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Carnegie Mellon University

SPRING 2016 ● CARNEGIE INSTITUTE OF TECHNOLOGY ● ALUMNI MAGAZINE

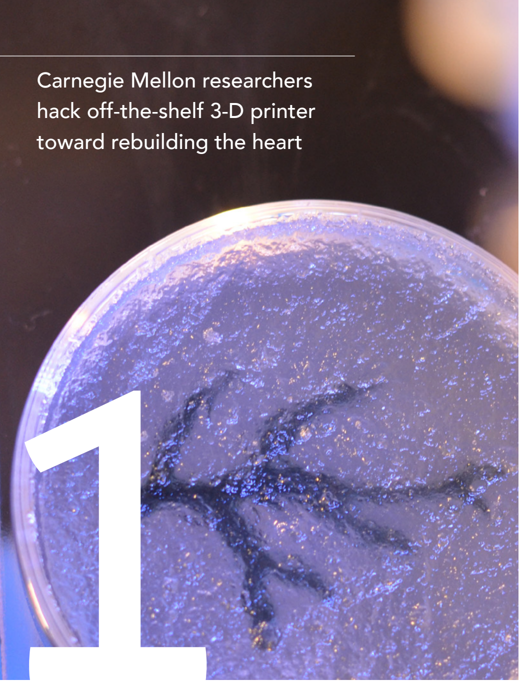
# Engineering

*THE **NEW** SHERMAN AND JOYCE BOWIE*

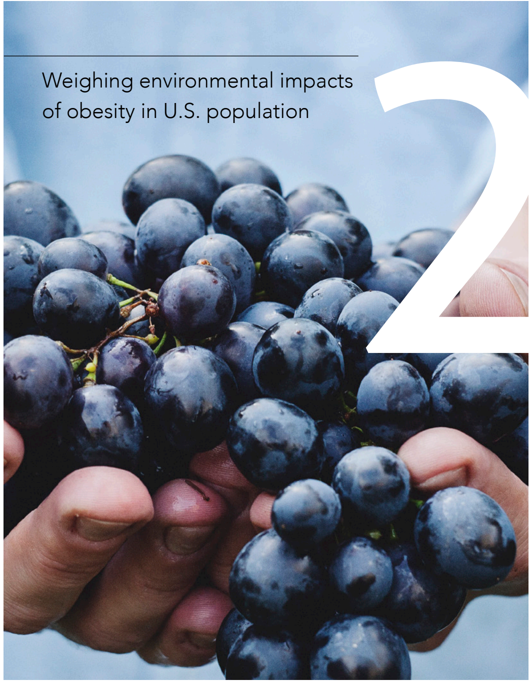
# SCOTT HALL

**A BUILDING SO UNIQUE IT COULD ONLY BE AT CARNEGIE MELLON UNIVERSITY**

# High Five




Carnegie Mellon researchers hack off-the-shelf 3-D printer toward rebuilding the heart




Weighing environmental impacts of obesity in U.S. population


Shen designs nanoscale solar absorbers that convert 90% of sunlight to heat


Emirates Group debuts CMU Silicon Valley-based Innovation Lab


New mechanical engineering faculty Reeja Jayan developing sensors to detect gluten proteins

There is a tremendous amount of amazing research and student activities underway in the college every day. To read the Top Five most popular stories on the College of Engineering's web site, visit:

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Carnegie Mellon University

# Engineering

## SPRING 2016



A VISUALLY STIMULATING BUILDING, SCOTT HALL IS DESIGNED WITH OUR CULTURE OF COLLABORATION AND SUSTAINABILITY IN MIND.

# From the Dean

## Dear Friends,

As I write this column, College of Engineering staff are moving into Scott Hall. My colleagues in Biomedical Engineering, headed by Professor Yu-li Wang, are moving into the 3rd and 4th floor of the North Wing. This is the first time that the faculty and staff of this department are all in the same place and all on the main campus. My colleagues in the Wilton E. Scott Institute for Energy Innovation are moving into new space that provides labs for energy technology development and energy systems modeling, in addition to space for graduate students working in these areas. The Scott Institute, directed by President Emeritus Jared Cohon, provides a focal point for all energy research going on at Carnegie Mellon. The 6th floor houses the Engineering Research Accelerator, directed by Associate Dean for Research Burcu Akinci, where faculty research is incubated, accelerated, and assisted in getting external funding. The Arthur Ruge Atrium and the Rothberg's Roasters Café will become a central gathering place for faculty, staff, and students in the College of Engineering and the university and is where many interdisciplinary collaborations for which CMU is famous will spawn.

Another important part of this new facility is the Claire and John Bertucci Nanotechnology Laboratory, which houses the 10,000 sq. ft. Eden Hall Cleanroom that will support a large number of faculty from across the college and university working on micro- and nanosystems research. This facility will become part of a much larger MakerEcosystem we are seeking to develop to support maker-based research and education in the College of Engineering. A strong maker culture and ecosystem can act as a multiplier for leveraging our physical making activities and help us to spread our intellectual and physical resources throughout the engineering departments, as well as across the university.

I sincerely thank all of the donors who helped to make Scott Hall a reality, especially Sherman and Joyce Bowie Scott, Claire and John Bertucci, the Eden Hall Foundation, Dan, Karen and John Swanson, and the many others who donated to the various parts of the building. You have made a transformational gift to Carnegie Mellon University. Thanks! My colleagues and I will continue to raise funds to bring other parts of this larger MakerEcosystem concept to reality. The support of our alumni, corporate donors and local foundations is gratefully acknowledged as you all play a major role in keeping the Carnegie Mellon University College of Engineering the cutting-edge and highly ranked education and research asset it is.

Sincerely,

James H. Garrett Jr.
Dean, College of Engineering

Carnegie Mellon University
Engineering

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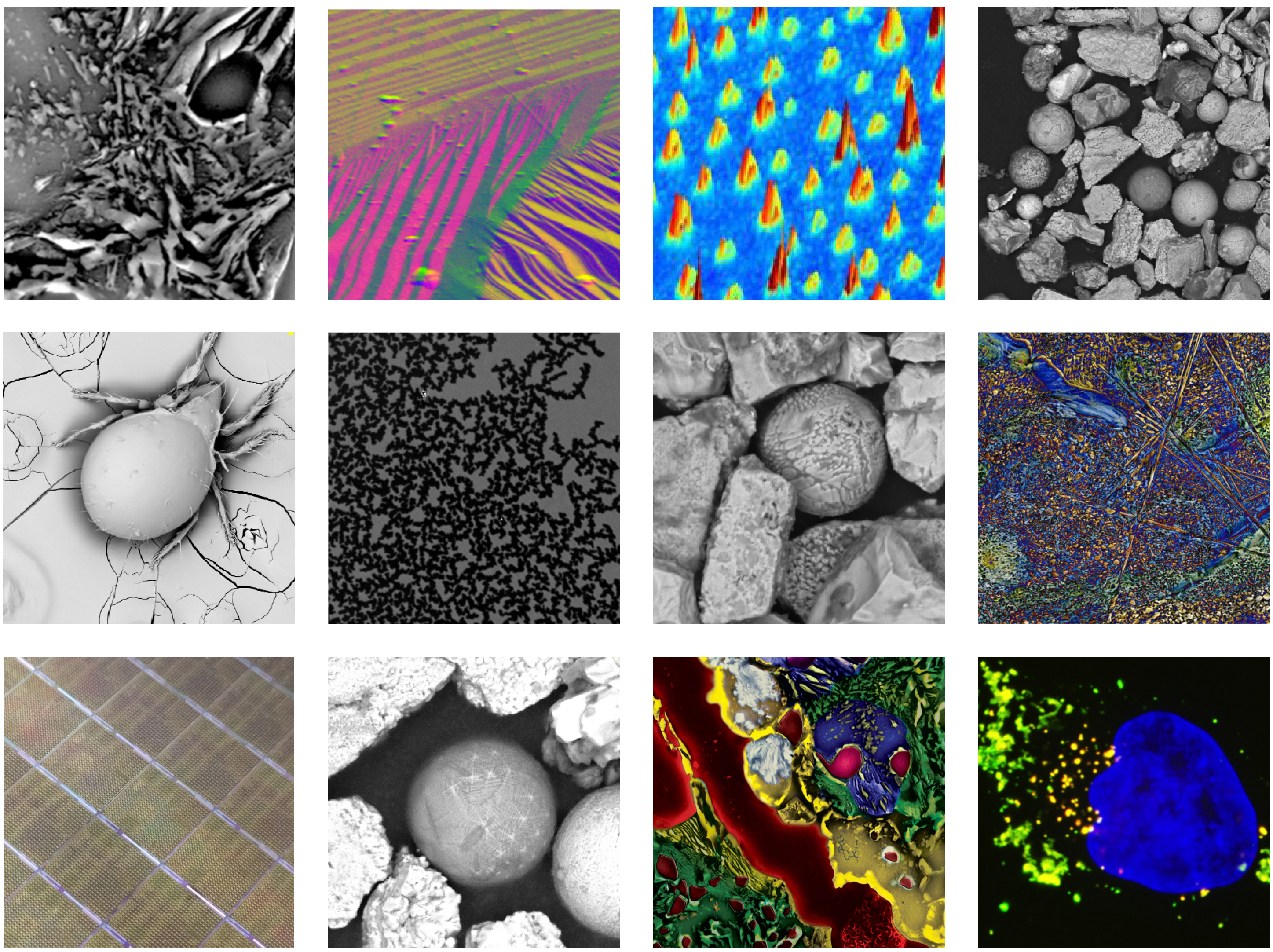
We want to hear from you!

**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.

# See What Our Researchers See

In labs throughout the College of Engineering, researchers use **advanced microscopy** to reveal intriguing imagery from once-hidden worlds.



**First row:** ultrahigh carbon steel, a shape memory alloy, polymer-grafted nanoparticles, micro meteorites

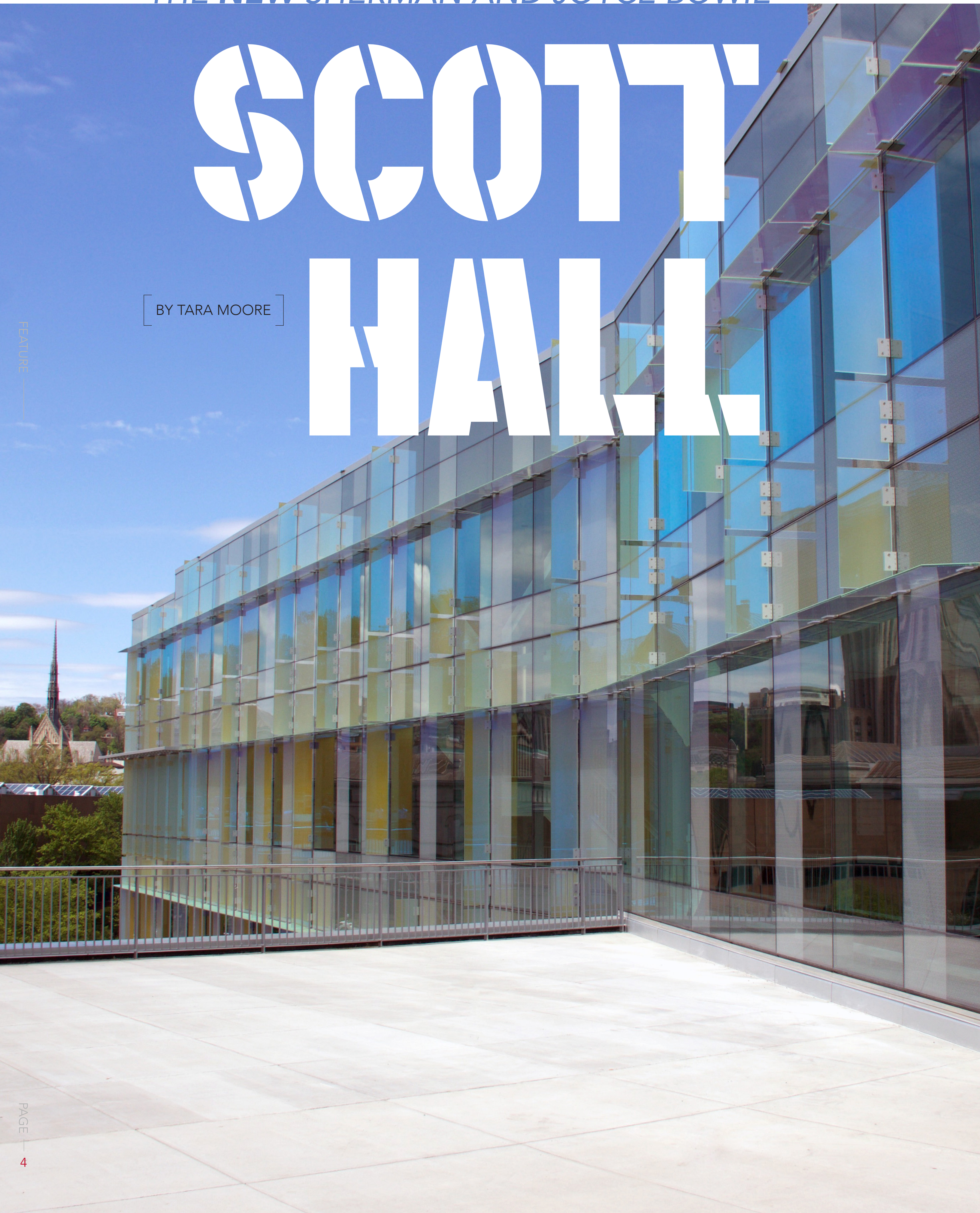
**Second row:** dust mite, co-alloy film taken with a Kerr microscope, micro meteorites, ultrahigh carbon steel

**Third row:** integrated electronic circuits, micro meteorites, ultrahigh carbon steel, nanoparticles entering a cell

# *THE **NEW** SHERMAN AND JOYCE BOWIE*
# SCOTT HALL

BY TARA MOORE






Driving along Forbes Avenue towards Carnegie Mellon University's campus now offers a new transformative view: the Sherman and Joyce Bowie Scott Hall, a building designed by OFFICE 52 Architecture to be as visually stimulating as it will be essential to interdisciplinary research initiatives at the university. Scott Hall fits like a jigsaw piece into Carnegie Mellon University's campus, and was designed with the university's culture of collaboration and sustainability in mind. The building officially opened April 30, 2016.

The building itself spans multiple disciplines, housing the Wilton E. Scott Institute for Energy Innovation, a program about shared research that has started a compelling new chapter for energy at CMU. It will also provide a new home for the Department of Biomedical Engineering, the Engineering Research Accelerator, the Disruptive Health Technologies Institute, and a nanotechnology research facility.

The 109,000 square foot Scott Hall has two main sections: the North Wing and the Claire and John Bertucci Nanotechnology Laboratory. The North Wing is a multicolored glass structure that sits elegantly over Junction Hollow on a sculptural composition of angled white steel columns, which are strategically placed in the overall design to avoid the utilities below. The Bertucci Nanotechnology Lab is tucked between Porter Hall, Hamerschlag Hall, Roberts Hall, and Wean Hall, turning what used to be a small service and parking area into a great deal of usable workspace.

Contained within the Bertucci Nanotechnology Lab is the 10,000 square foot Eden Hall Foundation Nanofabrication Cleanroom, which will allow nanoresearchers to explore new avenues of nanoscience and is easily available to those in all seven buildings surrounding the area. However, the cleanroom is not the only interesting aspect of the Bertucci Nanotechnology Lab: the area, entered through a glass pavilion, has a green roof with skylights that extends the lawn of the Hornbostel Mall in front of Hamerschlag Hall, providing more space for work (and relaxation) both inside and outside of the building, and which completely changes the space.

The Arthur C. Ruge Atrium and the Collaboratory, a four-story public space that connects the levels of the North Wing of the building, are where the North Wing and Bertucci Nanotechnology Lab meet.

The Collaboratory and Ruge Atrium, which contain a café, are based on the idea that informal discussions are one of the main generators of collaborative work, and are designed by the architects so that these informal interactions take place on a regular basis, since researchers in the building must go through these areas to reach their labs and offices.

Together, the three parts of the building directly connect the multiple disciplines within Scott Hall to four other buildings on campus and provide easy access to Porter/Baker Hall and Scaife Hall, resulting in an important new nexus on campus for the College of Engineering and giving physical form to the collaborative culture of the College of Engineering. "The building will physically bring together hundreds of faculty and students from a variety of disciplines, allowing them to work together in ways they had not been able to before," says James H. Garrett Jr., dean of the College of Engineering. "It will also reinforce our maker culture by adding valuable space and equipment into our maker ecosystem."

## A JIGSAW PUZZLE PIECE FIT PERFECTLY INTO CAMPUS

The original vision for the building was a seven-story tower built in Junction Hollow, but a progressive and interdisciplinary architecture firm, OFFICE 52 Architecture, took a risk during the initial architectural design competition for the building. The three other competing firms, well-established and large, proposed seven-story towers as requested, but OFFICE 52 decided CMU, with its innovative spirit, would welcome a more clever and elegant solution that combined technology and the arts–and they were right.

The problem with the seven-story tower was that it required ripping up the major utilities in Junction Hollow, an expensive undertaking that would also cause disruptions to major essential services on campus. In addition, the building would be built on a hill by a road and railroad tracks, which was not ideal for the sophisticated labs that the building houses.

"It was a wonderfully hard problem to solve, and we like difficult problems," says Isaac Campbell, echoing the spirit of the College of Engineering. Campbell leads the project for OFFICE 52 Architecture with his partner Michelle LaFoe.

OFFICE 52 turned the challenges of the location into advantages for the building: they proposed the North Wing, built on columns that are cleverly placed and sculpted to avoid vital utilities. The firm also moved the sensitive Bertucci Nanotechnology Lab up into the Hornbostel Mall adjacent to Hamerschlag Hall, which provides a flat location free from train and car vibrations for the cleanroom.

"The North Wing and Bertucci Nanotechnology Lab, plus the Collaboratory and Ruge Atrium, result in a building that connects that entire side of campus and results in impromtu meetings between those working in multiple disciplines," says Campbell. While the building is bigger than the original proposal, it costs less per square foot than the seven-story tower and provides more space for faculty, staff, and students.

Their plan also allows for a pedestrian bridge to be built in the future between Hamerschlag and Wean that will connect to Forbes Avenue, providing a safer passage that will facilitate university growth to South Craig street.

## SCOTT HALL AND SUSTAINABILITY

Scott Hall is a LEED Gold building, and has many adaptations for sustainability to fit with Carnegie Mellon University's and the College of Engineering's energy consumption goals.

*One of the Most Energy-Efficient Cleanrooms in the World*

Cleanrooms like the nanofabrication lab in Scott Hall are one of the most energy-intensive rooms architects can build because the air must constantly circulate, and therefore pose a major challenge to energy efficiency in high-intensity research lab buildings.

The cleanroom in Scott Hall is one of the most energy-efficient cleanrooms in the world. It uses an innovative fan design and increased filtration system, which allow for both the velocity of the fans and the speed at which air is moved to be decreased. Due to this creative design, the cleanroom uses 40% less energy than a usual cleanroom–impressive, since even with these modifications, it makes up 30% of the building's energy consumption.

*The Green Roof: Both Aesthetically Pleasing and Functional*

The green roof of the Bertucci Nanotechnology Lab serves more purposes than just extending the lawn and enhancing the beauty of CMU's campus; it also will capture rain. The green roof will reduce the amount of runoff and delay rainwater from going into the sewage system, reducing the strain on the system during storms. Some of the excess water can also be stored and later used in cooling tanks on campus.

*The Outer Glass Walls*

The glass used to enclose Wean Hall has a low-emissive coating on it that reduces infrared and ultraviolet light, keeping the building cooler in the summer. While this coating was more expensive, it will pay itself off easily in three years, and later save the university a substantial amount on utility bills and energy usage.

**40-60**

PERCENT

range of varying photonic quasicrystal pattern covering outer glass curtain wall

**10,000**

SQUARE FEET

size of the cleanroom located under the green roof

### ARCHITECTURAL DETAILS BEHIND THE MULTICOLORED SCOTT HALL

Scott Hall has what the designers at OFFICE 52 Architecture call a "curtain wall"—meaning it has a lightweight, nonstructural outside covering that serves primarily to keep weather out and the occupants inside, as opposed to a house with a brick wall. In Scott Hall's case, the curtain wall is made of glass. The architects purposely sought to artistically integrate concepts from the science taking place within the building in its architecture. For the nanoresearchers working in the building, the glass curtain wall has a special secret: it is covered in a geometric pattern common in nanoparticle research. The pattern has varying coverage that ranges from 40-60% throughout the building to allow privacy and shading for those inside, and appears differently depending on how close the viewer stands to the glass.

Protruding from the curtain wall are dichroic glass fins—a type of glass known for producing multiple colors based on how the light hits it and where the viewer is standing, which results in the building changing colors as the day progresses. The origins of dichroic glass are also germane to processes that are used almost every day in nanoscale exploration.

"The pattern and dichroic glass together are an architectural metaphor of how this building, from the standpoint of building and campus, is transformational," says Campbell and LaFoe.

"I THANK SHERMAN AND JOYCE BOWIE SCOTT, JOHN AND CLAIRE RUGE BERTUCCI, AND JONATHAN AND BONNIE GOULD ROTHBERG FOR THEIR GENEROUS GIFTS, WHICH HAVE ALLOWED US TO DEVELOP A HUB FOR ENERGY, NANOPARTICLE, BIOMEDICAL, AND HEALTHCARE RESEARCH. I ALSO THANK THE SCOTTS FOR THEIR CONTRIBUTION TOWARDS THE WILTON E. SCOTT INSTITUTE FOR ENERGY INNOVATION, WHICH WILL GALVANIZE FACULTY ACROSS CAMPUS TO CONDUCT NEW AND EXCITING ENERGY RESEARCH AND WILL ALSO INCREASE FUNDING FOR THIS WORK."

—JAMES H. GARRETT JR., DEAN OF THE COLLEGE OF ENGINEERING.

## The Founders

Scott Hall was made possible by a lead gift from Sherman Scott and his wife Joyce Bowie Scott, in addition to support from CMU alumni John Bertucci (E'63, TPR'65) and his wife, Claire Ruge Bertucci (MM'65); the Swanson Family; the Richard King Mellon Foundation, which also supported the Wilton E. Scott Institute for Energy Innovation; the Eden Hall Foundation; CMU alumnus Jonathan Rothberg (E'85) and his family; and other generous donors.

### SHERMAN AND JOYCE BOWIE SCOTT

Both the Sherman and Joyce Bowie Scott Hall and the Wilton E. Scott Institute for Energy Innovation were funded by Sherman Scott and his wife Joyce Bowie Scott. The institute is named for Sherman's father, Wilton E. Scott.

Like Carnegie Mellon University, the Scotts epitomize the marriage of technology and the arts. The two met while studying at CMU, with Sherman earning his undergraduate degree in Chemical Engineering and Joyce earning a Fine Arts degree.

Sherman is currently the president and founder of Delmar Systems, which he founded in 1968 and built into one of the world's leaders in mooring systems for the offshore oil and gas industry. Joyce is a trustee emeritus of Carnegie Mellon University and an artist at the J. Bowie Scott Studio, and has been a leader in visual arts organizations in Louisiana, New Mexico, and elsewhere.

### JOHN AND CLAIRE RUGE BERTUCCI

John, a member of the Carnegie Mellon Board of Trustees and longtime member of the CIT Dean's Advisory Council, and Claire Ruge Bertucci are both CMU alums. John holds a B.S. in Metallurgical Engineering and an M.S. in Industrial Administration, and built a successful career overseeing the growth and international expansion of MKS Instruments, Inc. Claire received a B.S. in Business from the Margaret Morrison Carnegie College, and her father, Arthur C. Ruge, for whom the Arthur C. Ruge Atrium is named, was also a Carnegie Tech alum. He invented the strain gauge.

**109,000**
SQUARE FEET
size of Scott Hall

# RESEARCH

# ICE FROM FLAME

BY EMILY DURHAM

INFLUENCE ON THE GLOBAL ENERGY BALANCE AND TEMPERATURE OF OUR PLANET

Ice nuclei are rare particles in the atmosphere that can cause cloud droplets to freeze and form ice crystals. Each individual droplet of water in a cloud can exist as liquid or ice, and liquid droplets can remain unfrozen down to extremely low temperatures—as low as -40°C if the water is very pure. However, if a supercooled liquid droplet encounters an ice nucleating particle, it freezes. Instantly.

## BUT HOW ON EARTH CAN FIRE FREEZE CLOUDS?

It turns out that some smoke particles from burning wood and grasses—biomass burning aerosols—can act as ice nuclei in the atmosphere. When these smoke particles collide with the surfaces of supercooled water droplets, a small fraction of the particles that are ice nuclei cause the droplets to instantaneously freeze and form ice crystals in the sky. These ice crystals grow quickly by sucking up water from any remaining liquid droplets. This is why frozen clouds are the main source of precipitation over land—glaciating a cloud is the best way to cause the cloud's particles to grow so large that they fall back to Earth as rain and snow.

"Biomass burning aerosol, or wood smoke, is a complex mixture of soot particles, organic carbon, and inorganic salt components," explains Ryan Sullivan, assistant professor of Mechanical Engineering and Chemistry. "We know that when you burn some fuels very hot, like certain tall grasses, they emit a large number of ice nuclei. We also know that biomass burning aerosol undergoes a lot of chemical reactions as the dense smoke is mixing and diluting with background air. So the biomass smoke particles' chemistry is rapidly evolving, but we don't know how that chemical evolution of the particles in the wood smoke changes their ice nucleation properties."

Figuring out on the molecular scale how individual ice crystals form is a tricky process, however—especially when you're flying through the clouds, trying to take accurate particle property measurements while your turbulent airplane is being violently bombarded with ice (as Sullivan has, of course, done). Now, though, Sullivan's research is more convenient—his research lab has designed several instruments and controlled environments in which to study ice nucleating mechanisms on individual particles.

## GAINING SOME CONTROL OVER CLIMATE CHANGE

"We have developed 'aerosol optical tweezers,'" says Sullivan, "a device that allows us to trap a single droplet in a bright green laser beam and hold it stably for hours, allowing us to watch how the droplet evolves or responds to changes in its gas phase environment or while being bombarded with potential ice nuclei. The trapping laser also induces the droplet's Raman vibrational spectrum which tells us, every second, the size and composition of the droplet, and when a particle collides with it, if it then freezes."

Sullivan observes changes in the particle like, for example, what happens if the humidity around the droplet is changed, or what products form when the particle is exposed to air pollutants such as ozone. Sullivan and his group have even successfully engineered the device to trap supercooled droplets at subzero temperatures—a first in his field.

But why would measuring this change in a particle's properties be important? Well, the short answer is that as clouds shift in their ratio of liquid particles to ice particles, they have a surprisingly large influence on the global energy balance and temperature of our planet.

"Liquid clouds reflect incoming solar radiation or sunlight, so they have a net cooling effect on the planet, but ice crystals actually trap outgoing infrared radiation so they have a net warming effect," Sullivan explains.

So, if smoke contains ice nuclei, then one can imagine the impacts of industrial air pollutants or wildfires on the proportion of ice in the clouds—if the proportion of ice crystals in the clouds increases, so does global warming.

But that understanding goes both ways. If we can learn how to change the abundance of ice nuclei in the atmosphere, some say we could influence the ratio of ice to liquid in clouds, thereby gaining some control over climate change.

# A Closer Look at Metal 3-D Printing

BY HANNAH DIORIO-TOTH


Aerospace is one of the possible applications for which 3-D printing may become the mainstream manufacturing process.

In the wee hours of a Saturday morning, Professor of Materials Science and Engineering Tony Rollett and graduate students Ross Cunningham and Tugce Ozturk sit in Sector 2 of the mile-wide Advanced Photon Source at the Argonne National Laboratory in Chicago, Illinois. In front of them is an enormous synchrotron x-ray machine, powerful enough to see through heavy metals down to one millionth of a meter, roughly one hundredth of a human hair. The unique equipment is in such high demand that the team has just forty-eight hours to use the x-rays before they must pack up and carry their data back to Pittsburgh.

Scientists who are able to secure time with the synchrotron study the internal structure of materials including polymers, biomedical biopsies, and alloys. The synchrotron takes detailed, 3-D images that are used to characterize materials. The images are so precise that researchers often turn to synchrotron technology to identify ancient insect fossils, which can barely be seen under a microscope. Instead of leveraging this powerful technology to learn about ancient materials, Rollett's group seeks to gain elusive information about 3-D printed metals.

By looking deep inside thin slices of 3-D printed titanium parts, the group examined defects in the printed metal that are difficult to detect even with current laboratory-grade equipment. These defects, called pores, make the part more susceptible to breakage when the part is exposed to repeated weight or stress. Potential for breakage might not be a big deal for your 3-D printed toothbrush holder, but it is significantly more important when it comes to a 3-D printed part for a jet engine.

> "Carnegie Mellon is bringing really unique research to the table because we are one of the only universities chasing after advanced characterization techniques in the metals 3-D printing space.
> – Tony Rollett"

Although 3-D printing, or additive manufacturing, is currently used for rapid prototyping, it may become the mainstream manufacturing process for grander applications such as aerospace parts, custom biomedical implants, and high performance automobiles.

Improving the internal structure of 3-D printed metal parts is a challenge that must be met in order for this manufacturing process to become more mainstream. Rollett's team published a paper in the *Journal of Minerals, Metals, and Materials Society* in collaboration with Professor of Mechanical Engineering Jack Beuth, which showed that a majority of the porosity in 3-D printed titanium could be eliminated by making adjustments to the process parameters of the machine. Less porosity means stronger, more reliable end-parts.

"Having a strong understanding of the fundamental science of additive manufacturing materials is necessary in order to use them in aerospace and other demanding applications," says Beuth. "The ability to visualize porosity and flaws in 3-D with such high precision is a breakthrough capability in additive research."

Rollett and his team plan to continue their research to determine if it is possible to eliminate all remaining porosity from 3-D printed titanium and other metals. This is an important goal because it is currently thought that some amount of porosity will always exist in 3-D printed materials.

"In a conventional material like steel, there aren't any of these pores," says Rollett. "In additive manufacturing materials, there they [pores] are. You have to figure out how to understand them and deal with them. It is a new challenge in the field of materials science."

Carnegie Mellon's NextManufacturing Center, where Beuth serves as director and Rollett as associate director, has focused its attention on materials science projects like this one. As one of the world's leading research centers for additive manufacturing, the center is advancing the field of additive manufacturing by meeting the research challenges of the industry.

# Recovering Data From Ever-Shrinking Disk Drives

BY KRISTA BURNS

Digital devices have come a long way in the last few decades, particularly as they continue to shrink in size. Many advances, including new recording media, disk drive heads, and disk architectures, have contributed to making today's computer drives compact while being able to store and read amazing amounts of data. But as the size of disk drives became relentlessly smaller and were able to store tremendously more data, a major challenge developed.

How can the computer successfully recover and read the bits of data stored on miniature disk drives?

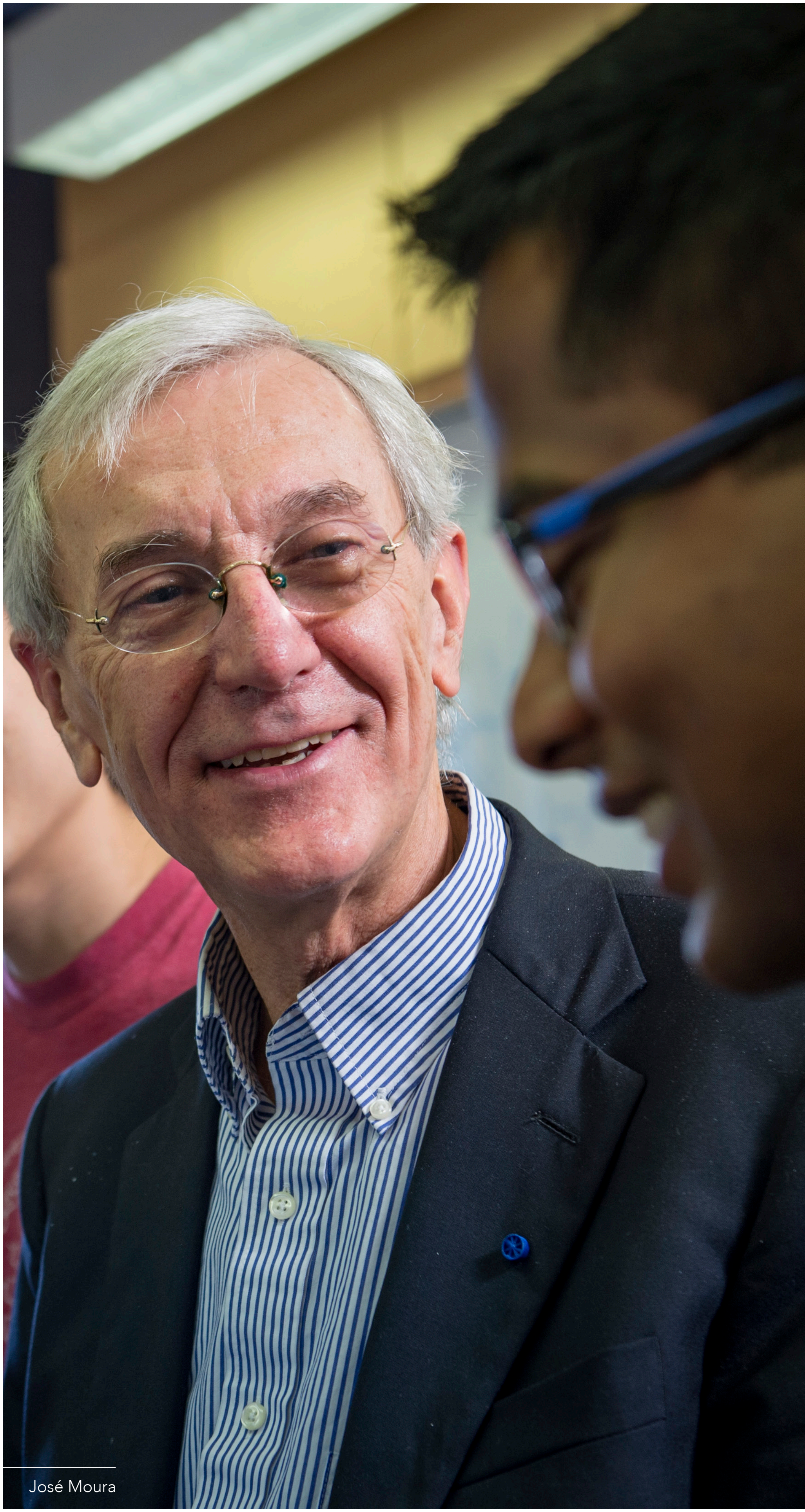
Over the last 30 years, Carnegie Mellon engineers have contributed in many different ways to the progress of disk drive storage and, in particular, significantly contributed to solving the challenge of accurately reading bits of data crammed into miniscule places.

Back in the 1950s, a typical computer disk drive was approximately five feet in diameter and could store no more than 1 million bits, or a megabyte (MB), of data. For reference, an MP3 audio file a few minutes in length, or a 10 million-pixel image from a digital camera, typically take up several tens of megabytes. Fast forward to present day where disk drives are a few inches in diameter and can store terabytes (TB) of data (1 TB = 1 million MB).

As disk drives decreased in size and the amount of data being stored increased exponentially, researchers became concerned about the ability to accurately recover and successfully read the stored bits of data. Carnegie Mellon's Data Storage Systems Center (DSSC) is a world-leading academic research institution in data storage that focuses on magnetic data storage technology for hard disk drive applications.

In the early 1990s, José Moura, a professor in Carnegie Mellon's College of Engineering, along with his then Ph.D. student Aleksandar Kavcic, now a professor at the University of Hawaii, set out to find an innovative way to accurately recover bits from the ever-shrinking storage disk drives of the future.

Kavcic and Moura invented and patented a detector that could safely and accurately extract recorded data from disk drives. When the early 2000s recording technology changed to



José Moura

perpendicular recording, their detector algorithm invention became a must-have technology.

"Alek Kavcic and I chose to target the limitations that were sure to arise in reading bits in magnetic recording in the future," says Moura. "Instead of looking for quick payoffs from incremental improvements, we invested our efforts in understanding and abstracting the fundamentals. In a moment of serendipity, we were able to develop a simple, fundamental new way to account for the main physical limitations of magnetic recording and to invent a detector that outperformed all others."

It is estimated that the disk drives in 60% of computers (over 3 billion) made in the last 14 years contain this detector technology enabling users to recover saved data.

"Our patience paid off in the 2000s when industry faced the inevitability of its own success," says Moura. "It needed a fundamentally new approach that was simple to implement and could read back the enormous amount of data being packed in very small spaces. The rest is history, and our patents became crucial to read channel chip manufacturers."

Looking to the future, Moura is developing algorithms that digest the tremendous amount of data being collected from multiple sources in everyday life. Nowadays, cities are covered in sensors that monitor security, weather, traffic patterns, energy consumption, pollution levels, and more. The data from these sensors allow us to understand the normal social behavior in a particular city. By addressing these data-rich environments, Moura hopes to understand the normal—and abnormal—behaviors of cities, from traffic jams to inconspicuous sources of pollution to unbearable sources of noise. Ultimately, Moura's data analytics may help urban planners rethink the way they envision cities.

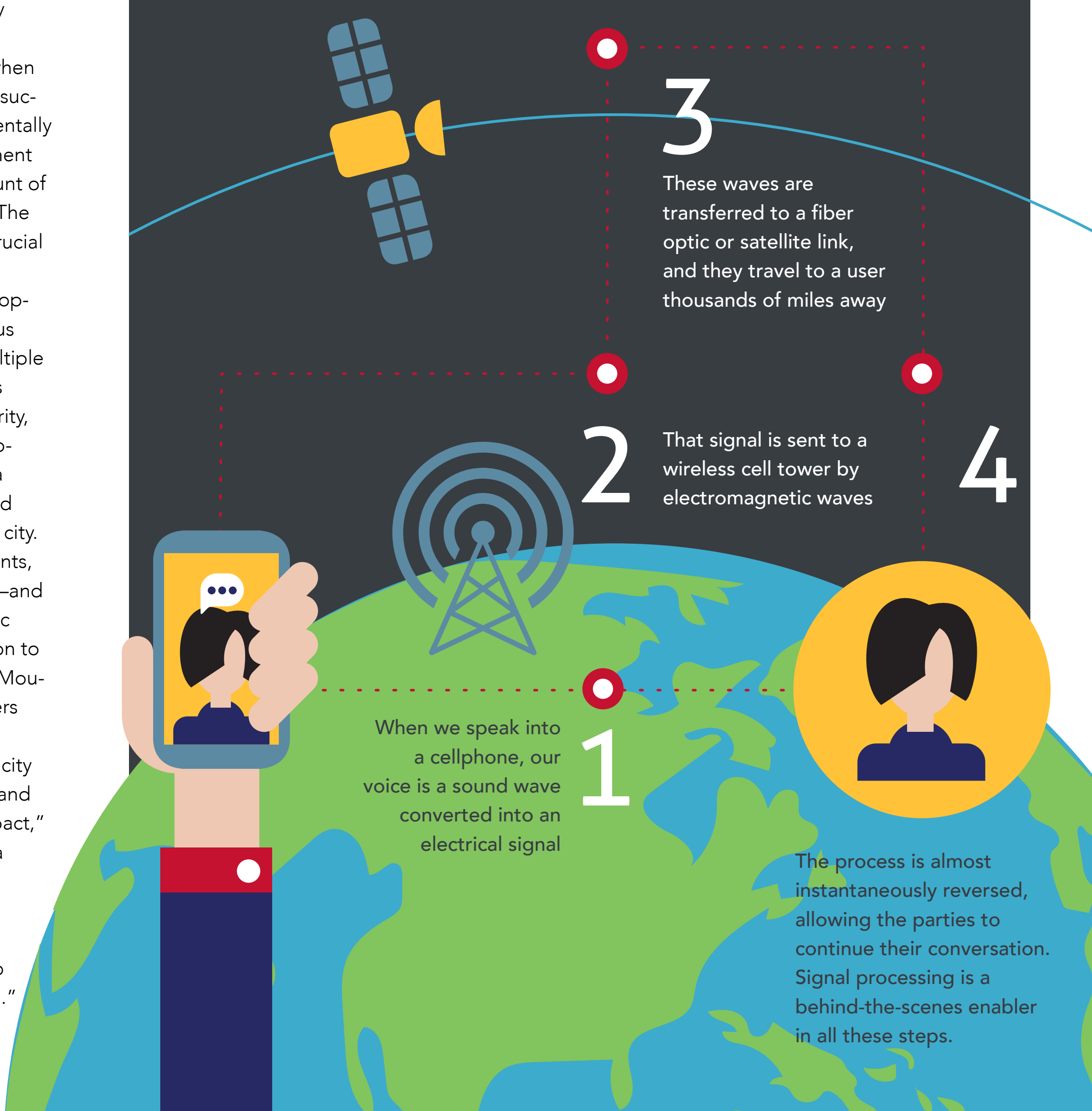
"If urban planners better understand city bottlenecks, they could reimagine a city and have major social and environmental impact," says Moura. "It would give city dwellers a more pleasant day-to-day life. I think we live in interesting times. For the past few decades, society has shaped technology. Moving forward, technology is helping to shape society. And that is pretty amazing."

**THE IMPACT OF SIGNAL PROCESSING** Signal processing is the technology behind technology. Signal processing involves developing algorithms to process the massive amounts of data generated, collected, and stored in disk drives and extracts knowledge and actionable wisdom. This enabling technology is vital in many fields, including wireless communications, smartphones, medical MRI/CAT scans, drilling for oil, aviation, cable and broadcast TV, radar, or sonar.

A simple cellphone conversation is a prodigy of successful technologies; but having that conversation would not be possible without the algorithms derived from signal processing. When we speak into a cellphone, our voice is a sound wave converted into an electrical signal that, in turn, is sent to a wireless cell tower by electromagnetic waves. These waves are transferred to a fiber optic or satellite link, then travel around the world to be delivered to a user thousands of miles away. The process is almost instantaneously reversed, and the parties can continue their conversation. Signal processing is a behind-the-scenes enabler in all these steps.

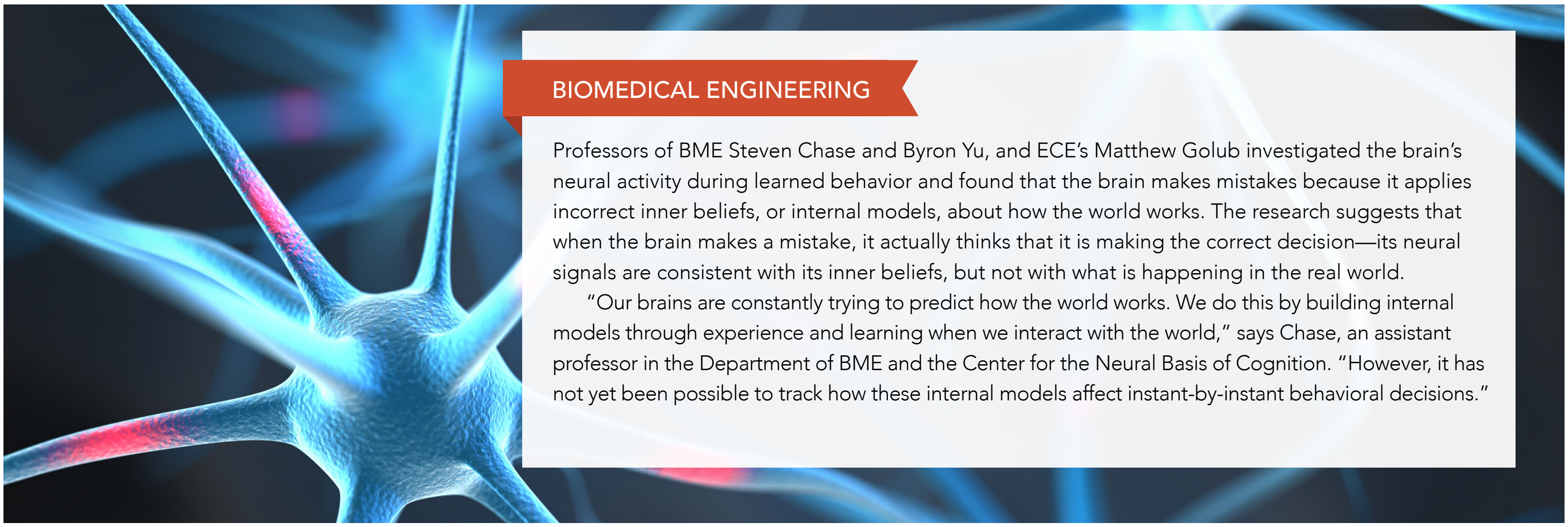
"Signal processing is often referred to as a stealth technology," says Moura. "It's something users can't see, but it is vital to our everyday life."

## HOW SIGNAL PROCESSING MAKES A CELLPHONE CALL POSSIBLE



# Department News

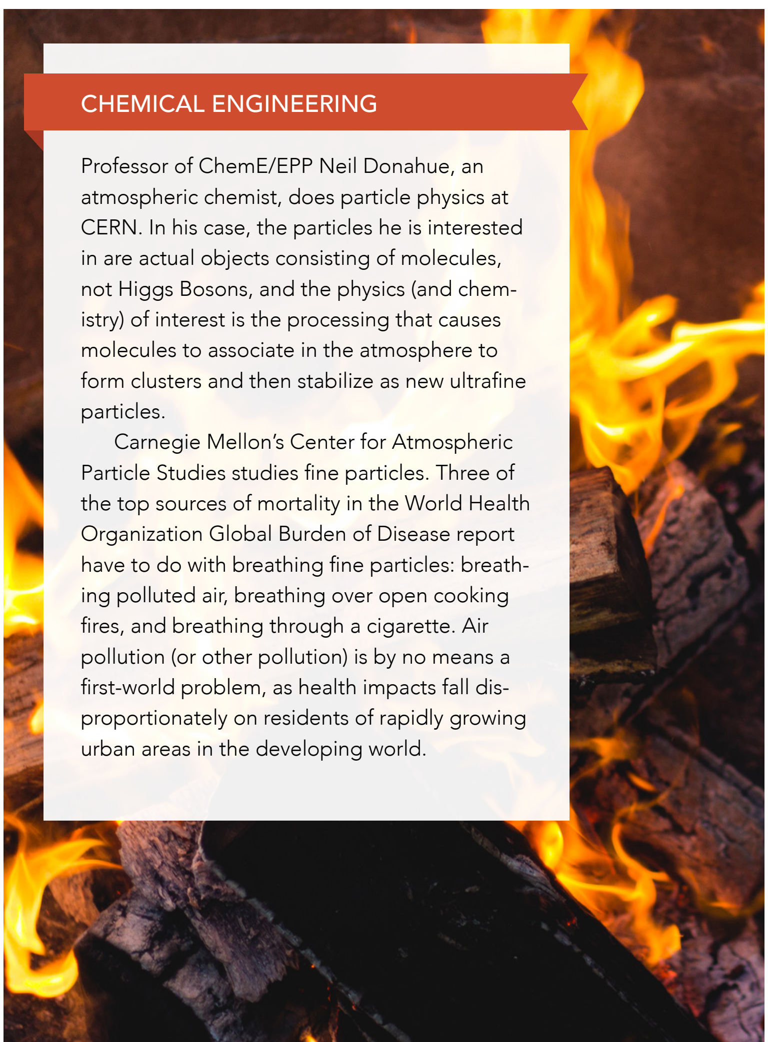
The initiatives underway in the College's departments embody the value we place on progress.  Here are some of our current projects and prides.



## BIOMEDICAL ENGINEERING

Professors of BME Steven Chase and Byron Yu, and ECE's Matthew Golub investigated the brain's neural activity during learned behavior and found that the brain makes mistakes because it applies incorrect inner beliefs, or internal models, about how the world works. The research suggests that when the brain makes a mistake, it actually thinks that it is making the correct decision—its neural signals are consistent with its inner beliefs, but not with what is happening in the real world.

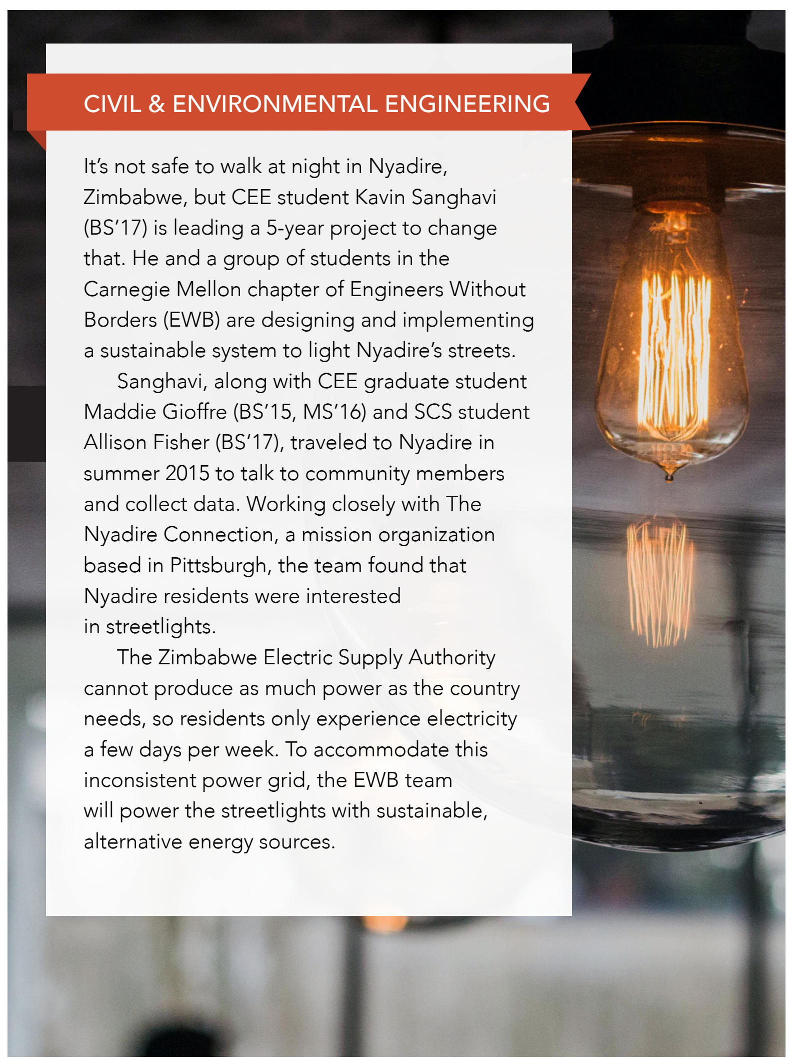
"Our brains are constantly trying to predict how the world works. We do this by building internal models through experience and learning when we interact with the world," says Chase, an assistant professor in the Department of BME and the Center for the Neural Basis of Cognition. "However, it has not yet been possible to track how these internal models affect instant-by-instant behavioral decisions."



## CHEMICAL ENGINEERING

Professor of ChemE/EPP Neil Donahue, an atmospheric chemist, does particle physics at CERN. In his case, the particles he is interested in are actual objects consisting of molecules, not Higgs Bosons, and the physics (and chemistry) of interest is the processing that causes molecules to associate in the atmosphere to form clusters and then stabilize as new ultrafine particles.

Carnegie Mellon's Center for Atmospheric Particle Studies studies fine particles. Three of the top sources of mortality in the World Health Organization Global Burden of Disease report have to do with breathing fine particles: breathing polluted air, breathing over open cooking fires, and breathing through a cigarette. Air pollution (or other pollution) is by no means a first-world problem, as health impacts fall disproportionately on residents of rapidly growing urban areas in the developing world.



## CIVIL & ENVIRONMENTAL ENGINEERING

It's not safe to walk at night in Nyadire, Zimbabwe, but CEE student Kavin Sanghavi (BS'17) is leading a 5-year project to change that. He and a group of students in the Carnegie Mellon chapter of Engineers Without Borders (EWB) are designing and implementing a sustainable system to light Nyadire's streets.

Sanghavi, along with CEE graduate student Maddie Gioffre (BS'15, MS'16) and SCS student Allison Fisher (BS'17), traveled to Nyadire in summer 2015 to talk to community members and collect data. Working closely with The Nyadire Connection, a mission organization based in Pittsburgh, the team found that Nyadire residents were interested in streetlights.

The Zimbabwe Electric Supply Authority cannot produce as much power as the country needs, so residents only experience electricity a few days per week. To accommodate this inconsistent power grid, the EWB team will power the streetlights with sustainable, alternative energy sources.

## MATERIALS SCIENCE & ENGINEERING

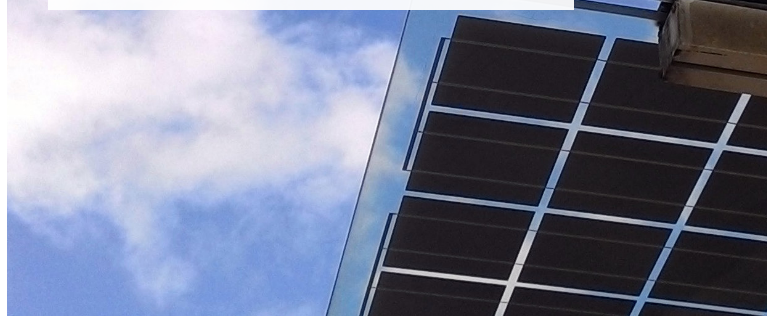
Professor Elizabeth Holm and W.W. Mullins Professor and Department Head Gregory Rohrer recently received a four-year $1 million grant from the W.M. Keck Foundation to explain why in some materials, atoms appear to behave in a manner contrary to the understood laws of physics. Understanding of this phenomenon could lead to the creation of stronger, more energy-efficient materials.

The project, titled "Anti-thermal behaviors of materials: reversing the trend of nature," represents a collaboration between CMU and Lehigh University. The researchers will study nanocrystalline metals. Because of their nano-sized crystal substructure, these metals are very strong and are currently used in industrial hard coatings. This material's strength makes it a candidate for other applications, such as automobile parts and aerospace components.

## MECHANICAL ENGINEERING

Professor Jeremy Michalek and CMU colleagues study greenhouse gas emissions from electric vehicles. They found that, while charging electric vehicles at night is cost-effective, it increases air emissions.

"We looked at how power plant operations would change in response to electric vehicle charging load, and we modeled emissions from those plants and their downwind air pollution consequences for human health and the environment," explains Michalek. "We found that charging late at night reduces power generation costs by a quarter to a third, largely by shifting to cheaper coal-fired power plants. But the extra emissions released as a result can cause 50% higher costs to human health and the environment."



## ELECTRICAL & COMPUTER ENGINEERING

As part of the United States Department of Energy's (DOE) Grid Modernization Initiative to improve the resiliency, reliability, and security of the nation's electrical power grid, the DOE has awarded $18 million in funding for six new research projects across the nation. These projects will enable the development of integrated, scalable, and cost-effective solar technologies that incorporate energy storage to power American homes after the sun sets or when clouds are overhead.

Assistant Research Professor Soummya Kar and Philip L. and Marsha Dowd University Professor José M.F. Moura have received $1 million to develop and demonstrate a distributed, agent-based control system to integrate smart inverters, energy storage, and commercial off-the-shelf home automation controllers and smart thermostats.

## ENGINEERING & PUBLIC POLICY

The Climate and Energy Decision Making Center (CEDM), a research center formed through an agreement with the National Science Foundation, has been awarded a new round of funding, totaling $4.5 million dollars through 2020. Professors Inês Azevedo and Granger Morgan serve as co-directors of CEDM.

The Center and its graduates develop and promulgate new and innovative, behaviorally and technically informed insights involving the intersection points between climate and energy. It also generates methods to frame, analyze, and assist key stakeholders in addressing important decisions regarding climate change and the necessary transformation of the world's energy system.




# COLLEGE UPDATES

## STRATEGIC MOVES IN CYLAB

BY DANIEL TKACIK

David Brumley was appointed to lead Carnegie Mellon CyLab Security and Privacy Institute. Brumley is the third director of the campus-wide cybersecurity research and education center, and succeeds Electrical and Computer Engineering Professor Virgil Gligor, who is stepping down after seven years to focus on his research.

Brumley, whose research focuses on software security and program analysis, began as an assistant professor in the Department of Electrical and Computer Engineering after receiving his Ph.D. from Carnegie Mellon's School of Computer Science in 2009. He was later promoted to Associate Professor and most recently served as CyLab's Technical Director.

Brumley, an advocate for cybersecurity outreach, is the faculty sponsor of picoCTF, a high school computer security competition that has drawn over 10,000 student participants in each of the past two years it has been held. Brumley also leads a student cybersecurity team that has received acclaim at international cybersecurity competitions. The team received first place rankings at the DefCon "Capture the Flag" cybersecurity competition—dubbed the "Super Bowl of Hacking"—in 2013 and 2014.

### BOSCH RECOGNIZES BRUMLEY

Coinciding with his appointment as the director of CyLab, Brumley was named the Bosch Distinguished Professor in Security and Privacy Technologies. The professorship was made possible with a $2.5 million dollar donation from Bosch, and it will always be awarded to the director of CyLab.

The goal of the new professorship is to support two critical research areas, including the creation of breakthrough technologies that enable internet-scale systems that connect the physical and cyber domains securely; and the development of next-generation technologies that enable and ultimately guarantee the use of personal data in accordance with individual privacy preferences in a ubiquitous computing world.

"As a global company focused on innovation and improving the quality of life, we work to provide innovative technological solutions to challenges facing our society now and in the future. The Internet of Things brings considerable promise, but also concern surrounding the security of our connected environment and the privacy of personal data," said Jiri Marek, senior vice president, Bosch Research and Technology Center – North America. "This Distinguished Professor position will address these concerns with research to find breakthrough technologies and a holistic approach to security."

David Brumley


## How have connected devices changed the cybersecurity landscape?

When we look at connected devices like home thermostats and other Internet of Things (IoT) devices, we know software will have bugs and other vulnerabilities. We need to ensure that devices are automatically updated at the same speed as smart phones because connected devices will be attacked just as much. A patch can only be placed if these devices are connected to the internet, but they are not always connected. Connectivity is a huge problem. IoT security and privacy are research thrusts in CyLab.

## There are nearly 1 million unfilled positions in cybersecurity in the US. Why is it difficult to fill cybersecurity positions in the United States?

Even though security and privacy professionals can easily command 6-figure salaries, there's a problem with the current perception of cybersecurity as a profession, and I believe there are things we can do to change this.

First, we need to stop stigmatizing hackers. Many of us hear in the news about hackers going rogue, but that isn't representative of the profession as a whole. The hackers I know are curious, imaginative professionals who can find the unexpected chinks in the armor. They can take a computer and bend it to their will.

People need to start recognizing cybersecurity as a uniquely skilled profession; IT professionals can't be rebranded as security. Cybersecurity is a unique way of thinking. In this profession, we are competing with intelligent adversaries who are always looking for the open window when the door is locked.

Finally, everyone—from the 7-year-old playing games on an iPad to the utilities technician controlling your town's power grid—needs to understand basic cybersecurity and privacy hygiene.

To initiate cyber education, at CMU, we run picoCTF, the hacking competition for high school students in which over 10,000 students have participated. Many discover they have a knack for computer security and decide pursue a degree in the field. Cybersecurity is a practice sport, and our hacking competition could become a template for educational activities on a national scale.

# Early Honors

BY ALEXANDRA GEORGE

The College of Engineering is proud to announce the recipients of the 2016 Dean's Early Career Fellowships. These fellowships will provide the following young faculty members with additional funding for their outstanding research.

## Carmel Majidi

*Assistant professor,*
*Mechanical Engineering*

Carmel Majidi specializes in the mechanics of soft multifunctional materials. His research group, the Soft Machines Lab, is developing new types of materials that could be used in soft robots and wearable computing.

"In order to engineer robotic systems that are safe and comfortable for physical interaction with humans, we have to be careful about the materials that we select," said Majidi. "We want materials that allow electronics and machines to be as soft, flexible, and lightweight as natural skin and organs."

With Majidi's research, soft robots will be more compatible with the human body and exhibit many of the robust mechanical features of soft biological organisms, like the octopus. Recently, Majidi received a Samsung Global Research Outreach Program grant to develop soft artificial muscles for robotics. This project is co-led by Prof. Yong-Lae Park (assistant professor in the Robotics Institute with a courtesy appointment in Mechanical Engineering) and is focused on the development of pneumatic actuators that are embedded with rigidity-tuning materials that change their stiffness in response to electrical activation. This work will improve the ability of a soft pneumatic gripper to adapt its shape, load bearing capacity, and functionality in robotics tasks.

## Sheng Shen

*Assistant professor,*
*Mechanical Engineering*

Sheng Shen investigates energy nanotechnology, or how to solve energy problems at the nanoscale level. Shen designed a nanoscale solar absorber that converts 90% of sunlight to heat—a remarkable amount of energy conversion. Once converted to heat, that energy can be converted to electricity as well.

"Solar energy is free, and it's clean and renewable. It's everywhere—every morning when waking up, we can start to use solar energy."

Shen's research will create new energy and thermal management while also cutting down on the cost. "It is my dream to use nanotechnology to make a real-world difference," said Shen. "Not just differences that researchers get excited about in the lab, but for everyone to see and be able to apply."

## Soummya Kar

*Assistant research professor, Electrical and Computer Engineering*

Soummya Kar's research delves into large-scale networks that emerge as abstractions of stochastic dynamical systems and cyber-physical networks. These networks look like the power grid or a transportation system, social networks, and financial markets.

One of his research objectives is to develop scientific foundations and algorithmic methodologies for understanding dependencies in data obtained from processes that model complex cyber-physical-socio-economic (CPSE) systems. For example, an urban metropolitan system has information that comes from business and enterprises, education, health, smart buildings,

and smart grid or transportation networks. Kar performs analytics that extract information to find meaning at different spatiotemporal scales.

"To extract relevant information from unstructured and distributed data, we are developing novel usable representations of data," said Kar, "or representations that are of lower complexity than the unprocessed raw data but capture the critical hidden dependencies among the data."

## Hakan Erdogmus

*Associate teaching professor of software engineering, Carnegie Mellon University's Silicon Valley Campus (CMU-SV)*

Hakan Erdogmus is advancing the Electrical and Computer Engineering master's program in Software Engineering. "Cécile Péraire, Jia Zhang, and I have been building the curriculum from the ground up since 2014," said Erdogmus. "We had help from other ECE and SV faculty, who contributed great ideas and supported us, including Bob Iannucci and Jelena Kovačević. The program launched in Fall 2014 and has been enjoying continual growth since."

On the research side, a CMU-SV team led by Erdogmus, Martin Griss, and Bob Iannucci recently finished a large project sponsored by the Department of Homeland Security on improving the Wireless Emergency Alerts (WEA) service, which delivers the government-issued text warnings we receive on our smartphones. The results showed how to achieve accurate geo-targeting, improve interpretability and actionability, and make the alerts "smarter" and more relevant. The work made a real-world impact, as a recent FCC ruling on the future of the WEA service cited their research and adopted many of their recommendations.

## Paulina Jaramillo

*Assistant professor, Engineering and Public Policy*

Paulina Jaramillo is involved in research that creates the knowledge that will be required to meet global energy needs. Recently, Jaramillo expanded her research to include issues related to energy access and development. She is particularly excited by the research endeavors of her students, who aim to identify the challenges and solutions for meeting the energy needs of the global poor.

"Over the next decades, meeting the infrastructure needs of developing countries will become a priority, particularly as we move to mitigate climate change," said Jaramillo.

> "Carnegie Mellon has the expertise in energy and environmental systems analysis to contribute knowledge that will support efforts to deploy truly sustainable infrastructure systems for global development."

"I am excited to pursue this area of research and help CMU become a leader in global-oriented engineering research and education."

# NSF Recognizes Up-and-Coming Faculty

The National Science Foundation's Early Career Development Award (CAREER) program offers the foundation's most prestigious awards to support junior faculty who exemplify the role of teacher-scholars through the integration of outstanding education and research efforts within the context of the mission of their organizations. Four Carnegie Mellon Engineering professors have received CAREER awards so far this year.

## Cohen-Karni Receives Grant to Monitor Electrical Activity of Cells in Three Dimensions

BY ALEXANDRA GEORGE

Knowledge of how cells communicate with each other has been constrained, in part because the electrical activity of cells has been limited to simple, 2-D measurements. However, that may change soon.

Tzahi Cohen-Karni, an assistant professor of Biomedical Engineering and Materials Science and Engineering, received an NSF CAREER award to develop nanosensors to monitor the electrical activity of cells in three dimensions.

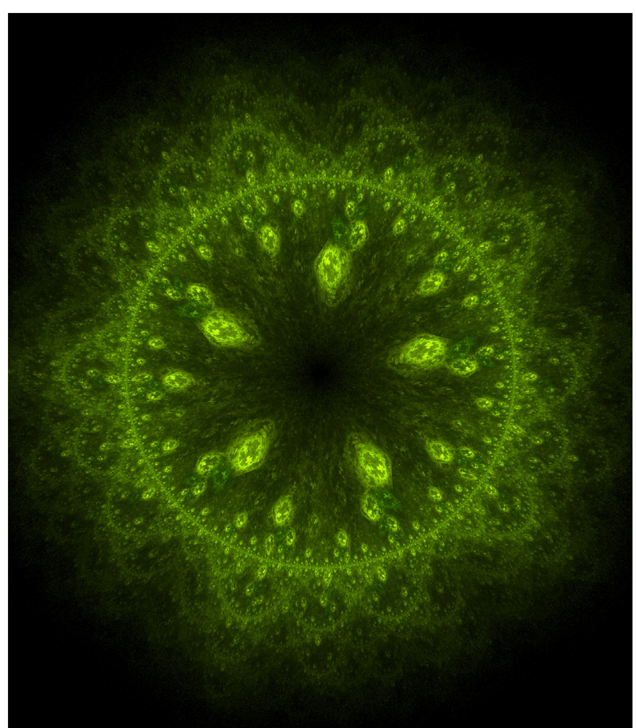
"We, as humans, are not two-dimensional," said Cohen-Karni. "When you culture cells in a dish, it is not as they are organized in nature. We are trying to measure the electrophysiology of a cellular arrangement that is closer to the way it is in nature."

Traditionally, cells are cultured on a 2-D flat surface where researchers cannot get a full sense of the electrical activity happening in a close to natural 3-D geometry. Cohen-Karni's technique surrounds the 3-D cell construct with sensors, and monitors it from all sides.

This project has huge long-term implications. In the biological field, heart cells, or cardiomyocytes, serve as a potential therapy for heart defects and conditions. Monitoring these cells in 3-D will provide more insight into the way cells really communicate.

"When it comes to the heart and the brain," said Cohen-Karni, "whatever we do is due to this intracellular communication. To some extent, we know what is happening inside. But having the tools to explore it in a quasi-controlled manner will help us to understand exactly how they talk to each other."

Cohen-Karni's device will monitor the electrophysiology of induced pluripotent cells derived cardiomyocytes (iPS-CM). In the future, the platform will be able to compare the electrical activity of normal heart or brain cells with that of diseased cells.




## Mauter Will Curb Power Plant Pollutants

BY EMILY DURHAM

Meagan Mauter, an assistant professor of Civil & Environmental Engineering and Engineering & Public Policy, will use her five-year CAREER award to reduce air and water pollutant emissions from power plants.

"Much of our electricity generation infrastructure was built in an earlier era when air, water, and $CO_2$ emissions were not tightly regulated," Mauter explains. "In the past decade, we have developed a much greater understanding of the human health and environmental costs of these emissions, and regulatory agencies have responded with strict new limits on emissions from coal fired power plants."

Mauter's CAREER research will build upon and unify her past research topics, which include studying waste heat driven water treatment processes, investigating the limitations of these processes, and looking at tradeoffs between air and water emissions at these power plants.

The project, titled "Integrated water, energy, and emissions decision making for a low-carbon future with coal-fired power plants," will develop decision support tools to help re-design coal fired power plants to cost effectively reduce emissions.

"Helping power plants to more efficiently treat water emissions will reduce the auxiliary power consumption and associated air emissions from running water treatment processes," says Mauter. "Avoiding these tradeoffs in air and water emissions will reduce the human health and environmental consequences of electricity production from coal fired power plants as we transition to a low-carbon electricity generation mix."

The award will also fund the development and characterization of new materials used in waste heat driven processes, as well as allow Mauter to include high school students in the collection and interpretation of data on the environmental impacts of water emissions from power plants.

## TWO MECHANICAL ENGINEERS EARN CAREER AWARDS

*by Lisa Kulick*

Ryan Sullivan

Venkat Viswanathan

**Ryan Sullivan**, an assistant professor of Mechanical Engineering and Chemistry, was awarded a five-year CAREER grant to study the effects of chemical aging on the ice nucleation properties of natural and anthropogenic atmospheric particles.

His research will improve our understanding of how air pollutants alter the ability of atmospheric particles to cause clouds to freeze. Glaciated clouds are the major source of precipitation over land, yet we lack a detailed understanding of the sources and behavior of these rare ice nuclei in the atmosphere. *(Read more about Sullivan's work on page 8.)*

The grant will support educational modules for K-12 teachers to introduce students to the chemical science and measurement of air pollution, acid rain, and cloud forming reactions.

**Venkat Viswanathan**, an assistant professor of Mechanical Engineering, was awarded a five-year CAREER grant to study engineering electrode-electrolyte interfaces through electrolyte selection for improved performance in lithium-air batteries and fuel cell electrocatalysis.

Because the mass-market adoption of environmentally-friendly electric vehicles requires significant improvements to battery technology, Viswanathan seeks to improve discharge capacity and rechargeability in lithium-air batteries. His findings could have an impact on other metal-air battery technologies such as sodium-air, magnesium-air, and potassium-air.

His grant will support his statistical thermodynamics massive open online course (MOOC) with 3-D printed learning kits.

# INI Renews Valued International Partnership with University of Hyogo

BY JESSICA CORRY



Carnegie Mellon University (CMU) has renewed an agreement with the University of Hyogo (UH) in Kobe, Japan to continue an information security dual-degree program.

In 2005, Carnegie Mellon partnered with the Hyogo Prefectural government to create the Kobe Master of Science in Information Technology – Information Security (MSIT-IS). The program blends information security technology with management and policy, and features core courses ranging from "Networking Security" to "Information Security Risk Analysis." Since 2005, the program has graduated 67 students drawn from countries across the globe.

"The continuation of this partnership is vital to meeting the demands of our global society and addressing the critical issue of information security," said Dena Haritos Tsamitis, director of the Information Networking Institute (INI). "The cross-cultural connection has redefined the CMU experience, highlighting the truly global nature of the challenges students will face as information security professionals."

With its recent renewal, the program will continue for five years with three cohorts of students. Building upon the initial focus in 2005, that of education and research closely intertwined, the renewed partnership will feature a research collaboration between UH and Carnegie Mellon CyLab.

"Recently in Japan, there have been large waves of financial frauds and APTs [advanced persistent threats], and thus, there is a growing demand for security specialists," explained student Kenta Okumoto. His company, the Japan Post Bank Co., Ltd., is sponsoring his enrollment so that he may gain advanced skills in information security that will enhance his role as a software engineer.

Fellow student Min Sok Hwang chose the program to gain exposure to the diverse security cultures of Japan and the United States.

"This program offers a superb chance to meet with top professors, alumni, and students from all over the world at the two locations," said Hwang. "Pittsburgh and Kobe are both excellent places to study and live in."

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The continuation of this partnership is vital to meeting the demands of our global society and addressing the critical issue of information security. The cross-cultural connection has redefined the CMU experience, highlighting the truly global nature of the challenges students will face as information security professionals.

– Dena Haritos Tsamitis

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# In Memoriam

## Jeremiah Mpagazehe

The College of Engineering was saddened by the sudden passing of our colleague **Jeremiah Mpagazehe** on January 18, 2016. Jeremiah, 31, earned B.S. (2006), M.S. (2010), and Ph.D. (2013) degrees in Mechanical Engineering at Carnegie Mellon and was an accomplished researcher and scholar who started an assignment as visiting professor at Carnegie Mellon-Rwanda shortly before his death.

As a project scientist, he secured a new algae biofuel lab, procured roughly a million dollars worth of research equipment, and supervised and mentored dozens of undergraduate and master's student researchers. Mpagazehe had received news that he won his first National Science Foundation (NSF) grant as a principal investigator to commercialize high-value algae products.

Deriving inspiration from his father, Charles, who is from Uganda, Mpagazehe's long-held dream was to explore research and educational opportunities in East Africa. In addition to serving as the Chief Technology Officer of the CMU start up company InnovAlgae, he was working towards his dream at the Kigali campus.

A memorial was held for Jeremiah in Pittsburgh on April 14, 2016. In honor of Jeremiah's legacy, an undergraduate scholarship has been established. If you would like to contribute to this fund, please go to *www.giving.cmu.edu/Jeremiah*.

## David Casasent

Professor Emeritus **David Casasent**, a pioneer in the pattern recognition, image processing, and product inspection fields, passed away on November 17, 2015. He was 72.

David joined the Department of Electrical and Computer Engineering in 1969 and retired in 2009. He developed algorithms using morphological processing, computer vision, distortion-invariant filters, and neural network techniques for a number of applications including product inspection, automation, robotics, pattern recognition signal processing, advanced computing, artificial intelligence, missile guidance and synthetic aperture radar, and IR and visible data. These concepts offered parallelism, high speed, flexibility, a wide variety of achievable operations, and many novel data-processing architectures and algorithms.

"Dave's service and contributions to the ECE Department were extraordinary," said Vijayakumar Bhagavatula, the U.A. and Helen Whitaker Professor of Electrical and Computer Engineering. "In addition to outstanding classroom teaching and developing optical data processing research facilities, he graduated nearly one hundred Ph.D. students under his research guidance and authored or co-authored nearly one thousand publications, a level of research productivity very rarely seen. Personally, I benefited significantly from his mentorship first as Ph.D. student and later as his colleague. Dave will be missed, but his contributions to the growth and increasing reputation of our department will last forever."

## Elio D'Appolonia

**Dr. Elio D'Appolonia**, founder of E. D'Appolonia Consulting Engineers (EDCE) and a former faculty member in Civil Engineering from 1948 to 1956, passed away on December 30, 2015. He was 97.

Elio truly helped to define and develop the multidisciplinary, creative problem-solving nature of civil engineering at Carnegie Mellon that remains a hallmark of the program. A structural engineer with classical mechanics training, he found the emerging field of geotechnical engineering, an intellectually rich area in need of a combination of mechanics knowledge and creative engineering problem-solving.

In 1956, Elio left the university to start EDCE and became an internationally renowned consultant in geotechnical engineering. He was widely recognized as one of the leaders who moved the field ahead significantly from the 1950s through the 1970s. The firm he founded provided employment opportunities for students from Carnegie Tech. In 2012, in recognition of the longstanding relationship between Elio and the college, the Department of Civil and Environmental Engineering announced the D'Appolonia Endowed Graduate Fellowship Fund.

*Contributions in honor of Elio D'Appolonia may be sent to the Dr. Elio D'Appolonia Graduate Fellowship Fund, Carnegie Mellon University, PO Box 371525, Pittsburgh, PA 15251-7525.*

## Elliott Glasgow

On March 30, the university community learned that **Elliott Glasgow**, 19, a first-year student in Engineering, had passed away. Elliott, who came to us from New York City, was a vital member of his residential community and a brother of Phi Delta Theta. He was known by his many friends for his wit and sense of humor. The College of Engineering extends its deepest sympathies to Elliott's family, friends, and classmates.


# BACK TO THE DRAWING BOARD WITH DIY DESIGN AND FABRICATION

BY ADAM DOVE

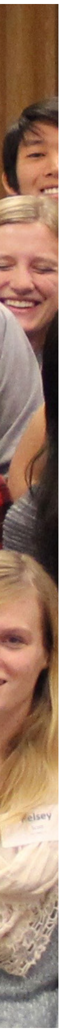
Carnegie Mellon Mechanical Engineering students undergo rigorous schooling, learning advanced computational and modeling techniques and difficult theoretical approaches. They certainly learn how to solve complex problems; however, when asked why they chose to become mechanical engineers, a lot of the students say that they just love to build.

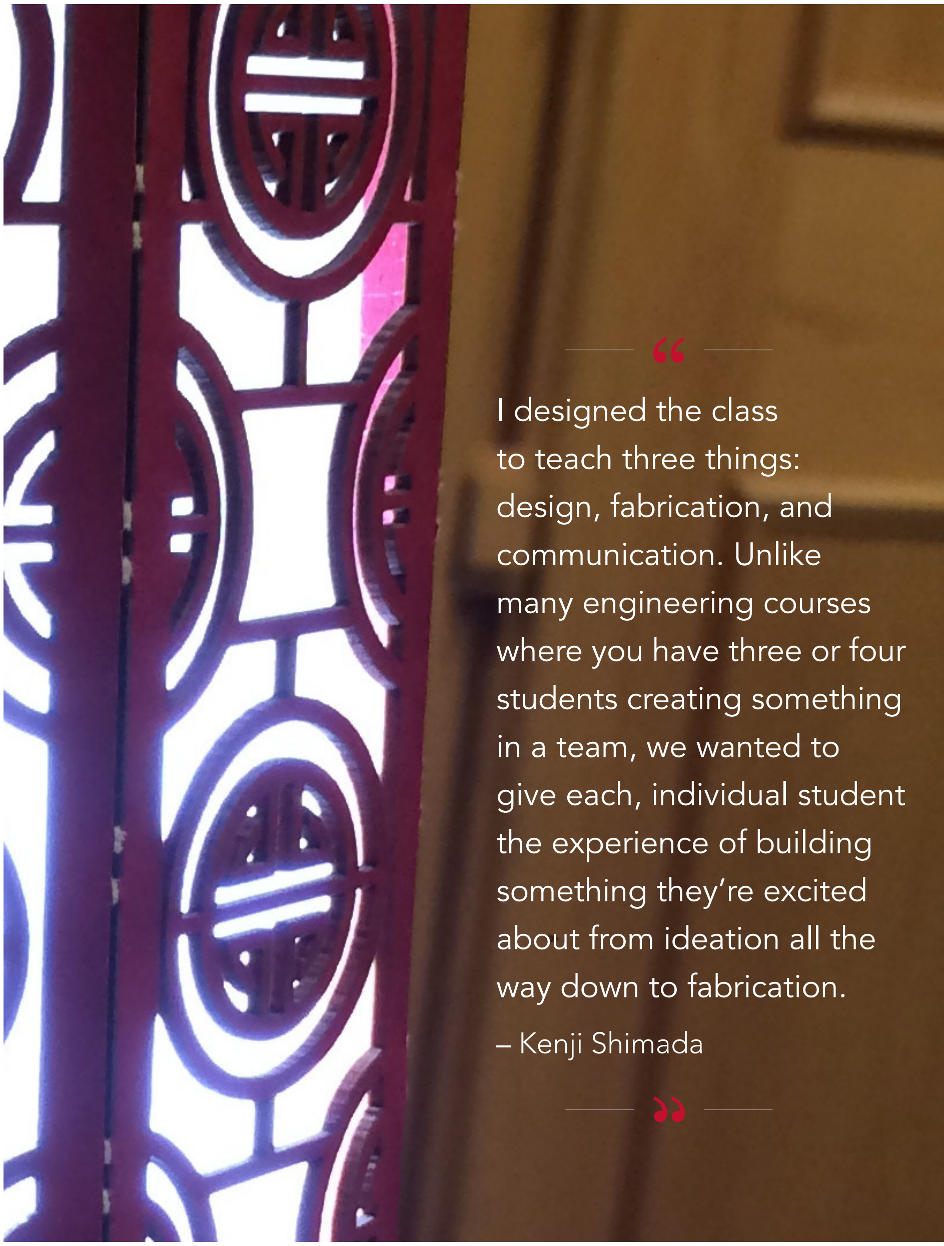
MechE Professor Kenji Shimada knows this, which is why he created a new course, titled DIY Design and Fabrication, to help foster that love in his students. But Shimada wanted his creation to be more than just another class, so he enlisted teaching assistants MechE master's student Matthew Powell-Palm and senior Judy Han to help him design and test the assignments.

"I designed the class to teach three things: design, fabrication, and communication," says Shimada. "Unlike many engineering courses where you have three or four students creating something in a team, we wanted to give each, individual student the experience of building something they're excited about from ideation all the way down to fabrication."

Design and fabrication are important skills, but for an engineer's work to have meaning, communication skills are key. That's why a major part of the course teaches students to make professional-looking documents and posters explaining their designs in ways that incorporate key principles of communication design: choosing typefaces and colors, and incorporating whitespace to make the information more digestible.

A typical class begins with Shimada reviewing students' work from the previous assignment, followed by a lecture to introduce new design methodology and fabrication techniques—from acrylic laser cutting, to resin casting, to polyure-





> I designed the class to teach three things: design, fabrication, and communication. Unlike many engineering courses where you have three or four students creating something in a team, we wanted to give each, individual student the experience of building something they're excited about from ideation all the way down to fabrication.
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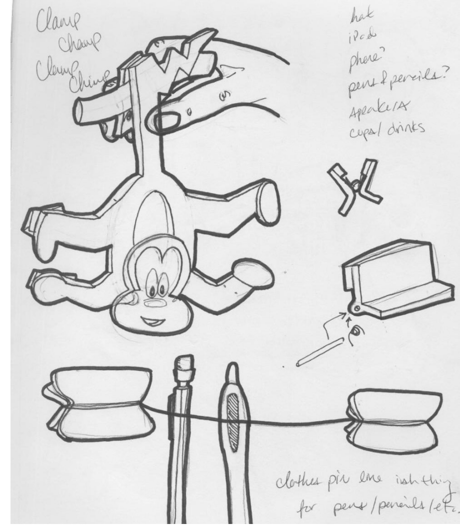

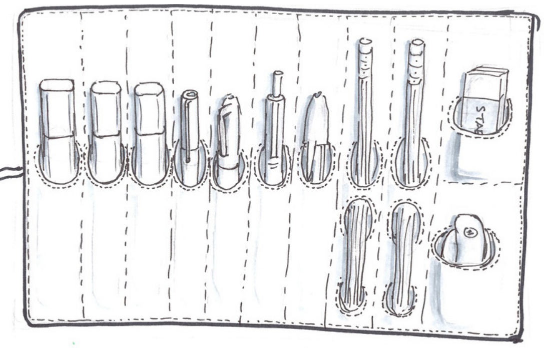

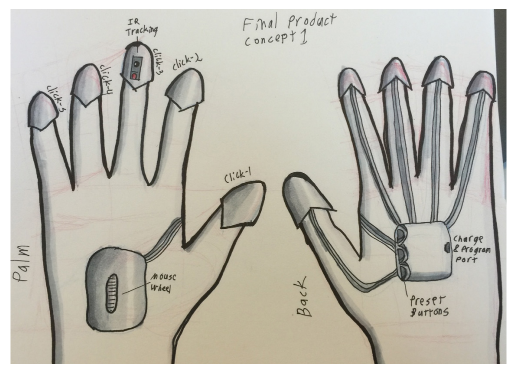


thane rapid expansion foam, and more. From there, Powell-Palm and Han take over.

"After that, we do a live demo of whatever technique we're talking about. We'll talk about what to keep an eye out for, which tools to use, what are the factors that contribute to the specific technique," Powell-Palm explains. "Then Judy Han, the design specialist of the group, along with MechE junior Melissa Zucker will teach sketching ideation tutorials to help students visually and materially conceptualize what they're thinking."

Rounding out the student teaching team is MechE doctoral student Recep Onler, who assists on the fabrication side.

Sketching ideation instruction is one of the primary functions of the class. In an ordinary class, a student will have an idea, then jump immediately to the computer to try to visualize it in a Computer-Aided Design (CAD) program. Suddenly, their designs are limited by their CAD skills, and by the parameters of the program itself. By learning how to sketch, students are free to ideate uninhibited, leading to more creative and free form development of ideas.

"Just twenty years ago, all mechanical engineering students were able to sketch—it was a fundamental skill," Shimada says. "We've emphasized the importance of computational modeling, and Carnegie Mellon is at the leading edge of computational tools. But the flip side is that students have lost the basic drawing skills, and we're starting to see the negative aspects of that."

The semester-long class, offered in the fall, culminates in a student showcase, at which students present their final project, along with other work they've done over the semester that they are proud of. For the final project, students are encouraged to use any of the methods and techniques of design that they have learned. The only parameter? *Build something that makes you or someone else happy.*

"That's one of Professor Shimada's big mottos," says Powell-Palm.

From that showcase, three students are selected for exceptional work. The winners of this fall's showcase were: The Yanagi, a slicing knife designed by Max Queenan; Puzzlight, an assembled lamp designed by Emily Yang; and Shimamock, a hand-woven personal hammock chair designed by Kelsey Scott.

But DIY Design is only one course—taken either in a student's senior year, or early in their graduate career. According to Powell-Palm, that's not enough.

"A lot of kids take this class and they say 'oh my goodness, imagine what I could have done in this other class had I known how to build things first," he says. "I think offering a DIY equivalent course to sophomores is a great idea. I predict you'll see a huge balloon in their productivity."

A full rundown of the class' final projects can be found at www.concepea.net.


# Entrepreneurship Accelerator Connects Portugal, Pittsburgh, and Silicon Valley

BY EMILY DURHAM


COLLEGE OF ENGINEERING PROGRAM IN PORTUGAL

A 6-year-old sits down and draws a racetrack with crayons. Her dad captures an image of the project, and minutes later the two of them are racing cars at their fingertips on a tablet screen.

Playsketch, a Portuguese startup, offers its consumers the ability to sketch an idea and bring it to life as a video game. Co-founders Luís Lucas Pereira and Pedro Machado Santa visited Pittsburgh to take their concept to market using contacts and entrepreneurial lessons learned from Carnegie Mellon University.

"The growth in our contact network really gave sense to the word 'acceleration,'" Santa said. "In just one month and a half, we established more than a thousand contacts with different companies and experts, and we gathered a contact network in the U.S. that it would take years to build up in Portugal."

inRes is an early stage acceleration program for Portuguese entrepreneurial teams. The program is part of the Information and Communication Technologies Institute, a partnership between Carnegie Mellon and the government of Portugal. Last fall, four Portuguese teams visited Pittsburgh for six weeks and also spent a week in Silicon Valley visiting startups and venture capitalists, while making connections with other innovators.

"The inRes program is a testament to CMU|Portugal's commitment to technology transfer and innovation, and is an invaluable expression of Carnegie Mellon's broader dedication to international collaboration," said José F. Moura, director of the CMU|Portugal Program and the Philip L. and Marsha Dowd University Professor of Electrical and Computer Engineering. "inRes is one very exceptional example of CMU|Portugal programs that have precipitated many successful spinoffs, such as Veniam and Feedzai."

Feedzai, a highly successful company stemming from the CMU|Portugal program, uses machine learning for fraud prevention. "I am excited to see how this year's group of entrepreneurs and all future teams chosen to participate in the inRes program will succeed in the tech innovation market," said Paulo Marques, CTO of Feedzai. "inRes and CMU|Portugal as a whole are proving to be an important pillar in the startup ecosystem of Portugal and the United States."

Along with Playsketch, the other inRes teams included Adapttech, which offers smart prosthetic-fitting solutions; Sceelix, a software that generates complex 3-D scenes on a massive scale; and Scraim, the provider of an online service for project and process management.

The teams were paired with experts from CMU's entrepreneurial ecosystem, including the Center for Innovation and Entrepreneurship (CIE) and the Center for Technology Transfer and Enterprise Creation.

Santa was not the only entrepreneur who returned home with vastly expanded contact lists—all of the entrepreneurs made contacts that will be enormously valuable to their companies.

"CMU|Portugal's inRes program gave us the opportunity to go into a country that has every single market we are trying to tap into on a huge scale," said Francisco Rebello de Andrade, general manager of Sceelix. "What we managed to do in terms of contacts will help us not only in the short term, but also in the long term."

# Lab Reveals the Secret Life of Materials

BY ADAM DOVE

In 1915, Sir William Henry Bragg and his son, William, received the first Nobel Prize ever given for materials characterization. Using x-rays, the Braggs revealed the crystal structure of rock salt, the first crystal structure ever characterized. Their success launched a century of exploration into the field of materials characterization or the practice of peering into a material's internal structure to learn its secrets—namely, its microstructure and chemistry.

Transmission electron microscopes and scanning electron microscopes are now the tools of choice for materials research. These are multi-million dollar pieces of complex equipment that require significant training to use. At Carnegie Mellon's Materials Characterization Facility (MCF), students and faculty have access to the full gamut of today's most advanced materials characterization technology.

"The microstructure is what gives a material its properties and performance," says Marc De Graef. "If we can understand the microstructure, we can begin to think about how we might change it to affect the behavior of the material—make it stronger, more conductive, more resistant to corrosion, anything you'd like."

De Graef is a professor of Materials Science and Engineering and co-director of the MCF. Under his supervision, graduate students at the MCF are taking materials characterization in novel directions.

Take Isha Kashyap, for example. As a second year Ph.D. candidate in Materials Science and Engineering, Kashyap studies the structure of ferromagnetic shape memory alloys. Using Lorentz Transmission Electron Microscopy (LTEM), one of only a handful of university-based LTEMs in the United States, Kashyap investigates defects and qualities of these alloys, which are used in magnetically induced mechanical actuators, a kind of motor that transforms energy into motion.

"The performance of the actuators depends on the properties of the alloys, which in turn depend on atomic level interactions. These interactions can only be observed using powerful instruments with nanometer level resolution," explains Kashyap.

*Over the period of 2011 – 2014, the Materials Characterization Facility has enabled the publication of more than 320 research papers in peer-reviewed journals.*

"My work is concerned with the experimental side," she says, "but Dr. De Graef's students are doing a lot of cool computational work to analyze the images we acquire."

One of those students is Saransh Singh, who has spent the past three years developing software to simulate the images and diffraction patterns observed in scanning electron microscopes. Singh's custom software, which he has made available for free online, can predict the outcome of materials characterization experiments without having to run the materials through high-powered, high-cost microscopes.

"Unless you have a theoretical understanding of what's going on in an experiment, you will have no clue how to interpret the results of that experiment," Singh says. "The software provides the theoretical framework to help people understand what's going on. We've taken the theory and turned it into a user-friendly computational platform."

One of the main applications of Singh's software so far is in industry. Often, manufacturers will develop a material they want to use, but they need to ensure that it does what it is designed to do. Not only that, but they need assurance it will continue to behave predictably throughout its entire lifespan. The instruments in the MCF, used in tandem with Singh's software, can gather the information necessary to predict how these materials will respond in the future.

"The instruments in the MCF are really essential for my work," says Singh. "I can immediately go check my theory to see if it is correct. You can come up with any theory you want, but unless you have some experimental validation of what you're doing, it's of no use to anyone."

# ALUMNI

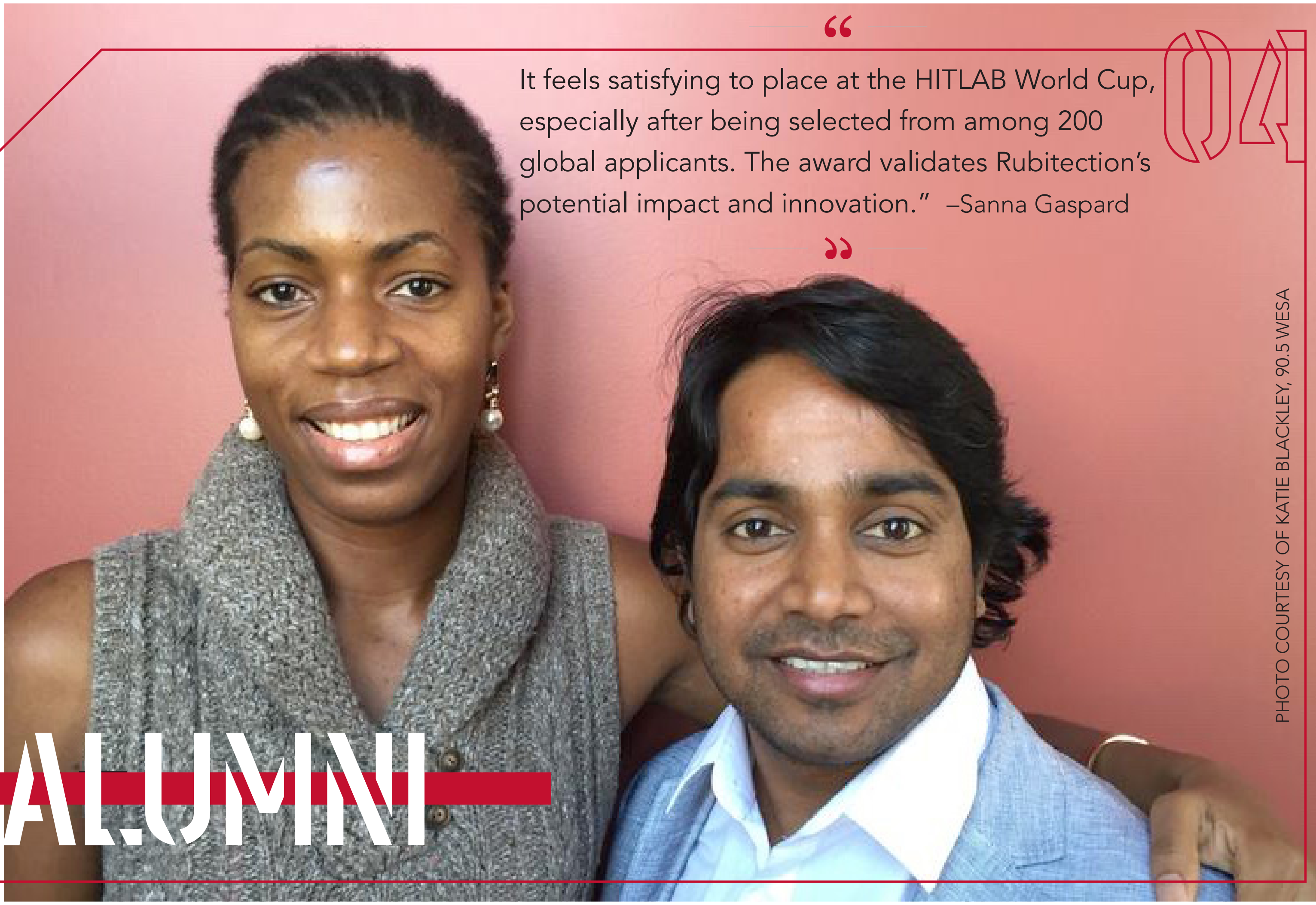

PHOTO COURTESY OF KATIE BLACKLEY, 90.5 WESA

"It feels satisfying to place at the HITLAB World Cup, especially after being selected from among 200 global applicants. The award validates Rubitection's potential impact and innovation." –Sanna Gaspard

## Startups Innovate to Save Lives

BY EMILY DURHAM

It's the 21st century. We've developed a polio vaccine. Penicillin. Eradicated smallpox. But even with all of our medical advancements, we still can make the world healthier. So it should come as no surprise that two Carnegie Mellon Engineering alumni founded startups to innovate contemporary healthcare.

The two companies, Pittsburgh-based Rubitection and RistCall, were finalists in the HITLAB World Cup, held on December 4, 2015 in New York City. This annual healthcare competition calls upon global innovators in design, medicine, and technology to fulfill unmet needs in healthcare access and delivery.

Biomedical Engineering alumna and CEO Sanna Gaspard's company, Rubitection, has developed a handheld device for early bedsore detection. As a graduate student in 2006, Gaspard researched the problem of bedsores and discovered they are common and may be severe. Complications arising from bedsores can lead to infection, sepsis, amputations, and even death. Nearly 2.5 million people are infected by bedsores annually, and out of those, a staggering 60,000 will die.

"Rubitection measures color changes in the skin that indicate bedsore development, detecting them at the earliest stages to support their prevention and management," said Gaspard. "The potential impact is a lower occurrence of bedsores and a significant reduction in associated costs."

The idea for RistCall, a patient-nurse communication system located on the patient's wrist, came to founder and Electrical & Computer Engineering alumnus Srinath Vaddepally when he was hospitalized for severe abdominal pains. He fell in the hospital and was unable to receive help for an excruciating 20 minutes. Vaddepally realized that the wall-based button method of patient-nurse communication is outdated, inconvenient, and—as evidenced—potentially dangerous.

"If a healthy 20-year-old college student can fall, imagine what can happen to older patients who are fragile and sick," said Vaddepally. "After being discharged, I researched the number of falls in healthcare, and the stats were alarming. The majority of hospital falls happen inside the patient's room where wall-based call buttons present an imminent danger. Patient falls in healthcare facilities is a $2 billion problem. The engineer in me couldn't stop thinking about a safer, wearable solution; one for patients and another for nursing staff."

As finalists in the HITLAB World Cup, Rubitection and RistCall presented their innovations before a panel of judges and industry leaders. Rubitection won second place and a $5,000 prize, and RistCall earned an honorable mention.

"It feels satisfying to place at the HITLAB World Cup, especially after being selected from among 200 global applicants," said Gaspard. "The award validates Rubitection's potential impact and innovation."

"We are saving lives, and the value we offer provides me with the encouragement to wake up every day, to make this innovation succeed," said Vaddepally.

# Knightscope: The Future of Security

BY EMILY DURHAM

The Knightscope K5 Autonomous Data Machine is a police robot, a 3-foot-wide, 5-foot-tall, 300-pound autonomous data machine built to predict and prevent crime.



Knightscope is currently hiring Carnegie Mellon University students and graduates. If you are interested in being considered for a position at Knightscope, visit www.knightscope.com.

**26.2** SECONDS frequency violent crime occurs

**90** TERABYTES amount of data collected per year, per Knightscope machine

**1,000,000,000,000** DOLLARS yearly cost of crime to the united states

**50** PERCENT decrease in crime expected result from knightscope

**3.5** SECONDS frequency property crime occurs

It roams on its own through Carnegie Mellon University's Silicon Valley campus. It's a technological marvel—its hulking physical presence and "furrowed brow" command respect while its rounded figure is "cute" enough to not scare babies. Its real-time, on-site, 24-hour, 360° data collection cameras and sensors gather every sound and image in its radius, collecting a total of 90 terabytes of data per year, per machine. Its unique powering capability is scheduled around two- to three-hour patrols with 30-minute autonomous docking recharge periods, playfully referred to as "coffee breaks."

And the K5 is just one model of many.

William Santana Li is the mastermind behind the tech. An alumnus of Carnegie Mellon's Department of Electrical & Computer Engineering, Li is now the Chairman and CEO of Knightscope, Inc., an advanced physical security technology company located in Silicon Valley. Li is impassioned when he talks crime; its impact on all of us is tremendous. Not only does society live in constant fear of the worst, but its economic toll on the United States is staggering.

"If you add up all the murders, all the jails, all the lawyers, and everything else," says Li, "crime is a hidden tax all of us are paying every single year."

Time for some statistics:

- A violent crime occurs every 26.2 seconds. Every 3.5 seconds, a property crime occurs.
- The private sector security industry has an employee turnover rate of 100-400% per year. "That means," says Li, "you get a new team every three months or every twelve months because you can't keep the people in the job."
- Crime costs the United States $1 trillion per year. A trillion. Per year.

"What if you could set up a whole plethora of technologies and be able to integrate them into a solution to cut crime by 50%?" asks Li. "How valuable would that be to society?"

Very valuable, as it happens. Not only do the Knightscope robots promise to quell crime by deterring criminals from negative actions, but they also make jobs safer for human security personnel by taking on the monotonous, computationally heavy, and dangerous aspects of the job, leaving the analysis and decision-making to the human professionals.

"So what if you could actually deliver this level of safety?" asks Li. "What are the effects on housing prices? What are the effects on insurance rates or the stability of financial markets, the quality of life, the business viability of a small business down the street or the safety of your family? It would be a huge game-changer for society.

"This is a worthy challenge to take on."

# Announcements

## Cranor Named Chief Technologist of FTC

Federal Trade Commission Chairwoman Edith Ramirez has appointed Lorrie Faith Cranor, professor of Engineering and Public Policy and Computer Science, as the agency's Chief Technologist.

Cranor, who took a leave from the university, joined the FTC staff in January, succeeding Ashkan Soltani. She is primarily responsible for advising Ramirez and the commission on developing technology and policy matters.

"Technology is playing an ever more important role in consumers' lives, whether through mobile devices, personal fitness trackers, or the increasing array of internet-connected devices we find in homes and elsewhere," Ramirez said. "We are delighted to welcome Lorrie to our team, where she will play a key role in helping guide the many areas of FTC work involving new technologies and platforms."

Cranor directs the CyLab Usable Privacy and Security Laboratory and is co-director of Carnegie Mellon's Privacy Engineering master's program. She has authored over 150 research papers on online privacy and usable security, and has played a central role in establishing the usable privacy and security research community, including her founding of the Symposium on Usable Privacy and Security.

The Federal Trade Commission works on behalf of consumers to prevent fraudulent, deceptive, and unfair business practices and to provide information to help spot, stop, and avoid them.

## Engineering Research Accelerator

To fortify our research initiatives, we are pleased to announce the formation of the Engineering Research Accelerator.

The Research Accelerator will subsume the Institute for Complex Engineered Systems (ICES) and other research support resources in an effort to provide a more integrated, coordinated, and college-wide set of services for research incubation, acceleration, and support.

The Research Accelerator, located on the sixth floor of Scott Hall, coordinates and co-locates functional areas of the college, such as research administration, corporate partnership, business support, and research incubation and acceleration activities.

The Associate Dean for Research, Burcu Akinci, will serve as the director of the Research Accelerator, and Burak Ozdoganlar will serve as the associate director, focusing on the areas of fellowship and broader impacts.

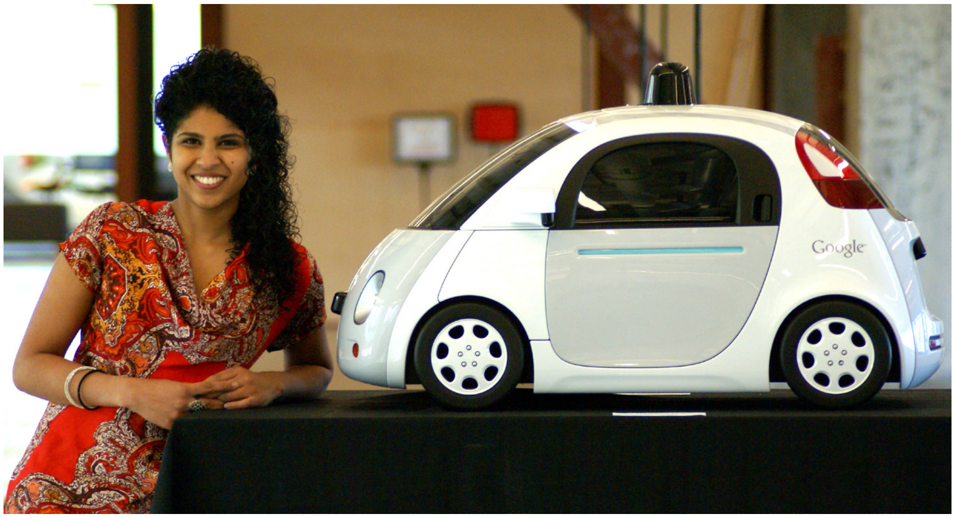


PHOTO COURTESY OF CHIRATH NERANJENA

## Shah Recognized by Forbes

Karishma Shah (MS '17), a current student of the Integrated Innovation Institute's part-time MS in Software Management program, has been selected for Forbes 30 Under 30 2016 list in the Consumer Technology category. Selected from a list of more than 15,000 of today's best and brightest, this prestigious honor is given to just 600 individuals across 20 sectors each year, whom according to Forbes are considered "America's most important young entrepreneurs, creative leaders, and brightest stars."


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# Final Words

## How will engineers advance technology to deepen our understanding of how the human brain works?

STUDENT

### João Semedo

*Ph.D. student*
*Electrical and Computer Engineering*

The human brain is an interconnected network of around a hundred billion neurons. Computation is implemented in a distributed fashion by populations of neurons, and as a result, no one neuron is especially informative as to how a given computation is implemented. Understanding the brain, then, requires that we have access not to single units but to the activity across an entire population of neurons or at least a representative portion of it. This poses two challenges, for which engineers are especially suited:

1) Recording activity from as many neurons in a population as possible.

2) Analyzing these high-dimensional signals. Deducing computation from the recorded activity is not a trivial task, and is made worse by the specific challenges presented by neuronal recordings.

FACULTY

### Byron Yu

*Assistant Professor*
*Electrical and Computer Engineering,*
*Biomedical Engineering*

Engineers have an increasingly critical role in the quest to understand brain function, in three ways. First, we need better technologies to monitor the activity of large numbers of neurons in the brain with high temporal resolution. These technologies should allow for reliable recording over months and years. We also need better technologies to perturb the activity of neurons to elucidate their causal role in brain function. Second, the technologies being developed are providing unprecedented views of the brain's activity. We need to develop statistical and data science methods that are appropriate for interrogating these huge data sets. Third, perhaps most importantly, we should apply these new technologies and analytical methods to discover something new about the brain. New insights about brain function will require close interaction between engineers and neuroscientists.

ALUM

### Matthew Golub

*Postdoctoral Scholar*
*PhD ECE '15*

Engineers will develop technologies for monitoring the electrical activities of neurons in the brain. Current technologies allow for recording from hundreds of neurons with fine time resolution, or from thousands of neurons with coarser time resolution. Moving forward, engineers will develop the technologies needed for fine time resolution recordings from larger populations of neurons across multiple distinct brain areas. Second, to make sense of these large-scale brain recordings, engineers will develop statistical tools for inferring what and how the brain is computing and communicating using those populations of neurons. Finally, engineers will advance current abilities for manipulating brain computations using electrical and optical stimulation. Oftentimes our best method for understanding the brain is to perturb it (e.g., by externally changing brain activity) and to see if the brain responds according to our predictions.