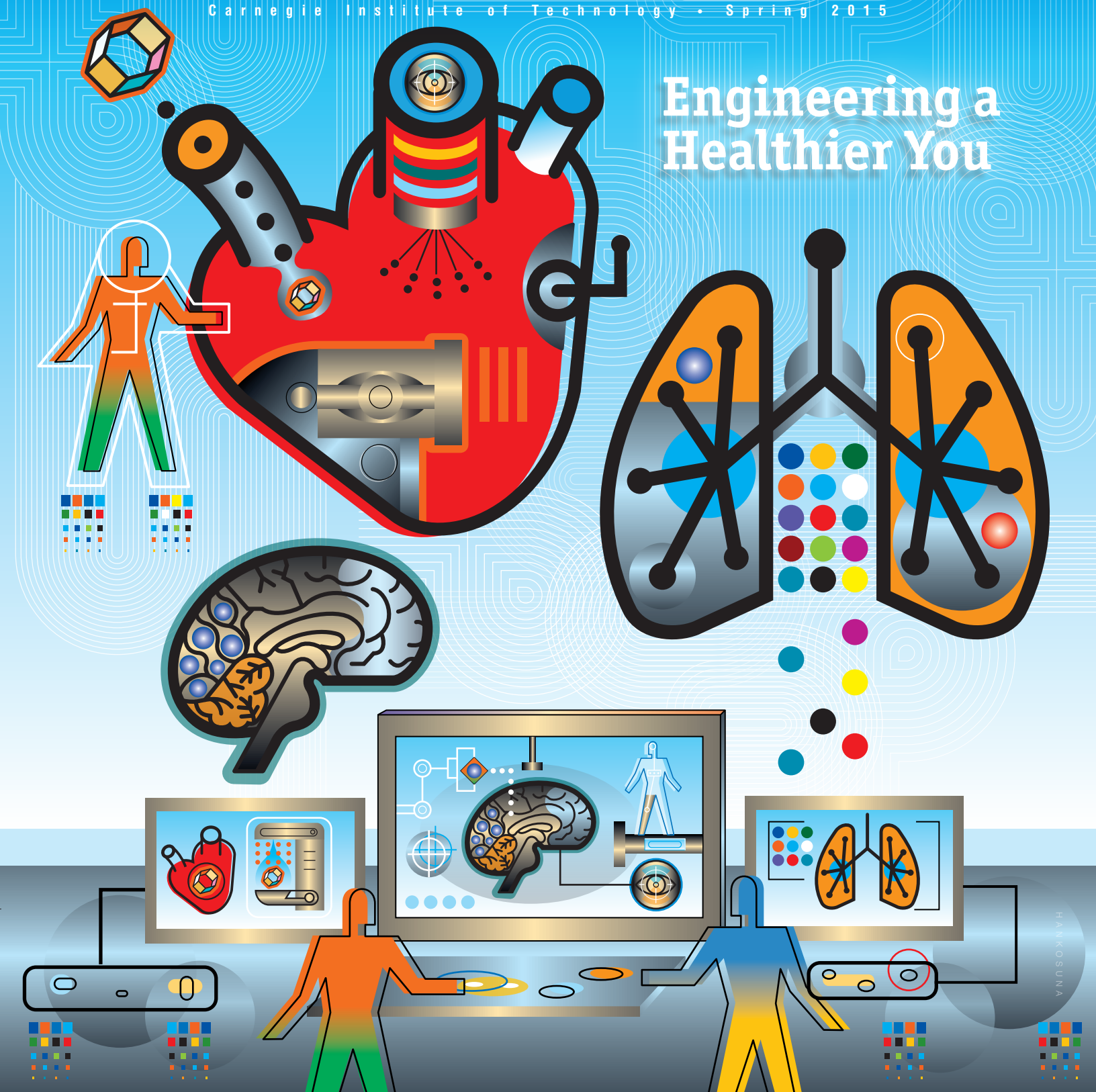
Carnegie Mellon University

# ENGINEERING

Carnegie Institute of Technology • Spring 2015

## Engineering a Healthier You



NEXT GENERATION 3-D PRINTING | FREESTYLE TINKERING EVENT | BETTER BATTERIES FOR ELECTRIC CARS

# AFRICAN INNOVATORS WHO WILL TRANSFORM THE WORLD

The College of Engineering's reach is truly global. In 2012, Carnegie Mellon University became the first American research institution to offer graduate engineering degree programs in Africa. Then in July 2014, Carnegie Mellon in Rwanda (CMU-R) achieved another monumental feat with the celebration of its first graduation. Twenty-two brilliant students graduated in Africa with master's degrees in Information Technology (MSIT).

This achievement highlights the students' determination, as well as the college's and the Rwandan government's commitment to graduate technically strong engineers who can address East Africa's unique challenges. This is important because Sub-Saharan Africa is becoming one of the fastest growing economic regions of the world, and yet, Africa has only 35 scientists and engineers per million inhabitants. All of our CMU-R graduates are working in Africa for global corporations or leading innovative startup ventures.

CMU-R adapts its curriculum to address regional challenges and opportunities. In 2014, a second master's program was launched, this time in electrical and computer engineering. Today, research at the campus includes work in mobile and wireless networks; energy topics, such as smart grids and renewable energy; health care, business and telecommunications policy; data analytics for business and government; and mobile solutions for small and medium enterprises.

It is critical for Carnegie Mellon to attract and retain excellent students as we move forward in our mission to become a Pan-African institution. Our current enrollment includes 44 students in the Information Technology program and 6 in Electrical and Computer Engineering. The countries these students represent include Rwanda (39), Kenya (5), Uganda (4) and the United States (2). Thirteen of CMU-R's current students and alumni are women.

Currently, all CMU-R students receive financial assistance. We have reached many achievements in East Africa. To keep the momentum going, the university established the Innovators Forward Fellowship Fund. We are seeking donor support for this fund so that we can provide resources for African students who have exceptional academic records and leadership abilities. If you wish to contribute, on the web visit: www.cmu.edu/rwanda/giving/index.html; or, return the envelope included in this magazine.

**To learn how you can become involved in CMU-R's mission to educate Africa's brightest students, please contact:**

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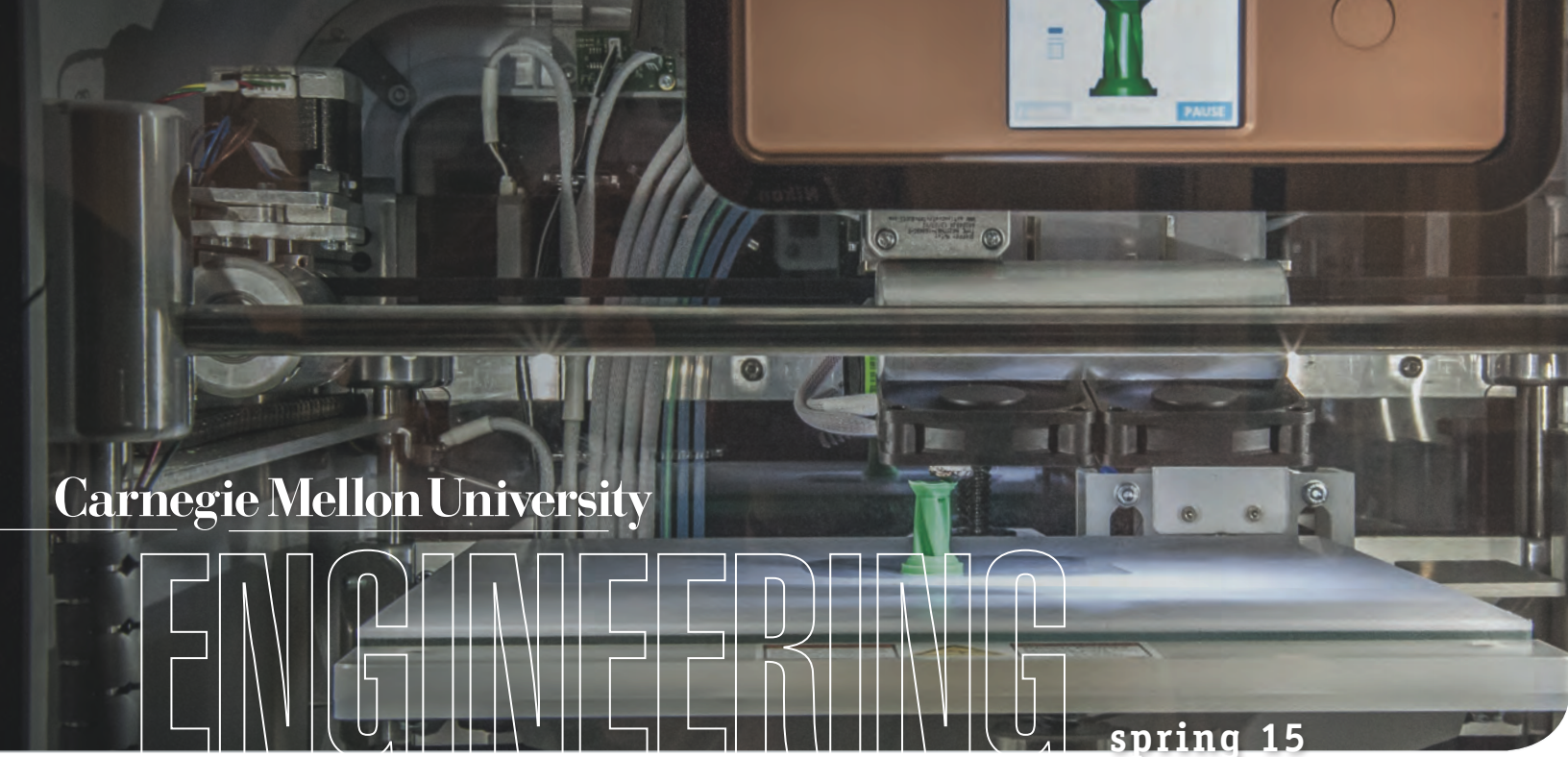

Carnegie Mellon University

# ENGINEERING

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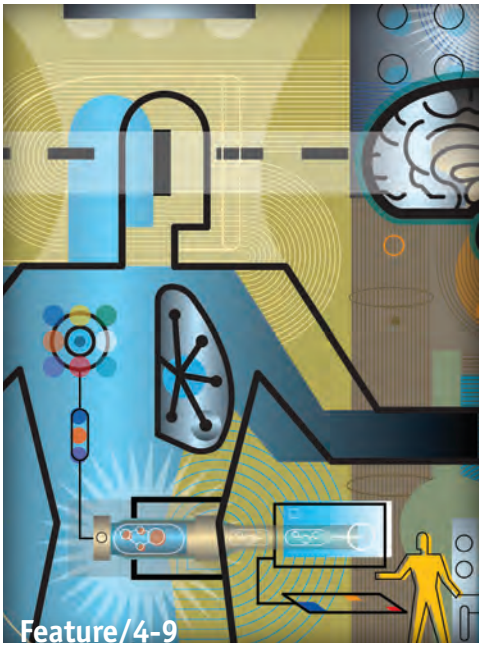

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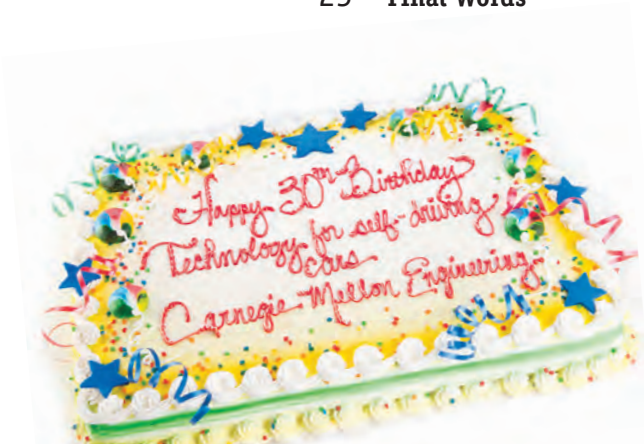
## Engineering a Healthier You

Engineers improve human health by delving into the complexities found where technology and the body interface.

Cover and feature illustrations by
HANK OSUNA




Carnegie Mellon is the birthplace of self-driving car technology | p.12

# The Strategy For Our Future

Dear Friends,

Together, the faculty, staff and students of the College of Engineering spent the better part of 2014 developing a strategic plan, and then we began to implement it. The process was broadly inclusive, collaborative and iterative, with the goal being the development of a plan that will shape the college's trajectory for the next few years. Our investments in research seeding and infrastructure, our efforts to improve internal and external communications, and our investments in faculty and staff development, along with other strategic investments, are already having positive impacts on the college.

The college's research reputation and accomplishments stand out from others by intentionally selecting problems to creatively and effectively solve through interdisciplinary collaborations inside and outside of the university. As part of our strategic plan, we will help faculty by seeding more far-reaching interdisciplinary research activity and providing more staff support for finding and pursuing research support.

The college has always been an innovator in the education of engineers. As part of the strategic plan, our faculty will be encouraged and supported to better understand and employ the science of learning and various forms of educational technology. Faculty will better engage our students' minds (so they can more easily grasp the concepts taught), hearts (to incite a passion for lifelong learning) and hands (to encourage a practical understanding and application of the concepts they are learning).

Anyone who has spent even a short time at Carnegie Mellon knows that the faculty, staff and students work very hard, strive for excellence, and expect a great deal of themselves and each other. As part of the plan, we will seek ways to further develop and improve the quality of life of those in our campus community as they so assiduously strive for excellence.

The College of Engineering is well known for working on problems of both scientific and practical importance. For reasons known and unknown, we have seen industrial support for our research activities become more and more limited. As part of the strategic plan, we will seek ways to reverse this trend and increase engagement with industry.

This past fall, I had the pleasure of attending the inaugural event of the Turkish Alumni Network in Istanbul. Halil Kulluk (MS, MechE'83) and his fellow alumni in Turkey arranged a talk for me at Bogazici University where I presented the activities in the college, and then we enjoyed a cultural event entitled "Andrew on the Bosphorus." The Turkish Alumni Network is exploring ways in which they might contribute to Carnegie Mellon University and I thank them for their hospitality and interest in helping the college. This trip and others are described later in this newsletter to better illustrate how we in the college are seeking to have more interactions with and support from our alumni.

CIT has been, and continues to be, a great place to work and study. We enjoy our culture of excellence and innovation, our collaborative and collegial spirit, our passion for whatever we do and our ethic of hard work. I remain proud of the current state of this college, but I know we must continue to evolve to be successful in the future. I hope you will continue to support us as we strive to continuously improve in all that we do.

Sincerely,

James H. Garrett Jr.
Dean, College of Engineering

Carnegie Mellon University
ENGINEERING

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**We want to hear from you.**

Send email to
**stokes@cmu.edu**
Please include your name and, if applicable, major and date of graduation. Letters will be edited for clarity and space.

## U.S. NEWS & WORLD REPORT RANKS GRADUATE ENGINEERING PROGRAM NO.4

***U.S. News & World Report*** **has named Carnegie Mellon University's College of Engineering fourth in its 2016 Best Graduate Schools Rankings, the highest rank the program has received in more than 15 years.**

" We are very excited about the momentum we have underway in the College of Engineering. With our strategic plan in place, we are poised for growth in the coming years," said Dean James H. Garrett Jr.

**In specialty rankings, the college is ranked fourth in computer engineering, seventh in environmental, eighth in electrical, eighth in mechanical, ninth in civil, 10th in materials, 14th in chemical and 29th in biomedical.**

## Our History Book

When **Leah Pileggi** interviewed several retired engineering professors, she was so fascinated by what she heard that she decided to research the history of engineering at Carnegie Mellon. Pileggi, a professional assistant for the Department of Electrical and Computer Engineering , was determined to find out "how a humble technical school became one of the world's premier engineering colleges." Her curiosity resulted in the book, *How to Design a World-Class Engineering College: A History of Engineering at Carnegie Mellon University*. By weaving together first-hand stories and recorded accounts, she reveals how key luminaries "established the institutional DNA that continues to drive engineering at Carnegie Mellon today." A mix of historic and modern photography supports Pileggi's insightful and easy-to-read narrative. The book may be purchased in the University Store or on book retailers' websites.

## Engineering Alumni Honored by University

The annual Carnegie Mellon Alumni Awards recognize alumni, students and faculty for their service to the university and for their achievements in the arts, humanities, sciences, technology and business. On October 10, 2014, the Alumni Association recognized a number of individuals from the college, and we are honored to have such excellent engineers in our community.

### 2014 Carnegie Mellon Engineering Alumni Award Winners

John M. Cohn (E'91)
ALUMNI DISTINGUISHED ACHIEVEMENT

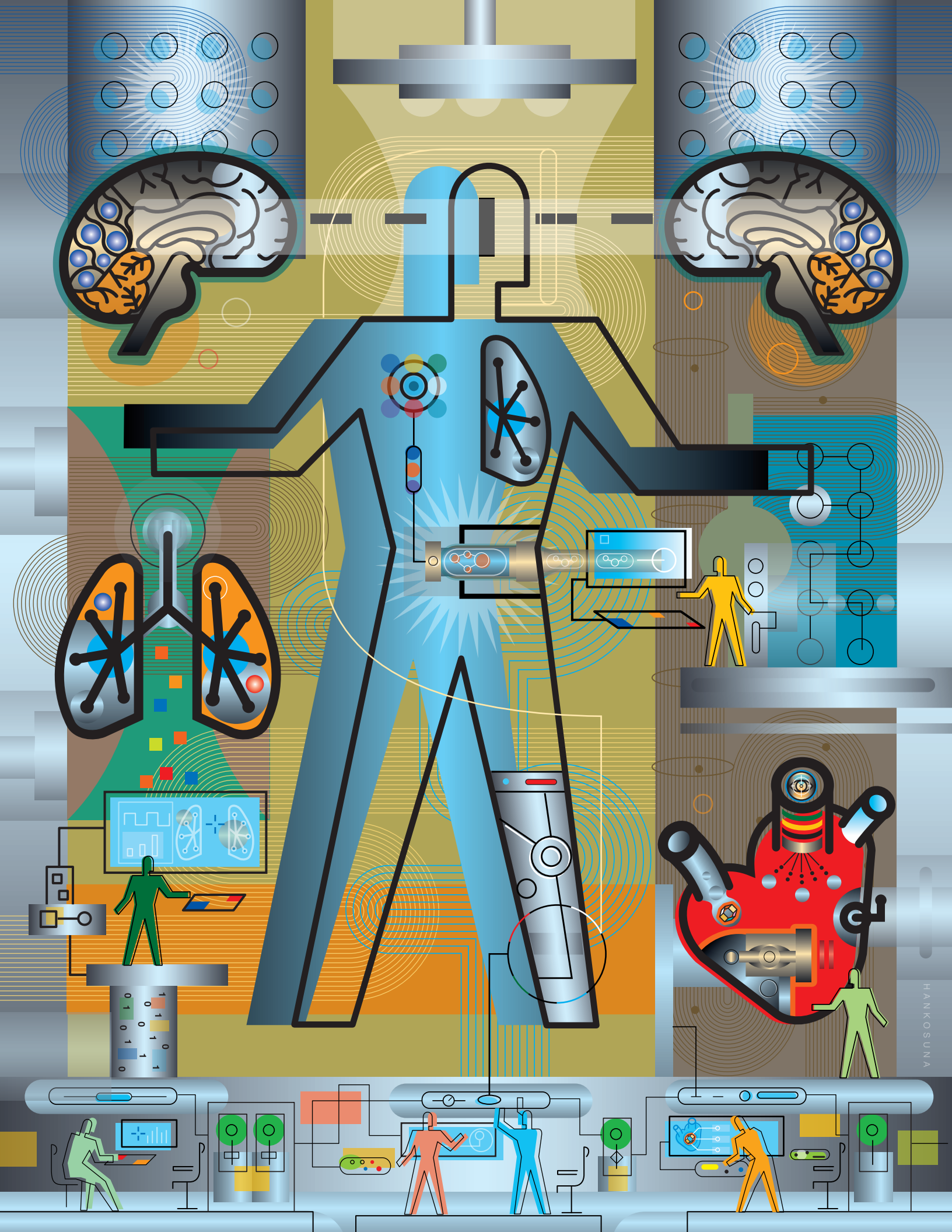
Joseph F. DiMario (E'54, TPR'60)
ALUMNI DISTINGUISHED SERVICE

F. Robert Dax (E'72, '77)
ALUMNI DISTINGUISHED SERVICE

Bowei Gai (E'06, '07)
RECENT ALUMNI

Linda M. Kaplan (E'07)
RECENT ALUMNI

Christine Sidoti (E'14)
STUDENT SERVICE


HANKOSUNA

# ENGINEERING A HEALTHIER YOU

**Engineers solve problems, period.** It doesn't matter if the challenge manifests in a hard drive or the human body. A holistic (think multidisciplinary) approach to problem-solving that combines creativity, technology and science, works whether engineers are seeking remedies for faltering infrastructure or failing hearts.

Faculty and students throughout the College of Engineering improve human health by delving into the complexities found where technology and the body interface. In the following pages, you will learn about the innovative contributions of some of the college's newest faculty members.

COVER & FEATURE ILLUSTRATION BY HANK OSUNA

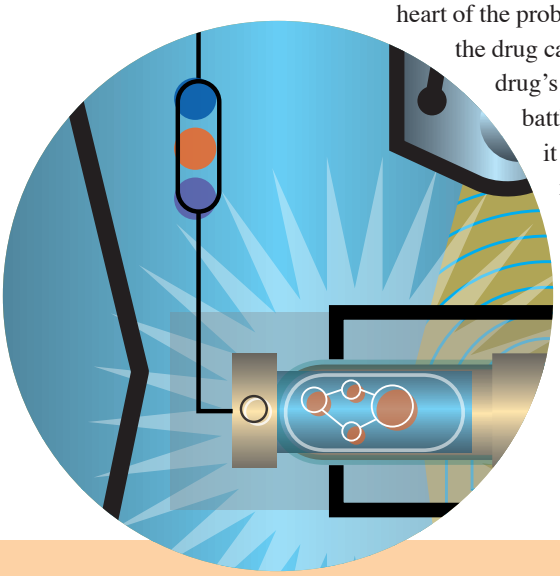
## Delivering Drugs Where They Are Needed

ASSISTANT PROFESSOR **Kathryn Whitehead** CHEMICAL ENGINEERING AND BIOMEDICAL ENGINEERING

It takes a dedicated team of researchers countless months of hard work to develop a disease-curing drug. Assistant Professor Kathryn Whitehead knows, however, that developing the drug is only the beginning. No matter how good a drug is, if it can't be delivered to the right place within the body, it can't be effective. Whitehead, whose research is based on this fact, seeks more effective methods of drug delivery that will lead to better, more effective cures.

The body does a great job of defending itself against foreign invaders. When those invaders are threats like disease, this can be a good thing. When they're things such as cancer-fighting drugs, however, the body could unknowingly fight its own healing. In order to get around this defense system, Whitehead and her team are working on a way to trick the body into leaving the drugs alone. They have developed a way to encapsulate the drug in a nanoparticle shell that protects it from the body's immune system. By altering the nanoparticles' chemical makeup, this shell can ferry the drug directly into the disease-affected cell and deliver it straight to the heart of the problem. Not only does this ensure that the drug can be as effective as possible, but it keeps the drug's potential from being wasted en route to the battlefield. This research will hopefully make it possible for drugs that normally need to be injected—such as insulin for diabetes—to be taken orally, making treatments much less invasive and painful for patients.

| ADAM DOVE

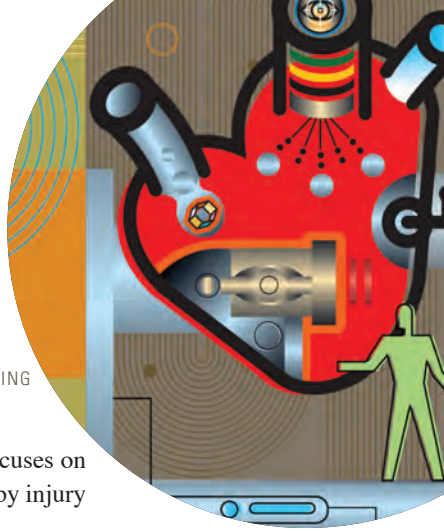


### OTHER ENGINEERS WHO ARE IMPROVING HUMAN HEALTH

**Tzahi Cohen-Karni**

ASSISTANT PROFESSOR OF BIOMEDICAL ENGINEERING

Tzahi Cohen-Karni received a $150,000 New Investigator Research grant from the Kaufman Foundation to examine how cells in the pancreatic islet communicate. Through the synthesis of nanomaterials (such as silicon nanowires) and the development of nanoscale sensors, they will be able to peek into the key mechanisms of glucose level maintenance with outstanding resolution. The nanomaterials-based measurement platform developed by the Cohen-Karni Lab will lay the groundwork for further investigations into disease abnormalities.



## Repairing Damaged Hearts

### ASSISTANT PROFESSOR Adam Feinberg MATERIALS SCIENCE AND BIOMEDICAL ENGINEERING

Adam Feinberg's heart is in his work — and his work is in the heart. Feinberg focuses on finding new ways to improve the health of human hearts that have been damaged by injury or disease.

In 2012, Feinberg received the National Institutes of Health Director's New Innovator Award for $2.25 million to develop new biomaterials and cardiac tissue engineering strategies to help repair human hearts. Feinberg's research has revolved around creating protein scaffolds that guide cell repair and regeneration. By developing biomimetic engineering design principles that help restore damaged hearts, Feinberg's research would ultimately lead to improved drug discovery and screening platforms, novel tools for biological investigation and engineered tissue grafts for disease and trauma repair.

Feinberg also received a grant from the Human Frontier Science Program in August 2014 to research cellular synchronization in the human heart. Feinberg is using the three-year, $750,000 award — which he is sharing with a cardiology professor at the University of Groningen in the Netherlands — to discover how heart muscles connect mechanically. Feinberg has developed tiny sensors that are inserted into bio-engineered heart tissue to measure cellular mechanical interaction. The biosensors — made from fluorescent materials and viewed through a special fluorescent microscope — allow researchers to observe cell synchronization as tissue forms and connects or doesn't connect. Feinberg hopes to determine links between certain genes and cells' ability to connect and communicate, which will provide medical experts with a better understanding of how specific genes affect a person's risk of heart disease.

Alongside his continuing heart-related research projects, Feinberg is also working on developing new technology for 3-D printing soft biomaterials. Feinberg and his team presented their innovative research to U.S. Commerce Under Secretary for Economic Affairs Mark Doms in 2013, showing a 3-D-printed rat femur as well as a human coronary artery. As Feinberg and his team continue to develop and improve this technology, it could eventually become a vital tool in his work toward fixing human hearts. | NICK LANGER

### Gustavo K. Rohde

ASSOCIATE PROFESSOR OF BIOMEDICAL ENGINEERING AND ELECTRICAL AND COMPUTER ENGINEERING

Gustavo Rohde is devising mathematical transforms to extract information from biomedical image data for the purposes of automated detection and characterization of cell and tissue morphology in disease states.

### Steven Collins

ASSISTANT PROFESSOR OF MECHANICAL ENGINEERING

From bionic shoes to robotic exoskeletons, Steve Collins is working on ways to help injured and disabled people walk with ease. In his Experimental Biomechatronics Lab, his team studies ways to improve stability and energy efficiency for individuals whose strength and coordination have been affected by amputation, stroke or aging through the use of robotic prostheses and exoskeletons. "We believe that appropriate mechanical assistance can not only restore function, but can enhance performance beyond typical human limits," says Collins.

# Artificial Lungs Support Patients Waiting for Transplants

ASSOCIATE PROFESSOR **Keith Cook** BIOMEDICAL ENGINEERING

Far more people need a lung transplant or an artificial lung than what's available. In the United States alone, around 12 million people have chronic lung disease, but fewer than 2,000 will receive transplants. Nearly 200,000 people will die from chronic lung disease each year.

To help patients waiting for a lung transplant, Keith Cook, with the support of a $2.4 million grant from the National Institutes of Health (NIH), is developing artificial lungs that patients will use long term in the comfort of their own homes as they wait for a transplant. Cook will lead the project and collaborate with researchers from the University of Washington, Columbia University and Allegheny General Hospital in Pittsburgh.

For the last 20 years, Cook and others have worked on artificial "bridge" lungs that support patients in need of a lung. These devices typically last no longer than a couple of weeks before failure and require close monitoring inside a hospital. Cook, now supported by the NIH grant, has been tasked with developing devices that last much longer and can be worn in homes.

"What got us this grant is that our initial results look very promising," Cook said. Their results showed a substantial decrease in the formation of blood clots inside the artificial lung. These clots are one of the largest hurdles in building a reliable long-term device.

"Anytime blood comes in contact with artificial material, it starts to clot," Cook explained. Cook's team was able to decrease blood clots through the design of the device. The fact that design was critical occurred to him about a year ago, when his team developed a novel design that prevented blood from pooling and clotting. That device reached his team's goal of lasting two weeks without forming significant amounts of clotting, but Cook thinks it may have lasted up to a month if the team had lengthened its testing period.

Coatings on the device's artificial surfaces also can help fight clotting, and this will be Cook's focus under the NIH grant. The team will combine several coating techniques that mimic how human blood vessel cells prevent blood clots. Once this is perfected, Cook believes the longevity of the artificial lung can increase to three months. Cook predicts that patients could be using one of these artificial lungs in the next five to 10 years. | DANIEL TKACIK

## Byron Yu

ASSISTANT PROFESSOR OF BIOMEDICAL ENGINEERING AND ELECTRICAL AND COMPUTER ENGINEERING

Byron Yu works in the field of computational neuroscience that lies at the intersection of signal processing, machine learning, biomedical engineering and basic neuroscience. His group develops statistical/machine learning methods for studying the activity of large groups of neurons recorded in the brain. There are two broad research aims. First, they ask basic scientific questions about how the brain carries out computations. Second, they apply this knowledge to develop biomedical devices that interface with the brain, in particular, brain-computer interfaces to assist paralyzed patients and amputees.

## Dennis Trumble

ASSISTANT RESEARCH PROFESSOR OF BIOMEDICAL ENGINEERING

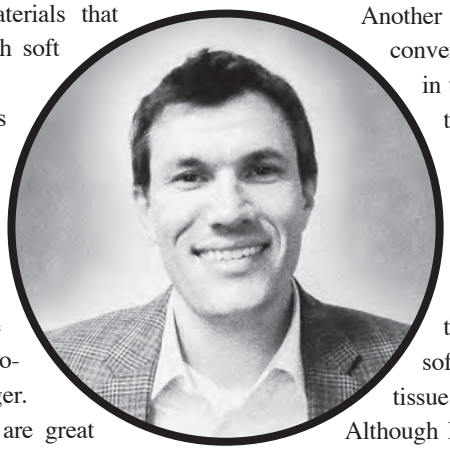
Dennis Trumble received a National Institutes of Health grant for his project, "Computational and In Vivo Analysis of Applied Apical Torsion for Cardiac Support." He is developing an artificial heart pump that mimics the heart's natural twisting motion. This innovative design will eliminate the possibility of blood clots, giving it a huge advantage over similar devices.

## New Materials Will Connect the Brain and Devices

ASSISTANT PROFESSOR **Chris Bettinger** MATERIALS SCIENCE AND ENGINEERING AND BIOMEDICAL ENGINEERING

Imagine plugging a device into the brain and uploading and downloading information in real time. This capability would provide incredible insight on how to convert thoughts into actions and robotic motion, and the ramifications would be significant — i.e., paraplegics could control prosthetics with their minds. Researchers working to connect the brain to computers face many challenges, one of the most pressing of which is finding a material that can remain in the body for years and interface with devices.

Chris Bettinger received a Defense Advanced Research Projects Agency (DARPA) Young Investigator Award to develop new materials that will interface computers with soft neural tissue.



"Think about the neurons firing in your brain. They create signals that can be mapped and potentially recorded by brain-machine interface devices. These devices are made of the same materials found in microprocessors: silicon," says Bettinger.

"While silicon devices are great for cell phones, laptops and solar panels, they are incompatible with the soft neural tissue of your brain or spinal cord. Initially the devices will work in the body, but over time, they fail. You don't want to fit a patient with a prosthetic that may only last six months or a year," says Bettinger.

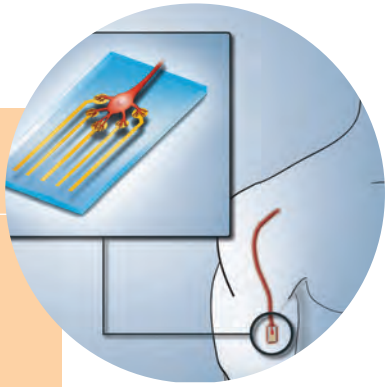
"There is a fundamental incompatibility between the biological realm and the synthetic realm," he explains. Silicon that's used in computer chips is brittle, but the human body is "soft and squishy." Microprocessors use electrons to communicate information, but the body's neurons use ions.

To resolve this issue, instead of designing new devices, Bettinger is developing materials that will coat existing sensor devices or arrays. These jellylike coatings would be "chemically" invisible to the human body. For example, if a splinter in your finger gets infected, the splinter is not chemically invisible. Bettinger wants to coat a device so the body will not know it is there.

Another key feature of this material is that it will convert electrons found in sensors into ions for use in the body. The coating will be very permeable to ions, which will allow the ions to transfer back and forth quickly between the device and the brain.

"The idea is to have a coating that converts electrons into ions. The ions will travel from the device, which is a sensing element that's on a piece of silicon, through a jellylike, soft network that is chemically invisible to tissue," says Bettinger.

Although Bettinger's research is in its early stages, he foresees it advancing the state of synthetic neural technology. This project aligns with Carnegie Mellon's strategic initiative called the BrainHub[SM], which aims to harness technology that helps the world explore the brain and behavior. | SHERRY STOKES



**Bettinger is coating sensor devices with novel materials.**

### Steven Chase

ASSISTANT PROFESSOR OF BIOMEDICAL ENGINEERING

Brain-computer interface, or BCI, is promising technology for alleviating motor deficits caused by injury or disease. BCIs can also be used as a tool for probing brain processes that would otherwise remain covert. Chase's research group has two main thrusts. The first is to develop novel computational and experimental techniques that leverage BCIs as a research tool for investigating the neural correlates of motor learning, adaptation and the representation of motor intent. The second is to design new BCI decoding algorithms to enhance the performance of these devices and hasten their clinical translation.

# NEXT GENERATION 3-D PRINTING

We're making the process of 3-D printing metals faster, cheaper and reliable.

BY DANIEL TKACIK

Additive manufacturing, or "3-D printing," has shown itself to be a powerful tool in producing objects that were previously impossible to make using "subtractive" methods, in which an object is cut out from a material. Research at Carnegie Mellon in the early 1990s set the stage for work going on today in refining the 3-D printing process, applying 3-D printing technology to medicine and empowering the general public with the ability to make things themselves.

**Professor Lee Weiss, a pioneer in the field of additive manufacturing, shows off one of the first parts ever made using direct metal additive manufacturing, or 3-D printing. The part was printed in 1990 and is made out of a zinc alloy.**

**Opposite page: In the Additive Manufacturing for Engineers course, students visualize their work before printing on a maker-scale polymer 3-D printing machine.**

## Pioneers of 3-D Printing

On a cool, cloudy afternoon in the fall of 1990, engineering research associate Lee Weiss stood in his lab, hovered over an odd-shaped object no larger than a deck of cards embedded in paper. Nervously, he began tearing away at the paper.

"When I peeled it open," Weiss recalled," it was like a butterfly emerging from a cocoon."

Weiss had just unwrapped one of the first metal objects ever produced using direct-metal additive manufacturing, colloquially termed "3-D printing." Although the process of additive manufacturing was born a few years prior, the process had been limited to polymers. The printing of this part was a milestone in making parts from metal.

The process Weiss and his colleagues used (and later patented) to produce the part opened the door to 3-D printing parts out of multiple materials. For example, electronic components made of metal could now be intimately integrated into plastics, leading to more compact and reliable parts.

"Back then, Lee and his colleagues were making some of the world's first wearable computers," recalls Gary Fedder, associate dean of research.

This "wearable computer," developed in 1998, was capable of holding pages and pages of instruction manuals and maps for Navy SEALS. Since the electronics were embedded intimately within the casing material, the machine was waterproof and cleverly named "Frogman."

Within a few years, Weiss would return to his roots in bioengineering to work on therapeutics for tissue engineering applications, while others at Carnegie Mellon carried the additive manufacturing flag on to new areas.

## Fleshing Out the Process

Today Carnegie Mellon researchers are working to make the process of 3-D printing of metals faster, cheaper and reliable.

Much of this research has been housed and made possible by Research for Advanced Manufacturing in Pennsylvania (RAMP), a $1 million manufacturing and innovation development program that Carnegie Mellon is managing in collaboration with Lehigh University, as well as a $1.9 million grant from the federal manufacturing program America Makes.

"America Makes' mission is to accelerate the adoption of additive manufacturing technologies by U.S. industry through open collaboration between industry, government agencies and community colleges," said Gary Fedder, who serves as secretary on America Makes' Executive Committee.

Jack Beuth, a professor of mechanical engineering, believes a key to moving additive manufacturing into mainstream requires knowledge of something called a "process map." Think of process maps like geographic maps: If you don't have a good map, you're probably not going to get to where you want to go.

Beuth, with Lee Weiss in the mid 90s, began process mapping — understanding how different "knobs" in the 3-D printing process, like print bed temperature or metal powder grain size — affect the quality of the material.

"For any of the metal processes, what are the major process variables and how do they map out the process outcomes?" Beuth asks. "The question we're trying to answer here is how do you take results from a very complicated process and present them in forms that engineers can use?"

'additive manufacturing'

**Piecing It All Together**

Down the hall from Beuth, Mechanical Engineering professors Burak Ozdoganlar and Levent Kara are trying to solve the size problem: How do you 3-D print something that is larger than the workspace of the printer? Breaking the object down into smaller pieces for printing and post-assembly may be an obvious answer, but it turns out that how the part is partitioned requires some careful consideration.

Another problem is to decide the print direction. Ozdoganlar and Kara are aiming to understand and optimize the orientation of the part to be printed.

"Current software packages are able to partition large parts to minimize time and material used, but they do not consider the effects of print orientation on material strength," explains Ozdoganlar, who is the Ver Planck chair professor of Mechanical Engineering and director of the Institute for Complex Engineered Systems (ICES).

"Depending on the direction you print an object — vertically, horizontally — that same object could be significantly stronger or weaker," Ozdoganlar says.

**3-D Printing for the Body**

In addition to honing the 3-D printing process, in a separate project, Ozdoganlar is leveraging additive manufacturing's ability to produce lightweight, complex-shaped parts that may eventually be used in the medical world.

"We are focusing on surgical tools, what I would call 'mock' components for knee and hip implants," explains Ozdoganlar. "They have the same geometry as the implants themselves. The surgeons use these trial components to ensure the correct fitting of an implant. They need to try the size of everything to make sure it fits before they put in the actual component."

Stephen Collins, a professor of mechanical engineering, is harnessing 3-D printing to help stroke victims regain the ability to move their ankles. To help these people, Collins' group is working on an exoskeleton that is worn around the ankle. The key? It's super lightweight.

"For each 1 percent of body mass carried at each foot, energy cost increases by 8 percent," explains Collins. 3-D printing was able to produce lighter parts that are just as strong as their conventionally made counterparts.

Meanwhile, Adam Feinberg, a professor of biomedical engineering, is focusing his applications of 3-D printing inside the body.

"Think of the way neurons are connected in the brain, or the liver where you have this complex network of blood vessels that are highly optimized for filtration," explains Feinberg. "There's just no fabrication technology that we know that can do that. With additive manufacturing, you have the potential to build and mimic that complexity. That's the promise of 3-D printing."

One hurdle (of many) to overcome when printing soft materials is keeping it from collapsing under its own weight as it is being printed. This requires careful support, and it is the focus of Feinberg's latest research.

**Empowering People To Design and Make**

Outside of the lab and the factory, additive manufacturing is having an impact on consumers, as 3-D printer prices have dropped to affordable levels. However, Kenji Shimada and Levent Kara, professors in mechanical engineering, believe there's one thing missing: software that allows users of all levels — doctors to engineers to children — design their own 3-D objects to be printed.

"We are trying to make 3-D printing accessible to the general public, so anyone can design and print an object in their home," says Kara.

The design tool will enable a wide range of users — ranging from well-trained designers to untrained builder enthusiasts — to create objects ranging from aesthetic trinkets like jewelry to more practical objects like chairs or tablet stands. The designs created using this tool will be compatible with any 3-D printer, making it even easier to create solutions — like a replacement for a broken bracket or even a cracked smart phone case — on the spot.

"These tools will be integrated into everyday life," Shimada explains. "It's not just for creating jewelry or toys. This is something that will help us day to day."

# SELF-DRIVING CARS WERE BORN HERE

Celebrating 30 years of self-driving car technology.

BY SHERRY STOKES

Carnegie Mellon is the birthplace of self-driving or autonomous vehicle (AV) technology, and last November, the College of Engineering celebrated 30 years of self-driving car technology.

"The evolution of AV technology at Carnegie Mellon is a remarkable success story that epitomizes how innovation advances when engineers, computer scientists and robotics researchers collaborate," says Farnam Jahanian, the vice president for research at Carnegie Mellon. To date, CMU has filed more than 140 invention disclosures for AV technologies.

Carnegie Mellon's 14th self-driving car, a 2011 Cadillac SRX, takes ramps, merges onto highways and cruises at 70 mph. The test vehicle looks like a production model SRX because its sensors are integrated into the vehicle's body. The sophistication of this vehicle sharply underscores how far AV technology has progressed since 1984, when CMU's first autonomous vehicle, the Terregator, rolled along at the whopping speed of several centimeters per second. Fast forward 30 years, in June 2014, Congress members rode through Washington, D.C., in the self-driving Cadillac.

As self-driving technologies mature, they are gradually assimilated into auto production. Adaptive cruise control and parking assist are commercially available now. In the 2020s, cars will have traffic jam assistance and virtual valet, a feature that enables cars to park themselves via a smartphone app.

"Features of automated self-driving cars will appear incrementally and organically, with vehicles eventually driving themselves. This will make the cars affordable and encourage public adoption," says Raj Rajkumar, a professor of electrical and computer engineering and the co-director of the GM Collaborative Research Lab at Carnegie Mellon.

In the next decade, self-driving cars will revolutionize transportation worldwide. "In the not-so-distant future self-driving cars will provide society with many benefits pertaining to safety and quality of life," states Rajkumar, who also directs the Center for Technologies for Safe and Efficient Transportation (T-SET), which is one of five U.S. Department of Transportation National University Transportation Centers.

To ensure that self-driving cars become reliable, CMU is working to accurately analyze the data that sensors collect about driving environments. Algorithms process this information, which is used to control the vehicle, so it is imperative that environmental data is interpreted correctly.

A number of engineers who work on AV technology for automakers, Google and other universities got their start at Carnegie Mellon. Beginning in 1984, CMU's Robotics Institute ran the NavLab project, which yielded 11 generations of semi- and fully autonomous vehicles. Another research wave, from 2004 to 2007, focused on the Defense Advanced Research Projects Agency (DARPA) Grand Challenges. CMU won the 2007 "DARPA Urban Challenge" with Boss, a Chevy Tahoe that traveled a 55-mile course autonomously.

"The college has developed a tremendous body of work during the past 30 years in the area of self-driving technology, and we will continue our efforts in shaping the future of transportation," says James Garrett, dean of the College of Engineering.

"In the not-so-distant future self-driving cars will provide society with many benefits pertaining to safety and quality of life."


**A lot changes in 30 years. Raj Rajkumar with CMU's 14th self-driving vehicle and the first.**

autonom

climate change

Examining infrastructure planning in light of climate change.

BY TARA MOORE

A team of Carnegie Mellon engineers have been awarded a National Science Foundation (NSF) $1.44 million Resilient Infrastructure Systems and Processes (RIPS) grant for their work on the resilient operation of water and electricity infrastructure under climate change.

The team's research focuses on how climate change impacts energy systems. While research continues on climate impact and mitigation strategies, this grant provides the ability to make the necessary preparations to adapt to the impacts of climate change. The project aims to develop methods for studying the implications of climate change on electric power generation and water supply.

"This project will look at the climate induced risks on water resources in the southeastern U.S. and identify how these risks may affect the operations of the power system," explained Engineering and Public Policy (EPP) Assistant Professor Paulina Jaramillo, the lead principal investigator on the project. "We will also be looking at risk mitigation strategies, which may include changes in the operations of the water supply infrastructure, changes in the operations of the power system and long-term infrastructure planning."

The project will serve as a jumping-off point for a larger effort to develop climate adaptation strategies for engineered infrastructure systems."We get to work with researchers from a variety of fields, providing us with a unique opportunity to explore the problem from a multitude of angles. Adaptation to climate change is a very complex and interdisciplinary problem," said Civil and Environmental Engineering Assistant Professor Mario Bergés, one of the project's co-principal investigators.

The team includes Jaramillo, Bergés, EPP and Social and Decision Sciences University Professor Baruch Fischhoff, EPP Assistant Research Professor Haibo Zhai, EPP Research Scientist Gabrielle Wong-Parodi and Electrical and Computer Engineering Assistant Professor Gabriela Hug. The team also includes collaborators from the University of Washington and George Washington University, who received additional funding for the project. The budget for the project across the three universities totals $2.5 million.

## NSF GRANT TO STUDY HOW CLIMATE CHANGE WILL AFFECT INFRASTRUCTURE

nous

communication technology

# INI CELEBRATES 25 YEARS OF WORLD-CLASS GRADUATE EDUCATION

## THE INI:

### An innovative model driving success for 25 years and beyond

When the Information Networking Institute (INI) was established 25 years ago, the world could only imagine where communications technologies might lead us. The INI hit the mark with an innovative curriculum designed to prepare graduate students for what was to come. Over the years, with the advent of the World Wide Web and smaller, faster mobile devices, INI graduates have been consistently sought after by recruiters and have pursued diverse career paths that reflect a blend of engineering, computer science, business and policy.

It began in 1989. A need in industry called for adept professionals who could lead multifunctional teams that would advance communications technologies and research. Bellcore sent out a request for proposals and selected CMU to create the first interdisciplinary master's program in information networking to primarily develop its current and prospective workforce. Since 1994 when the Bellcore contract ended, CMU has been recruiting students worldwide for the INI's growing program offerings.

In the 1990s, the INI's founder Marvin Sirbu, professor of Engineering & Public Policy (EPP) and the Tepper School of Business, engaged students in research and industry partnerships that developed into exciting projects. The Wireless Andrew project, led by the INI's first director, Alex Hills, distinguished service professor in EPP, made CMU the first wireless campus in the world and laid the foundation of Wi-Fi technology. Other student projects built upon the ideas and research that society now puts to use every day, such as e-commerce, digital libraries and voice-over IP. Exciting startups, including Schell Games and Clearspring Technologies (which later became AddThis, named after its content-sharing widget), came from INI alumni.

Pradeep K. Khosla, former INI director and former College of Engineering dean, had the foresight pre-9/11 to recruit some of the top faculty in information security in preparation for the launch of a new degree program in the INI and a research agenda in Carnegie Mellon CyLab. Dena Haritos Tsamitis, current INI director and a founding director of CyLab, joined as associate director in 2002 and later was appointed director in 2004. She led efforts in attaining three distinct federal designations as a National Center of Academic Excellence for its merits in cyber education, research and cyber operations and being awarded more than $21.6M in federal scholarships for students who have gone on to serve the nation.

In 2002, the INI launched a master's program in Greece, the first CMU degree program offered fully abroad. The INI later launched master's programs in Japan and Portugal. The INI designed a unique bicoastal structure for programs in 2008 that would allow students to integrate both the rich academic environment of Pittsburgh and the high-tech industry opportunities in Silicon Valley. Based on market demand, the INI established a bicoastal master's program in mobility, whose growing enrollment numbers reflect the rapid growth of mobile devices, applications and services.

"Throughout its 25-year history, the INI has demonstrated relevance and agility in effectively delivering multiple interdisciplinary programs through a variety of innovative delivery models," said Haritos Tsamitis.

"Today, the INI has more than 1,500 alumni who are in cross-functional positions and leadership roles around the globe," Haritos Tsamitis added. "The INI is proud to showcase the accomplishments of its alumni, faculty and students in celebration of its 25th anniversary."

**Dena Haritos Tsamitis, INI director**

# Lithium Air

## TRANSFORMING BATTERY TECHNOLOGY

### AN INTERVIEW WITH VENKAT VISWANATHAN

BY LISA KULICK

Venkat Viswanathan

**Accelerating innovation in the battery sector is Venkat Viswanathan's goal. In the following interview, the new assistant professor in the Department of Mechanical Engineering explains what battery innovation will entail and the benefits we'll reap.**

**What is the purpose of your research?**

The main goal is to enable widespread consumer adoption of electric vehicles by making them go 300 to 500 miles in a single charge of a battery pack.

Today, the best electric vehicles go about 200 miles on lithium ion batteries. If you add more batteries to get to 500 miles, the battery pack becomes more than half the weight of the car. This is very inefficient.

We are excited about lithium air battery technology. If successful, lithium air could make a vehicle go 300 to 500 miles without increasing the weight of the battery pack.

**What's the difference between lithium ion and lithium air batteries?**

In a lithium ion battery, the lithium ion leaves the anode to enter a host material — this is how you get energy. When you charge the battery, the ion goes back into the anode. Lithium ion batteries are heavy because of the presence of large metal ions, like manganese, cobalt or iron.

A lithium air battery no longer works on the principle of putting lithium into a host material. Instead, in a sense, oxygen is your host material. As the cell is discharged, a new compound is formed called lithium peroxide. You derive energy from this reaction. The beauty of it is that lithium and oxygen are both light so we get an enormous gain in energy density.

**Why should we adopt this technology?**

Lithium air has the potential to transform the battery market. The progress made over the last five to 10 years is impressive and shows there is promise in this technology. In terms of a "holy grail" battery, this is absolutely it.

**What are the obstacles blocking the development?**

The three biggest challenges are oxygen purification, electrolyte instability and electrode instability.

The first obstacle is that the way a lithium air battery runs today, it cannot use air — it can only use pure oxygen. We need to add a purification step and this adds weight to the battery.

The second obstacle is that in the environment of these lithium oxygen batteries, the electrolyte is unstable. It degrades and affects the chargeability of the battery.

The third obstacle is that carbon, the electrode material typically used in these batteries, is unstable. It corrodes when you discharge the battery, forming lithium carbonate. In order to recharge the battery, you must remove the lithium carbonate by using very high voltage. This destroys several of the cell components of the battery.

**How are you addressing these obstacles?**

We are working on all of these obstacles. Of note, we've made significant progress to address electrolyte instability. We've launched the System for Electrolyte Exploration and Discovery (SEED), a search engine to accelerate the pace at which researchers can identify an electrolyte that is stable for use in lithium air batteries.

## New Leader in Engineering and Public Policy

Douglas Sicker

**Douglas Sicker** has joined the College of Engineering as head of the Department of Engineering and Public Policy (EPP). He succeeds EPP's founding department head, University and Lord Professor of Engineering M. Granger Morgan, who has stepped down after leading the department for 38 years.

With extensive experience in academia, government and industry, Sicker brings a unique and balanced view to the Department of Engineering and Public Policy. He was the DBC Endowed Professor in the Department of Computer Science and director of the Interdisciplinary Telecommunications Program at the University of Colorado at Boulder. His research interests include dynamic spectrum access, which deals with the radio frequency spectrum that our society uses for radar communications (e.g., smartphones and Wi-Fi) and other services; security and privacy; and Open Internet, also known as network neutrality.

"I tend to work on applied industry problems and think of them from the perspective of what policy decisions might mean for industry and consumers," he said.

Sicker was involved in federal government as the chief technology officer and senior adviser for Spectrum at the National Telecommunications and Information Administration (NTIA). He also served as the chief technology officer of the Federal Communications Commission (FCC) and as the senior adviser on the FCC National Broadband Plan. Sicker has held many advisory roles across the branches of government, including adviser to the Department of Justice's National Institute of Justice and chair of the Network Reliability and Interoperability Council Steering Committee.

"I understand the difficulty for policymakers in government," Sicker said. "Many of them are not technical subject matter experts, and furthermore, even if they are, they often don't have access to data or the resources required to answer the tough questions."

Moving forward, Sicker would like to see an even stronger EPP presence in Washington, D.C. He hopes to encourage faculty to be more actively involved in engaging law and policymakers and serving in government roles, such as sitting on advisory committees and spending sabbaticals working within government agencies.

"Being able to help shape technical and engineering policy is a passion of mine," Sicker said. "Long before it was my passion, it was EPP's passion. There aren't many of these programs in the country, or in the world for that matter, that actually impact public policy with thorough technical analysis. That really resonates with me, and I hope to continue to improve and refine EPP's ability to provide impactful resources for policymakers to utilize."

By TARA MOORE

## Jared Cohon Named Director of Scott Institute

Carnegie Mellon University has named President Emeritus and University Professor **Jared L. Cohon** the director of the Wilton E. Scott Institute for Energy Innovation. Cohon, a thought leader for energy-related research and policy issues throughout his career, is an expert on environmental and water resource systems analysis. He has worked on water resource problems around the world.

The Scott Institute focuses on improving energy efficiency, expanding the mix of energy sources in a clean, reliable, affordable and sustainable way, and creating innovations in energy technologies, regulations and policies.

Jared L. Cohon

José M.F. Moura

## Moura Named a Fellow of the National Academy of Inventors

**José M.F. Moura**, the Philip L. and Marsha Dowd University Professor in the Department of Electrical and Computer Engineering, has been named a fellow of the National Academy of Inventors (NAI).

Moura was elevated to NAI Fellow status in part because of his research and patent contributions in statistical signal and image processing. He holds 11 U.S. patents ranging from image video processing to biomedical areas, several of which have been adopted by industry. A sequence detector from two of his patents (co-inventor Aleksandar Kavcic) has been placed in 2.4 billion disk drives and 60 percent of all computers sold worldwide in the last 10 years. Moura co-founded SPIRALGen, a company to commercialize SPIRAL technology under license from Carnegie Mellon University.

The academic inventors and innovators elected to the rank of NAI Fellow are named inventors on U.S. patents and were nominated by their peers for outstanding contributions to innovation in areas such as patents and licensing, innovative discovery and technology, significant impact on society, and support and enhancement of innovation.

## Jelena Kovačević receives the David Edward Schramm Professorship

**Jelena Kovačević**, the head of the Electrical and Computer Engineering Department, received the David Edward Schramm Memorial Professorship on January 30.

Kovačević, a dedicated faculty member in the college since 2003, is a professor of electrical and computer engineering, biomedical engineering and director of the Center for Bioimage Informatics. On April 1, 2014 she was appointed head of the Department of Electrical and Computer Engineering.

Kovačević is a passionate educator whose research involves bioimaging and multiresolution techniques such as wavelets and frames. A prolific writer, she has co-authored the textbooks, *Wavelets and Subband Coding, Foundations of Signal Processing*, and *Fourier and Wavelet Signal Processing*. She co-authored a top-10 cited paper in the *Journal of Applied and Computational Harmonic Analysis*, and a top-100 downloaded paper on the IEEE Xplore.

She is a fellow of the IEEE and has served as editor-in-chief of the *IEEE Transactions on Image Processing*, and associate editor, guest editor and editorial board member of several publications and special issues. She has given numerous plenary and keynote presentations at international conferences and meetings.

*About the Schramms: Charles Schramm received a bachelor's of science degree in mechanical engineering from the Carnegie Mellon College of Engineering in 1942. Charles S. and Benetta B. Schramm established the David Edward Schramm Memorial Professorship in the Carnegie Institute of Technology in loving memory of their son.*

**Jelena Kovačević is the first woman to head the Department of Electrical and Computer Engineering.**

# To Travel is To Live, . . . & Work

## Especially if you head the College of Engineering

The College of Engineering is based in Pittsburgh, but its reach extends around the world. Just ask James Garrett, the dean of the college. It's his job to strengthen the college's reputation for all that we do and he does so in a global spotlight. His mission entails bolstering industry relations, connecting with potential and present academic partners, fostering new research opportunities, exerting influence in government circles, and of course, staying in touch with alumni. To see how busy he is, here's a glimpse into his travels.


**Dean James Garrett provided the Turkish Alumni Network with an update on the College of Engineering, opening the door for collaborations.**

JULY 2014 | **Rwanda**
Carnegie Mellon in Rwanda celebrated the graduation of its first class in Kigali, and Dean Garrett was proudly in attendance. Graduating this class was a landmark step, underscoring our commitment to educate technically strong engineers and entrepreneurs who will make an economic impact in East Africa.

NOVEMBER | **Turkey**
Garrett was the inaugural speaker at an event called "Andrew on the Bosporus," which was held at Bogaziçi University. The event was arranged by MechE alum Halil Kulluk and the Carnegie Mellon Turkish Alumni Network (our alumni are everywhere!). Garrett's speech highlighted college activities and provided entry points for collaboration.

JANUARY 2015 | **China**
Dean Garrett and President Subra Suresh were among a CMU delegation that met with Chinese government officials and academic leaders from Sun Yat-sen University to celebrate the inauguration of two new buildings: the SYSU-CMU Joint Institute of Engineering (JIE), on SYSU's East Campus in Guangzhou, and the SYSU-CMU Shunde International Joint Research Institute (JRI) in the city of Foshan. During the trip, high-level meetings ensued to explore opportunities befitting this remarkable global partnership.

FEBRUARY | **Yachay University, Ecuador**
Driven to foster innovation and educational excellence in seemingly remote places, Garrett was part of a CMU team that met with leaders from Yachay Tech to discuss potential collaborations for a proposed City of Knowledge in Ecuador.

FEBRUARY | **Washington, D.C.**
Returning to the States, Garrett had a packed schedule in D.C. He attended the 2015 Engineering Deans Council Public Policy Colloquium (PPC), sponsored by the American Society for Engineering Education (ASEE). The event's purpose was to strengthen discussion between engineering deans and key public policymakers and to enable the deans to refine their public policy agenda. He spent a day on Capitol Hill and met with representatives from the National Science Foundation, a primary source of university research funding.

FEBRUARY | **California**
Garrett met with the CMU Board of Trustees. Later he attended a fundraising dinner entitled, "Integrated Intelligence: San Francisco and Beyond." California is home to more than 4,400 CMU alumni.

MARCH | **Washington, D.C.**
Back in our nation's capital, Garrett enjoyed dinner with a group of undergraduates and mentors as part of the college's Real World Engineering program. This successful event shows students what engineering is like in industry and government. The students network with mentors and alumni, all while learning about future career opportunities.

MARCH | **Philadelphia, Pa.**
Garrett attended the ELATE at Drexel® symposium that honored the work of Professors Burcu Akinci and Lorrie Faith Cranor, both 2014-2015 ELATE Fellows. This fellowship is a unique development program for women in the academic STEM fields. It increases professional leadership effectiveness and creates a network of exceptional women who bring organizational perspectives and deep personal capacity to the institutions and society they serve.

# Lunar Agriculture:

## One Student's Journey Aboard the "Vomit Comet"

BY COLLEEN CASEY

Students and alumni of the College of Engineering have said that travel experiences have enriched not just their education, but their lives. To ensure that students have the opportunity to explore different cultures and working environments, the college's Dean's Office awards travel stipends to students and student groups who plan to complete a study or work program, either during the academic year or over the summer.

Joshua Chen (B.S., MechE, BME'14) received one such grant to visit NASA in Houston, Texas, so he could test a plant-watering system that he helped design. This system is part of a larger project called Lunar Plant Habitat, which intends to grow crops on the moon. However, in order for the system to work on the moon, it needed to consistently and successfully water the seeds while experiencing one-sixth of the Earth's gravity. The only way to verify the system's design is to take it into a simulated lunar environment. In Houston, he spent seven days conducting experiments alongside other university students on the C-9 Reduced Gravity Aircraft, also known as the "vomit comet."

Below is an excerpt from Chen's travel log:

*… [The plane] works by diving and climbing during its flight. During these dives and climbs, the aircraft traces a perfect parabola in the sky... At the apex of each parabola, the cabin of the aircraft experiences simulated zero gravity while at the trough, the cabin experiences double the gravity, or 2G.*

*The technician announces "THIRTY SECONDS," and I go over the experiment in my head again. The water bags and seed paper were already primed, so I don't need to reload them. All I need to do this first round is shine my flashlight inside the aluminum chamber and verbally verify that the experiment is running. "TEN SECONDS." I stare at the cabin lights and squeeze the strap around my legs. "OKAY, HERE WE GO!" And suddenly, I'm looking down at the ground. Or is it the ceiling? Whoa. I was looking at the ceiling and my back was still planted to the ground, but my confused brain cannot reconcile the contradicting signals from my eyes and my inner ear. My eyes saw and understood what was the ceiling, but the rest of my body feels like it is pointing down. Before I get too distracted by this surreal sensation, I slowly sit up and guide my hand to the window of our experiment, and turn on the flashlight to take a look inside. The system had successfully delivered water to the seeds!*

The Lunar Plant Habitat has huge implications for the future of space travel, because it would allow astronauts to grow their own food instead of relying solely on prepackaged food. This would open doors for space travel by making longer missions possible, allowing us to explore other planets such as Mars and observe deep space.

"If you think about it, one of the main reasons why humans were able to thrive is because they were able to control their source of food from crops. This project would provide proof whether growing plants in deep space is possible," Chen said.

After this experience, he says that the most valuable learning experience he's gained is that he now has a better understanding of zero gravity, and can use this experience to design better hardware for use in space.

**Joshua Chen (top-center) and a teammate test the Lunar Plant Habitat watering system aboard the "vomit comet."**

# Students Seek Solutions to Social Problems

## The College Hosts First Innovation Palooza and Impact-a-Thon

BY TARA MOORE

Forecasts of a particularly cold winter raised concerns about space in Pittsburgh's homeless shelters, which contain only 375 beds while there are an estimated 1,500 homeless individuals in the city. Carnegie Mellon University students applied their creativity to find solutions to this problem during the College of Engineering's Impact-a-Thon, part of the Innovation Palooza event that took place on October 1, 2014.

Student teams were given five days to research the problem and come up with temporary and economically viable shelters that could be erected during cold weather.

"The most difficult part was trying to grasp the problem in such a short time," says Rajlakshmee, who is working on her master's at the Integrated Innovation Institute. "We had to go from understanding the problem to building the prototype in five days." The teams were required to have at least one engineering student, but many were interdisciplinary groups with students from across Carnegie Mellon. "You need the diversity of perspectives," says Alex Surasky-Ysasi, who too, is a student in Integrated Innovation.

The third place prize of $400 went to Porchlight, the truly innovative idea of not building shelters at all. After careful research, the group discovered that a major hurdle is the stigma of homelessness. They found that it is hard to open new shelters, but that 68 percent of the people they surveyed said they would harbor those in need in their own homes. Based on this information, the team developed a third-party service that would match hosts with those needing a place to stay.

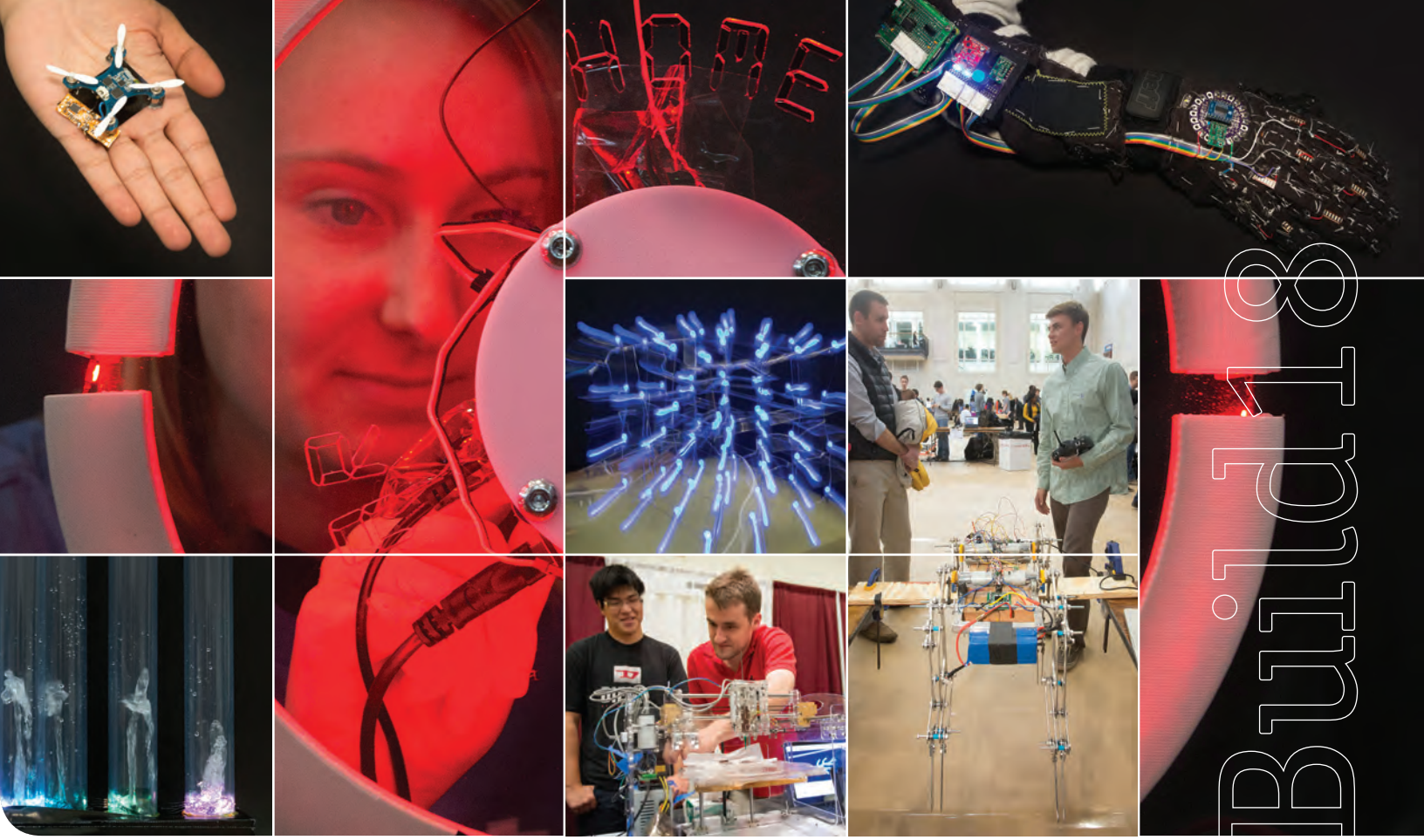
"We introduced the concept of having a third party, a caseworker, who does a background check so there's confidence that the people in your house are reputable and don't have any problems," says Michael Richardson, a graduate student of Human-Computer Interaction (HCI) who was on the team with fellow HCI students Katarina Shaw, Jason Azares, Ron Kim, Jim Martin and ECE student Joseph Carlos. The second place team won $600 by developing the Satellite Shelter, which individuals can sleep in and stay warm through insulation that traps body heat. The structure is flat when folded, but opens into a tentlike sleeping bag. It is insulated with Mylar, an affordable material used in space blankets, and has a waterproof layer with ventilation. Wool blankets help keep occupants comfortable. This team included Rajlakshmee and Surasky-Ysasi (Integrated Innovation), Priya Ganadas (School of Architecture) and Linh Thi Do (Tepper School of Business).

Green Residence won $1,000 for their first-place win, and included Wei-Hsun Chen, Fan Sai Kuok, Vanessa Li, Hongqiao Lu and Ruyao Wu, all from the Integrated Innovation Institute. Their project was a structure that could be set up in Pittsburgh's parks. During the day, the structures fold up into billboards, which the team proposed selling for $100/month to cover maintenance costs. Homeless individuals can check in for these structures after 8 p.m. using an ID system that reveals which units are available. With the swipe of a card, the temporary residences open. Inside, are a heating element and fan that can be plugged into the city's lampposts. In addition, the ID system aids homeless individuals with job placement.

The Impact-a-Thon was part of a larger College of Engineering event called the Innovation Palooza. It highlighted research such as 3-D bioprinting from Adam Feinberg, a professor of biomedical engineering and materials science and engineering, and also included a lesson from Mechanical Engineering Professor Phil LeDuc and Subha Das, a chemistry professor, on how to make butter from whipping cream using mechanics.

The Palooza had demos and lightning talks from industry leaders such as Merline Saintil, head of Operations for Mobile & Emerging Products at Yahoo!, and Bill Fuller of Big Burrito.

**Pictured from left to right: Priya Ganadas, Rajlakshmee, Alex Surasky-Ysasi shown with the Satellite Shelter.**




# Strategic Freestyle Tinkering

BY KRISTA BURNS

Seven years ago, the Department of Electrical and Computer Engineering (ECE) asked students what would improve their experience at Carnegie Mellon. Their response: They wanted to work on ideas of their choosing purely for joy and not for a grade. And with that, the freestyle tinkering event Build18 was born. (The name is a shout-out to the 18-prefix used for ECE courses.)

Build18 serves as an intellectual playground for creative engineers from across the college. This past January, for five straight days and nights, over 200 engineers built intricate projects, ranging from desk-top water fountains to hand-gesture controlled puppets. The event has become so large and well attended that the students needed the Cohon University Center's Weigand Gym to present their work.

While Build18's main event starts in January with "Build Week," the process leading up to it starts in the fall with a Kickoff Event and Tutorial Series. At the Kickoff, students learn how to apply, while the Tutorial Series introduces them to electronics and project design through hands-on learning. In late fall, participants form teams (each team must contain one ECE student) and submit their project applications. Build18 officers review the applications, confirming that they meet criteria for safety, feasibility and engineering merit. A giant list of parts is aggregated and ordered (each team is given a budget of $250), and the wait for Build Week begins.

"Build18 was created with the sole purpose of giving engineers an opportunity to exercise their creativity in engineering," said Aaron Reyes, Build18 chair and ECE senior. "We welcome big ideas, whether they work out or not, because they are excellent ways to learn something new."

This year, Build18 received funding from alumni and at least 23 corporate sponsors. Several sponsors hosted "Innovation Tech Talks" exclusively for CMU students, including Stern, Kessler, Goldstein & Fox; AlphaLabs; and Amazon.

For students, Build18 is often the highlight of the spring semester. "I participate because it's a great chance to take the things I've learned from my ECE classes and apply them to a project of my choosing," said Robert Maratos, ECE sophomore. Maratos was on the "FPGA on the Web!" team, which won the faculty award. This project gives ECE students online access to the field-programmable gate array (FPGA) boards used in ECE's digital logic classes. "This would allow students to work on their labs remotely, without going all the way to Hamerschlag Hall," Maratos explains. His teammates included Jake Weiss, Edward Shin and Chia Dai.

Build18 Week concluded with a banquet at Phipps Conservatory, but the tinkering didn't stop there—K'nex were placed on each table, and a race ensued to see who could build a structure to the ceiling. After dinner, keynote speaker Mike Calcagno, Microsoft Director of Engineering for Bing Experiences, inspired students by giving a rousing talk about the creative process behind Windows phone features.

"Simply put, Build18 serves as an engineer's playground for students who love the art of engineering," says Aaron Reyes, Build18 chair and ECE senior.

# TALK ABOUT A SURPRISE ENDING

BY NICK LANGER

Dr. John Berg (above) went from studying the Chemical Engineering curriculum to transforming it.

When **Dr. John Berg** graduated from Carnegie Mellon University with a B.S. in chemical engineering in 1960, he had no idea that 50 years later, students in the same program would be using a book he wrote.

Berg's experience in the College of Engineering helped shape his future as a professor of chemical engineering at Washington State University, and Berg returned the favor with a surprise donation of $100,000 to Carnegie Mellon's Chemical Engineering Department (ChemE).

After presenting at the 2014 Ethel Z. Casassa Memorial Lecture in Colloids, Polymers and Surfaces on March 25, Berg concluded his discussion by writing a check to the department, a gift he'd been planning to give for years.

"I'd been thinking about it for a long time," Berg says, "I think it was way overdue. I was so grateful for the support I got on the Westinghouse Scholarship."

As an incoming freshman in 1956, Berg received a George Westinghouse Scholarship, which enabled him to study at Carnegie Mellon's Chemical Engineering Department without having to worry about financial matters. Berg now hopes to give future students similar financial support.

Berg had many happy experiences at Carnegie Mellon that have stuck with him throughout his life. He recalls in particular how his adviser encouraged him to not worry about grades but just to do his best in whatever work he was doing.

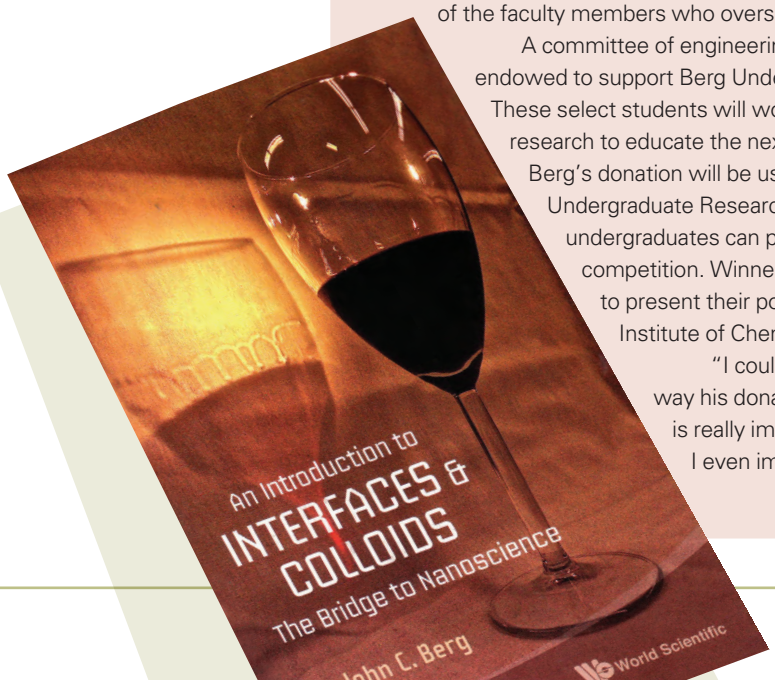
"It was almost life-changing," Berg says about the advice. Rather than give in to the pressure of having to be in the top 10 percent of his class in order to keep his scholarship, Berg focused on just enjoying his schoolwork and doing his best. The lesson carried over into Berg's career.

After his undergraduate days, Berg found great support from Carnegie Mellon professor and fellow chemical engineer Ethel Casassa, who helped him establish a surface and colloid science laboratory lecture class at Washington State University. "When I came out last spring to do that seminar I was so happy," Berg says, "because it honored Ethel. She couldn't have been more helpful. I welcomed the opportunity to be able to say that to an audience." Berg decided that presenting at the lecture series dedicated to his late friend would be the perfect time to give the donation to the Chemical Engineering Department.

"It was a nice surprise and was very generous," says Annette Jacobson, the College of Engineering's associate dean for undergraduate studies. Jacobson was one of the faculty members who oversaw the handling of Berg's donation money.

A committee of engineering professors decided to have the funds endowed to support Berg Undergraduate Research Scholars for one year. These select students will work alongside faculty and present their research to educate the next group of Berg Scholars. Additionally, Berg's donation will be used by the department to host an annual Undergraduate Research Symposium, in which all participating ChemE undergraduates can present their research in a "Best Poster" competition. Winners of the competition will have the opportunity to present their posters at the annual meeting of the American Institute of Chemical Engineers.

"I couldn't be happier," Berg comments about the way his donation will be used. "Undergraduate research is really important. This was a greater outcome than I even imagined."



# HONORING A LEADER: ANGEL JORDAN FACULTY RECOGNITION FUND

BY NICK LANGER

The College of Engineering acknowledges with gratitude the generous commitment of $500,000 from **Frank Marshall** (E'69) to establish a fund to support faculty in electrical and computer engineering (ECE). This endowed fund will be named in honor of a long-esteemed member of the university, Dr. Angel Jordan, who served as ECE department head (1969 -1979), dean of the Carnegie Institute of Technology (1979 -1983) and provost of the university (1983 -1991).

Working closely with Jordan, Marshall earned a B.S. degree in electrical and computer engineering in 1969. Marshall's career began at Hughes Aircraft Company, where he worked as a design engineer in the Advanced Technologies group and was responsible for several unique projects in Military Aerospace. He later became vice president/general manager of Cisco System's Core Business Unit. Today, he is a consultant to high technology companies, as well as a member of Engineering's Silicon Valley Advisory Council.

Jordan was critical in helping Marshall create a solid foundation for a career as an electrical engineer. Jordan made Carnegie Mellon his life's work after graduating from the Carnegie Institute of Technology in 1959. His pioneering research and technical leadership helped create one of the first university research laboratories in semiconductor devices. As an administrator, he helped lead the transformation of Carnegie Mellon into a prominent world-class educational and research institution. He championed the formation of the Robotics Institute and was instrumental in attracting the Software Engineering Institute to the Pittsburgh campus. As a university professor emeritus, he remains active in ECE and in the Robotics Institute that he helped establish.

Jordan's guidance, enthusiasm and understanding of core engineering principles is something Marshall often looks back upon with admiration, feeling fortunate to have studied under such a prominent scholar.

Our challenge: Endowed professorships are instrumental in supporting and attracting the best faculty possible. To this end, we would like to raise $2.5 million dollars to transform this new fund into the Angel Jordan Faculty Recognition Professorship. If you wish to contribute, please contact Trish Bloemker Sowers; phone: 412-268-3421, email: tsowers@andrew.cmu.edu.

# NEW SATHAYE PROFESSORSHIP SUPPORTS ECE FACULTY

BY KRISTA BURNS

Committed to supporting junior faculty members, **Shirish and Archana Sathaye** have generously endowed the Sathaye Family Foundation Career Development Professorship in Electrical and Computer Engineering, and the department is proud to announce that **Gianluca Piazza** is the inaugural recipient.

Both Sathayes earned their Ph.D.s at Carnegie Mellon University in Electrical and Computer Engineering (ECE) in 1993. Archana's career spans industry, academia and, more recently, nonprofits. In addition to serving as a member of the ECE Alumni Council, she is president of the Sathaye Family Foundation and serves on a variety of advisory boards.

Shirish currently serves as a member of the College of Engineering Dean's Advisory Council and the ECE Alumni Council. He joined Khosla Ventures as a general partner after acquiring a decade of investment experience at Matrix Partners and holding positions at Digital Equipment Corporation, FORE Systems and Alteon Web Systems. His current areas of investment focus on wireless and wireline networking, clean tech and cloud-based software and storage and systems.

Piazza, an associate professor, is recognized internationally for his work on microelectromechanical systems (MEMS) piezoelectric resonators. His group's research interests focus on the invention, design and demonstration of micro- and nano-electromechanical systems (M/NEMS) for five main areas: low power mechanical radios, nanomechanical computing, integrated chemical and biological sensing platforms, opto-mechanical and acousto-optic systems, and micro- and nano phononics.

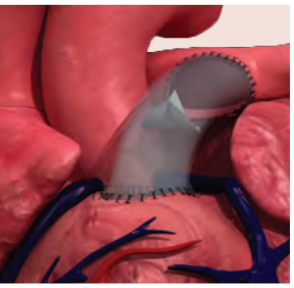
Piazza says that the professorship "is recognition for the quality of work that my students and I have done over the past few years. It's also a stimulus to instill in students the same values of entrepreneurship, scholarship and altruism that characterize the Sathayes."

This professorship will make it possible for Piazza and his graduate students to travel internationally to conferences and present their work. It will also allow them to purchase specialized equipment — something for which federal or industrial support is hard to find.

"I am particularly grateful to the Sathayes for establishing the professorship," says Piazza. "This is a clear sign of their desire to give back to the university, and it showcases the importance that their Carnegie Mellon education has had in their professional lives. Their professional accomplishments will serve as an inspiration for myself and hopefully all of my students."

# HIS HEART TRULY IS IN HIS WORK

BY COLLEEN CASEY

**Doug Bernstein (above), co-founder of PECA Labs, is working to prove that rare medical issues can be solved through technology, despite the supposed financial risk.**

**Left: Model of PECA Labs' pediatric heart valve in action.**

**Doug Bernstein** (B.S., MechE, BME'12), co-founder of PECA Labs, has been working to bring a novel pediatric heart valve to market. This small device, an iteration of research that Bernstein assisted on as a student, would help about 3,000 critically ill children annually.

As a junior, Bernstein saw an ad for a research assistant position with the Pediatric Cardiovascular Fluid Mechanics Lab at Carnegie Mellon, and Dr. Masahiro Yoshida, a surgeon at the Children's Hospital of Pittsburgh of UPMC. Yoshida was developing a pediatric heart valve (now named the MASA Valve after Yoshida), and the team needed a research assistant with a background in mechanical and biomedical engineering. Bernstein was a perfect fit for reasons beyond his double major.

"I have experience with pediatric cardiothoracic surgery from the patient side," says Bernstein, who was born with a congenital defect. Bernstein instantly connected to the research because he understood how few options are available for children undergoing open-heart surgeries. The issue, however, was not a lack of available technology, but rather a lack of resources to support research into alternative devices for children.

During the course of Yoshida's research, the MASA Valve was implanted into 70 children. After five years, there was a statistically significant reduction in the number of reoperations those children underwent. While reoperations cannot be eliminated, the device's design postponed the first reoperation and reduced the number of overall surgeries.

This success made Bernstein wonder: Why isn't this device available everywhere? At this point, he became interested in entrepreneurship — he had a product that worked, and he got permission from his fellow researchers to bring the product to market. All he had to do was figure out how to get it to patients.

Unfortunately, pediatric heart valves are far from a lucrative business. After speaking to entrepreneurship professors at Carnegie Mellon, he learned that the numbers didn't add up: bringing a medical device to market costs an average of about $70 million, and with only 3,000 patients in the U.S. per year, the market was only about $60 million.

"Anyone who knows business will tell you that's not a venture," Bernstein says.

Bernstein, however, would not be deterred, and he eventually got lucky. The FDA changed their regulations around what's called the Humanitarian Device Exemption, which provides an expedited pathway to getting a device approved when it will benefit populations fewer than 4,000 U.S. patients per year. Because of this exemption, PECA Labs will be able to bring their valve to market for about $2 million.

Bernstein knew that if he could start PECA Labs, he could show that it is possible to help smaller populations of people and still make money, which would open the door for others to create devices for rare conditions.

"There are thousands of rare diseases that don't have proper treatments, and this affects hundreds of thousands of people," Bernstein says. He explains that treating some of these diseases would not be exceedingly difficult, "but it is particularly difficult to get funding. That is a real issue, and that issue shouldn't exist."

Bernstein's partners in PECA Labs include two other Carnegie Mellon alumni, Jamie Quinterno (B.S., DC'13) and Arush Kalra (M.S., BME'13). Quinterno tackles the company's operations and Kalra was a pediatric surgeon in India before coming to Carnegie Mellon to pursue a master's degree. The three possess the perfect skillset for taking PECA off the ground: business, engineering and medicine.

Now that PECA Labs is close to penetrating the pediatric cardiac market, they are working on future devices within that market, including a device that will enlarge so that children won't need to undergo replacement surgeries as they outgrow their implants.

"Hopefully, we can change the way that people look at the rare disease market," Bernstein says.

# FINAL WORDS

How will self-driving cars affect the future road and highway systems that support them?

**George Lederman**
Ph.D., Advanced
Infrastructure Systems
2013 CMU T-SET UTC
Student of the Year

Like most Americans, I think of myself as a good driver, but I can't wait to relinquish control to a more qualified robotic chauffeur. According to a survey by Allstate, two thirds of drivers think of themselves as excellent or very good drivers compared with the other motorists. Clearly, not all of these drivers could be above average. A robotic driver, thoroughly tested, could objectively be a better driver. Their response time could be faster, they wouldn't suffer from fatigue or intoxication, and they wouldn't get irrationally angry at other drivers. Of course, autonomous cars won't be perfect, but because they will be safer than human drivers, we owe it to the 30,000 people who die in vehicular accidents each year to implement this technology as soon as possible.

Student

**Chris Hendrickson**
Hamerschlag Professor
of Engineering
Director, Traffic21 Institute

Self-driving cars would have transformative and broad ranging effects, both good and bad. The burden of vehicle crashes could be largely avoided, making small, fuel-efficient vehicles desirable and reducing insurance costs. Congestion could be reduced, both from fewer incidents and more efficient driving. Reduced congestion could obviate investments in roadway capacity expansion. Urban form could change, with many people opting to use shared vehicles rather than owning a vehicle. Elderly and physically handicapped individuals could have new mobility opportunities, which is particularly important as our elderly population increases. On the other hand, whole categories of jobs might be eliminated, such as taxi and transit drivers. Vehicle travel and congestion could actually increase as empty cars shuttle themselves around, urban form becomes even more sprawling, and drivers elect to travel more.

The introduction of self-driving cars will take considerable time, as the technology matures, drivers gain confidence in vehicle automation and public policy evolves. We can expect incremental improvements in vehicle automation. A final major policy step will be the decision to allow self-driving cars on the road without a driver required to be ready to take immediate control.

Faculty

**Maryanna Saenko**
Research Analyst
Lux Research Inc.
B.S. MSE'10, BME'10;
M.S. MSE'11

*This is an excerpt from Saenko's response. Her take on this topic can be read in its entirety at our website at www.engineering.cmu.edu/magazine.*

Where driverless technology may have its greatest impact is in public transportation. There is precedence for automated operation in public transport; for example in the airline and rail industries, but the difference is the severe constraints of those environments as compared to highway and city driving. It's easy to foresee a future where fully autonomous driving will happen, and may in fact be mandated, but only in similarly constrained environments. For example, in high-population density cities in Europe and Asia there are already severe traffic restrictions on how many and which vehicles may enter; it's feasible that in the future similar areas may mandate autonomous technology. Autonomous vehicles will change transportation in cities, but it may be a result of cities investing in "autonomous pods" rather than in driverless cars.

Alumni

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