engineering/video)

**A career in science has honed Mark Zondlo’s skills of observation and analysis, and last year, he decided to put those talents to a different use by starting a business.**

The technical part of his plan to market a portable greenhouse-gas sensor is based on scientific techniques that Zondlo, an assistant professor of civil and environmental engineering, and his co-researcher, Lei Tao, developed at Princeton over several years. But the business end is grounded in a new startup methodology that is now being used to teach Princeton undergraduates, among many other groups.

Called the Lean Launchpad, the method helps entrepreneurs start a company with a minimal amount of capital investment. The program, created by entrepreneur Steve Blank, relies heavily on collecting data such as customer preferences and possible markets.

James Hornthal (A.B. '76), the 2012 James Wei Visiting Professor in Entrepreneurship worked with Zondlo on his business and taught Launchpad to Princeton undergraduates in a course last year. Hornthal said the system is well suited to first-time entrepreneurs. “Undergraduates don’t come in with the accounting and financial skills that graduate students might have,” he said. “But I found them to be fearless, relentless. If you told them to talk to 12 customers, they would talk to 15.”

Hornthal is currently using the Launchpad methodology to advise students participating in the Keller Center’s eLab summer accelerator program.

Zondlo and his team came to the Launchpad system after the National Science Foundation created a program to help researchers bring their scientific breakthroughs to the marketplace. Called I-Corps, the NSF program sends selected research teams to an eight-week business boot camp to learn the basics.

“Basically, you learn to ask the right questions,” Zondlo said.

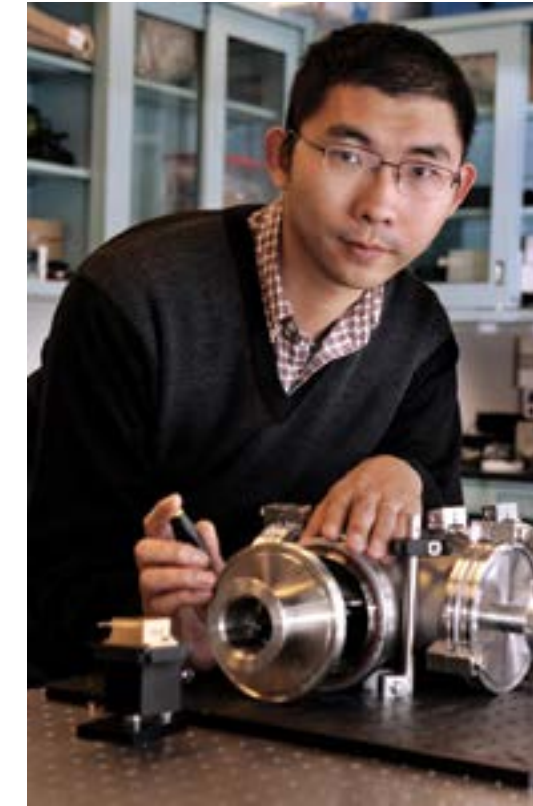


Photo by Frank Wojciechowski

**LAUNCHPAD**  
*helps blast*  
**NEW TEAMS**  
*into business*

by John Sullivan

The idea for a greenhouse-gas sensor began after Zondlo and Tao’s laboratory model became so popular in the research community that they began receiving requests from their fellow scientists. “A lot of people came up to me at conferences and asked if we had plans to sell them,” said Tao, a postdoctoral researcher in civil and environmental engineering.

Launchpad was critical in helping the team answer questions about how their ideas could translate into a successful business. In part, Launchpad does that by requiring the teams to follow an extensive checklist and carefully log information into a database for analysis.

“Launchpad really allows you to focus and learn where your weaknesses are,” Zondlo said. “It is extremely helpful in clarifying what you have to do to be successful.” **E**

Postdoctoral researcher Lei Tao, above, participated in a program called Lean Launchpad for starting businesses. Visiting professor James Hornthal, below, is using Launchpad to teach an undergraduate course and to advise students in Princeton’s eLab accelerator program.





# Course turns learning into **SERVICE PROJECTS**

by John Sullivan



**Cara de Freitas Bart's favorite part of class is not spent in the lecture hall or the lab, but in the field, helping to assemble a wind turbine or checking the wiring of a solar panel.**

"I really enjoy being able to design a power system that addresses a real-world need," said de Freitas Bart, a junior majoring in computer science.

Designing and building is central for students involved in EPICS – Engineering Projects in Community Service. The class, created by Princeton Engineering alumni Leah Jamieson (Ph.D. '77), now at Purdue University, and Ed Coyle (Ph.D. '82), now at Georgia Tech, allows teams of students to solve engineering problems in the real world. De Freitas Bart's team is working to create a transportable power station that assembles quickly at remote or disaster-stricken locations.

"It is a way to take the engineering skills I was learning in class and apply them to a service project," she said.

Catherine Peters, one of two professors supervising the project, called Power-in-a-Box, said EPICS balances two important goals.

"One is engineering design and construction and all that goes along with it," said Peters, a professor of civil and environmental engineering. "The other is addressing a need in a community and quantifying the impact of the technology. It is enormously challenging to do both."

The power project, which packs a wind turbine and solar panels inside a shipping container, has already made strides toward both goals. In 2012, the project won a \$90,000 grant as part of a national competition run by the U.S. Environmental Protection Agency. The students are now performing field tests and working on improving the original model.

Photos by Frank Wojciechowski



Undergraduate students Lynn Nehme '15 and Theodore Eyster '13 work with Ismaiel Yakub (Ph.D. '12), a lecturer in mechanical and aerospace engineering, on the frame for a "green roof" for their class's modular housing structure.

In another section, Ismaiel Yakub (Ph.D. '12), a lecturer in mechanical and aerospace engineering, led a team last academic year that worked to create modular housing units that could be quickly deployed to disaster areas. In addition to designing the housing, the team worked on a sustainable system to provide water and manage waste from the units.

Michael Littman, a professor of mechanical and aerospace engineering, leads several other teams involved in a range of projects from restoring an antique player piano to building a working replica of a historic electromagnet. The original electromagnet was used in 1835 by Professor Joseph Henry to lift weights in excess of 3,000 pounds.

These projects are for teaching science and engineering in local schools and for public exhibition.

The newest EPICS project, an easily manufactured water pump, was proposed by a group of students led by engineering undergraduates Yan Wu and David Newill-Smith. The team plans to design a pump that uses a type of magnetic switch to drive a piston. If it works, the pump should prove to be easier to manufacture and maintain than a classic rotary pump.

"It's easier to make, but it's harder to design," Newill-Smith said. "That is the challenge for us." **E**



# From a BIG IDEA and a single course, ENTREPRENEURIAL CULTURE GROWS

by John Sullivan

After 16 years of teaching at Princeton, Ed Zschau bowed out with a song.

In 16 years as a visiting professor at Princeton, Ed Zschau taught his students that entrepreneurship was not just about starting companies but “about changing the world for the better.”



Photo by Frank Wojciechowski

Ed Zschau (A.B. '61), who transitioned this spring from a visiting professorship to a post as a senior researcher at the engineering school, wrapped up his final “High Tech Entrepreneur” course with his version of “My Way.” The song is a call for his students to pursue their own paths after Princeton, but it also reflects the change that Zschau and his colleagues helped bring to the engineering school itself.

When then-Dean James Wei first asked him to fill a temporary slot – in 1997 – the school had no classes designed to assist young engineers with starting their own businesses. Now, the engineering school’s Keller Center offers a number of courses dedicated to entrepreneurship, as well as competitions, internships and the eLab startup accelerator. The offerings are not only open to engineers; students from around the University frequently take the classes and participate in other events.

“Jim’s original vision, and the work of colleagues like Ed and Stu Schwartz, have made all this possible,” said H. Vincent Poor (Ph.D. '77), the dean of the engineering school. “What began as a single course has grown into an entire program that introduces

students, and faculty, to entrepreneurship both as a possible career and as a way to approach their professional goals.”

When Wei originally decided to expand the engineering school’s curriculum to include more business-oriented classes, he viewed it as a practical means of achieving a broader mission.

“It’s not just about starting companies,” Zschau said. “It’s about innovation; about economic growth, creating jobs. It’s about changing the world for the better.”

It started with a meeting after a reunion weekend when Zschau, a member of the Class of 1961, sat down with Wei and several faculty members to talk about ideas for expanding the school’s curriculum. Then a professor at Harvard Business School, Zschau offered a unique perspective with a resume including several business startups, two terms in Congress and academic positions at Harvard and Stanford.

The meeting went well. “It was a confluence of ideas and events,” Zschau recalled. Wei, now the Pomeroy and Betty Perry Smith Professor in Engineering, Emeritus, had been working to increase the school’s focus on the

practical applications for engineering innovations, and had recently appointed Norman Augustine (BSE '57, MSE '59), the former chairman of Lockheed Martin Corp., as a visiting professor to teach students about engineering in the corporate world.

“I thought we ought to broaden the education of students to include how science leads to applications that help people to have better lives,” Wei recalled recently.

Wei said visiting professors, such as Augustine and Zschau, presented a way of introducing new ideas into the school. Stuart Schwartz, then-chairman of electrical engineering, was eager to appoint Zschau to his department, Wei recalled.

“You have great people who you want to have an influence on the faculty or the students,” Wei said. “Sometimes they are temporary; sometimes they will stay for a long time. The thing is to get started.”

Wei said that Zschau wanted to start teaching immediately, even though the academic calendar had already been set for the year and it was too late to add his course to the

official listings. They decided to send out an email announcing the class and invite anyone interested to report for the first session.

“Eighty-five students showed up for the first day of class, and we only had 45 chairs,” Zschau said.

Since then, students were selected based on written applications. It has remained popular – the most recent offering was originally limited to 60 students but Zschau allowed 68 to enroll. Zschau keeps in touch with many of his students, and he estimates that of the more than 1,700 who took the course, about 300 have been engaged in entrepreneurial enterprises over the years.

“The most profound impact Ed and the class had was to make success in a startup company actually seem possible in a way that no other experience at Princeton could,” said Darren Hammell (BSE '01), a co-founder of Princeton Power Systems, a manufacturer of advanced electronics for power systems. “Ed once described an entrepreneur as ‘someone who is trying to change the world using resources that they don’t control.’” ▶

**VISITOR: FAITH MORRISON**, *William R. Kenan, Jr. Visiting Professor for Distinguished Teaching of Chemical and Biological Engineering and the Keller Center for Innovation in Engineering Education*



Photo by Julie Gereck-Sefta

Faith Morrison (left) has helped the engineering school refine its program in laboratory safety during her stay as a visiting professor.

It has been a busy year for Faith Morrison (BSE '83).

Morrison, a professor of chemical engineering at Michigan Technological University, began her visiting year at Princeton by teaching a course in polymer rheology (the study of how

matter flows). Along the way, she produced an episode on the subject for her YouTube channel with her co-instructor Rodney Priestley, an assistant professor of chemical engineering.

She also helped update the curriculum for the chemical engineering core lab, incorporating recent industry procedures for process safety. Morrison, whose work at Michigan Tech has focused on the topic, said students are well versed in laboratory safety, but also need to “get a good understanding of safety culture and how it works in industry.”

Morrison also finished her book, “An Introduction to Fluid Mechanics,” and attended the 30th reunion of her class at Princeton.

“It’s been busy,” she said, “but very enjoyable.”



**VISITOR:  
DANIEL GIAMMAR,**

*William R. Kenan, Jr. Visiting Professor for Distinguished Teaching of Civil and Environmental Engineering and the Andlinger Center for Energy and the Environment*



Photo by Denise Applewhite



Photo courtesy of Daniel Giammar

Students (top) tour the Princeton University cogeneration plant as part of their course on the connections between energy and water.

Often analysts take a narrow view of energy sources, focusing on the carbon efficiency of nuclear power or the availability of wind. Daniel Giammar, a visiting professor from Washington University in St. Louis, is spending his time at Princeton trying to broaden that perspective by examining the impacts of energy sources on a much wider scale.

A specialist in water quality and water treatment, Giammar spent the fall semester assisting Princeton's Sankaran Sundaresan and Eric Larson teach their course on the "energy-water nexus." In the spring, he developed a new course on the environmental implications of energy technologies.

"Princeton has quite a few courses focused on energy, mostly from the perspective of energy technology or energy policy," he said. "The idea of looking at energy as a cycle, both upstream and downstream, fills a niche."

**VISITOR: JOEL REIDENBERG,** *Microsoft Visiting Professor of Information Technology Policy*



Photo courtesy of Joel Reidenberg

Joel Reidenberg

An expert in the laws that govern the often fractious intersection of privacy and technology, Joel Reidenberg's contribution to Princeton's Center for Information and Technology Policy could not be timelier.

"The whole firestorm over the National Security Administration's (NSA) data access is a current event," said Reidenberg, who will join the faculty as a visiting professor in the fall. "The deeper issue is what does the law allow, and what are the policy rationales for access to citizens' personal information."

*Continued from page 21*

Hammell, who started his company just before graduating from Princeton in 2001, credits Zschau with helping Princeton Power develop into a successful firm. Hammell frequently returns to Princeton as a guest lecturer.

"Ed made the less obvious career paths seem fun, and made sure that by the end of the semester we would at least consider a more entrepreneurial direction," he said.

Coming full circle, Zschau and a group of alumni helped endow the James Wei Visiting Professor in Entrepreneurship at the Keller Center. Since Julian Lang first filled the post in 2008, the professorship has seen a number of popular appointees including John Danner and Derek Lidow.

"Visitors add a great deal to what the school has to offer," said Sanjeev Kulkarni, director of the Keller Center and professor of electrical engineering. "They teach things that are outside the traditional departmental and curricular silos."

Kulkarni said the goal is to "educate students to have a significant and positive impact on the world."

"Entrepreneurship is one area in which we feel that students can have a significant impact," he said.

A professor of law and the director of the Center on Law and Information Policy at Fordham Law School, Reidenberg will be Princeton's first Microsoft Visiting Professor of Information Technology Policy, starting this fall. Besides his academic work, he has served as an adviser to the Federal Trade Commission and the European Union. At Princeton, Reidenberg plans to lecture and conduct scholarly research in the fall semester and teach a course in the spring.

Besides the visiting professorships, the Keller Center also sponsors the Princeton Entrepreneurial Internship Program, which places students at startup companies (which don't typically accept interns in the way large corporations do). The center also hosts the eLab accelerator, a 10-week summer program which offers office space, stipends and mentorship to teams of student entrepreneurs.

The Keller Center collaborates with the student-led entrepreneurship club and hosts numerous talks and panel discussions that bring active entrepreneurs and business leaders to campus. The Keller Center's annual Innovation Forum extends the entrepreneurial focus to faculty members and graduate students, who receive coaching from business leaders as they compete for business-development funds.

"These are things that they can't learn in a classroom and probably can't learn at a

traditional internship," Kulkarni said. He said that the engineering school has broadened its curriculum to offer a large range of opportunities to students. "Some of the most defining experiences cut across the line that defines inside the classroom and outside the classroom."

Those experiences might prove to be the most valuable legacy. In the end, the students' achievements will do far more to define the future of Princeton than anything else, Zschau said.

"The most exciting part of this whole experience for me over these past 16 years has been what I have learned from the graduates who have gone out and done great things," he said. "They have the ability not just to see the future, but to seize it." **E**



Photo by Denise Applewhite

Derek Lidow, the founder of the iSuppli corporate research firm, now shares his knowledge with students at Princeton.

much more perilous than starting one," said Lidow, whose long business career includes the successful startup iSuppli, a supplier of business information for the global electronics industry. "Getting a company to the point at which it is value-producing and self-sustaining

**VISITOR: DEREK LIDOW,** *Professional Specialist, Electrical Engineering and the Keller Center*

While most entrepreneurship classes focus on starting a new company, Derek Lidow spends most of his time discussing the next stage: the time between a new company's first steps and when it begins to run on its own.

"Growing an enterprise is actually much more perilous than starting one," said Lidow, whose long business career includes the successful startup iSuppli, a supplier of business information for the global electronics industry. "Getting a company to the point at which it is value-producing and self-sustaining

is something that maybe one in 10 entrepreneurs succeed in doing."

When Dean H. Vincent Poor asked him to come to Princeton as a visiting professor after the successful sale of iSuppli in 2010, Lidow, a 1973 alumnus, said he wanted to focus on that critical second stage of a new company's life. His highly popular course, "Entrepreneurial Leadership," is one of the Keller Center's offerings for students interested in a future career in business.

"I try to teach them something that will make them more successful," Lidow said. "If I can help people take their ideas – and they don't necessarily have to be a for-profit company – and create a tangible reality, that is about as fulfilling as it gets."



## RECENT FACULTY AWARDS

### CHEMICAL AND BIOLOGICAL ENGINEERING

#### Ilhan Aksay

Fellow, American Association for the Advancement of Science



Lynn Loo

#### Pablo Debenedetti

Institute Lecturer, American Institute of Chemical Engineers

#### Christodoulos Floudas

Fellow, Society for Industrial and Applied Mathematics

#### James Link (BSE '00)

Sloan Fellow

#### Lynn Loo (Ph.D. '01)

Fellow, American Physical Society



Rodney Priestley

#### Athanassios Panagiotopoulos

Fellow, American Association for the Advancement of Science

#### Rodney Priestley

PPG-DPOLY Polymer Lecture Exchange  
2013 Emerging Scholar, *Diverse* magazine

### CIVIL AND ENVIRONMENTAL ENGINEERING

#### Erik Vanmarcke

Distinguished Member, American Society of Civil Engineers

### COMPUTER SCIENCE

#### Moses Charikar

Paris Kanellakis Theory and Practice Award,  
Association for Computing Machinery



Moses Charikar

#### Zeev Dvir

Sloan Foundation Research Fellowship

#### Kai Li

SIGOPS Hall of Fame Award, Association for Computing Machinery

#### Jennifer Rexford (BSE '91)

Named to "Ten Cloud Trailblazers for 2013" by *GigaOM*

### ELECTRICAL ENGINEERING

#### Mung Chiang

PROSE award, Association of American Publishers  
Frederick Emmons Terman Award, American Society for Engineering Education

#### Hisashi Kobayashi (Ph.D. '67)

C&C Prize Group B Award, NEC Corp.

#### H. Vincent Poor (Ph.D. '77)

Corresponding Fellow, Royal Society of Edinburgh

### MECHANICAL AND AEROSPACE ENGINEERING

#### Philip Holmes

Inaugural Fellow, American Mathematical Society

#### Chung (Ed) Law

Fellow, American Association for the Advancement of Science

### OPERATIONS RESEARCH AND FINANCIAL ENGINEERING

#### Jianqing Fan

Pao-Lu Hsu Prize, International Chinese Statistical Association

#### William Massey (A.B. '77)

Inaugural Fellow, American Mathematical Society



William Massey

## TOP NATIONAL AWARD FOR YOUNG RESEARCHER GOES TO MUNG CHIANG

Mung Chiang, a professor of electrical engineering, was awarded the National Science Foundation's highest honor for young researchers, the Alan T. Waterman Award.

The Waterman Award is granted annually to one outstanding young researcher in science or engineering fields supported by the foundation. The award, open to researchers aged 35 and younger, provides a \$1 million grant to support further research. The award cites Chiang's "fundamental contributions to the analysis, design and performance optimization of wireless networks."

Chiang, who uses innovative mathematical analysis to simplify and strengthen the design of wireless networks, is the founder of Princeton's EDGE Laboratory, which works to bridge the gap between network theory and real-world applications.

Princeton University also recently honored Chiang by conferring him with the endowed title of Arthur LeGrand Doty Professor of Electrical Engineering.



Mung Chiang

## ENGINEERS ELECTED TO NATIONAL ACADEMIES



Edward Felten

Edward Felten, professor of computer science and public affairs, has been elected as a member of the National Academy of Engineering, the highest honor in the United States across all engineering disciplines.

Felten, who is the founding director of Princeton's Center for Information Technology Policy, was recognized for "contributions to the security of computer systems and for impact on public policy."

A nationally recognized authority on computer security and privacy, Felten and his co-researchers have produced critical analyses of electronic voting systems, digital copyright protection plans and the Secure Digital Music Initiative. Frequently, his reports have exposed security flaws and led to policy changes.



Jennifer Rexford

Felten served as chief technologist for the U.S. Federal Trade Commission from 2011 to 2012.

Naomi Leonard (BSE '85), the Edwin S. Wilsey Professor of Mechanical and Aerospace Engineering, and Jennifer Rexford (BSE '91), the Gordon Y.S. Wu Professor in Engineering and professor of computer science, have been named fellows of the American Academy of Arts and Sciences. Founded in 1780, the academy honors achievement in science, the arts, and civic and business leadership.

Leonard specializes in control theory and nonlinear dynamics. Her current research focuses on the feedback mechanisms of collective motion and collective decision-making in multi-agent systems with application to studying animal group dynamics and to designing mobile robotic sensor networks for environmental monitoring. Her work also explores the intersection of engineering and art. One project, Flock Logic, used designed feedback to develop choreographic tools for dance.

Rexford specializes in computer networking, with an emphasis on making future networks easier to design and manage. Her current research focuses on software-defined networking, a technique for enabling innovation through greater programmability inside the network.



Naomi Leonard



**'BIG GOALS' AND 'INFECTIOUS ENTHUSIASM' CITED IN TEACHING AWARDS**



Andrew Houck



Claire Gmachl



Michael McAlpine (left) and graduate student Manu Mannoor

Five members of the Engineering School faculty were honored this year for their accomplishments in teaching and mentoring students.

**Andrew Houck** (BSE '00), an associate professor of electrical engineering, received the President's Award for Distinguished Teaching. Houck was one of four faculty members who received the award at Commencement June 4.

Colleagues credited Houck for fueling interest in electrical engineering courses at the undergraduate and graduate levels. Under his oversight, the course "Introduction to Quantum Computing" has more than doubled in enrollment, drawing students from across the sciences and engineering. "Andrew's high-quality teaching and his infectious enthusiasm for the topic, which at times can be very technical, have made the course a major hit," noted a faculty member.

"When working with me, he has spent a lot of time teaching me how to think and be a good experimentalist, rather than just solving my problems," one graduate student said.

**Claire Gmachl**, the Eugene Higgins Professor of Electrical Engineering, was awarded the School of Engineering and Applied Science Distinguished Teaching Award. Since joining the Princeton faculty in 2003, Gmachl has developed several new courses, including an introductory optics class and the engineering school's graduate-level ethics research course.

In voicing support for her award nomination, colleagues cited Gmachl's innovative teaching methods and her dedication to her students. "The School of Engineering is blessed with many great teachers. What sets Claire apart is her amazing record of mentoring," one wrote. "She takes on the mentoring role with almost a missionary zeal."

Students recounted examples of Gmachl working late or making an extra effort to help them with their projects. "I wish to someday be as much of an inspiration to a peer of mine as she is to me," one said.

**Michael McAlpine**, an assistant professor of mechanical and aerospace engineering, received the University's Graduate Mentoring Award, which honors faculty for their support of graduate students' development as teachers, scholars and professionals. McAlpine, whose research focuses on combining electronic and biological materials, recently taught classes including an introduction to nanotechnology and mathematics in engineering.

"Professor McAlpine told me in our first meeting that he encourages us to pursue big goals," one student wrote. "To achieve a big goal, novelty is essential, and therefore the very first thing I learned from Professor McAlpine was creativity."

**Robert Sedgewick**, the William O. Baker \*39 Professor in Computer Science, and **Kevin Wayne**, the Phillip Y. Goldman '86 Senior Lecturer in Computer Science, were awarded the excellence in undergraduate teaching award by the Princeton chapter of Phi Beta Kappa. The two lead courses in algorithms and introductory computer science (see page 12). In the past academic year, Sedgewick and Wayne taught more than 250,000 students as part of the University's participation in the Coursera educational website (see page 14).

"Their hard work has paved the way for countless students to go from not knowing the first thing about computer science to being able to apply it and even making it the centerpiece of fulfilling professional lives," then-seniors Max Rabinovich '13 and Ilias Giechaskiel '13 wrote in their commendation.

**GRADUATING SENIORS HONORED FOR SCHOLARSHIP AND SERVICE**

At the Class Day ceremonies on June 3, engineers received a range of honors from the School of Engineering and Applied Science as well as from the University as a whole. The winners listed below were among the 237 recipients of the degree of bachelor of science in engineering in the Class of 2013.

**J. Rich Steers Award**

**Rory Loughran**  
Mechanical and Aerospace Engineering  
**Tessa Maurer**  
Civil and Environmental Engineering

**Jeffrey O. Kephart '80 Prize in Engineering Physics**

**Amaresh Sahu**  
Chemical and Biological Engineering

**Tau Beta Pi Prize**

**John Subosits**  
Mechanical and Aerospace Engineering  
**Jennifer Tang**  
Electrical Engineering

**Joseph Clifton Elgin Prize**

**Amy Ousterhout**  
Computer Science  
**Kaitlin Stouffer**  
Computer Science

**Allen Macy Dulles '51 Award**

**Kitan Akinosho**  
Operations Research and Financial Engineering

**Class Of 1916 Cup**

**Rory Loughran**  
Mechanical and Aerospace Engineering

**George J. Mueller Award**

**Candace Button**  
Computer Science  
**Hannah Safford**  
Chemical and Biological Engineering

**Calvin Dodd MacCracken Senior Thesis/Project Award**

**Gregory Hughes**  
Mechanical and Aerospace Engineering  
**Hayk Martirosyan**  
Mechanical and Aerospace Engineering  
**Brendan O'Leary**  
Mechanical and Aerospace Engineering  
**Thomas Owlett Jr.**  
Mechanical and Aerospace Engineering  
**Christopher Payne**  
Electrical Engineering

**Lore Von Jaskowsky Memorial Prize**

**Kaitlin Stouffer**  
Computer Science  
**Peter Szerzo**  
Civil and Environmental Engineering

**James Hayes-Edgar Palmer Prize in Engineering**

**Aman Sinha**  
Mechanical and Aerospace Engineering



Photos by Frank Wojciechowski

Clockwise from top: Dean H. Vincent Poor congratulates Kaitlin Stouffer; Aman Sinha; Thomas Owlett Jr., Christopher Payne and Hayk Martirosyan; Peter Szerzo; Poor and Amaresh Sahu; Poor and Jennifer Tang; Amy Ousterhout and Stouffer.





Photos by Denise Applewhite



ENGINEERS WIN  
INTERNATIONAL FELLOWSHIPS

**A number of members of the engineering school's Class of 2013 won highly competitive scholarships to support their continuing studies after graduation.**

**Among them:**

**AMAN SINHA**

Sinha, a mechanical and aerospace engineering major from Ivyland, Pa., was the valedictorian of the Class of 2013 (see page 1). Sinha will go on to study information engineering at the University of Cambridge on a Churchill Scholarship. In 2014, he is scheduled to pursue a doctorate in electrical engineering at Stanford University on a Hertz Fellowship, which carries \$250,000 in funding. Sinha plans to concentrate his future work at the intersection of control systems, which deal with input and feedback, and machine learning, which deals with making decisions based on data. In his senior thesis, he proposed an improvement to a current system for analyzing how groups of individuals come to common decisions.

**VICTORIA SOLOMON**

An electrical engineering major from North Wales, Pa., Solomon plans to pursue a master's degree in medical electronics and physics in the United Kingdom on a Marshall Scholarship. Solomon said she wants to concentrate her studies on developing technological systems that can assist people with physical disabilities. She said that her time at Princeton, including an independent project on remote biomedical sensors, showed her how to make technology that can lead to social improvements. In an independent project in her senior year, Solomon collaborated with other researchers to build a more affordable, portable communication device for patients with the neurodegenerative disease amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease.

**AMY OUSTERHOUT**

Ousterhout, a computer science major from Palo Alto, Calif., also was awarded a Hertz Fellowship for graduate studies. She also has been offered a National Science Foundation fellowship and is a winner of a Google Anita Borg Memorial Scholarship. Ousterhout's work focuses on computer networks. During her junior year, she developed a system that relies on short-range telecommunications methods to circumvent widespread censorship. The system uses Bluetooth or Wi-Fi devices to disseminate short message that, because they do not use conventional cellular networks or the Internet, are difficult to block. Ousterhout plans to pursue a Ph.D. in computer science at the Massachusetts Institute of Technology, continuing her work in networks and distributed communications.

**KAITLIN STOUFFER**

A computer science major from Potomac, Md., Stouffer was awarded the Daniel M. Sachs Class of 1960 Graduating Scholarship and a Gates Cambridge Scholarship. She will pursue a master's in medical genetics at Cambridge. Stouffer plans to pursue her Sachs Global Scholarship in South Africa after she completes her master's program at Cambridge. She plans work at the K-RITH Institute in the South African coastal city Durban, building a computerized prediction mechanism that will use machine-learning algorithms and other tools to estimate drug resistance based on a tuberculosis strain's genetic makeup. The goal is to allow for tuberculosis patients to be treated more effectively at an earlier point in the disease. Stouffer hopes also to earn a medical degree and a Ph.D. in computer science, eventually becoming a physician-scientist.

**ANNA KORNFELD SIMPSON**

A senior from San Diego, Calif., Kornfeld Simpson was one of two national winners of the Palantir Scholarship for Women in Technology and also received a Google Anita Borg Memorial Scholarship. A computer science major, she worked with Professor Michael Freedman on a project to improve website security and ensure that users' data remains secure even if certain accounts on a site are compromised by hackers. She has also worked on autonomous navigation for an underwater robot, which has been used for archeological fieldwork in Malta. Kornfeld Simpson, who is pursuing a certificate in technology and society, also won a 2013 scholarship from Microsoft.

**SOCIAL ENTREPRENEUR HEADS TO G20 MEETING**

Carmina Mancenon, a senior, is representing Japan at this summer's G20 meeting in Russia as part of a program in which each G20 nation sends one representative to the G(irls) 20 Summit. Mancenon, who is from Tokyo and Manila, is majoring in operations research and financial engineering and pursuing certificates in environmental studies, technology and society, and engineering and management systems. She serves as vice president of the Undergraduate Student Government, and was one of nine recipients of this year's Spirit of Princeton Award. Active in social entrepreneurship through Princeton's Keller Center, Mancenon cofounded the Sustainable Fashion Initiative, a nonprofit organization that seeks to minimize environmental harm throughout the lifecycle of clothing, from raw materials to disposal.



Photo by Brian Wilson

Carmina Mancenon, majoring in operations research and financial engineering, helped start an organization that promotes environmental responsibility in fashion.





**The graduate students who come to Princeton Engineering from around the world bring extraordinary talents and strong research interests. Teaming up with their faculty advisers, fellow students and post-doctoral colleagues, these students take leading roles at the highest levels of research. These pages offer just a few examples.**

**JOSEPHINE ELIA**

**CHEMICAL AND BIOLOGICAL ENGINEERING**

**Previous Institution:** Massachusetts Institute of Technology  
**Adviser:** Christodoulos Floudas

Elia's research focuses on optimizing energy systems for the transportation sector in the United States. Her goal is to design processes to convert domestically available resources such as coal, biomass and natural gas to liquid fuels like gasoline, diesel and kerosene. Elia's work also optimizes the nationwide and regional supply chains associated with these processes for the United States and addresses strategic planning approaches to developing these supply chains over a long time horizon. Key questions she seeks to resolve are when the fuel synthesizing plants should be built, and where they should be located across the country to replace or supplement the petroleum-based fuels.

**NATHANIEL CHANEY**

**CIVIL AND ENVIRONMENTAL ENGINEERING**

**Previous Institution:** University of California-Berkeley  
**Adviser:** Eric Wood

Accurate monitoring and prediction of the water cycle allows time to prepare and mitigate the effects of floods and droughts on ecosystems, crops, infrastructure and the population's water needs. The advent of global water observation networks, satellite data, and computer models now provide reliable hydrologic data to address this challenge. Chaney is developing and improving these hydrologic computer models through the use of supercomputers and state-of-the-art mathematical models. Another challenge is timely and effective dissemination of the water information to local farmers, government agencies and other stakeholders. To this end, Chaney also is developing software and Web-based tools to enable easy and intuitive access to the information. Already, an African water monitor has been designed, implemented and is actively being used by local governments throughout Africa.

**PRAKASH PRABHU**

**COMPUTER SCIENCE**

**Previous Institution:** Indian Institute of Science, Bangalore, India  
**Adviser:** David August

As computer-hardware makers run into limits on making ever faster and more powerful chips, a current trend is to speed up complex programs by running them on multiple chips at once. This approach, however, has required extensive reprogramming of software originally designed to work on a single chip. Prabhu has been designing a range of techniques to enable parallelization of sequential programs with minimal programming effort. Currently, he is evaluating the effectiveness of his techniques on several programs that are actively used by scientists at Princeton in their day-to-day research. Many of these programs are data-intensive, and execute together for days and weeks. Parallelizing them without requiring significant programmer effort would go a long way in accelerating the pace of scientific research at large.

**MAIKA TAKITA**

**ELECTRICAL ENGINEERING**

**Previous Institutions:** International Christian University, Tokyo, and Columbia University  
**Adviser:** Stephen Lyon

A key challenge for realizing the potentially revolutionary benefits of quantum computing is to control small numbers of electrons without disturbing the information each carries. Takita and her collaborators have built a charge-coupled device (CCD) – similar to the sensor in a digital camera – that controls the movements of electrons that float on liquid helium. The device efficiently moves electrons over billions of pixels without transfer failure. She also designed electron “turnstile” that single out individual electrons to be moved around the CCD array, necessary in using these electrons as quantum bits. Takita currently is fabricating a new device to measure the duration of spin relaxation and coherence, which is how quantum information is stored and is critical for practical quantum computing.

**FADI ABDELJAWAD**

**MECHANICAL AND AEROSPACE ENGINEERING**

**Previous Institution:** North Carolina State University  
**Adviser:** Mikko Haataja

Abdeljawad's research takes an interdisciplinary approach to investigating the behavior of materials systems in response to various physical, chemical and/or mechanical cues. A specific area of interest is the role of materials interfaces in solid oxide fuel cells (SOFCs), a promising route to the efficient production of electricity. Materials aging and reduction-oxidation (redox) cycles are some of the degradation mechanisms that hinder the use of SOFCs in large-scale commercial applications. Abdeljawad is developing mathematical models to understand the interplay between performance degradation due to materials aging and redox cycles and SOFC attributes at the microscopic scale. Furthermore, he is using computer simulations to devise SOFC systems that are tolerant to degradation mechanisms and can sustain a high level of electrochemical performance for extended periods of time.

**DANIEL LACKER**

**OPERATIONS RESEARCH AND FINANCIAL ENGINEERING**

**Previous Institution:** Carnegie Mellon University  
**Adviser:** René Carmona

Lacker is working on “mean field games,” a promising new method for studying certain types of competitive games consisting of large populations of agents. Many large-population games encountered in economics, finance, biology and other fields have a symmetry or anonymity about them; a single agent is not concerned with who is making what decision, but only with the distribution of the decisions of the other agents. For example, a single fish in a school of fish bases its movements on the movements of the whole school, not on any single fish. A single investor is not concerned with how his neighbor invests, but rather with the movements of the market as a whole. Since this approach is relatively young, Lacker is contributing to developing mathematics that can be used to study a wide variety of large-population games that arise in applications.



**ENGINEERING ALUMNI  
HONORED FOR ACHIEVEMENTS**



Drexel University's College of Engineering awarded its annual Engineer of the Year Award to **Linda Abriola**, dean of engineering at Tufts University. Abriola, who earned her Ph.D. in civil engineering from Princeton in 1983, was the only woman to earn a bachelor's in civil and environmental engineering in Drexel's Class of 1976.

**Frances Arnold**, the Dickinson Professor of Chemical Engineering, Bioengineering and Biochemistry at the California Institute of Technology, won the U.S. National Medal of Technology and Innovation, which she received at a White House ceremony in June. She also won the Eni Award from the Italian-based energy company, Eni, for her work in the discovery of new methods for the production of biofuels. Arnold earned a bachelor's in mechanical and aerospace engineering from Princeton in 1979.

**Eli Harari**, the cofounder of the SanDisk Corporation, was elected to the National Academy of Engineering. The academy recognized Harari for "technology advances of commercial flash memory systems." Harari earned his Ph.D. in mechanical and aerospace engineering at Princeton in 1973.

**Robert Kahn**, widely credited with being one of the fathers of the Internet, was named a winner of the first-ever Queen Elizabeth Prize for Engineering. Organizers of the prize, which includes an award of 1 million British pounds, cited Kahn, along with Louis Pouzin, Tim Berners-Lee, Marc Andreessen and Vinton Cerf, for "major contributions to the development of the Internet and the World Wide Web." Kahn received his Ph.D. in electrical engineering from Princeton in 1964.

**Sherilyn McCoy**, CEO of Avon Products and a former executive at Johnson & Johnson, gave the undergraduate commencement address at the University of Massachusetts-Dartmouth this May. She also received an honorary doctor of business at the ceremony. McCoy earned an M.S. in chemical engineering from Princeton in 1982.



The American Society of Civil Engineers (ASCE) named **Jameelah Muhammad** one of its "10 under 30" in its 2013 New Faces of Civil Engineering program. A structural engineer at Parsons Brinckerhoff's

Chicago office, Muhammad works in the movable bridges department to preserve, inspect and modify those structures. Muhammad graduated from Princeton in 2004 with a BSE in civil and environmental engineering and a certificate in architecture and engineering.

**John Seinfeld**, the Louis E. Nohl Professor and Professor of Chemical Engineering at the California Institute of Technology, has been elected to the National Academy of Sciences. Seinfeld earned his Ph.D. in chemical engineering at Princeton in 1967.



**Eric S.G. Shaqfeh**, chair of the Department of Chemical Engineering and Lester Levi Carter Professor in the Departments of Chemical Engineering and Mechanical Engineering at Stanford University, has been elected to the National Academy of Engineering. Shaqfeh graduated from Princeton in 1981 with a BSE in chemical engineering and a certificate in engineering physics.

**ALUMNI TAKE ON  
LEADERSHIP POSITIONS**

**Alex Blanco** has joined Ecolab, a St. Paul-based provider of water, hygiene and energy technologies and services, as executive vice president and chief supply chain officer. Blanco earned a BSE in mechanical and aerospace engineering from Princeton in 1982.



**Rajiv De Silva** was named president and chief executive officer of Endo Health Solutions Inc., a Pennsylvania-based company specializing in pain management and urology. De Silva also became a member of the pharmaceutical company's board of directors. De Silva received a BSE in civil engineering and operations research from Princeton in 1989.



**Douglas Hensler** was named the 14th provost of the Naval Postgraduate School in Monterey, Calif. Hensler, who was previously dean of the W. Frank Barton School of Business at Wichita State University, received a BSE in mechanical and aerospace engineering from Princeton in 1969.



The Pittsburgh-based aluminum producer Alcoa promoted **Eric Roegner** to chief operating officer of investment castings, forgings and extrusions. Roegner earned a BSE in mechanical and aerospace engineering from Princeton in 1991.

**Fred Smagorinsky** was appointed chief executive officer of Artic Glacier Holdings, Inc., a Winnipeg-based producer and distributor of packaged ice. He also sits on the company's board of



directors. Smagorinsky earned a BSE in civil engineering and operations research in 1981 from Princeton.

Flatfrog Laboratories, a provider of precise touch-control technology based in Lund, Sweden, announced that **Dhwani Vyas** was appointed president and CEO. Vyas earned an MSE in chemical engineering from Princeton in 1993.

**SEEING THE CEILING: OCHSENDORF  
SHEDS LIGHT ON THE ICONIC WORK  
OF A LITTLE-KNOWN BUILDER**

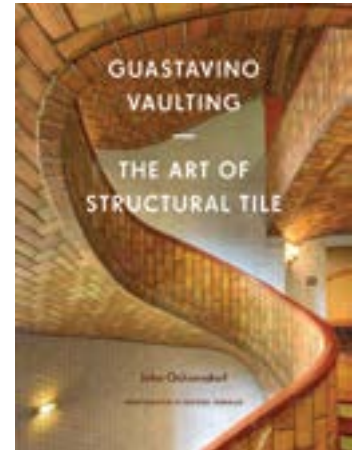
It was sitting in lectures by now-emeritus professor **David Billington** (BSE '50) that **John Ochsendorf** (MSE '98) began to appreciate the powerful synthesis of art and engineering that can emerge from structural surfaces such as shells and vaults.

"I came to Princeton for one reason and that was David Billington," said Ochsendorf, who was a teaching assistant in Billington's iconic course, "Structures and the Urban Environment," before earning his master's degree in 1998. Fifteen years and a MacArthur Fellowship later, Ochsendorf is a professor at the Massachusetts Institute of Technology, and a leading scholar in the mechanics and aesthetics of historical buildings.

In recent years, Ochsendorf has turned his attention to the work of Spanish architect and builder Rafael Guastavino, whose family company built spectacular vaulted ceilings in scores of public buildings in the early 20th century. Ochsendorf published the book "Guastavino Vaulting: The Art of Structural Tile" in 2010 and has now organized an exhibit at the National Building Museum in Washington, D.C. The exhibit, "Palaces for the People: Guastavino and America's Great Public Spaces," opened March 16 and is scheduled to run through Jan. 20, 2014.

Guastavino vaults, characterized by bold tile work spanning vast open spaces, are defining elements of buildings such as Grand Central Terminal and the Supreme Court. Princeton's chapel has a Guastavino ceiling. More than decoration, the ceilings represent a bridge between ancient craftsmanship and modern engineering, spanning distances that had not previously been possible, but predating reinforced steel, which became prevalent later in the 20th century.

"They took a method that was somewhat limited and traditional, and they took it to a whole new scale," Ochsendorf said.







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