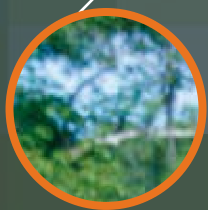
Is it a SUNNY DAY?

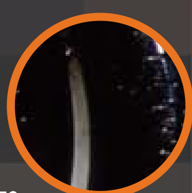
Is this person SCARED?

Is this OUTSIDE?



ece 2015

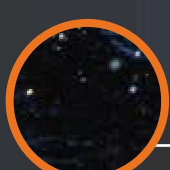
THE BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING



Is this a CAR TIRE?

WHAT IS THIS SCENE?

A car accident?
Trees in a parking lot?
One person running?



Is this the GROUND?

Virginia Tech
Invent the Future®

MACHINES SEE
PATCH BY PATCH

THE HUMAN BRAIN is said to process 11 million pieces of information every second. This ability, largely working below the conscious level, enables people to understand complex situations seamlessly and holistically.

A DIGITAL BRAIN, on the other hand, tends to have "tunnel vision," as assistant professors of ECE Dhruv Batra and Devi Parikh explain. A computer must piece together understanding of the situation from these individual ambiguous parts. Batra and Parikh are working to inject into machines human-like abilities of dealing with uncertainty by making multiple guesses and using common sense.

This report was produced with funds from the Harry Lynde Bradley Foundation.

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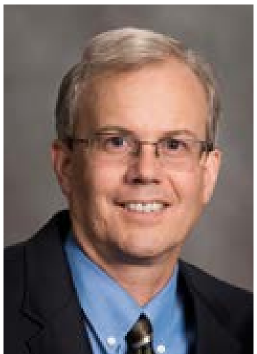
MACHINE PERCEPTION

By teaching computers common sense and giving them the opportunity to make several informed guesses, Dhruv Batra and Devi Parikh want to help machines come to correct conclusions.

CONCLUSION

These are children playing in a lake with a tire swing.

from the ece DEPARTMENT HEAD



Luke Lester
Department Head

IT IS MY PLEASURE to once again greet you as the department head of the Bradley Department of Electrical and Computer Engineering. This past year has been an eventful one for our department as we experienced a significant growth spurt in new undergraduate students during calendar year 2014. A record 442 new students declared ECE as their major this past year, which is in contrast to the 230 B.S. degrees that were granted over roughly the same time period. Meanwhile, the College of Engineering estimates that there will be approximately 2,600 new engineering students coming to campus in the next academic year, of which history shows us that ECE will recruit about 18-20 percent.

This impressive growth certainly comes with challenges in terms of classroom space and having a sufficient number of faculty members to teach this growing cohort of students. Thankfully, the department is positioned well from the point of view of personnel and finances to recruit new tenured/tenure-track faculty and instructors to meet the increased demand for our major.

I think the more interesting question is why has Virginia Tech ECE become so popular? My fellow department heads at a recent national meeting were not nearly so sanguine about the future of ECE and are still struggling with the decade-long decline in ECE enrollment at the hands of our colleagues in mechanical engineering, which is due in large part to their leadership in the field of robotics. Of course, I know what you are probably now thinking…haven't the exciting advances in robotics been fueled by the incorporation of more and more electronics? That's ECE! True, but what students see at an early stage in their engineering education are mechanical systems that interact compellingly at a human level. In the area of robotics, I think we may have lost the battle over what makes a lasting first impression.

Not to worry because ECE now has the Internet of Things. It is estimated that by 2020 there will be 50 billion electronic devices in the world and 35 Zettabytes (1 ZB = 1 billion terabytes) of data to manipulate. The growing demand to connect all these components and transmit information in a trusted environment is creating an unprecedented opportunity for ECEs. Key drivers are computing electronics, big data analytics, and ubiquitous devices that will have an aggregate of as many as 7 trillion embedded sensors.

The Internet of Things plays well into Virginia Tech ECE's research strengths of wireless communications, embedded systems, cybersecurity, and nanoelectronics among others. Having this expertise allows us to create a dynamic and up-to-date learning environment that I believe is being recognized by prospective engineering students. Virginia Tech ECE also has a balanced curriculum between its computer and electrical engineering degree programs and a dedication to comprehensive, hands-on instructional labs. This pedagogical emphasis positions us well to take advantage of the revolution that some are calling the Industrial Internet.

I am happy to report that each one of our ECE faculty members has prepared a Google Scholar profile, which automatically tracks research scholarship and who is citing it. You can find these profiles as a link on each faculty departmental webpage. Our use of this Google Scholar resource is extremely valuable in promoting our research accomplishments, which better enables us to recruit new students and faculty. Soon our research portfolio will be aggregated on our department website into a continually updated collection of our faculty's seminal works and trending publications. I'm sure you will agree that this concerted effort to promote our scholarship will further enhance the visibility of our department. Although it is perhaps too early to tell whether this project has had an impact, there is good news to report in the rankings arena. Our graduate program in electrical engineering has improved to 24th in the country and computer engineering to 26th. This encouraging progress combined with our burgeoning undergraduate enrollment demonstrates that Virginia Tech is a destination for many students interested in ECE. Go Hokies!

Luke Lester
Department Head

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Editor: **Scott Bailey**

from the Chair

of the ADVISORY BOARD

Steve Poland
Chair
ECE Advisory Board

LAST YEAR I was elected to succeed Michael Newkirk as the ECE Advisory Board (AB) Chair. Being a second generation Hokie, thanks to my dad, Virginia Tech has been a big part of my life for as long as I can remember. My mother can still pull out the second-grade essay in which I wrote that I will go to Virginia Tech, I will become an electrical engineer, and that I will die near an electrical socket.

I was not quite sure what an electrical engineer did, but my fascination with batteries, lights, magnets and all things electrical started very early and I was fortunate enough to be able to come to Virginia Tech, feed that interest, and have it become the basis for my profession. My gratitude to the university, College of Engineering, and department for helping me achieve my dreams is immense. And, as far as my predictions go, I'm happy holding at two out of three as I always try to keep an awareness of the electrical sockets around me.

As ECE AB chair, I'm very honored to be able to give back to Virginia Tech. Participating on the ECE Advisory Board has exposed me to the many ways alumni, students, faculty, and corporate partners, make ECE at Virginia Tech so special. I highly encourage all ECE alumni and stakeholders to find a way to pay forward what the ECE department has done for you or your organization—whether through increasing awareness of Virginia Tech in your local schools, providing direct financial support to the Department, helping with undergraduate ECE student projects, funding faculty research, or advocacy of the department through social media. Our united goal should be to help make Virginia Tech's ECE department the best it can be, and to help make sure it receives the recognition that it deserves.

A great example of how those outside of ECE can contribute is the new two-semester capstone design course. Two years ago, our Advisory Board strongly recommended establishing a two-semester Senior Design Capstone sequence. The objective of this class is to provide students with a real-life industry experience, focusing on developing their professional and business skills. Hiring managers have always been impressed with the technical skills of graduating ECE students. This class provides our students a distinct competitive advantage as they are formally trained in important skills and perspectives, such as teamwork, communications, ethics, project management, and company metrics.

Our inaugural class, initiated in the fall, consists of 61 students working on 16 sponsored projects. We have received very positive reviews from sponsoring customers and students, and have decided to grow the class. Currently, with the assistance of the Advisory Board and the leadership of previous AB member and current Professor of Practice, Gino Manzo, we have secured 26 sponsorships and expect to have over 100 students enroll in the Fall 2015 class sequence. The AB is confident that this new course offering will pay significant dividends for the department and its graduates for years to come and express our sincere appreciation to all of the sponsors.

I feel comfortable speaking for the Advisory Board in saying that we look forward to an exciting 2015, including helping the department deliver President Sands' new Inclusion and Diversity Plan, continuing to build the two-semester Senior Design Capstone sequence, assisting with the retooling of Virginia Tech's Masters of Information Technology program, and overall, helping Luke Lester realize his vision for the department.

As a final note, I would like to thank outgoing members Rodney Clemmer, Matthew Gardner, Mike Hurley, Gino Manzo, Alan Wade, and Joyce Woodward for their years of service on the AB, and welcome the newest members of the board: Peter Savagian, Nam Nguyen, Bernard Chau, Dave Rea, Nathan Cummings, Brian MacCleery, and Lynne Hamilton-Jones. Go Hokies!

Steve Poland (BS '92, MS '94)
Chair, ECE Advisory Board

MACHINE *PERCEPTION*

PROGRAMMING INTELLIGENCE

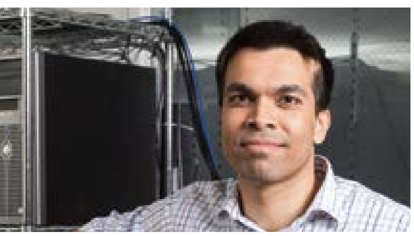
Teaching machines to ask the right questions and understand context

WE HUMANS LEARN from our experiences, so when the forecast calls for rain, we know to bring an umbrella. If ECE assistant professors Devi Parikh and Dhruv Batra have their way, our smart devices will also learn from their experiences, learn to ask the right questions, and eventually make decisions that are not pre-programmed.

Their research may help the future smart vehicle determine whether a blowing sheet of paper or the neighbor's cat is crossing its path and act accordingly—or the future system that can automatically comb through hours of surveillance footage to determine whether a missing child passed through a crowded shopping mall.

PATCHWORK *PERCEPTION*

Looking at a blurry photograph, you might be able to discern the image. Shapes, shadows, and colors allude to a person driving a car, a cyclist, or a street scene. But zoom in on a tiny aspect of the photo—a corner, a small chunk of the middle—and the context is lost. A shadow could be a dinner plate, a human foot, or a bicycle wheel. It's impossible to tell.



DHRUV BATRA

> "It's the most obvious things that might be hard to learn for a machine."

"You need context, and that's what we're asking our algorithms to do," says ECE Assistant Professor Dhruv Batra. His research is focused on developing scalable algorithms for holistic scene understanding—teaching computers to understand the interconnected complexity of the human world.

For computers, the human world is like a tiny segment of a blurry picture. Humans expect animate and inanimate objects to behave in a certain way. Human understanding draws from a range of experience people collect and process. Computers do not have this innate knowledge.

"No one writes down these expectations," Batra says. And so far, computer scientists do not know how to encode human intuition into logical rules. "It's the most obvious things that might be hard to learn for a machine," he adds. There have been efforts throughout history to record all human knowledge; however, the list can never be complete.

Rather than trying to isolate specific rules, more data may be the key to teaching computers to make better predictions.

"I'm interested in building the next generation of perception algorithms, called cross modality algorithms," Batra explains. By attempting to replicate the way a human would experience the world—combining vision and language—an algorithm gives the computer a better chance of making a correct prediction of a scene. "It gets easier in the ability to answer, but harder in the computational sense because now you have more data to parse," he says.

The computer is given an image, and then it generates several guesses as to what it thinks the input could be. Instead of limiting the computer to just a single answer (which is likely to be spectacularly wrong), multiple, diverse predictions help the computer arrive, eventually, at a more correct conclusion. "Several guesses are far more useful than any single guess," Batra says.

In one photograph, a dog is standing next to a woman on a couch. There is a well studied ambiguity in the image's textual description—without seeing the picture, it is unclear whether the dog is on the couch with the woman, or on the floor next to her. It is difficult for machines to learn with only text because the ambiguities inherent in language are not easy resolved, like homonyms or puns. Ambiguities can become clearer, however, when text is paired with an image. "The problems you run into are not perception, but computational," Batra says.

"With the image, you can see that the dog is not on the couch. Interestingly, much research in language assumes machine vision is perfect, and research in machine vision assumes language parsing is perfect. Of course, neither is true. And that's what we are trying to tackle here by simultaneously resolving the ambiguities in vision and language," he explains. In this instance, the textual description works with the image to help the computer eliminate ambiguity.

Another photograph shows two people petting horses along a fencerow. "The machine is confused by this one," Batra explains. First, the computer thinks that all the figures in the image are people. Then it recognizes the horses as dogs. With multiple guesses, however, the computer eventually gets to the correct conclusion.

Batra works with researchers at the Virginia Tech Transportation Institute (VTTI) on one of the largest naturalistic driver studies ever conducted. More than 3,200 test subjects drove their cars for a year equipped with cameras, GPS, and acceleration measurement tools, and collected 2,000 terabytes of data. "Using this information, we may be able to help identify what causes road crashes," Batra says. "These problems have never been addressed at this scale. This feels like something we should already know, but our understanding is fairly coarse."

BATRA IS USING a collection of machine perception modules to produce a list of guesses about the image. Once each module has its guess, a "mediator" program identifies the most likely possibility. In this example, hypothesis #1 of the human pose estimation module believes that tree-branches are human limbs, while hypothesis #2 identifies the person on the bicycle.

Researchers at VTTI have gone into the data and annotated certain instances, like crashes and near-crashes. The cameras recorded each driver's expression, so the researchers can make predictions about whether drivers are drowsy, distracted, or driving in poor weather conditions. "We can then produce a model that can figure out the probability of getting into a crash given environmental variables such as weather and drive alertness," Batra says.

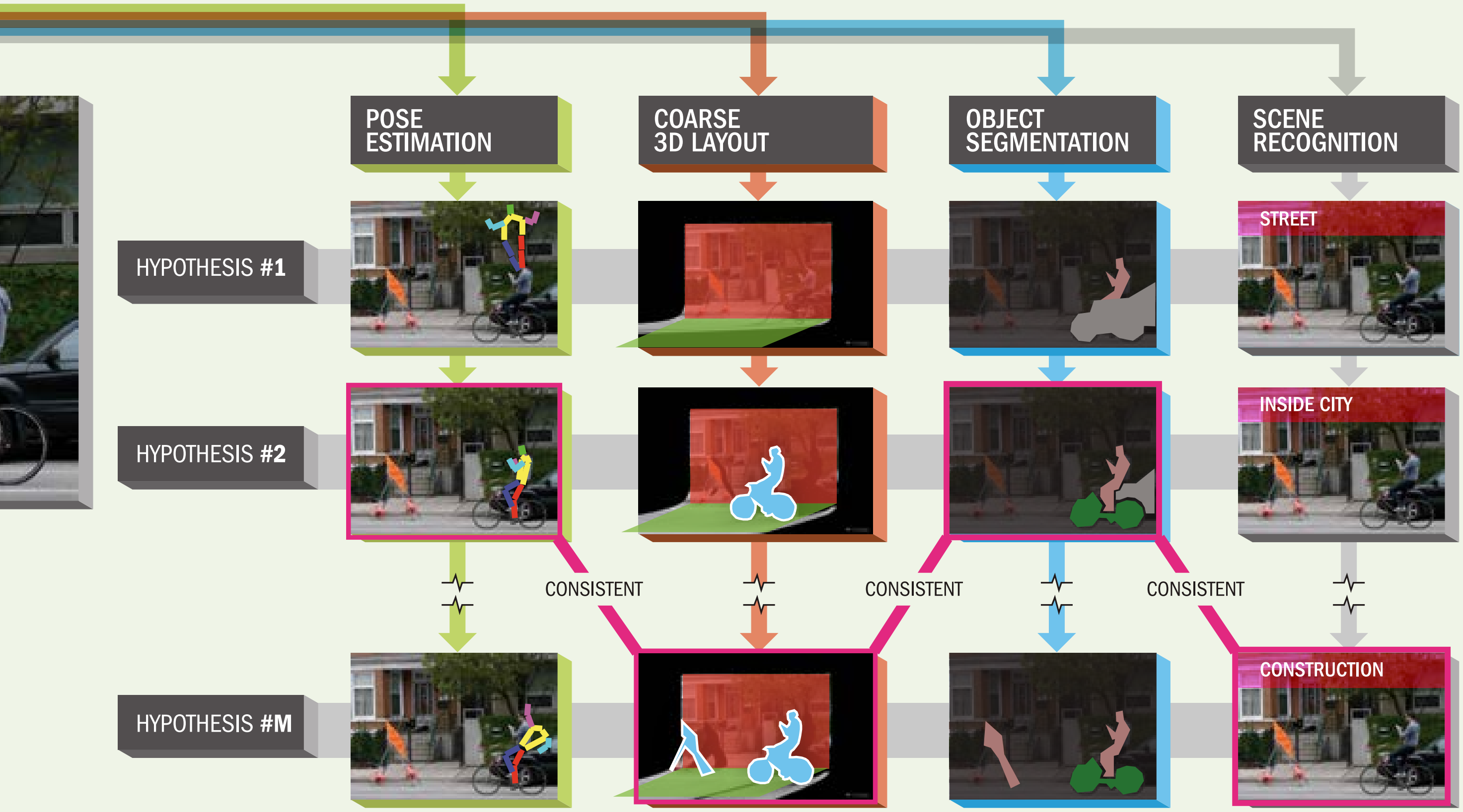
The ultimate goal of Batra's work is a more intelligent robot—a robot with cameras, sensors, and speech-to-text capability that can perceive the world and interact with a person relatively seamlessly. He has received a National Science Foundation CAREER award, a Google Faculty Research award, and an Army Research Office Young Investigator Program award in recognition of his work. He was also recently named an Outstanding New Assistant Professor by the College of Engineering.

On a day-to-day basis, Batra most enjoys working with his students. "There are parallels between students getting smarter and machines getting smarter. I'm interested in learning, whether it is people or algorithms. That's exciting to me."

BODIES IN MOTION

AN IMPORTANT ASPECT of machine perception is human pose estimation—teaching a computer to understand where a human's head, arms, and legs may be. However, the human body can vary greatly in size. Elements such as clothing can obscure the body. And humans can position themselves in countless ways. These complications make human pose estimation a challenge for computers.

Batra's approach of allowing the machine to make multiple guesses may help. In one example, the computer thinks that a person's legs are not moving, but her hands are flailing, although the opposite is true. "Sometimes the algorithm places both legs at the same location, known as the 'double counting' problem," Batra says. If the computer has access to a video "we can extract multiple guesses in every frame, and 'smooth' the guesses over time," he adds. This may let the computer reach a correct conclusion more quickly.



QUESTIONING

COMMON SENSE

CARTOONS have found their way into the classroom, but Devi Parikh is using them to teach not kindergarteners, but computers. Cartoon-like clip art scenes have fewer distractions than photographs, making them ideal for helping computers start to understand the common sense behind a scene.

Researchers in machine perception have typically created restricted microcosms of our world where a computer reacts to one specific scenario. "We're trying to break away from that," says Devi Parikh, assistant professor of ECE.

Her goal is to leave restricted worlds behind by teaching computers to respond to any question that might be asked, and even respond to questions with a follow-up question. If the computer can ask its own questions and learn from the answers it receives, it will build a body of knowledge that will help it draw more correct conclusions—and ultimately respond in a more human-like fashion.

DEVI PARIKH

"When you see a ridiculous response by a machine, it's because of lack of common sense," Parikh says. "The problem is that to learn common sense, you need to understand everything that is happening, and computer vision isn't accurate enough right now." She is developing databases that can provide enough data and context to help machines expand beyond generic descriptions. "If we have a database, we can mine it for common sense, both visual and textual," she says.

To build a database big enough for the level of machine learning Parikh imagines, she has employed thousands of workers through Amazon Mechanical Turk, an online marketplace for work.

"The Turkers come from all over the world," Parikh says. "Some have Ph.D.s. A lot of people are doing this in their spare time." Parikh stipulates that her Turkers must be proficient in English and have an approval rating of at least 95 percent. They are paid a small amount of money for their time—many tasks pay less than a dollar. Parikh provides guidelines for what she wants, and can approve or reject their work as necessary. With this human assistance, Parikh can build a simple, accurate database quickly and inexpensively.

As an example, she holds up a photograph of a toddler smiling gleefully while brandishing a pair of scissors.

She directs the Turkers to ask a question about the photograph a human might be able to answer, but a computer could not. Her Turkers respond with "Is she having fun? What should this girl not be doing? Is it safe for this baby to be holding this object?"

"Just the image is not enough," Parikh explains. Rather than go on an initial assumption—a happy baby means everything is okay—questions guide the computer to better answers. For the computer to comprehend the nuances of the image, it has to find the baby, understand what it means to

ASKING THE RIGHT QUESTIONS

What is Jenny pretending to be?

Is Mike or Jenny wearing the pirate hat?

What is the king holding?

How many red apples can you see on the tree?

Is there anything that Mike can use to cut his pizza?

What is he holding in his arms?

be holding something, and have the common sense to know that kids should not hold (or at least be very careful with) sharp objects.

Parikh is also combining clip art with text to enhance the computers' learning experience. Cartoons may seem silly for high-level machine learning research, but according to Parikh, "what's relevant is where objects are and how they're interacting."

Clip-art scenes have less noise and fewer background distractions than photographs. Again employing her army of Turkers, she is building a database of simple scenes that can give computers a place to study common sense.

The combination of text and simple images gives machines a broader base to learn common sense. "If you rely on text to learn common sense, you might not learn it all," Parikh says.

One clip art scene shows a boy holding a pizza with a helicopter, a little girl, and a tree nearby. "Is there anything in this image that Mike can use to cut his pizza?" Parikh asks, demonstrating the kind of thought process she hopes computers will come to understand. "Recognizing the objects is easy because it is a clip-art scene, but you still need to have some common sense about what can be used to cut a pizza."

In another scene, the clip-art boy Mike grimaces as he sits in a sandbox with a duck. "Does Mike like playing with the duck in the sandbox?" Parikh asks. "You need to realize his expression is not happy."

As each clip-art scene is created, the computer knows precisely which objects are included and where they are placed.

Once she has a large enough dataset,

DEVI PARIKH, Ph.D. candidate Stanislaw Antol, and Dhruv Batra discuss some of the most recent work submitted by their Mechanical Turk workers, and the changes they will make for the next set of assignments.

Parikh will begin working to address specific aspects of machine perception. "We expect some natural language processing and visual detection," she says. "This is a very high level pipeline. We don't know how we will do every single step. We're looking at one dataset based on real images and also a clip-art dataset."

Common sense in machine perception is important for society at large. "It's important for visually impaired users, who may ask a question and need an answer that is actually useful for them," Parikh says. "Or an analyst with tons of surveillance video can ask 'did someone in a white dress pass the elevator between 3 and 3:30?' It will be extremely useful if the computer vision system can automatically answer such questions about visual data."

Using these approaches to leverage abstract scenes has garnered attention for Parikh's work. She has received a U.S. Army Research Office Young Investigators' Program award, two Google Faculty Research awards, an Outstanding New Assistant Professor award from the College of Engineering, and has been named an Allen Distinguished Investigator in artificial intelligence by the Paul G. Allen Family Foundation.

As research in computer vision focuses on image description, "we're trying to think of the next step," Parikh says, "to have machines describe scenes, notice subtleties, and answer detailed questions about them."

MORE POWER
BETTER MACHINE LEARNING

DEALING WITH MORE DATA—multiple images, video, text, and larger data sets—means that Parikh, Batra, and their students need access to a great deal of power.

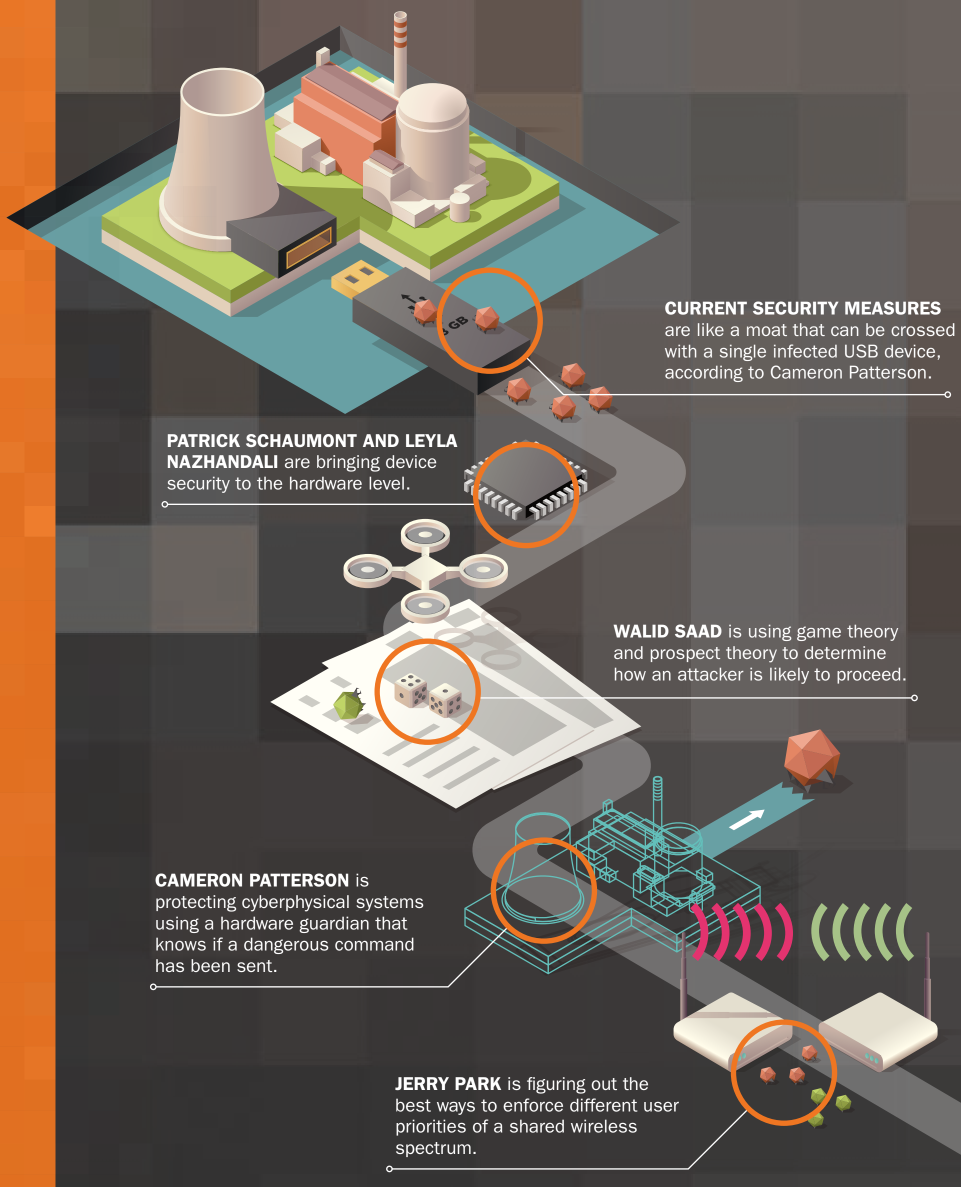
Parikh and Batra lead the Computer Vision Lab and the Machine Learning & Perception lab respectively, where they share a 500-core CPU cluster, each an order of magnitude more powerful than a laptop, and a GPU cluster with 27 NVIDIA GPUs. Each machine also has 512 GB RAM. With increased RAM, they can work with larger data sets; increased CPU and GPU power allows them to generate answers more quickly.

More power means that researchers can revisit the revolutionary ideas established by their predecessors—models that were attempted, but abandoned, because these early computer scientists did not have enough computing power to execute them. For example, the first artificial neuron was developed in the 1940s, but the technology at the time limited the scientists' ability to do much with it. "The solutions were ahead of their time," Batra says. "They just required more data and more computer power. Computing has become a crucial aspect of machine learning and perception."

WITH 27 high-powered GPUs and approximately 500 cores in their CPU cluster, Batra and Parikh are able to explore methods that would have been computationally impossible just a few years ago.

When more than
OUR DATA IS AT RISK

IN THIS SECTION:



Our security cameras send alerts to our cellphones. Our grill tells us when it needs more gas. Forget to change your household thermostat before traveling to Europe? No problem. You can set it online.

We have come to expect our data on websites and personal computers to be at risk, but the small technologies that make our lives easier are equally vulnerable. Or possibly more so. "Look at how the technology has changed over the last decade," requests Charles Clancy, director of the Ted and Karyn Hume Center for National Security and ECE associate professor. "We have moved from computers being connected, to people being connected [by smartphones], to things being connected." These cyberphysical systems are at risk, and traditional security measures are struggling to keep up.

According to ECE Associate Professor Cameron Patterson, the security measures we rely on today are similar to a medieval moat—a moat that can be crossed with a single infected USB device.

ECE researchers are securing our systems, figuring out what attackers are likely to do, discovering attacks before they become disasters, and planning ways to rapidly recover after our systems have been damaged. Attacks may be inevitable, but our researchers are making attackers work harder for a smaller payoff at greater risk.

MOVING SECURITY TO HARDWARE

CHRISTINA O'CONNOR

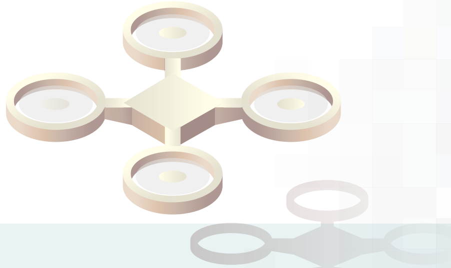
LEYLA NAZHANDALI and PATRICK SCHAUMONT

MOST OF OUR current anti-hacking technologies focus on monitoring the software that runs our devices. Firewalls attempt to keep villains out of our systems, and antivirus software tries to step in when our firewalls fail. Attackers are also targeting the hardware itself, however. Two ECE associate professors, Patrick Schaumont and Leyla Nazhandali, are moving security from software to hardware.

Schaumont and Nazhandali were recently awarded a grant from the National Science Foundation (NSF) and Semiconductor Research Corporation (SRC) Secure, Trustworthy, Assured and Resilient Semiconductors and Systems (STARSS) program. This program supports research into hardware solutions to improve the security of microprocessors. Ten universities received grants totaling nearly $4 million.

Virginia Tech's focus is to develop hardware techniques for microprocessors to detect physical attacks and reduce damage. For example, one way to tamper with a microprocessor is to shoot it with a beam of ions. Nazhandali and Schaumont's microprocessor design will detect such an attack using both static and dynamic techniques and generate a software response.

"Detecting these kinds of attacks in hardware makes the chip significantly harder to attack," says Nazhandali. "The techniques we are developing add a significant layer of security to already-in-place software solutions."



What is the attacker thinking?

EVEN IF WE can detect an attack, we rarely know exactly how the attacker will proceed. To get into the minds of both the attackers and the defenders, Walid Saad and Anibal Sanjab (Ph.D. '18) are applying game theory and prospect theory to figure out how to best respond to an attack. Saad, who joined the department in August as an assistant professor, is studying the role of human behavior from the attacker and the defender point of view.

According to Saad, "we have to understand the attacker's side and the defender's side. We have to determine the optimal attack and the optimal defense."

Saad employs a mathematically rigorous approach to the human role in securing and attacking both networks and cyberphysical systems, such as the smart grid and the Internet of Things. "It's not just speculation," he says, "it's proven with real math." The goal of game theory is to find the optimal solution to a situation involving multiple decision makers. Prospect theory takes into account how humans are likely to respond to a scenario when they know the probabilities of each outcome.

However, because humans are involved in both the attack and the defense, "they might not follow what you actually want them to do," says Saad. "They can be irrational, which might be good or bad. We don't know."

DRONES TO THE RESCUE

SAAD IS ALSO WORKING on ways to minimize the negative effects of an attack on our cellular network. If our communications systems are disrupted, either by computer malfunction or by physical attacks, we might notice a fleet of drones going to the rescue.

Mohammad Mozaffari (Ph.D. '18) is working with Saad to determine how to deploy drones to enhance communications after an attack. They are working on algorithms to determine how many drones are needed, and where they need to be located.

> “We assume a virus has already penetrated and reprogrammed your controllers.”

GRADUATE STUDENTS Omkar Harshe, Pallavi Deshmukh, and Teja Chiluvuri test the TAIGA security approach using an inverted pendulum.

The **model within**

EVERY SYSTEM controlled by a computer is at risk from malicious software. Current security approaches, however, treat embedded systems like information systems, according to Associate Professor Cameron Patterson. “The standard approach is to safeguard the computer to safeguard what it’s controlling, so we apply the standard network monitoring, firewall, and antivirus.”

Patterson’s approach is different. “It’s kind of cynical,” he says. “We assume a virus has already penetrated and reprogrammed your controllers. It may even have come that way from the manufacturer.” Rather than protecting the computers, or even the controller, Patterson focuses on protecting the physical system being controlled, such as a car, robot, or power plant.

His approach, called the Trustworthy Autonomic Interface Guardian Architecture (TAIGA), is similar to the physical failsafes that exist for safety-critical systems like power plants. “A reactor has an independent temperature limit. If that limit is exceeded, it will shut down no matter what the computer control system or operators in the control room do.” Patterson is implementing this idea in a digital form by adding an independent microcontroller, called a process guardian, between the main controller and the output.

This guardian monitors what the controller is doing. It senses the state of the system, and determines if that state is different from the desired state. “The guardian is aware of the system’s limits, and if those limits are ever exceeded, it will intervene,” he explains. “We can only do this with something self-contained—it wouldn’t work if the controller could override or update our guardian.”

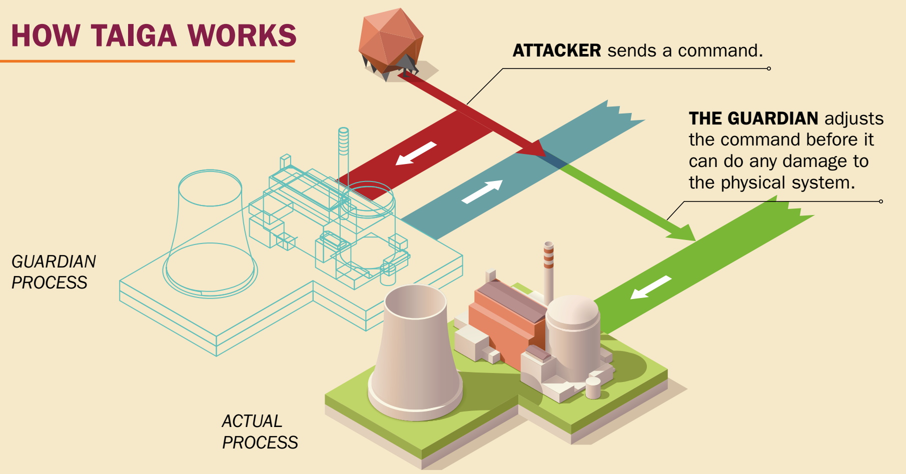
In addition, the guardian is programmed with a model of the process it watches. “This enables something really cool,” Patterson says. “We don’t want to wait until the limit is almost exceeded. We want to preempt it completely by looking into the future.”

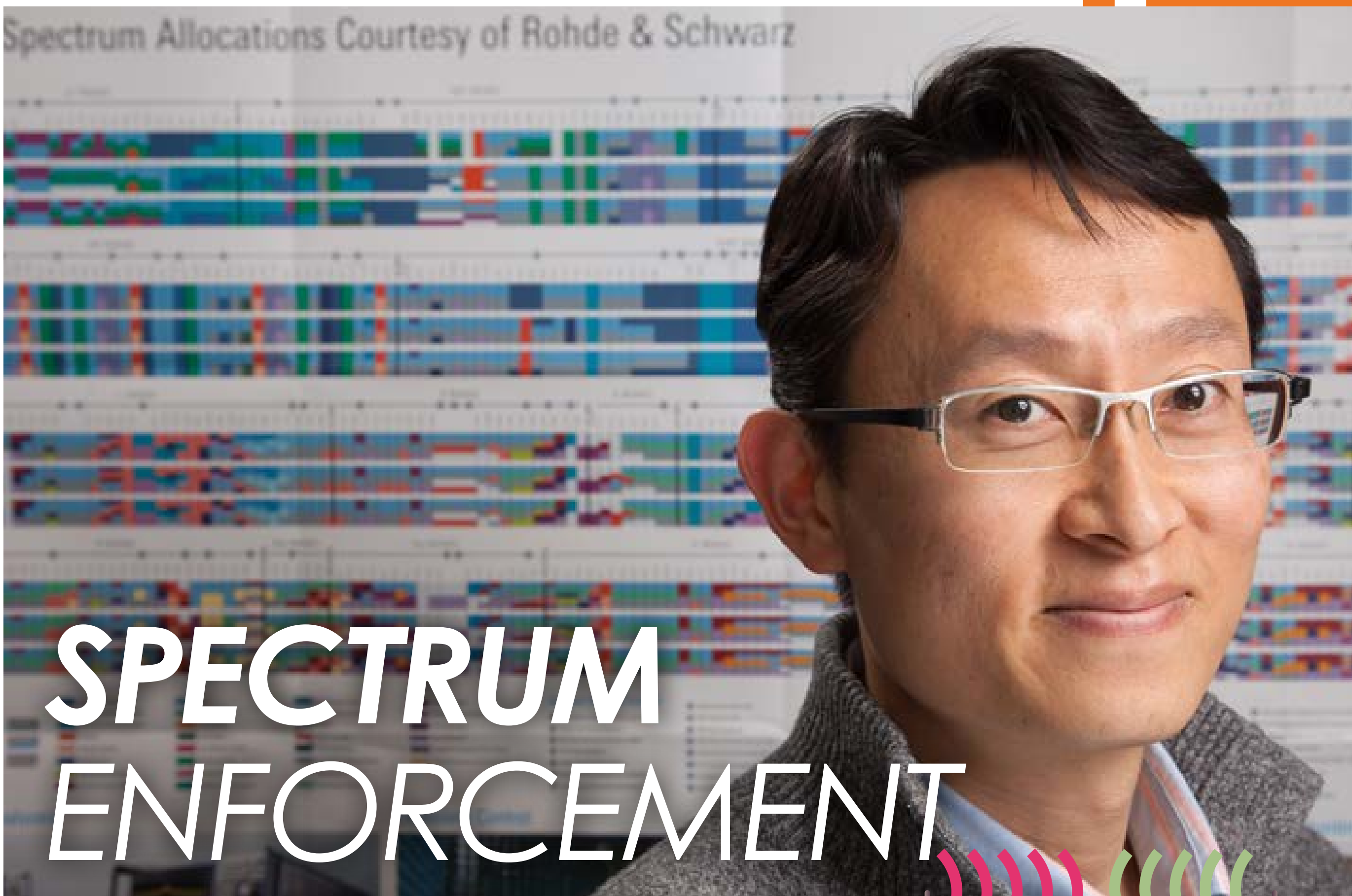
If the guardian waits to intervene until the system has reached its limits, it is hard or impossible to return to stable operation, explains Patterson. The guardian’s control won’t be full-featured, or easily updated, “but it will keep the physical process from damage,” says Patterson.

Patterson and his team are testing their guardian system first on an inverted pendulum (a deceptively simple control system, according to Patterson), and then on a robot used by researchers at Georgia Tech. The concept, however, can be applied to many physical systems.

“Not that long ago, nobody worried about malware. Nobody was attacking or protecting these systems,” Patterson notes. “The classic control engineering approach never considered malware.” Now that embedded systems are all around us, they are the focus of attacks.

HOW TAIGA WORKS





SPECTRUM ENFORCEMENT

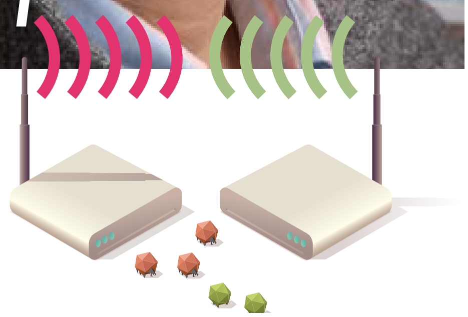
THERE MAY BE a brief period of safety after the introduction of a new technology, but once that technology becomes mainstream, it is at risk. As the number of wireless devices we rely on every day continues to grow, we face the challenges of both interference and security.

The wireless spectrum faces the demands of new devices every day. To allow more data to be transferred across this finite resource, the U.S. Federal government has proposed opening up some of the restricted bands, including the 3.5 GHz band, to secondary users, according to Jerry Park, associate professor of ECE. The primary users, including Federal Government and military entities, would have higher priority access. If the primary user needs to use a given channel, the secondary users—including commercial users—would switch to another channel. Park is working on enabling technologies to enforce this tiered access.

"Whether it is due to malware, hacking, or intentional jamming, these commercial systems have the potential to cause significant interference to primary user systems. We need to detect, identify, localize, and gather evidence to adjudicate rogue, non-compliant transmitters," says Park, who is focusing on identifying potential miscreants.

One way to identify a transmitter is by embedding uniquely identifiable information into a signal without degrading the fidelity of the signal, he explains. "In the U.S., every commercial wireless device must be certified by the Federal Communications Commission (FCC)." If each device sends its identification along with its signal, we have taken care of the first part of ex-post enforcement (i.e., detection and identification).

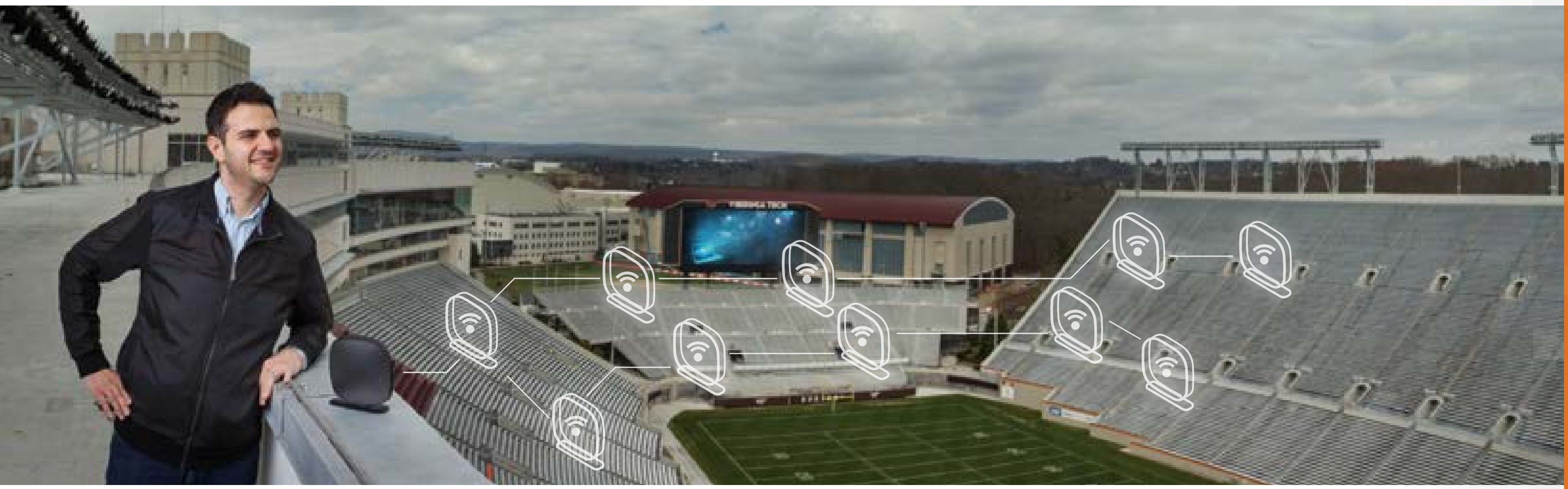
Privacy makes this more complicated. "Once information is embedded in signals, it contains your unique identity and location," Park says, "which would potentially pose a serious threat to the users' privacy." Balancing enforcement with privacy is challenging. "It's a very challenging technical problem as well as a regulatory policy problem."



WHEN TWO USERS are sharing a wireless frequency, the secondary users must yield to the primary users to avoid interfering with critical operations.

> "We need to detect, identify, localize, and gather evidence to adjudicate rogue, non-compliant transmitters."

WALID SAAD is using small base stations to provide wireless services to areas without wasting energy.



CACHING IN **CONTEXT**

IN ADDITION TO MAKING networks robust, efficient, and secure, Walid Saad is using fundamental techniques from game theory and machine learning to use our resources—both energy and wireless spectrum—more efficiently.

Although we want enough wireless base stations for fast data access, we are wasting energy if we have more base stations operating than we need, explains Saad. For example, during a football game, there is much demand for wireless access in a stadium. At other times, there is almost none. Ideally, the base stations serving the stadium should be able to sense the demand and turn on only when needed.

Using the same kinds of models that he uses for sending out drones to keep communications stable after an emergency, Saad is optimizing the wireless small cell networks serving locations like Lane Stadium for everyday use.

Turning his mind towards efficient use of the radio spectrum, Saad also believes that smarter networks can save bandwidth and increase the data speeds. "Networks can learn from your behavior," he says. "If a network is smart enough, it can solve problems adaptively, by itself." By making networks aware of your location, habits, and device type, Saad plans to achieve faster data using less bandwidth.

You check the weather and the news when you get to the office every morning at 8:00. Your coworker checks the weather and sports scores when she comes in at 8:30. Once your network knows these habits, says Saad, it can cache the weather data instead of resending the data each time. "If your network can predict your patterns, it can cache your data and respond quickly," he says.

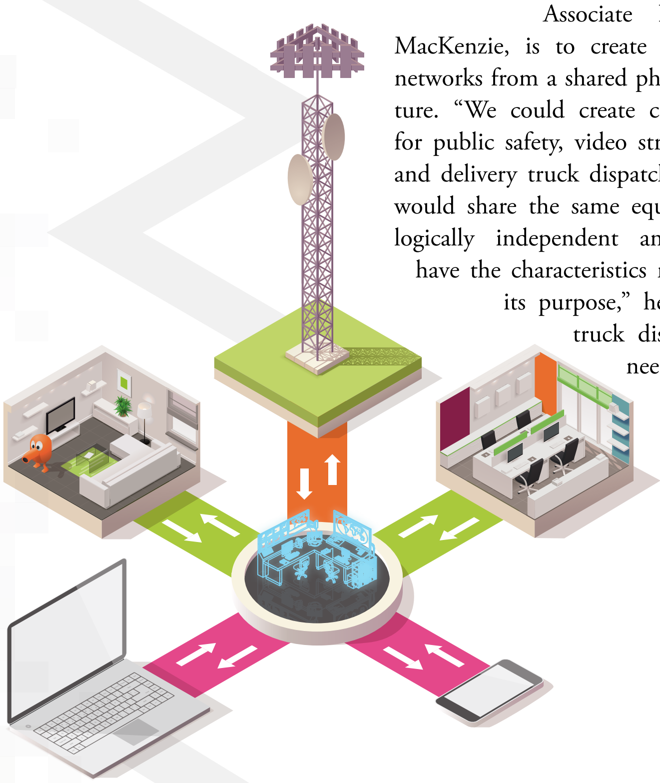
Context-aware networks must know the users' circumstance to best serve them. "Why should I give you a high data rate on a phone that you can't use?" asks Saad. "These networks already know your location and device." Soon, they might use this information.

Saad joined ECE in August 2014. He earned his Ph.D. at the University of Oslo in Norway, and was a postdoctoral research associate at Princeton University. He has authored more than 100 peer-reviewed conference and journal articles, and is co-author of the book "Game Theory in Wireless and Communication Networks: Theory, Models, and Applications," published in 2012. Saad comes to Virginia Tech from the University of Miami, where he earned a National Science Foundation CAREER award for his collaborative research project, Towards Context-Aware, Self-Organizing Wireless Small Cell Networks.

WIRELESS ***EFFICIENCY***

Tailoring **bespoke networks** *from a* **common pool**

ALLEN MACKENZIE envisions a system that allows different kinds of wireless devices on custom networks that share infrastructure. Bandwidth from multiple sources would be bought and sold via real-time markets.



IF THE BOLD VISION of a group of Virginia Tech and University of Pittsburgh researchers is realized, consumers may soon enjoy custom-tailored wireless networks that precisely suit their needs while enabling a much more efficient use of the wireless spectrum.

The idea, says ECE Associate Professor Allen MacKenzie, is to create multiple virtual networks from a shared physical infrastructure. "We could create custom networks for public safety, video streaming services, and delivery truck dispatch. The networks would share the same equipment, but be logically independent and each would have the characteristics most needed for its purpose," he explains. "The truck dispatch does not need indoor service and has low rate requirements, while public safety networks need complete coverage and top priority, but only sporadically." By sharing infrastructure, such virtual networks could coexist.

"Networking today is very siloed," he says. "You've got your home wireless network and your campus wireless network, and then you go out and buy access to a cellular network. What's exciting to me is to integrate these networks into things that work together so that people who want to use network services have to worry less about the network. The networks basically disappear."

The research, funded by a collaborative National Science Foundation grant with the University of Pittsburgh totaling nearly $600,000 over three years, is just getting started. Making it work will require creating an architecture that enables the dynamic formation of virtual networks using resources from multiple entities. New wireless resource management techniques must be developed to allow resources to be pooled and distributed in the most efficient manner.

Finally, the team will investigate how new markets in virtual wireless capacity would work in conjunction with existing wireless networks. Bandwidth available on base stations owned by a communications firm like AT&T as well as WiFi access points belonging to a university could all be bought and sold in real-time markets, according to MacKenzie.

This should lead to a more efficient use of wireless resources, lower costs, and better services to consumers, the researchers be-

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lieve. There will be a lower barrier to entry for smaller wireless providers, who will be able to offer unified services across larger geographic areas by pooling their resources with existing infrastructure deployed by others. This will also make it more attractive to deploy network resources in currently underserved areas, because a single operator won't have to foot the entire bill.

The ideas are not entirely new. Large, national networks today sell access to their infrastructure to smaller cellular companies—Virtual Mobile Network Operators (VMNOs). But right now VMNOs can only work with one company. TracFone, for instance, can only buy access to AT&T's network.

"We want to make it possible to do this across providers," says MacKenzie. "A VMNO could build a network using resources from AT&T, regional providers, even Virginia Tech's campus network."

This vision presents more than just a technical challenge. It will create entirely new markets and market dynamics. Martin Weiss, associate dean and professor at the School of Information Sciences at the University of Pittsburgh, will be concentrating on these market aspects.

The research team also plans to organize a workshop to bring together stakeholders from industry, academia, and government to discuss and assess the profound impact the new wireless architecture could have on both industry and society.

"The challenge will be figuring out how to design these market mechanisms and resource allocation mechanisms so we can put things together in a way that the whole really is greater than the sum of the parts," says MacKenzie. The project is the brainchild of Luiz DaSilva, an adjunct research professor at Virginia Tech and Professor of Telecommunications at Trinity College, Dublin, Ireland.

HARPREET DHILLON hopes to use wireless resources more efficiently by transferring certain kinds of data from one device to another instead of forcing each device to download the same data independently.

On the path to *drop and play networks*

CELLULAR NETWORKS were originally designed to provide ubiquitous voice coverage, according to Harpreet Dhillon, a former Virginia Tech student (MSEE 2010) who returned last year as an assistant professor. Then came smartphones and the whole game changed, he says.

"Due to the increasing popularity of smartphones, there has been a shift towards using more data-hungry applications such as video streaming and real-time video calls," says Dhillon. "This is putting a lot of pressure on networks that were not designed to handle this sort of behavior." As a result, he adds, some studies have predicted that the cellular capacity will need to be increased by around 1000 times in the coming decade.

According to Dhillon, one of the more plausible ways to increase this capacity is to deploy more base stations at places with high user density, often called hotspots. "This transforms our networks into heterogeneous cellular networks consisting of base stations with disparate capabilities, some of which are deployed irregularly without much planning. This demands rethinking in the way these networks are modeled and analyzed."

"When we started this work during my PhD around four years ago, there were limited mathematical models to predict the performance of these complex networks," he notes. Since then, Dhillon has applied point

process theory and stochastic geometry to build realistic and flexible models for these networks. This line of work has led to three best paper awards, including the IEEE Communications Society Leonard G. Abraham Prize.

In his first few weeks at Virginia Tech, Dhillon submitted his first grant application to the National Science Foundation. He has been awarded $175,000 to study the performance limits of self-powered cellular networks.

As small cells—various types of low-power base stations—proliferate to help meet the increasing data demand, Dhillon is working on powering them through self-contained energy-harvesting modules. His research will look at the impact of potentially unreliable power sources on networks.

"These self-powered small cells will have access to a finite amount of energy that needs to be used very judiciously," Dhillon says. "If one node has to shut down because it has no backup source of energy, it could cause a cascade effect that could potentially collapse the network. It is therefore very important to develop formal understanding of this new networking regime."

His work could eventually lead to the deployment of "drop and play" base stations that would result in a truly wireless network.

Dhillon is also investigating device-to-device communications that enable direct communication between devices that could help make more efficient use of resources in a wireless networks.

"Say you have two people sitting in a sports bar," he explains. "They both want to stream video of a live football game to their tablets. With device-to-device communication, the base station can just stream to one tablet, then that tablet can stream to the other. That halves the bandwidth used by the base station."

HELLO WORLD

SECURING THE FUTURE OF OUR ENVIRONMENT

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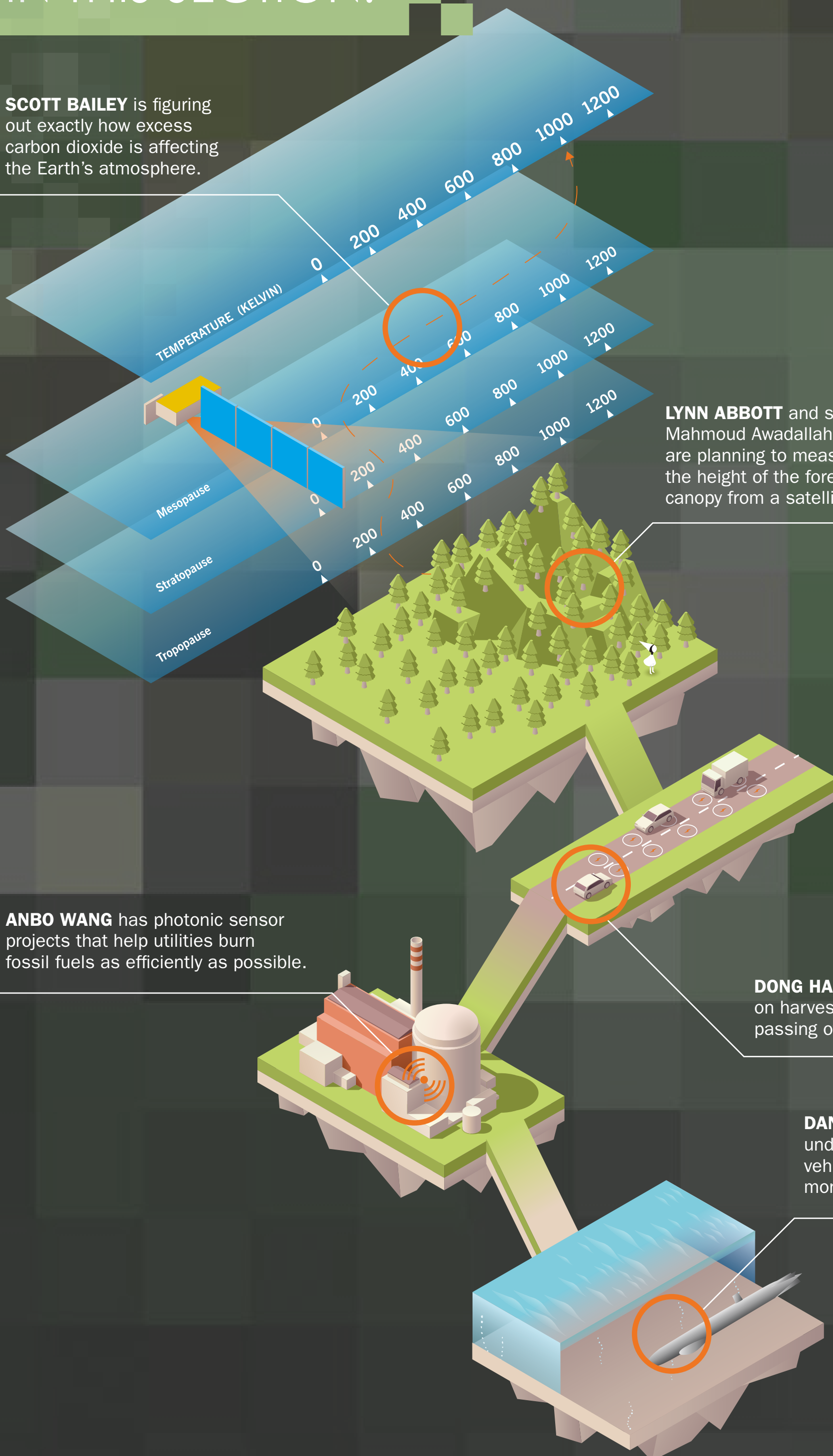


SCOTT BAILEY is figuring out exactly how excess carbon dioxide is affecting the Earth's atmosphere.

LYNN ABBOTT and student Mahmoud Awadallah are planning to measure the height of the forest canopy from a satellite.

ANBO WANG has photonic sensor projects that help utilities burn fossil fuels as efficiently as possible.

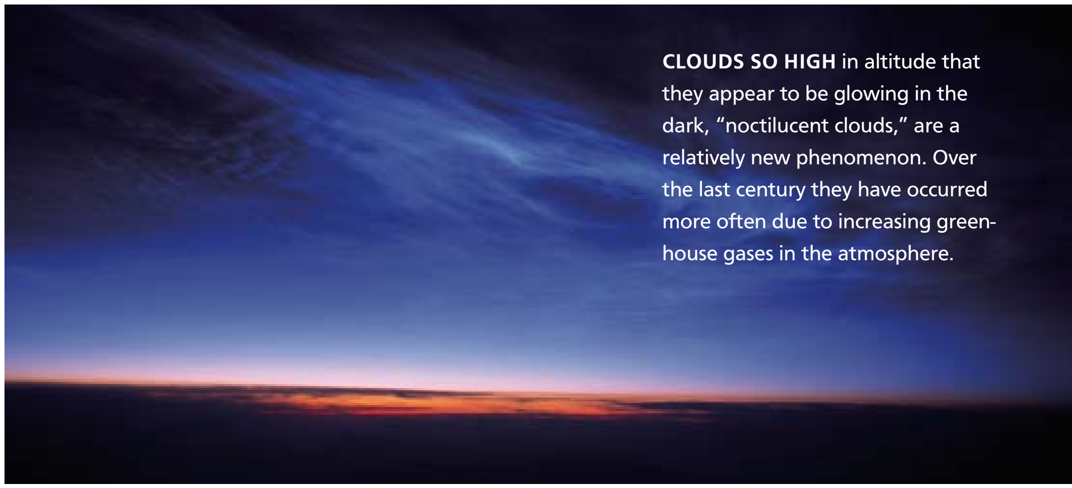
DONG HA'S research focuses on harvesting energy from cars passing over a roadway.

DAN STILWELL'S underwater autonomous vehicles could help monitor the ecosystem.

As society grapples with issues of humanity's impact on the earth, electrical and computer engineers are developing the technology to measure and analyze the problem, to develop new energy sources, and to conserve resources in as many activities as possible.

From sensors and satellites that help measure greenhouse gases to more efficient solar cells and circuits that optimize energy harvesting from roadways, ECEs at Virginia Tech are developing innovations that will pave the way to a greener future.

DIAGNOSING *THE PROBLEM*



JOHN BOARDMAN

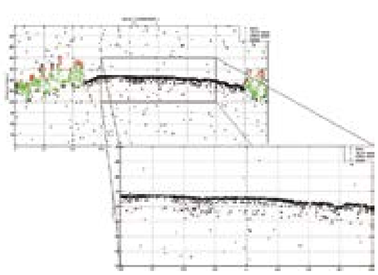
CLOUDS SO HIGH in altitude that they appear to be glowing in the dark, "noctilucent clouds," are a relatively new phenomenon. Over the last century they have occurred more often due to increasing greenhouse gases in the atmosphere.

MUCH OF THE RESEARCH conducted by Associate Professor Scott Bailey is aimed at figuring out exactly how excess carbon dioxide is affecting the Earth's atmosphere.

"The more we can understand how the atmospheric regions interact and how energy and pollutants are transferred through the system, the more we can understand the entirety of the problem," Bailey said.

For Bailey, gaining that understanding means launching satellites that measure the temperature and chemistry of the different layers of atmosphere. The higher you get, the more observable the changes caused by increased carbon dioxide become. "We see all those things more easily than how we see temperature increasing at the surface," Bailey said.

"The atmosphere is changing in more ways than you hear about in the press. Greenhouse gases radiate energy very efficiently. Some of that energy is directed downward. Because the upper atmosphere is radiating energy more efficiently, it's cooling. In the stratosphere, this cooling is easy to see. The difference is in the tens of Kelvins." The picture gained from studying the upper atmosphere is much clearer than at ground level, according to Bailey.



DATA from high altitude airplane flights, color-coded to show the forested areas (left). An image of ICESat-2, the satellite that will gather data on arctic ice as well as forests (right).

Associate Professor Lynn Abbott's work also involves a satellite. He and graduate student Mahmoud Awadallah are helping NASA prepare to measure the heights of forest canopies from ICESat-2, a satellite primarily tasked with measuring polar ice, which will launch in 2017.

Because a geosynchronous orbit is not possible over the poles, the satellite will be covering a lot more latitude—and NASA researchers want to put its sensors to use measuring the size and shape of forests. They believe this information can help characterize the state and health of forests, which in turn, will help them estimate carbon deposits and sequestration in vegetation, and ultimately understand global climate phenomena.

A challenge is that the satellite's sensor package—the Advanced Topographic Laser Altimeter System, a space-based LIDAR—uses lasers at a wavelength that is good for measuring ice characteristics, but not so good for measuring trees and vegetation.

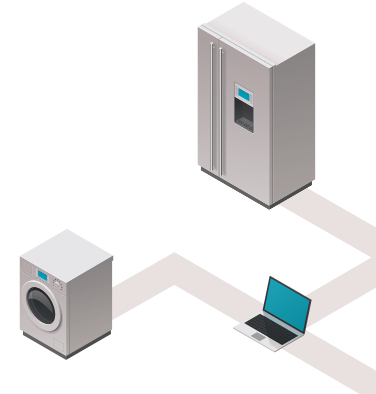
"This is a new type of laser ranging, especially for high-altitude sensing," Abbott said. "It's a photon-counting LIDAR system. It sends bursts of photons toward the ground, and measures how long each photon takes to reflect back to the sensor platform. It can be a very noisy signal during daylight hours."

Using data from a similar sensor deployed in high-altitude airplane flights, Abbott and Awadallah are developing software techniques to remove the noise without removing the signal photons. Their system then estimates curves to represent the ground and canopy.

Not all environmental monitoring is from above, however. The underwater autonomous vehicles Professor Dan Stilwell's teams have developed can monitor waterways for security problems, but they can also be used to monitor the health of rivers, bays, and oceans. Stilwell sees applications worldwide.

As the newest member of the European Union, for instance, Croatia has a new obligation of monitoring *Posidonia*, a native sea grass important to the Mediterranean ecosystem. Currently, Croatia monitors the health of the sea grass using divers who can only cover a fraction of the country's thousands of miles of coastline.

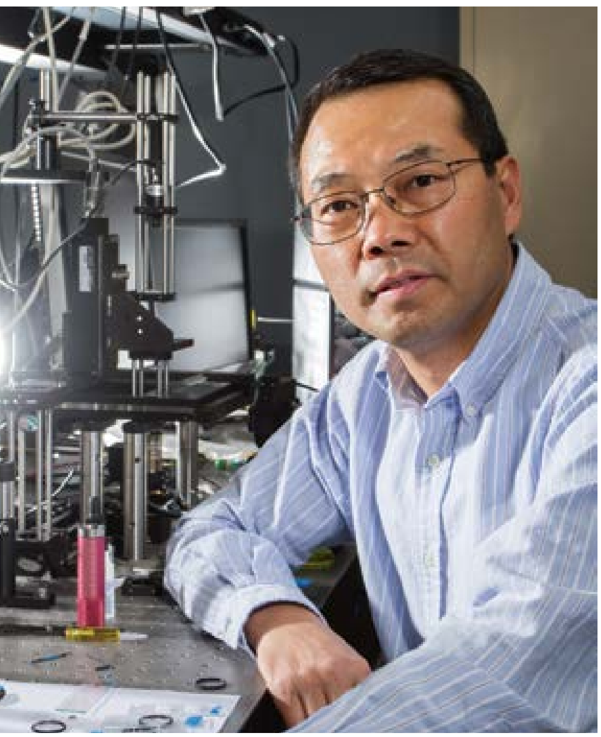
Stilwell envisions his vehicle doing the same work using advanced search algorithms that would enable it to cover much more ground at a fraction of the cost.



MAKING THE MOST
OF TRADITIONAL ENERGY

PROFESSOR ANBO WANG has been working for years on photonic sensor projects that help utilities burn fossil fuels as efficiently as possible and help drillers wring the last drop of oil out of the depths of a well.

"Concern about global warming is pushing the country and the world toward fossil fuel efficiency with lower emissions," Wang said. "Higher operating temperature for power systems is understood to be the best way to increase efficiency with lower emissions, but the increased temperatures render existing sensors no good."



Traditional semiconductor pressure sensors can only operate in temperatures below 500°C, Wang said. Optical sensors can go much higher—above 1,000°C.

One of the most challenging environments imaginable for sensors is inside a coal gasification furnace. When coal is subjected to incredibly high temperatures, it breaks down chemically and forms a gas that can be burned efficiently with minimal waste and far lower emissions.

"This is the best clean-coal technology," Wang said. But the challenge is to heat the coal to the optimal temperature. Too low, and the gas could freeze, "which is a nightmare," Wang said. Too high, and you waste the electricity used to heat the coal, and increase the corrosiveness of the gas.

Traditional thermocouples do not last in a coal gasification furnace. "In just a few hours, they entirely disappear, just eaten up by the corrosion," Wang said.

Even with special protection, thermocouples only last a couple of weeks. But in research funded by the U.S. Department of Energy, Wang developed a crystal sapphire sensor. It has a melting point higher than 2,000°C and can stand up to the corrosive gas.

In a test at the coal gasification unit at TECO Energy's Polk Power Station outside Tampa, Florida, a crystal sapphire sensor endured the entire seven-month power cycle. "I believe that is a record among sensing technologies in a coal gasifier environment," Wang said.

While some researchers squeeze more energy from traditional fuels, the Center for Power Electronics Systems (CPES) is making electrical conversion more efficient, with the goal of cutting electrical energy consumption by 33 percent. The energy savings from a 1 percent improvement in power electronics efficiency is equivalent to the output of 40 nuclear power plants.

CPES engineers are working on power management, point-of-load conversion, vehicular power conversion, and renewable energy systems.

Silicon-based power semiconductor devices have dominated power conversion applications for the past 60 years. To improve efficiency, performance, and power density, researchers are exploring wide-bandgap semiconductor technologies. CPES has demonstrated success with Galium Nitride (GaN)-based design examples, ranging from point-of-load to microprocessors and off-line power supplies. CPES GaN devices can operate at switching frequencies more than 10 times higher than current practice, with a 5-10 times higher power density.

Walid Saad's work on the optimization of cyber-physical systems also helps the power grid make better use of renewable energy, electric vehicles, and storage units. He hopes that

ANBO WANG'S TEAM developed a crystal sapphire sensor that operates in high-temperature, harsh environments of coal gasification plants. Coal gasifiers burn fuel efficiently with minimal waste.

by creating smarter, user-centric energy management mechanisms, utilities can be more efficient with how they distribute power. “Renewable energy can be intermittent, but we hope that by smartly exploiting its availability, we can reduce the requests for coal or other dirty, non-green energy,” Saad said. This work also feeds back into his work on wireless networks, in which small cell base station can be powered by renewable energy sources—thus providing sustainable communication.

He has also applied prospect theory, an Nobel Memorial Prize winning economic theory that describes how people make choices, to optimizing energy usage. “Some power companies offer incentives for customers to, say, run their dishwashers at night,” he said. “Most of these incentives are based on rational objective measures, but our research shows that the optimal prize may not be the ones they give.” If the dishwasher is not full at night, a family may decide to run it after breakfast, despite the discount to their energy bill.

> “Fuel consumption from idling cars could support all the vehicles in Virginia.”

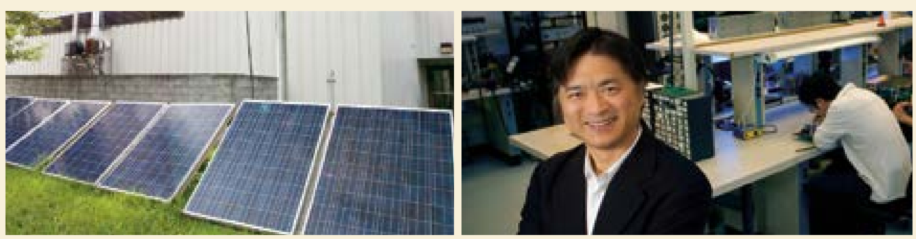
Haibo Zeng is interested in energy efficiency in cyber-physical systems, for example, the transportation sector. “Transportation systems consume more than one quarter of the energy in the United States every year,” Zeng said. “The industry has a large environmental impact in terms of global warming and energy efficiency.”

Zeng is working on a smart start-stop system that can figure out whether a situation calls for automatically turning off an engine or if it is more efficient to leave the engine running. “We want to reduce this kind of unnecessary waste in a smart way,” he said. “The savings can be quite significant. The fuel consumption from idling cars could support all the vehicles in Virginia.”

Zeng is also pursuing energy-efficient routing algorithms that can help drivers get where they are going on time, using the least amount of fuel.

IMPROVING ***ALTERNATIVE ENERGY*** SYSTEMS

ECEs are on the forefront of making solar, wind and other renewable energy systems more efficient, more affordable, and more widely used. Jason Lai and his students in the Future Energy Electronics Center (FEEC) are part of the Department of Energy High Penetration Solar Deployment initiative that is focused on improving today’s photovoltaic (PV) power technologies.



SOLAR CELLS harvest energy outside the Future Energy Electronics Center, directed by Jason Lai.

His team has developed an inverter with 99.3 percent efficiency along with “related power-conditioning systems that have built-in communication lines and digital computing capabilities that can be further developed into the ‘brain’ of an intelligent, controllable power grid,” according to Lai. The team is extending this ultrahigh efficiency inverter technology in an effort to increase the efficiency of photovoltaic systems and move the cost from about $1 per watt to $.10 per watt.

FEEC research has also been applied to a low-voltage, high-current fork-lift motor drive, an induction cooker, and LED lighting drivers.

Improving the effectiveness and promise of solar power also requires boosting the efficiency of PV cells. Currently, the efficiency of silicon-based solar cells has peaked at about 25 percent efficiency, according to Mantu Hudait, director of ECE’s Advanced Devices & Sustainable Energy Laboratory. However, III-V compound semiconductor-based solar cells have shown a record efficiency of nearly 46 percent with tremendous headroom for performance improvement, he said. “We believe that integrating these high-efficiency III-V multijunction solar cells on the significantly cheaper and large area silicon substrate is a promising avenue for future low-cost and high-efficiency photovoltaics.” Hudait has several projects in his lab to address this issue, in addition to a direct thermal-to-electric energy conversion process.

ARI awarded **$2 MILLION** *TO HELP BUILDINGS SAVE ENERGY*

GRADUATE STUDENTS at the Advanced Research Institute (ARI)conduct tests on the Building Energy Management Open Source Software (BEMOSS) project.

THE ADVANCED RESEARCH INSTITUTE (ARI) has been awarded nearly $2 million from the U.S. Department of Energy to continue research and development of its Building Energy Management Open Source Software (BEMOSS) for commercial buildings 50,000 square feet or smaller.

These buildings, which fall outside the scope of most commercial building automation systems, account for more than 90 percent of commercial buildings in the United States and 50 percent of the energy consumed each year.

"Buildings 100,000 square feet and larger can afford to install building energy management systems up front because the incremental cost is relatively small and the opportunity for energy savings is high," explained Saifur Rahman, the Joseph R. Loring Professor of ECE, and ARI director. "However, smaller buildings do not benefit because vendors don't find the market big or profitable enough to make it affordable for them."

The Virginia Tech open-source software platform—which will work from a tablet, smartphone, or computer—is a good alternative for small and medium-sized commercial buildings, Rahman said, "because it serves as a backbone for improving and interconnecting automation systems for major building components."

The open-protocol system operates on plug-and-play, offering scalability and robustness, as well as local and remote monitoring. This allows it to work with load control devices from different manufacturers that operate on different communication technologies and protocols. As a result, the system can more effectively adjust temperature and lighting to account for changes in a building's heating, ventilation, air conditioning, and lighting levels during the day.

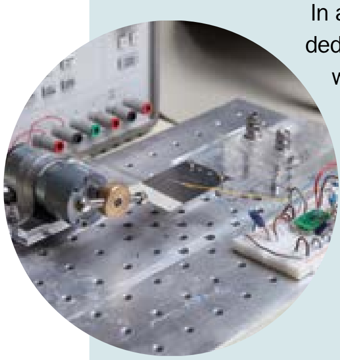
More interconnection among these systems will improve occupant comfort and, at the same time, reduce the use of energy and the cost of owning and operating the building.

—Barbara Micale

FINDING NEW SOURCES OF RENEWABLE ENERGY

WHEN YOU THINK of renewable energy, you probably think of solar, wind, geothermal or hydroelectric. Talk with Professor Dong Ha for a while, and you will start thinking about many other potential sources for energy: roadways, body heat, the vibration in cars—even the freezing and melting of certain materials.

Ha's research focuses on harvesting energy in both small- and large-scale applications. In one large-scale application, he's involved in a project sponsored by the Korean government to generate electricity from cars passing over a roadway.



DONG HA and his students test a circuit that will collect electricity from cars driving on a road without wasting energy when there is no traffic.

In a 1-kilometer pilot project, piezoelectric stacks will be embedded in a roadway that can generate pulses of electrical energy when cars pass by. Ha is working on circuitry that can sense the voltage generated by a car and process it quickly to harvest electrical energy and then be deactivated after the car passes.

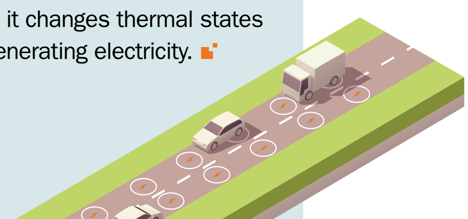
If 1,200 cars pass over the roadway per hour, the roadway could generate about one megawatt of power a year.

There are smaller-scale applications as well that could reduce the need for batteries. Ha is working with Ford Motor Co. to develop wireless sensors for electric car batteries that would be powered by energy harvested from the car's vibration and heat.

Why not just use power from the electric car's batteries? "The battery engineering is done by different guys than the sensor work," Ha said with a laugh. "The battery guys don't want battery power consumed by other things."

Another unique application Ha is working on involves power for an unmanned submersible vehicle. The vehicle travels between thermal layers in the ocean, and Ha is working on using a phase-change material that will freeze at the lower temperatures and thaw at the higher temperatures to generate electricity.

The expansion and contraction of the material when it changes thermal states will drive gears that change linear motion into rotation, generating electricity.



SAFETY, EFFICIENCY, SECURITY
FOR CYBERPHYSICAL SYSTEMS

HAIBO ZENG, who joined ECE last fall, specializes in cyberphysical systems: the interface between computers and mechanical systems.

Cyberphysical systems is a relatively new term, but its increasing use emphasizes that computer systems and the physical systems they control—cars, planes, and other devices—need to be designed in an integrated fashion, Zeng said.

Much of Zeng's work has been in the automotive industry—he worked for General Motors for three years before moving to academia—but the tools and theories he is developing should be broadly applicable to many other areas.

Today's automobiles are extremely complex. A single car can contain more than 100 microcontrollers with more than 100 million lines of code telling them what to do, according to Zeng.

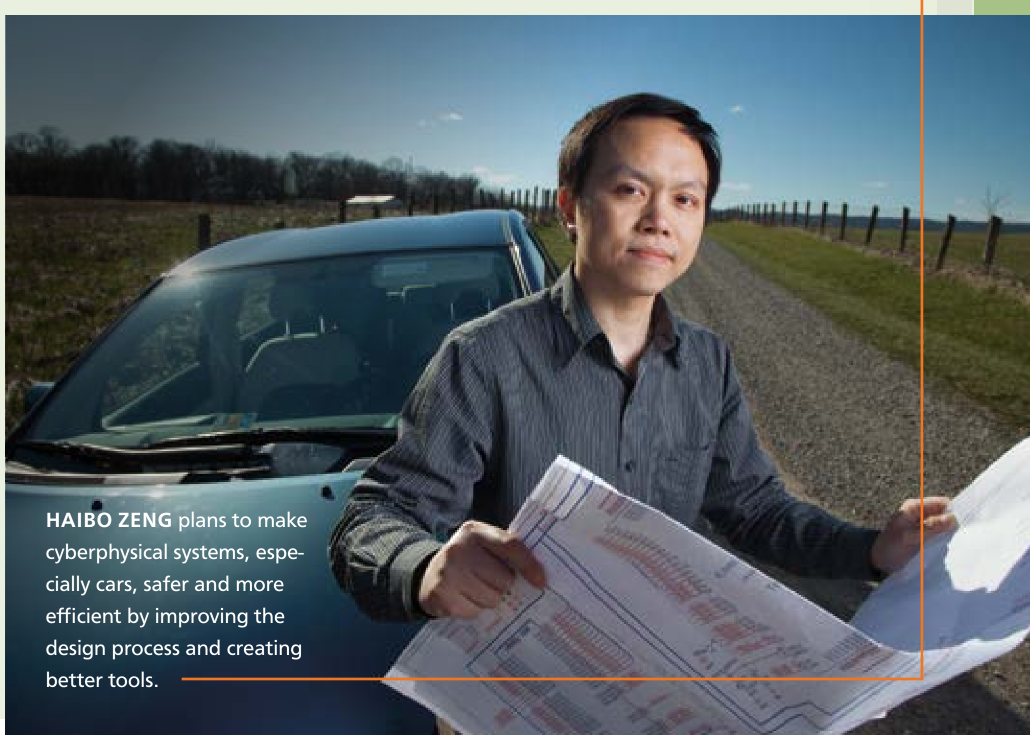
"Safety is one of the top priorities for cyberphysical systems," Zeng said. But it is also important to optimize designs for cost savings. "With mass production, even if you save a small amount of money on each processor in a car, it can make a huge difference because of the volume."

But safety issues can also have a tremendous impact on the bottom line, he said, pointing to the millions of recalls in the industry every year.

"Those are a big failure in design," Zeng said. "We certainly want to minimize that by having a better design methodology and process, and better tools."

In addition to safety, Zeng is interested in research on security for cyberphysical systems. "The damage that can be done on cyberphysical systems is much greater than what could be accomplished on a general purpose computer," he said.

Zeng earned his Ph.D. in electrical engineering and computer sciences from the University of California-Berkeley in 2008. He received his master's and bachelor's degrees in electrical engineering at Tsinghua University in China.



HAIBO ZENG plans to make cyberphysical systems, especially cars, safer and more efficient by improving the design process and creating better tools.

JI HOON HYUN (MSEE '16) and Dong Ha discuss their solar lamp project. It is both cheaper and more efficient than previous models.

MAKING LIGHT **MORE AFFORDABLE**

DONG HA and his students have been working on a project that may help light the darkness in areas that do not have a stable source of electricity.

Working with international partners, they are helping to perfect a design for a cheap solar lamp that can charge during the day and light homes in the evening.

"The first model had very low efficiency," Ha said. "We're improving the efficiency of the circuit."

Keeping the price down is one of the paramount goals. "It's a very interesting constraint," Ha said. "Usually, we don't worry about cost much in a lab, but this project is different. We know many schemes to improve the efficiency, but we have to ask how much a scheme would cost and find the right balance between efficiency and cost."

They have been working on the project for a couple of months. "My students and I really enjoy this project because it's such a good cause," he said.

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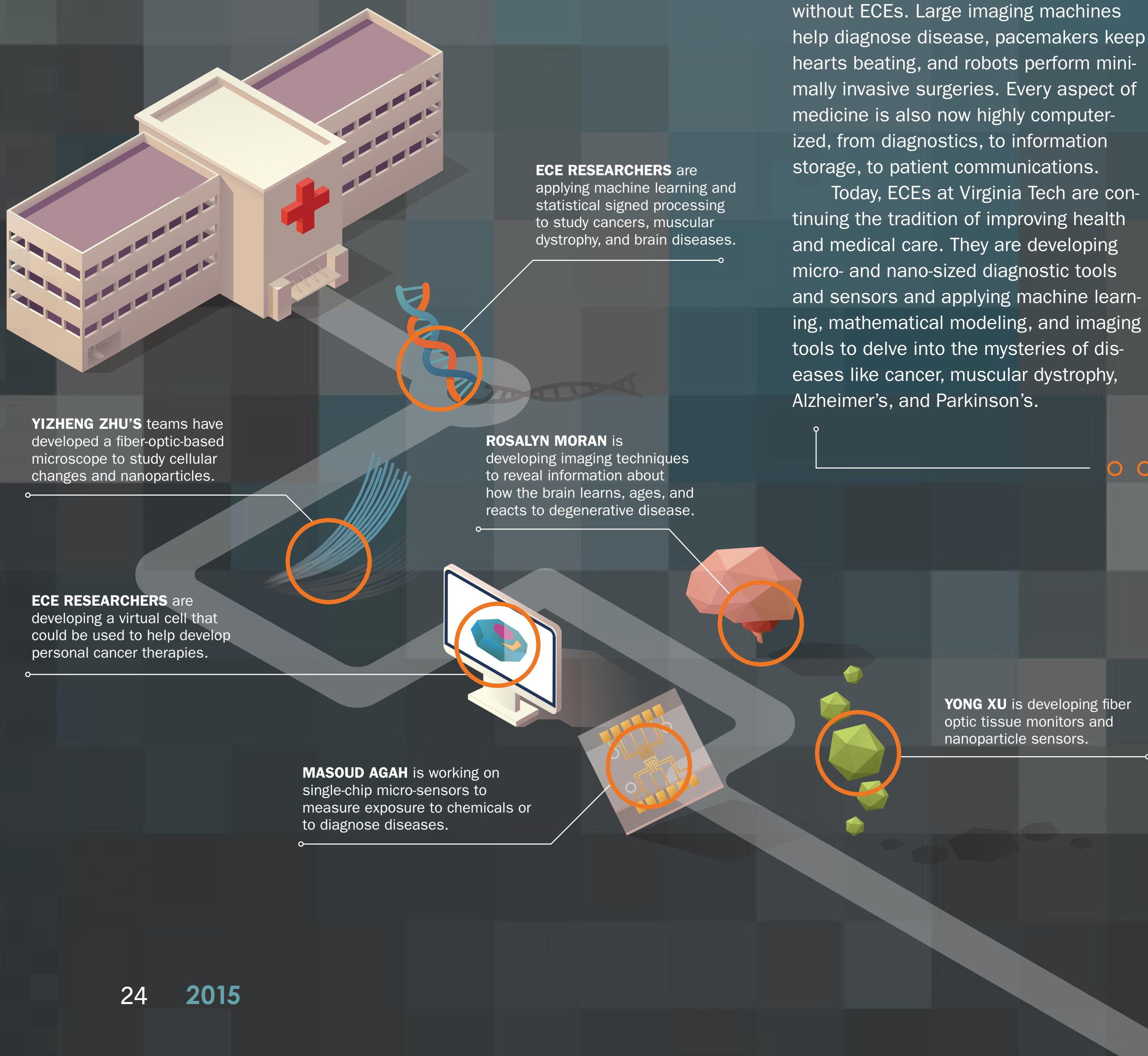
IN THIS SECTION:

None of today's life-saving medical technologies would be possible without ECEs. Large imaging machines help diagnose disease, pacemakers keep hearts beating, and robots perform minimally invasive surgeries. Every aspect of medicine is also now highly computerized, from diagnostics, to information storage, to patient communications.

Today, ECEs at Virginia Tech are continuing the tradition of improving health and medical care. They are developing micro- and nano-sized diagnostic tools and sensors and applying machine learning, mathematical modeling, and imaging tools to delve into the mysteries of diseases like cancer, muscular dystrophy, Alzheimer's, and Parkinson's.



DAN SNOOK

GUOQIANG YU and JASON XUAN

Tapping MACHINE LEARNING *to discover disease patterns*

AN ECE RESEARCH TEAM in Arlington, Virginia has built a powerhouse group that analyzes human diseases at the molecular and systems levels, using machine learning and statistical signal processing. The Computational Bioinformatics and Bio-imaging Laboratory (CBIL) is noted for its collaborative ties with biologists and clinicians, and high-impact publications in Nature Reviews, Nature Medicine, and Nature Communications.

"We are standing at a major inflection point for biomedical science," says Yue (Joseph) Wang, the Grant A. Dove professor of ECE and founding director of CBIL. "Systems biology—an interdisciplinary and data-driven approach to biomedicine—will increasingly transform medicine from disease-driven and reactive to health-driven, predictive, and preventative," he says.

CBIL research has been instrumental in a number of advances in the fight against cancer, including identifying biomarkers that can characterize drug resistance and dormancy in breast cancers, identifying gene interactions in breast and ovarian cancers, and finding that exposure of a pregnant mother to estrogenic compounds can increase the risk of cancer in daughters, granddaughters, and even great-granddaughters.

The team contributed to recent findings that suggest that asynchronous repopulation of various cells in muscle leads to developing excess connective tissue in Duchenne muscular dystrophy.

Much of their work involves mining the huge datasets created by genomics and proteomics investigators. Currently, the team is applying its machine learning, bioinformatics, and imaging expertise to breast cancer, ovarian cancer, cardiovascular and brain disease, and muscular dystrophy.

Jason Xuan, associate professor of ECE, leads breast cancer projects in partnership with cancer researchers at Georgetown University. One project involves analyzing protein-protein interaction data and breast cancer gene expression data to uncover estrogen receptor-signaling networks. "We hope to ultimately use this information to identify new therapeutic targets for drug discovery," Xuan explains. Another effort Xuan is leading is the study of transgenerational effects of a high-fat diet in increasing breast cancer risk.

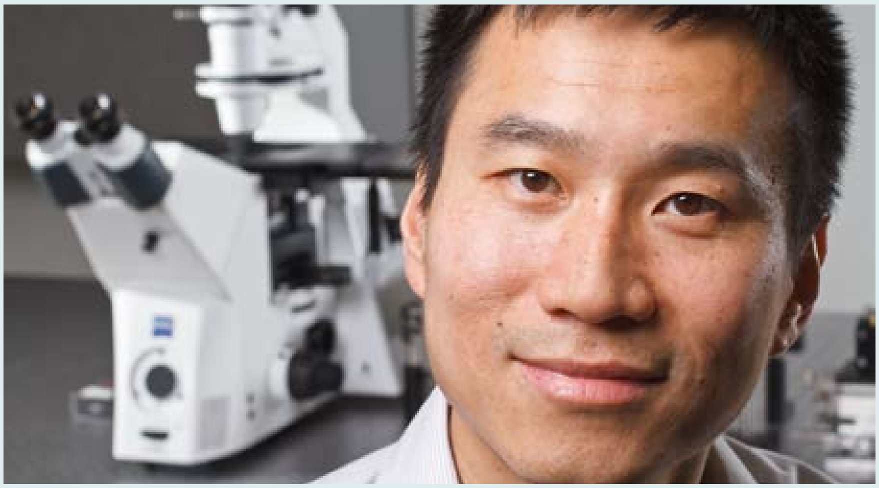
> "We are standing at a major inflection point for biomedical science."
>
> *Yue (Joseph) Wang*

Wang is leading an investigation that involves a huge computational effort to identify and understand which changes in the genome are involved in different diseases. When a single nucleotide, an A, C, G, or T in the genome, is different between members of a population, it is called a single-nucleotide polymorphism, or SNP (pronounced snip). Genome-wide studies have identified thousands of common SNPs associated with major diseases, but their functions are elusive.

Guoqiang Yu is heading up the Virginia Tech effort in a multi-university project to understand DNA changes related to premature atherosclerosis. "The data may provide novel insights concerning interdependent networks of genes and proteins that put some individuals at risk for premature cardiovascular events," says Yu, who is an assistant professor of ECE. "Ultimately, this information could lead to new screening strategies and identify novel therapeutic targets."

The research is important to improve individual risk prediction and to develop more effective treatments, according to Yu. "Despite the success of lipid-lowering and platelet inhibition, the number of individuals we need to treat to prevent just one heart attack is extraordinarily high," Yu explains. "Our overarching goal is to discover patterns of genomic and proteomic factors that will lead to better prevention in those likely to develop atherosclerosis early in life." The team is working on the project with researchers from The Johns Hopkins University, Wake Forest, Harvard, and Louisiana State University.

YIZHENG ZHU has developed a microscope that captures several hundred images every second with sub-nanometer sensitivity.



Using fiber optics to ***capture fast cellular changes, nanoparticles***

A RESEARCH TEAM led by Yizheng Zhu, an assistant professor of ECE, has developed a novel microscope for imaging biological specimens based on fiber optic technology. Using what the team calls spectral modulation interferometry (SMI), the microscope captures images with sub-nanometer sensitivity and high speed (several hundreds of hertz).

"Our technique is well suited for studying fast cellular dynamics, such as membrane fluctuation in red blood cells and contractions of cardiomyocytes," says Zhu. "The quantitative measurements our technique makes possible will provide insights into cellular biophysics and biomechanics."

SMI integrates the high sensitivity of spectral-domain interferometry with the high speed of spectral modulation, and eliminates laser speckles, according to Zhu. The microscope can be used to quantify the size, thickness, volume, and mass of fast-changing cells, improving analysis of cellular dynamics associated with various diseases and biological processes.

The team is also involved in a project to track nanoparticles, using quantitative measurement of nanoparticle scattering as a means to determine particle location in 3D with nanometer accuracy. "Gold nanoparticles have great potential as therapeutic and contrast agents in biomedicine," says Zhu. Visualizing movement inside cells will help researchers understand the molecular and functional mechanisms of different processes, he says.

BUILDING A **VIRTUAL CELL TO FIGHT CANCER**

ECE RESEARCHERS are tackling the critical problem of drug resistance in cancer cells using tools from mathematical modeling, parameter estimation, and optimization theory.

While cancer cells often initially respond well to drug treatments, it is not unusual for the therapy to ultimately fail as cells adapt and become resistant to treatment. In the case of breast cancer, William Baumann, an associate professor of ECE, is developing detailed dynamic models of key cellular systems to explore how this resistance develops.

The models can then be used to suggest therapeutic approaches that can prevent or delay the onset of resistance, he says. As the models become increasingly accurate, it will be possible to determine the optimal sequence and timing of drugs to prevent resistance, kill the cancer cells, and reduce the level of undesired side effects.

"Ultimately, we would like to have a mathematical model of an entire cell—a virtual cell," he says. "But this is probably far in the future. Modeling a cell is much harder than modeling engineered systems, such as a complex integrated circuit, because of the incredible number of interactions among its components."

BRADLEY FELLOW Hunter Long works with Rosalyn Moran to learn how degenerative diseases harm the brain.

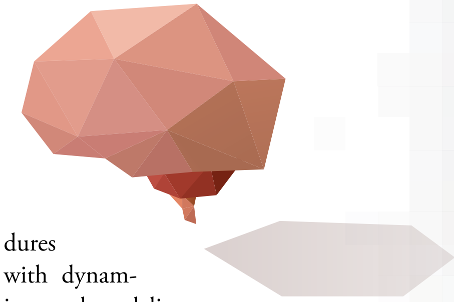
TESTING THE BAYESIAN BRAIN

ROSALYN MORAN seeks to understand the network of electro-chemical activity in the brain, how degenerative diseases disrupt normal brain function, and how life experiences can impact the brain. An assistant professor of ECE, Moran holds a dual appointment with the Virginia Tech Carilion Research Institute (VTCRI), where she collaborates with psychiatry and behavioral medicine researchers.

Her research ranges from basic theories of brain function to studying Alzheimer's and Parkinson's diseases. Her goal is to develop neuroimaging modeling approaches to build what she calls "a mathematical microscope" that can reveal chemical and synapse-level data from macro-level time series.

Moran is working to experimentally test a recent theory of how the brain learns. Researchers have long used Bayesian estimation theory to estimate parameters in mathematical models of engineered and natural systems—including the brain. A new theory posits that the components of a particular estimation algorithm (hierarchical empirical Bayesian estimation based on free energy minimization) can be mapped to specific types of neurons and cortical layers in the brain. In this view, the brain operates much like a predictive coding algorithm, where the brain predicts what it expects to happen based on its current model of the world and acts on the world to fulfill its predictions. Then it looks for errors between its prediction and its sensory data, and uses the errors to refine its model. Moran intends to test the formal mathematical language of this framework at the cellular level using detailed measurements of neuron spiking in the auditory cortex of rodents in response to auditory stimulation.

She is using Bayesian inversion procedures with dynamic causal modeling to study episodic memory in healthy aging and in Alzheimer's. Her team recently found that the prefrontal cortex might be crucial to understanding memory disruption over the lifespan. "This region," she says, "is not traditionally thought of as the brain's memory center, but appears to 'over control' the input into temporal regions of the brain as it codes new memories." Hyperactivity in this region, combined with subsequent heightened signal progression to the medial temporal regions plays a role in age-related memory encoding deficits, she says. "We believe this region needs more study and could



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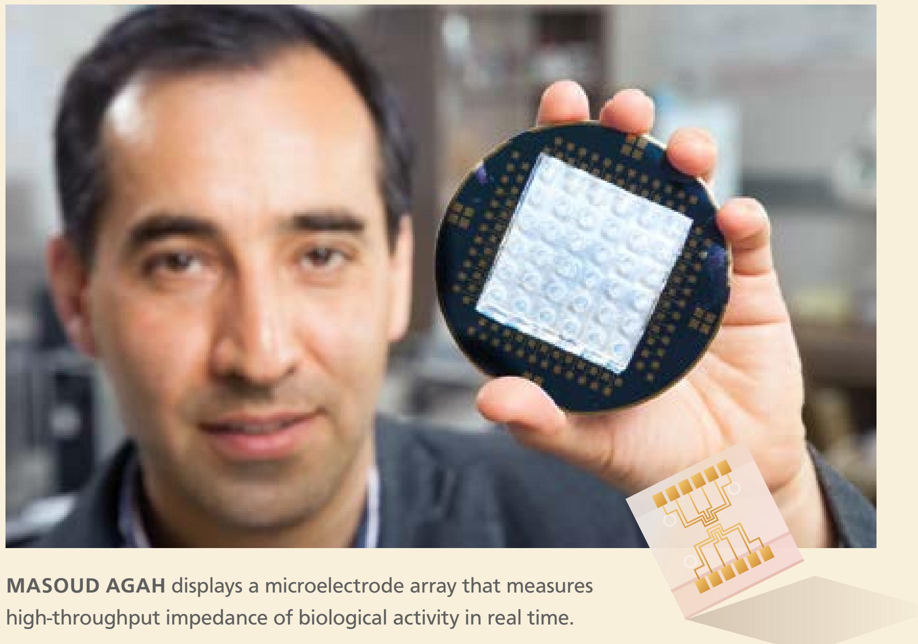
be a potential target for deep brain stimulation to ameliorate cognitive decline in patients with Alzheimer's."

Moran's group is also working to understand the mechanisms that cause movement problems in patients with Parkinson's disease. "The medical world has known for some time that reduced dopamine release and oscillatory neural activity in the beta band (16-32 Hz.) are implicated in Parkinson's," she says. "However, how this degeneration leads to the subsequent movement disorder remains unclear."

Recent VTCRI experiments led by Professor Read Montague have provided the first-ever human *in vivo* measurements of striatal dopamine at sub-second time scales. "These measurements, acquired from patients with Parkinson's, provide exquisitely precise neurochemical assays of basal ganglia during task performance. We are excited to collaborate with Prof. Montague's team on this groundbreaking technology to understand how dopamine and beta oscillations fundamentally shape impairment," Moran says. "In the long term, we believe these sensorimotor tests could aid in individualized treatment and disease management strategies that combine drug and surgical interventions."



MASOUD AGAH displays a microelectrode array that measures high-throughput impedance of biological activity in real time.

SINGLE-CHIP **DIAGNOSTICS**

MASOUD AGAH, an associate professor of ECE, is developing a number of micro-sized chemical and gas sensors with environmental, safety and biomedical applications. Agah's teams in the Virginia Tech Microelectromechanical Systems (MEMS) Laboratory have focused on integrating the three aspects of gas chromatography (GC) sensing—preconcentrator, separation column, and detector—onto a single chip.

Compared to conventional, bulky gas chromatography systems, an integrated μGC chip has many advantages: lower fabrication costs, improved performance, elimination of the need for signal transfer from one chip to another. The sensor has many potential applications and can be modified for use with gas or liquids.

One potential application is using saliva to monitor exposure to pesticides. Another would be an inexpensive breath monitor that could help detect the presence of diseases such as breast cancer.

"Researchers have shown that breast cancer and lung cancer can present in indicators in the breath," Agah said. "If those indicators show up, it indicates the need for more tests to see if there is an issue. A negative result means you're okay."

Agah said making such a device available in doctors' offices could dramatically reduce the need for mammograms and other invasive tests.

He is also working on sensors that could monitor the exposure of truck drivers to gasoline fumes almost in real time. "There's no way right now to get even a five or 10-minute resolution," Agah said.

Developing **fiber optic tissue monitors, nano-particle sensors**

YONG XU, an associate professor of ECE, is using fiber optic imaging for monitoring muscle-tissue formation to help better understand organ development, and eventually grow synthetic organs.

"The hardest part of working with organs is looking into tissue deeply," Xu says. "Humans and lab animals aren't transparent. How do you look deeply into the tissue to really see what's going on? To really understand the process of tissue/organ development, you have to keep the organ's three-dimensional architecture and look through the opaque 3D structures."

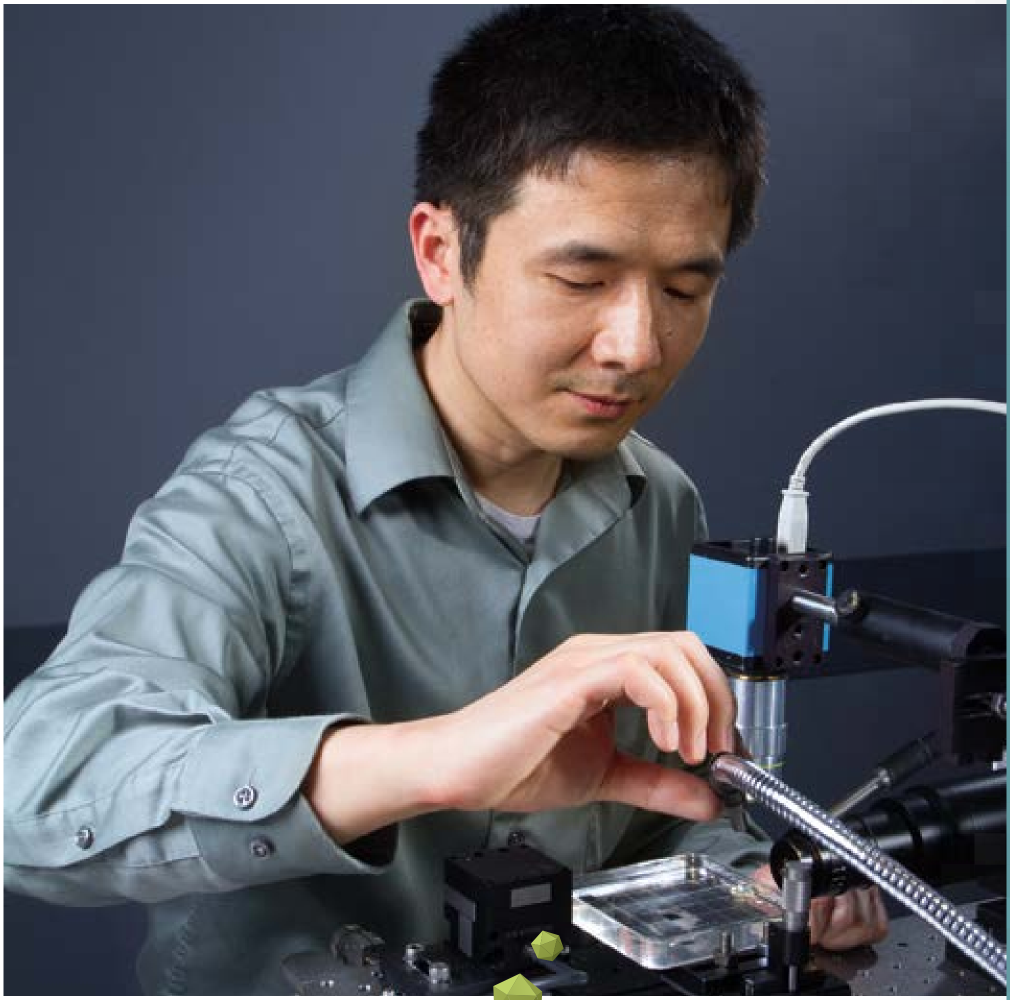
Xu's solution is to incorporate fiber optics directly into the tissue's architecture. So far, the work is confined to the lab and bioreactors where tissue is cultivated and grown. "We're not ready to put this into a whole animal, yet," Xu says.

This work could assist in the efforts to create artificial organs in the lab, which might one day alleviate the shortage of organ donors. "It's a major component—not the final step at all," Xu explains. "But it is an important intermediate step toward creating a functional organ."

Xu is also working on developing low-cost sensors to detect nanoparticles, either those generated by common construction processes (such as welding) or those purposefully created in the lab.

Traditional sensing technologies use air pumps to collect particles and measure the total weight of the collected particles. There are two issues with this. First, given the difficulty of accurate weight measurements, this approach is not particularly sensitive. Second, nanoparticles collide and clump during this collection process. "Because of this, we may not have an accurate picture of the size of particles humans may breathe during their work," Xu says.

Xu is investigating the use of an optical fiber as a sensor that could detect such very small particles, like the ones created during the welding process. "It's exciting because no one has looked into this area much," he says. "It's concerning because we may have ignored a serious problem."



YONG XU works on fiber optic sensors that will help us visualize human tissue, and eventually develop artificial organs.

Nanoparticles have been associated with lung cancer, bronchitis, airway irritation, and other issues. The small particles of heavy metal released by welding may cause brain diseases if they enter the central nervous system.

If nanotechnology comes into more common usage, sensors that can detect and monitor tiny particles will be vital.

LEARNING
THE BUSINESS

Two-semester capstone course provides ECE majors with real-life, real-time industry projects

"There are no grades in the real world," comments one student halfway through ECE's new two-semester capstone design class. The course, ECE 4806, provides teams of students with simulations of the post-college world via projects specified and directed by industry partners. Students need to adjust to the new ways they will be evaluated in the workplace—effectiveness, timelines, and the ability to cooperate with professional colleagues.

"We know that Virginia Tech students come to the table with excellent technical skills, and that is going to open the door to their first jobs," said Gino Manzo, a professor of practice who directs the program, drawing on his 37 years of experience at BAE Systems. He hopes to instill in his students the importance of business and professional skills to supplement their technical acumen.

"You have to know how to work on a team, and the best ideas come from the most diverse set of people you can put together," he says. Advancement, according to Manzo, is based in part on being a good team player and leader.

He presented ECE 4806's 16 projects, and had students identify their top three choices. "Many teams came together with students who did not know one another," he says. Since then, he has worked to train the students in teamwork, through lecture, team-building exercises, and reading assignments.

He has watched the groups gel. "I see them come back from lunch together and talking in the breakout rooms," he says.

Each of the 16 projects is sponsored by a company or institution, and experienced engineers at those organizations keep in regular communication with their teams, serving as the "Customer." The projects cover a range of areas, so each team also has an ECE subject-matter expert to provide technical guidance.

In the first semester, Manzo gave lectures and met with teams individually to

CAPSTONE *PROJECTS*

"When you start communicating, you build rapport, then comes trust and confidence, which is the foundation for a high-performing team."

gauge their progress. This spring, as deadlines loom, more time is focused on completing the project. "I'm trying to be a coach and mentor," Manzo says.

Once the projects are assigned, it is up to the teams to decide how much time to devote to their project.

Manzo surveyed his students at the end of the first semester and found that they struggled with the freedom he gave them. "They love it because they can be creative and do what they think is right, but they hate the ambiguity," he says.

For the spring semester, he had his students dig through the 10-K reports available through the SEC. The mandated filings will give students an unfiltered perspective of the kinds of places they may work, according to Manzo.

In February, students presented their progress to their peers. Most groups took longer than they had expected to figure out what the project needed to be. Even with directions from industry partners, the teams rescaled projects, adjusted budgets, and devoted additional hours to research and planning.

The students are learning how to adjust their projects, develop workarounds, and even rescale projects and at the same time manage their customer expectations.

"It's okay to re-scope a project. That's not failure, that's learning," Manzo says. "In real life, their supervisors will be out of town and give an assignment due in two weeks. There won't be a grade, but maybe accolades and constructive criticism."

GINO MANZO mentors 16 teams of students through design projects for industry partners.

Students send their industry contacts a monthly status report, but Manzo encourages them to engage their customers—if an industry partner does not respond to an email, then give her a call, he suggests.

"When you start communicating, you build rapport, then comes trust and confidence, which is the foundation for a high-performing team." Manzo says. In the world of work, projects do go awry, people make mistakes, change directions, and change them again, he says. "If your customer has trust and confidence in you, he or she will accept what you say."

When ECE 4806 begins again in Fall 2015, Manzo will have 26 projects and over 100 students.

"I don't want them to take a job and be just a pair of hands," Manzo says.

Asymmetric Material Design

SPONSOR: **Lockheed Martin**

CHALLENGE: Identify new materials that can be used to build basic circuit components and catalog those materials into a database. Then design circuits with those new components implemented.

LOCKHEED MARTIN

Wireless Sensor Interface

SPONSOR: **Virginia Tech Transportation Institute and General Motors Company**

CHALLENGE: Develop a reliable wireless interface between interface and signal transformation sensors, a distributed antenna system interface, radio signals, and a central data acquisition system. The sensors need to support a variety of common input interfaces.

VirginiaTech Transportation Institute

GM

Thermo-Photovoltaic Fabrication and Optimization

SPONSOR: **Micron Technology**

CHALLENGE: Fabricate a set of thermophotovoltaic cells designed to extract energy from the heat of propane combustion. The design should have a lower resistance and higher efficiency than previous, similar projects.

Micron

Magnetic Levitation System

SPONSOR: **National Instruments**

CHALLENGE: Achieve permanent magnetic levitation with a six-inch, 15 lb. magnet. Use an FPGA to simulate the process, which can also act as a control system with a working prototype.

NATIONAL INSTRUMENTS

High-Speed Scalable Packet Switch

SPONSOR: **Northrop Grumman**

CHALLENGE: Develop a switch able to route signals from N antennas to M receivers and create a working model in Simulink. The signal generator will produce an analog signal, which is then translated to digital, modified by an FPGA, retranslated to analog, and then processed by a signal analyzer.

Mobile Single Sign-On

SPONSOR: **Virginia Tech Information Technology**

CHALLENGE: Create a mobile app that gives the user permission to use and access every app within an organization with a single sign-on. The app will also provide greater security and ease of use.

High Voltage Waveform Generator

SPONSOR: **General Electric**

CHALLENGE: Design, build, and test specialized electronic equipment with a web page interface that can produce, read, measure, and analyze waveforms, and then pinpoint any faults.

Data Compression and Encryption

SPONSOR: **Lockheed Martin**

CHALLENGE: Develop an FPGA based solution to take a stream of variably formatted data, compress it to reduce memory storage requirements, and encrypt it to meet Triple Data Encryption Standards.

Low K Interconnect Structures

SPONSOR: **Intel Corporation**

CHALLENGE: Develop a test and new test structures that will help to understand the nature of time-dependent dielectric breakdown (TDDB). Identifying what stressors induce TDDB will help improve semiconductor technology as it continues to scale.

Infrared Sea Surface Temperature Sensor

SPONSOR: **The Johns Hopkins University Applied Physics Laboratory**

CHALLENGE: Design a compact, inexpensive, low powers and highly accurate sensor to measure the infrared light reflected off the sea's surface. The sensor uses IR spectrum to measure the relative emissivity of the light from water from 8-14 microns (longwave infrared).

IEEE Robotics Team Competition

SPONSOR: **Virginia Tech Electrical and Computer Engineering**

CHALLENGE: Design an autonomous robot with sensing, learning, and reading capabilities. The robot must be able to play games, navigate a maze, and complete tasks within an allotted time frame.

Self-Organized Coherent Distributed Radio Frequency Transmitter

SPONSOR: **The Johns Hopkins University Applied Physics Laboratory**

CHALLENGE: Build a localization module that uses both wireless and ultrasonic transceivers to communicate with other nodes and determine range information. The goal is to achieve 90 percent of theoretical coherent gain at a specified location using localization, clock synchronization, and phase adjustment.

Emergency Shutdown System

SPONSOR: **Virginia Tech Transportation Institute and General Motors Company**

CHALLENGE: Create a system that sends a wireless signal from a remote location to shut off a vehicle in an emergency situation.

Simultaneous Programming of Multiple Identification Tags

SPONSOR: **General Electric**

CHALLENGE: Develop a device that can simultaneously program up to six integrated identification tags, and reduce programming time of existing devices. Create a PC-based interface for users to manipulate data stored in the ID tags.

Fluxgate Magnetometer

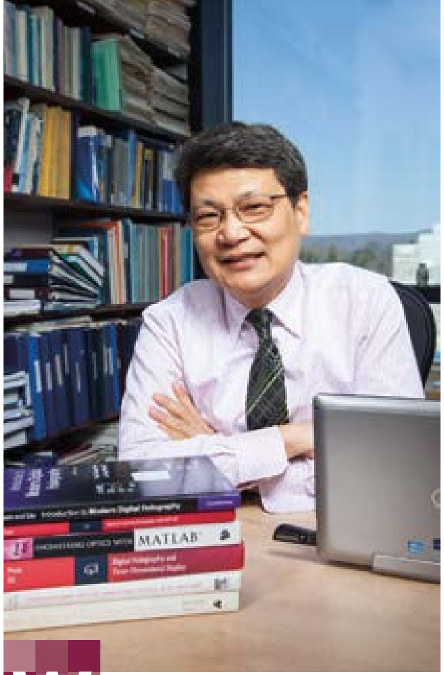
SPONSOR: **Prime Photonics**

CHALLENGE: Create a device that measures the strength of a magnetic field. This device, the fluxgate magnetometer, will be used to test the new core material developed by Prime Photonics for NASA.

Radiation Test and Characterization Methodologies

SPONSOR: **VPT Inc.**

CHALLENGE: Design, build, and test a universal characterization circuit that can test any operational amplifier to reveal the amplifier's current parameters. The intended use is during radiation testing. Where a component is irradiated, its parameters change, and the testing system can measure the operational amplifier for its new values.



HOLOGRAM TECHNOLOGY

MAY ILLUMINATE 3D FUTURE

When you have an affordable holographic television in your living room that gives you real 3D without the need for glasses, T.-C. Poon will be one person to thank.

Poon, a professor of ECE, has spent years developing new techniques for digital holography. One of the most intriguing is called Optical Scanning Holography.

"It is a radically different technique," Poon said. "It uses a single-pixel camera to record holographic information."

Most 3D scanning processes use high-resolution Charge-Coupled Device (CCD) cameras. But Poon's technique has several advantages. A decent scan using CCDs would require a gigapixel sensor, something that does not exist yet. Current sensors do not have enough pixels to scan a large object with enough resolution to capture 3D information.

Poon's technique employs a laser beam that scans an object, moving across the X and Y axes and reflecting light back to a sensor that captures and records one pixel at a time.

Theoretically, this system could be used to record moving objects, Poon said. It would require a faster scan, necessitating a higher signal frequency and faster electronics at the back end. All that generates a lot of expense.

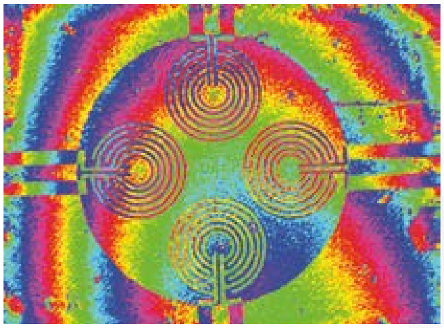
Poon said his job as a university researcher is to perfect the principle and make the information public. Then private enterprise can take the technology and develop marketable applications.

That holographic TV is still years away. "It's not real world," Poon said. "Even a 1-inch by 1-inch image is very expensive to produce. Once we can get a big image, we'll be in business. But we're not in business yet. It's still science fiction. Right now, we can achieve only very small figures. We're almost at the Star Wars level of technology with R2-D2 and the hologram of Princess Leia."

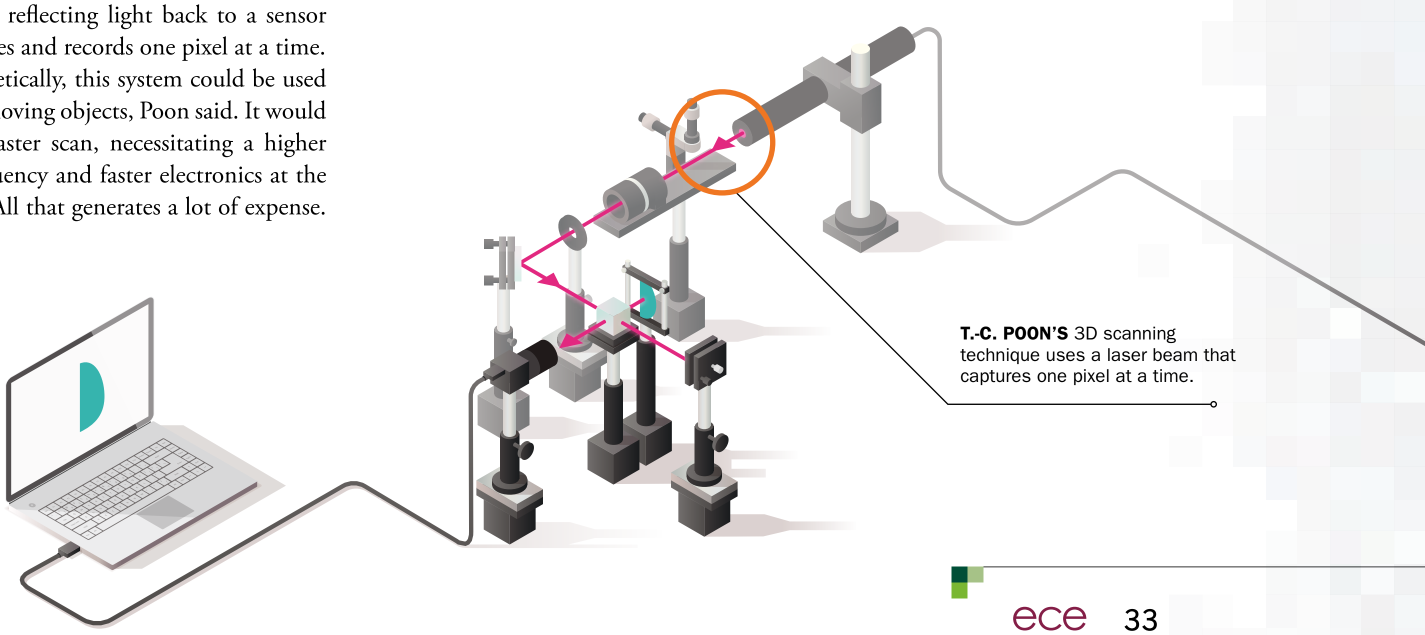
Poon is also working on creating computer-generated holograms—images of objects that are not real. The challenge is to speed up the process of calculating the 3D information. An image of 4 million points can take a long time to calculate.

Digital holography combines many aspects of electrical and computer engineering, according to Poon. "You have to involve optics, lasers, and lenses," he said. "The output is electrical signals that require signal processing. Many disciplines come into play."

Poon has written several textbooks, which will help guide the next generation of students.



A RECONSTRUCTED IMAGE of a MEMS hologram. The different colors denote different heights.



T.-C. POON'S 3D scanning technique uses a laser beam that captures one pixel at a time.

2014 | 2015
BRADLEY & WEBBER HONORS

PAUL URI DAVID
BSEE '13
Clemson University

ADVISOR:
Robert McGwier

RESEARCH:
David is developing the Virginia Tech Satellite Ground Station's core software for signal processing, operations, and usage. The station will support low-earth orbit missions such as CubeSats and amateur radio satellites. He is also investigating methods for wireless signal identification.

BRADLEY ALUMNI

JoAnn Adams (S)
(BSEE '94)
Co-owner
Big Fish Design
Centreville, Va.

Robert Adams (F)
(MSEE '95, Ph.D. '98)
Associate Professor, ECE
University of Kentucky
Lexington, Ky.

Shawn Addington, PE (F)
(BSEE '90, MSEE '92, Ph.D. '96)
ECE Department Head and Jamison-Payne Institute Professor of EE
Virginia Military Institute
Lexington, Va.

Sarah S. Airey (S)
(BSCPE '01)
Speech Scientist
RecordSure
Cambridge, U.K.
She is working in speech recognition for a startup applying speech to the UK banking sector to allow banks to ensure compliance in financial sales.

Christopher R. Anderson (S/F)
(BSEE '99, MSEE '02, Ph.D. '06)
Associate Professor
U.S. Naval Academy
Annapolis, Md.

Matthew E. Anderson (S)
(BSCPE '08)
Systems Engineer
Cisco Systems
Philadelphia, Pa.

Nathaniel August (F)
(BSCPE '98, MSEE '01, Ph.D. '05)

Stephen P. Bachhuber (F)

Matthew Bailey (F)
(BSCPE '09)
Graduate Student
Virginia Tech

Mark Baldwin (F)
(BSEE '93, MSEE '05, Ph.D. '08)
Engineer
Dominion Power
Glen Allen, Va.
He is involved in modeling, control, and protection of electric power generation equipment.

William D. Barnhart (S/F)
(BSEE '00, MSEE '02)

Benjamin Alan Beasley (S)
(BSEE '09)
Associate
Zeta Associates Inc.
Fairfax, Va.
Pursuing an MSEE.

Brian Berg (F)
(BSEE '90, MSEE '91, Ph.D. '01)
President and Founder
Dimmersion LLC
Agoura Hills, Calif.
Launched a social media company that allows users to synchronously play media tracks with existing audiovisual content without violating copyrights.

Ray Bittner (F)
(BSCPE '91, MSEE '93, Ph.D. '97)
Senior Hardware Engineer
Microsoft
Redmond, Wash.
He is working in Microsoft Research on topics spanning FPGAs, high speed computation, data centers, GPUs, and portable devices.

Aric Blumer (F)
(Ph.D. '07)

Brian Browe (F)
(BSEE '97, MSEE '99)

Kirsten Ann Rasmussen Brown (S)
(BSEE '94)
Vice President, Office of the Chairman
MicroStrategy Inc.
Tysons Corner, Va.
In addition to executing the CEO's vision and company priorities for MicroStrategy, Brown is a member of the ECE Advisory Board.

Steven Edward Bucca (F)
(BSEE '87, MSEE '89)

Mark B. Bucciero (F)
(BSCPE '01, MSCPE '04)
Computer Engineer
Logos Technologies
Raleigh, N.C.

R. Michael Buehrer (F)
(Ph.D. '96)
ECE Professor
Virginia Tech

Charles Bunting (F)
(MSEE '92, Ph.D. '94)
Associate Dean of Research, College of Engineering, Architecture and Technology
Oklahoma State University
Stillwater, Okla.
Director of the Robust Electromagnetic Field Testing and Simulation Lab.

Carey Buxton (F)
(Ph.D. '01)

Scott Cappiello (S)
(BSCPE '94)

Matthew Carson (S)
(BSEE '98)
Logistics Coordinator
He is currently in South Asia, learning a new language. He will be doing logistical support for other foreigners in the country and assisting NGOs there.

Matthew Carter (F)
(BSEE '09, MSEE, '14)

Ricky Castles (S)
(BSCPE '03, MSCPE '06, Ph.D. '10)

CHRISTINA DIMARINO

BSE '12

James Madison University

ADVISOR: Dushan Boroyevich

RESEARCH:
After characterizing a variety of 1.2 kV silicon carbide power transistors, including MOSFETs, BJTs, and normally-on and normally-off JFETs in high temperatures, DiMarino has started exploring the packaging, driving, and testing of transistors up to 10 kV.

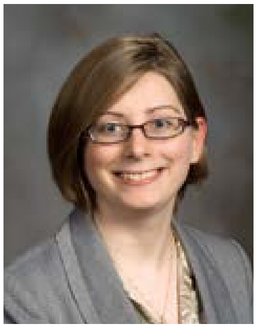
MICHAEL DRESCHER

BSCPE '13

Virginia Tech

ADVISOR: Binoy Ravindran

RESEARCH:
Drescher is helping to develop KairosVM, a project that converts real-time systems, such as media or web servers, into virtual machines. This will allow multiple systems to run on a single machine while isolated from each other, and make it easier to move systems from one machine to another.



KRISTEN HINES

BSECE '13

Tennessee Tech University

ADVISOR: Tom Martin

RESEARCH:
Hines is incorporating fabric stretch sensors into an ambulatory monitoring suit, which will help provide a more comfortable environment for activity classification. She is also developing a construction safety vest for collision avoidance, improving safety for workers on busy roads.

(S) Scholar (F) Fellow

Eric D. Caswell (F)
(Ph.D. '01)

Daniel (Dae) Cho (S)
(BSEE '06)
Intellectual Property Attorney
Winston & Strawn LLP
Los Angeles, Calif.

Jeffrey R. Clark (F)
(MSEE '03, Ph.D. '06)
Proprietor
Black Dog Writing & Editing
Blacksburg, Va.
He provides technical writing and editing services and is a novelist.

Ross Clay (S)
(BSCPE '09)
Software Developer
Amazon
Palo Alto, Calif.
Working on DynamoDB, Amazon Web Services' database service.

Brittany Clore (S)
(BSCPE '10, MSCPE '12)
Senior Cyber Security Engineer
The MITRE Corporation
McLean, Va.
Working on cybersecurity policy, cross domain solution evaluations, and risk decision processes.

Kevin B. Cooley (S)
(BSEE '02)
Electrical Engineer
Automation Controls Inc.
Newport News, Va.
Makes, designs, and builds UL electrical panels. He still does some work with www.buildmy-product.com.

Thomas Alan Cooper (S)
(BSEE '10, MSEE '12)
Software Design Engineer
KEYW Corp.
Severn, Md.
He writes firmware for a custom tracking/communications device and writes apps to interface user with device data.

Carrie Aust Cox (F)
(MSEE '00)

David Casteel Craven (S)
(BSCPE '08)

Stephen Douglas Craven (F)
(Ph.D. '08)
Electrical Engineer
Tennessee Valley Authority
Chattanooga, Tenn.

Cass Dalton (S)
(BSCPE '03)

Phillip A. Danner (S)
(BSCPE '91)

Bradley A. Davis (F)
(BSEE '86, MSEE '88, Ph.D. '00)
Vice President, Engineering
Nanosonic
Pembroke, Va.

Daniel A. Davis (S)
(BSCPE '99)
Principal Member of the Technical Staff
AT&T
Chesapeake, Va.
Serving as senior network security engineer.

Scott Davis (S)
(BSCPE '00)
Software Engineer Manager
Kollmorgen
Radford, Va.
He is leading a team writing embedded firmware for an industrial motion controller.

T. Shaver Deyerle (F)
(BSEE '10, MSEE '13)
Graduate Student
Virginia Tech

Joel A. Donahue, PE (F)
(MSEE '94)
Joel passed away June 6, 2014

Brian Michael Donlan (F)
(MSEE '05)

Thomas H. Drayer (F)
(BSEE '87, MSEE '91, Ph.D. '97)

Bradley Duncan (F)
(Ph.D. '91)

Gregory D. Durgin (F)
(BSEE '96, MSEE '98, Ph.D. '00)
ECE Professor
Georgia Tech
Atlanta, Ga.
Promoted to full professor. He and his co-author received the 2014 IEEE Microwave Magazine Best Paper Award.

William Ashley Eanes (S)
(BSEE '95)

Richard Ertel (F)
(Ph.D. '99)

Brian Flanagan (S/F)
(BSEE '97, MSEE '98)
Senior Design Engineer
Intel
Austin, Texas
He is working in memory design automation for the Atom Processor Division.

Kevin Flanagan (S)
(BSCPE '00, MSCPE '01)
ASIC Design Engineer
Micron Technology Inc.
Folsom, Calif.

Todd B. Fleming (F)
(BSCPE '94, MSEE '96)

CHRIS JELESNIANSKI
BSCECE '13
Rutgers University

ADVISOR:
Binoy Ravindran

RESEARCH:
Jelesnianski is focusing on compiler support for the Popcorn Linux project, which will provide a system to run on top of heterogeneous hardware. He is also working on automatically partitioning programs so that each part will run on the optimal hardware for its purpose.

MARKUS KUSANO
BSCPE '14
Virginia Tech

ADVISOR:
Chao Wang

RESEARCH:
Kusano is investigating how to automatically detect bugs in concurrent software programs. This is challenging when there are too many possibilities for even a computer to reason through. When critical software, such as avionics systems, run on multiple-core processors, avoiding bugs is vital.

VIRGINIA LI
BSEE '13
Virginia Tech

ADVISOR:
Qiang Li

RESEARCH:
Li's goal is to achieve the fastest possible response in current-mode control schemes—a single-cycle load-transient response. For DC-DC converters, variable frequency controls are used to improve light-load efficiency, increase transient response speed, and reduce output capacitors by using high-bandwidth designs.

BRADLEY ALUMNI

Ryan Fong (S/F)
(BSCPE '01, MSCPE '04)
Senior Engineer
Fourth Dimension Engineering
Laurel, Md.

Michael Fraser (F)
(BSEE '09, MSEE '12)
Graduate Student
Virginia Tech

Jayda Blair Freibert (S)
(BSEE '98)
Segment Sales Manager
GEA PHE Systems
Richmond, Va.

Daniel Friend (F)
(Ph.D. '09)
Associate
Zeta Associates Inc.
Aurora, Colo.

Bradley Heath Gale (S)
(BSEE '97)

Robert Matthew Gardner Sr. (F)
(BSEE '03, MSEE '05, Ph.D. '08)
Manager, Operations Research
Dominion Resources
Richmond, Va.

Kelson Gent (F)
(MSCPE '13)
Graduate Student
Virginia Tech

Daniel Joshua Gillespie (S)
(BSCPE '95)

Brian Gold (S)
(BSEE '01, MSCPE '03)

Jonathan Graf (S)
(BSCPE '02, MSCPE '04)
Director of Technology
MacAulay-Brown Inc.
Roanoke, Va.

Timothy Gredler (S)
(BSCPE '03)
Design & Development Leader
Lutron Electronics Co. Inc.
Coopersburg, Pa.

Christopher Griger (S)
(BSCPE '02)
Principal Hardware Architect
National Instruments
Austin, Texas

Daniel Hager (S)
(BSCPE '08, MSCPE '09)

Adam P. Hahn (S)
(BSCPE '03)

Alexander Hanisch (S)
(BSCPE '03)
Modeling and Simulation Scientist
Joint Warfare Analysis Center
Dahlgren, Va.

Nathan Harter (F)
(MSEE '07)
Systems Engineer
G3 Technologies Inc.
Mount Airy, Md.
During his tenure at G3, he has worked with cellular systems from mobile and base station physical layer up to core network infrastructure. He has been a project engineer, leading software development and hardware production, and supported the development and testing of software defined radios.

Dwayne Allen Hawbaker (F)
(BSEE '89, MSEE '91)
Principal Professional Staff
The Johns Hopkins University Applied Physics Lab.
Laurel, Md.

William C. Headley (F)
(BSEE '06, MSEE '09)

Matt Helton (S)
(BSEE '01)
Control Systems Support Supervisor
Eastman Chemical Co.
Kingsport, Tenn.

Ben Henty (F)
(MSEE '01)

Jason Hess (F)
(BSEE '97, MSEE '99)
Manager for HW Engineering, Internet of Things Group
Cisco Systems
Austin, Texas

Erik Hia (F)
(BSCPE '99, MSCPE '01)
Manager, Engineering-Software
Overture Networks
Morrisville, N.C.
Managing the Core Platform Software group and its Overture 6500 platform—a scalable, high-resiliency Carrier Ethernet aggregation and switching platform.

Daniel J. Hibbard (F)
(BSEE '02, MSEE '04)
Engineering Director
Trident Systems
Fairfax, Va.

James E. Hicks (F)
(MSEE '00, Ph.D. '03)

Hugh Edward Hockett (S)
(BSCPE '03)

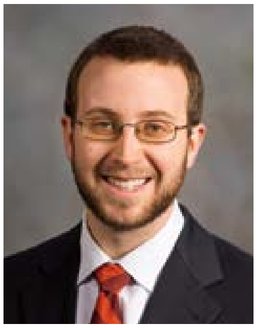
Allison Hofer
(BSEE '14)

HUNTER LONG

BSEE '14
Virginia Tech

ADVISOR:
Rosalyn Moran

RESEARCH:
Long is working on techniques to analyze data from fast-scan cyclic voltammetry probes, which are used to measure concentrations of dopamine in human patients as they perform decision making tasks.

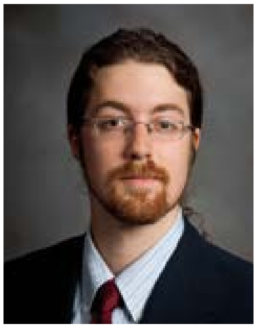


ROBERT LYERLY

BSCPE/BSCS '12
Virginia Tech

ADVISOR:
Binoy Ravindran

RESEARCH:
Lyerly is applying compiler analysis and optimizations to obtain the performance benefits of emerging processor architectures and facilitate the scheduling of applications.



ELLIOTT MITCHELL-COLGAN

BSECE '12
Lafayette College

ADVISOR:
Virgilio Centeno

RESEARCH:
Mitchell-Colgan is developing a unified optimization framework that will incorporate investment in solar and wind energy systems, transmission, and support systems such as energy storage, capacitor banks, and static VAR compensators. This framework may help displace traditional energy sources while maintaining energy reliability.

(S) Scholar (F) Fellow

Spencer Hoke (S)
(BSCPE '03)
Staff Software Engineer
Qualcomm
Raleigh, N.C.
Working on the Snapdragon cell phone and tablet software for Windows.

Russell T. Holbrook (S)
(BSCPE '03)

Andrew Scott Hollingsworth (S)
(BSCPE '03)
Software Engineer
Argon ST
Fairfax, Va.

Michael Hopkins (F)
(Ph.D. '14)
Virginia Tech
Blacksburg, Va.
Working as technical lead on Virginia Tech's DARPA Robotics Challenge team.

Ellery L. Horton (S)
(BSCPE '04)
Software Test Engineer
ChannelAdvisor
Roanoke, Va.

Keith C. Huie (F)
(MSEE '02)

Ryan Hurrell (S)
(BSCPE '03)
Senior Engineer
Siemens-Healthcare Molecular Imaging
Knoxville, Tenn.

John Todd Hutson (S)
(BSEE '93)

Ryan Irwin (F)
(M.S. '10, Ph.D. CPE '12)

Daniel A. Johnson (F)
(BSEE '98, MSEE '01)

Edward Andrew Jones (S)
(BSEE '07)
Graduate Research Assistant
University of Tennessee
Knoxville, Tenn.
Pursuing a Ph.D. in power electronics and energy science, working with the Center for Ultra-wide-area Resilient Electric eNergy Transmission (CURENT) and the National Transportation Research Center.

Nicholas Kaminski (F)
(BSEE/BSCPE '10, M.S. '12, Ph.D. '14)

Basil Thomas Kalb (S)
(BSEE '98)

Adam Steven Kania (S)
(BSEE '01)
Customer Support Territory Manager
Caterpillar Inc.
Hamburg, Germany

David Kapp (F)
(MSEE '93, Ph.D. '95)
Avionics Protection Team Lead
Wright-Patterson Air Force Base, Ohio
His current research focus is on biologically inspired cyber defense.

Dimosthenis Katsis (F)
(BSEE '95, MSEE '97, Ph.D. '03)
President
Athena Energy Corp.
Seattle, Wash.
Developing alternative energy products and consulting on DoD power supply design projects.

Nathan Kees (F)
(M.S. '13)
Control Engineer
TMEIC Co.
Roanoke, Va.

David L. Kleppinger, Jr. (S)
(BSCPE '04, MSCPE '08, Ph.D. '10)

Paul A. Kline (F)
(Ph.D. '97)

William Kuhn (F)
(BSEE '79, Ph.D. '96)
ECE Professor
Kansas State University
Manhattan, Kan.
Recent funded NASA project on biomedical sensors and associated wireless links for astronauts on long-duration missions.

Zachary La Celle (S)
(BSCPE '09)

Evan Lally (F)
(BSEE '03, MSEE '06, Ph.D. '10)

Jeff Laster (F)
(BSEE '91, MSEE '94, Ph.D. '97)
Principal Technical Manager, Raytheon
Mentor Graphics
Dallas, Texas

Mark Alan Lehne (F)
(Ph.D. '08)
Principal Engineer
Rohde-Schwarz Inc.
Beaverton, Ore.

Charles Lepple (F)
(BSEE '00, MSEE '04)
Senior Research Engineer
Johns Hopkins University
Applied Physics Laboratory
Laurel, Md.

Jason E. Lewis (S/F)
(BSEE '99, MSEE '00)

Joseph C. Liberti (F)
(BSEE '89, MSEE '91, Ph.D. '95)

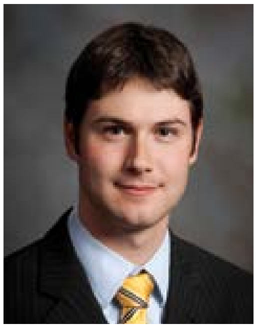
Zion Lo (S)
(BSEE '94)
Senior Software Engineer/Architect
IQNavigator Inc.
Centennial, Colo.

TIMOTHY PIERCE, JR.

BSEE '13
Hampton University

ADVISOR:
Alfred Wicks (ME)

RESEARCH:
Pierce is fusing hybrid technologies with renewable energy sources, such as solar and wind, to produce a mobile power system capable of efficiently integrating them. He is specifically focused on the control algorithms that will combine multiple sources into a useful output.



RICHARD TILLMAN

BSEE '12
Virginia Tech

ADVISOR:
Steven Ellingson

RESEARCH:
Tillman is developing an interferometer for array calibration that uses high-linearity front ends with internal noise calibration to implement precision measurements of astrophysical source flux densities below 100 MHz. He is also investigating the use of astronomical measurements for in situ characterization of HF/VHF antenna patterns and self-impedances.

JASON ZIGLAR

BSEE/Biomedical Engineering '05
Duke University
M.S. Robotics '07
Carnegie Mellon University
ADVISOR: Tomonari Furukawa (ME)

RESEARCH:
Ziglar is the software lead for two projects in the Terrestrial Robotics Engineering and Controls (TREC) Lab: SAFFiR and Team VALOR. He is developing perception systems that will help robots handle uncertain and challenging environments by understanding the world around them and communicating with a remote human operator.

BRADLEY ALUMNI

Janie A. Hodges Longfellow (S)
(BSCPE '01)
Senior Software Developer
Acronis
Arlington, Va.

Daniel L. Lough (F)
(BSCPE '94, MSEE '97, Ph.D. '01)

Andrew Love (F)
Graduate Student
Virginia Tech

Amy Malady (F)
(BSEE '09)

Annie Martin (F)
(M.S. '13)
Graduate Student
Virginia Tech

Cheryl Duty Martin (S)
(BSEE '95)
Research Scientist
Applied Research Lab.
University of Texas at Austin
Austin, Texas

Stephanie Martin (S)
(BSEE '04)
Engineer, Assistant Section Supervisor
The Johns Hopkins University Applied Physics Laboratory
Laurel, Md.
Working on Navy Electronic Warfare programs including the Manner Technique Optimization team and Next Generation Jammer.

Michael Frederic Mattern (S)
(BSEE '02)
Systems Lead – Telematics
Cummins Inc.
Columbus, Ind.
His team just released the Cummins Connected Diagnostics application.

Christopher Allen Maxey (S)
(BSCPE '02, MSEE '04)
Associate
Booz Allen Hamilton
Arlington, Va.
Pursuing a Ph.D.

Eric J. Mayfield (S)
(BSEE '97, MSEE '98)
Technical Director
Department of Defense
Ft. Meade, Md.

David Mazur (S/F)
(BSEE '11, MSEE '12)

Patrick McDougle (S)
(BSEE '03)

Brian J. McGiverin (S)
(BSCPE '96)

John McHenry (F)
(BSEE '98, MSEE '90, Ph.D. '93)
Senior Electrical Engineer
Department of Defense
Fort Meade, Md.
He is also a member of the ECE Advisory Board.

Keith McKenzie (F)

David Robert McKinstry
(MSEE '03)
Principal Systems Engineer
3 Phoenix Inc.
Chantilly, Va.

James W. McLamara (F)
(BSEE '02)
Electrical Engineer
Lockheed Martin Laser Systems
Apex, N.C.

Garrett Mears (S)
(BSCPE '00)
Chief Technology Officer
Codilink
London, U.K.
Leading the technology team for an Internet startup company.

Vinodh Menon (S)
(BSCPE/ISE '02)
Chief Operating Officer
EveryoneOn
McLean, Va.

Michael Mera (S)
(BSEE '03)
Lead Electrical Engineer
Picatinny Arsenal
N.J.

Carl Edward Minton (F)
(BSEE '97, MSEE '02)
Systems Engineer
Arion Systems Inc.
Chantilly, Va.

John Morton (F)
(MSEE '98)
Senior Systems Engineer
Engenium Technologies
Columbia, Md.
Responsible for developing, modeling, and implementing signal processing algorithms used in Engenium's wireless communication devices.

Christian Murphy (F)

Stephen Nash (S)
(BSCPE '03)
Senior Software Engineer
Verite Group
Dulles, Va.

Troy Nergaard (F)
(MSEE '02)
Senior Project Engineer
1Energy Systems
Seattle, Wash.
He joined 1Energy Systems in August. They design control systems and do system integration for utility-scale energy storage projects.

Michael Newkirk (F)
(BSEE '88, MSEE '90, Ph.D. '94)
Principal Professional Staff
Johns Hopkins University Applied Physics Laboratory
Laurel, Md.
ECE Advisory Board Chair
Serves as assistant group supervisor for the Radar System Analysis and Phenomenology Group in the Air and Missile Defense Department. He is a Senior Member of IEEE and USNC-URSI Commission F Chair.

Paul Nguyen (S/F)
(BSEE '98)

J. Eric Nuckols (F)
(BSEE '97, MSEE '99)
Communications Engineer
Zeta Associates
Fairfax, Va.

Abigail Harrison Osborne (S)
(BSCPE '04)
Centreville, Va.

Neal Patwari (S)
(BSEE '97, MSEE '99)
ECE Associate Professor
University of Utah
Salt Lake City, Utah
Serves as director of research for Xandem Technology, an RF sensing system manufacturer.

Joseph Allen Payne, Jr. (S)
(BSEE '00)
Advisory Engineer
Northrop Grumman
Linthicum, Md.

Linh My Pham (S)
(BSCPE '07)
Post-Doctoral Fellow
Harvard University
Cambridge, Mass.
She is finishing her post-doc at Harvard and will start working at MIT Lincoln Laboratory in May.

William B. Puckett (F)
(MSEE '00)

Yaron Rachlin (S)
(BSEE '00)

Parrish Ralston (F)
(BSEE '06, MSEE '08, Ph.D. '13)
Principal Engineer
Northrop Grumman Electronics Systems
Linthicum, Md.
She is working in a new business development group for the Advanced Concepts and Technologies Division. Her work includes design and development for DARPA SHIELD and DARPA Multifunction RF.

David Reusch (F)
(BSEE '04, MSEE '06, Ph.D. '12)
Director of Applications Engineering
Efficient Power Conversion Corporation
Blacksburg, Va.
He has published more than 25 peer-reviewed technical papers and is co-author of GaN Transistors for Efficient Power Conversion.

Justin Rice (F)

Richard Steven Richmond (F)
(MSEE '01)

Amy M. Ridenour (F)
Lead Power Conversion Engineer
GE Energy Management
Salem, Va.
Develops power converters for wind and solar applications.

Christian Rieser (F)
(MSEE '01, Ph.D. '04)
Capabilities & Innovation Leader
The MITRE Corporation
Charlottesville, Va.

Jamie N. Riggins (S/F)
(BSEE '04, '06)
Electrical Engineer
United States Air Force
Fort Meade, Md.

Gray Roberson (F)
(Ph.D. '07)
Technical Staff Engineer
Kollmorgen
Radford, Va.

Pablo Max Robert (F)
(MSEE '98, Ph.D. '03)

Thomas Rondeau (S/F)
(BSEE '03, MSEE '06, Ph.D. '07)
Rondeau Research LLC
Shelburne, Vt.
His company develops GNU radio. Also serves as a research associate at the University of Pennsylvania.

Thomas Rose (S)
(BSEE '94)
Senior Engineer
Boeing
St. Louis, Mo.
Designs radar and other sensors for airborne platforms.

Jonathan Scalera (F)
(MSCPE '01)
Radiology Fellow
Brigham and Women's Hospital
Boston, Mass.

Javier Schloemann (F)
Graduate Student
Virginia Tech

Amy L. Schneider (S)
(BSCPE '03)

David Craig Schroder (S)
(BSEE '05)

Steven Schulz (F)
(MSEE '91)

Ian Schworer (F)
(BSCPE '03, MSEE '05)
Vice President
TriplePoint Capital
Menlo Park, Calif.
He joined a venture capital firm and is responsible for providing equity and debt investments for emerging technology companies.

Jeffrey T. Scruggs (F)
(BSEE '97, MSEE '99)

Kashan Ali Shaikh (S)
(BSCPE '02)

Adam Keith Shank (S)
(BSCPE '07)
Software Engineer
IBM
Raleigh, N.C.

Raymond Ashley Sharp (S)
(BSEE '02)

Rebecca Kay Shelton (F)
(MSEE '08)
Electronics Engineer
United States Army Primary Standards Laboratory
Huntsville, Ala.
She serves as a technical expert in measurement science for the Electromagnetic Standards Laboratory, calibrating and maintaining RF microwave standards and calibration systems, and conducting research an development to improve existing and create new standards and techniques.

Jacob R. Simmons (S)
(BSCPE '08, MSEE '10)

Roger Skidmore (F)
(BSCPE '95, MSEE '97, Ph.D. '03)

Chelsy Smidler (S)
EE Student
Virginia Tech

Jeff Smidler (S)
(BSEE '99)

Amanda Martin Staley (S/F)
(BSEE '99, MSEE '01)
Lead Engineer
The MITRE Corporation
McLean, Va.

Graham D. Stead
(BSCPE '93)

Jennifer Hastings Steele (S)
(BSEE '96)

Neil Steiner (F)
(MSEE '02, Ph.D. '08)
Computer Scientist
USC Information Sciences Institute
Arlington, Va.
Serving as technical lead on projects for DARPA and AFRL. Lead developer of Torc, an open-source tool set for reconfigurable computing hardware.

Douglas Sterk (F)
(BSEE '00, MSEE '03)
Senior Design Engineer
VPT Inc.
Blacksburg, Va.

Scott Stern (S)
(BSEE '93)
Program Manager
Compunetix Inc.
Monroeville, Pa.
Managing development of mission-critical conferencing systems for the government and military. His current project focuses on replacing voice systems for U.S. homeland air defense.

Samuel Spencer Stone (S)
(BSCPE '04)
Associate
Wolf, Greenfield & Sacks
Boston, Mass.

Anne Palmore Stublen (S)
(BSEE '91)

Seema Sud (F)
(Ph.D. '02)

Juan Suris (F)
(Ph.D. '07)

Ethan Swint (F)
(Ph.D. '12)
Motor Designer
Applimotion Inc.
Loomis, Calif.

David L. Tarnoff (F)
(BSEE '87, MSEE '91)
Associate Professor, Applied Science & Technology
East Tennessee State Univ.
Johnson City, Tenn.
Teaches hardware, embedded systems, iOS application development, and web technologies. Research includes embedded systems, and applications using ARM-based processors.

Alexander J. Taylor (F)
(BSEE '02, MSEE '04)

Daniel J. Tebben (F)
(Ph.D. '06)
Senior Professional Staff and Project Manager
The Johns Hopkins University Applied Physics Laboratory
Laurel, Md.

Benton Thompson (F)
(MSEE '11)
Software Engineer
G3 Technologies
Ashburn, Va.
Designs custom mobile radio solutions to improve quality of life.

BRADLEY ALUMNI

Jerry Towler (S)
(BSEE '08, MSEE '11)
Research Engineer
Southwest Research Institute
San Antonio, Texas
He has been developing autonomous ground vehicles for military and commercial applications, from ATVs to semi trailers. He has recently returned to UAV work, focusing on ground-air cooperation.

Rose Trepkowski (F)
(MSEE '04)

Christian Twaddle (S)
(BSCPE '01)

Matthew C. Valenti (F)
(BSEE '92, Ph.D. '99)
Professor
West Virginia University
Morgantown, W.Va.
In 2014, he was appointed Director of WVU's Center for Identification Technology Research (CITeR), an NSF I/UCRC Site.

Michael Vercellino (F)

Michael G. Vondrak (S)
(BSCPE '05)

Wesley T. Wade (S)
(BSEE '93)

Kristin Weary (S)
(BSEE '03)

Major Michael Lee Webber (F)
(BSEE '02, MSEE '04)
Technical Director
United States Air Force
Wiesbaden, Germany

Paul C. Weinwurm (S)
(BSEE '03)

Matt Welch (S)
(BSEE '09)
Test Engineer, Fleet and Prototype Test Engineering
GE Power and Water
Greenville, S.C.
Test lead engineer for gas turbine plant field testing for domestic and international sites. He completed the GE Edison Engineering Development Program.

Jason S.K. Wienke (S)
(BSEE '02)

William Worek (S)
(BSCPE '99, MSCPE '02)

Kai Xu (S)
(BSEE '95)
Director of Product Management - International
Houzz
Palo Alto, Calif.

Matthew A. Yaconis (F)
(BSEE '97)

Jason Yoho (F)
(MSEE '98, Ph.D. '01)
Design Engineer
Tektronix
Boulder, Colo.

Ben York (F)
(MSEE '10, Ph.D. '13)
Senior Project Engineer
Electric Power Research Institute
Knoxville, Tenn.

Phillip Andrew Zellner (F)
(BSEE '07, MSEE '12, Ph.D. '13)

Richard Zimmermann (S)
(BSCPE '07)

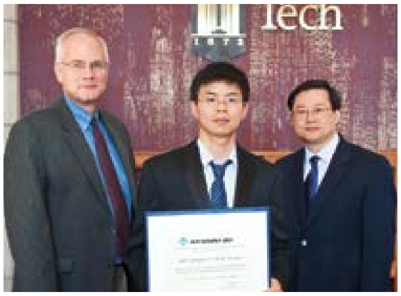
Gregory A. Zvonar (S)
(BSEE '90, MSEE '91, Ph.D. '98)

(S) Scholar (F) Fellow

STUDENT AWARDS

Peter Nguyen (BSEE '14) was awarded an NSF Graduate Research Fellowship. Nguyen is a member of the Advanced Devices & Sustainable Energy Laboratory (ADSEL), where he has been investigating the integration of high-K dielectric oxides on Germanium for low-power applications.

Huacheng Zeng (Ph.D. '15) was awarded the Best Student Paper Award at the 9th ACM International Conference on Underwater Networks & Systems, Rome, Italy (Nov. 12-14, 2014). The paper, titled "Shark-IA: An interference alignment algorithm for multi-Hop underwater acoustic networks with large propagation delays," was co-authored with Zeng's advisor Tom Hou, and a team of students and ECE and CS faculty members.

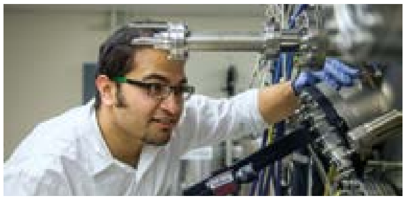

VP of IT Scott Midkiff, Huacheng Zeng, and Tom Hou.

Milisav Danilovic (Ph.D. '15) and **Zhemin Zhang** (Ph.D. '15), with their advisor Khai D.T. Ngo, won a best student poster prize and best student poster presentation overall at the IEEE Energy Conversion Congress and Exposition (ECCE), Pittsburgh, Pennsylvania (Sept. 14-18, 2014) for their presentation: "Compression of the Load Resistance Range in Constant Frequency Resonant Inverters."

Woochan Kim (Ph.D. '15) and collaborators won an outstanding student paper award at the International Microelectronics Assembly and Packaging Society (IMAPS), San Diego, California (Oct. 13-16, 2014) for their work: "Compressive-Post Packaging of Double-Sided Die."

Lingziao Xue (Ph.D. '15), **Henry Chen** (Ph.D. '13), **Bo Wen** (Ph.D. '14), **Pei-Hsin Liu** (Ph.D. '15) and their co-authors received outstanding presentation awards at the 29th Annual IEEE Applied Power Electronics Conference & Exposition (APEC 2014), Fort Worth, Texas (March 16-20, 2014).

Nikhil Jain (Ph.D. '15) was named one of seven inaugural members of Virginia Tech's chapter of the Edward A. Bouchet Graduate Honor Society.


NIKHIL JAIN monitors the surface reconstruction during III-V-on-Si growth using molecular beam epitaxy (MBE).

Ahmed S. Ibrahim (VT-MENA), with his advisors Lynn Abbott and Amira Youssef received the best poster award at the 5th International Conference on Imaging for Crime Detection and Prevention (ICDP-13), in London, UK, Dec. 2013.

Karthik Venkataramani (Ph.D. '16) won an Outstanding Student Paper Award at the American Geophysical Union, San Francisco, Calif. (Dec. 15-19, 2014).

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2013 2014 PH.D. DEGREES AWARDED

Ahmad, Syed A.
Autonomous Link-Adaptive Schemes for Heterogeneous Cellular Systems with Congestion Feedback
Committee Chairs: DaSilva, L.; da Silva, C.

Alsawaha, Hamad W.
Synthesis of Ultra-Wideband Array Antennas
Committee Chair: Safaai-Jazi, A.

Badayos, Noah G.
Machine Learning-Based Parameter Validation
Committee Chair: Centeno, V.

Bae, Hyojoon
Fast and Scalable Structure-from-Motion for High-Precision Mobile Augmented Reality Systems
Committee Chair: White, C.

Bahrak, Behnam
Ex Ante Approaches for Security, Privacy, and Enforcement in Spectrum Sharing
Committee Chair: Park, J.-M.

Bishnoi, Hemant
Behavioral EMI-Models of Switched Power Converters
Committee Chair: Boroyevich, D.

Chen, Quan
Risk Management of Cascading Failure in Composite Reliability of a Deregulated Power System With Microgrids
Committee Chair: Mili, L.

Chen, Zheng
Electrical Integration of SiC Power Devices for High-Power-Density Applications
Committee Chair: Boroyevich, D.

Dalala', Zakariya M.
Design and Analysis of a Small-Scale Wind Energy Conversion System
Committee Chair: Lai, J.

Datla, Dinesh
Wireless Distributed Computing in Mobile Ad-Hoc Cloud Computing Networks
Committee Chairs: Bose, T.; Reed, J.

De Larquier, Sebastien
The Mid-Latitude Ionosphere Under Quiet Geomagnetic Conditions: Propagation Analysis of SuperDARN Radar Observations From Large Ionospheric Perturbations
Committee Chairs: Baker, J.; Ruohoniemi, J.

Deshpande, Kshitija B.
Investigation of High Latitude Ionospheric Irregularities Utilizing Modeling and GPS Observations
Committee Chair: Clauer, C.

El-Shambakey, Mohammed T.
Real-Time Software Transactional Memory: Contention Managers, Time Bounds, and Implementations
Committee Chair: Ravindran, B.

Fayez, Almohanad S.
Design Space Decomposition for Cognitive and Software Defined Radios
Committee Chair: Bostian, C.

Garlapati, Sharavan K.
Enabling Communication and Networking Technologies for Smart Grid
Committee Chair: Reed, J.

Gu, Bin
Hybrid Transformer DC-DC Converters for Photovoltaic AC Module Applications
Committee Chair: Lai, J.

Gu, Jinghua
Novel Monte Carlo Approaches to Identify Aberrant Pathways in Cancer
Committee Chair: Xuan, J.

Hassanzadeh, Mohammadtaghi
A Novel State Forecasting Model for Smart Grids
Committee Chair: Evrenosoglu, C.

Hilal, Amr E.
Incentivizing Cooperation in Mobile Ad Hoc Networks: An Experiment, A Coalition Game Theory Model, and OLSR Integration
Committee Chair: MacKenzie, A.

Huang, Daocheng
Investigation of Topology and Integration for Multi-Element Resonant Converters
Committee Chair: Lee, F.

Jung, Jae S.
Development and Deployment of Renewable and Sustainable Energy Technologies
Committee Chairs: Tam, K.S.; Broadwater, R.

Kaminski, Nicholas J.
Social Intelligence for Cognitive Radios
Committee Chair: Bostian, C.

Kang, Byung O.
New and Improved Methods to Characterize, Classify, and Estimate Daily Sky Conditions for Solar Energy Applications
Committee Chair: Tam, K.S.

Kim, Junwhan
Scheduling Memory Transactions in Distributed Systems
Committee Chair: Ravindran, B.

Koran, Ahmed M.
Photovoltaic Source Simulators for Solar Power Conditioning Systems: Design Optimization, Modeling, and Control
Committee Chair: Lai, J.

Kunduri, Bharat S. R.
A Study of Interhemispheric Magnetic Conjugacy and Large-Scale Magnetosphere-Ionosphere Coupling Using SuperDARN Radars
Committee Chairs: Baker, J.; Ruohoniemi, J.

Li, Meiyan
Transient Stability Prediction Based on Synchronized Phasor Measurements and Controlled Islanding
Committee Chair: Phadke, A.

Livani, Hanif
Intelligent Fault Location for Smart Power Grids
Committee Chairs: De La Ree, J.; Evrenosoglu, C.

Lu, Peng
Resilire: Achieving High Availability Through Virtual Machine Live Migration
Committee Chair: Ravindran, B.

Mokhtar, Bassem Mahmoud M.A.
Biologically-Inspired Network Memory System for Smarter Networking
Committee Chairs: Hou, Y.; Eltoweissy, M.

Onen, Ahmet
Economics of Smart Grid Automation Based on Time-Varying Analysis of Smart Grid Data Sets
Committee Chairs: De La Ree, J.; Broadwater, R.

Pal, Anamitra
PMU-Based Applications for Improved Monitoring and Protection of Power Systems
Committee Chair: Thorp, J.

Refai, Wael Y.
A Linear RF Power Amplifier with High Efficiency for Wireless Handsets
Committee Chair: Davis, W.

Ribeiro, Alvaro J.
SuperDARN Data Simulation, Processing, Access, and Use in Analysis of Mid-Latitude Convection
Committee Chairs: Baker, J.; Ruohoniemi, J.

Salehi, Mohsen
Time-Varying Small Antennas for Wideband Applications
Committee Chair: Manteghi, M.

Samimi, Alireza
Study of Narrow-Band Spectral Characteristics of Stimulated Electromagnetic Emission (SEE) During Second Electron Gyro-Harmonic Heating
Committee Chair: Scales, W.

Sreedharan Nair, S.
MicroGC: Of Detectors and Their Integration
Committee Chair: Agah, M.

Taha, Mostafa M.
New Directions in Side-Channel Analysis
Committee Chair: Schaumont, P.

Thomas, Evan G.
Dynamics of the Geomagnetically Distrubed Ionosphere as Measured by GPS Receivers and SuperDARN HF Radars
Committee Chairs: Baker, J.; Ruohoniemi, J.

Tsai, Tsung-Heng
Bayesian Alignment Model for Analysis of LC-MS-Based Omic Data
Committee Chair: Wang, Y.

Wu, Zhongyu
Synchronized Phasor Measurement Units Applications in Three-Phase Power System
Committee Chair: Phadke, A.

Xie, Liguang
Modeling and Optimization of Rechargeable Sensor Networks
Committee Chair: Hou, Y.

Yamada, Randy M.
Identification of Interfering Signals in Software Defined Radio Applications Using Sparse Signal Reconstruction Techniques
Committee Chair: Mili, L.

Zaghlool, Shaza B.
Dynamic Causal Modeling Across Network Topologies
Committee Chair: Wyatt, C.

Zellner, Phillip A.
Three-Dimensional Passivated-Electrode Insulator-Based Dielectrophoresis (Ed-PiDEP)
Committee Chair: Agah, M.

Zeng, Kevin
Enhancing FPGA Productivity with Back-End Similarity Matching of Digital Circuits for IP Reuse
Committee Chair: Athanas, P.

Zha, Wenwei
Facilitating FPGA Reconfiguration Through Low-Level Manipulation
Committee Chair: Athanas, P.

Zhang, Jingyao
Hardware-Software Co-Design for Sensor Nodes in Wireless Networks
Committee Chair: Yang, Y.

Zhang, Xuning
Passive Component Weight Reduction for Three-Phase Power Converters
Committee Chair: Boroyevich, D.

Zheng, Yi
Biological Agent Sensing Integrated Circuit (BASIC): A New CMOS Magnetic Biosensor System
Committee Chair: Tront, J.

Zhu, Yan
Mixed As/Sb and Tensile Strained Ge/InGaAs Heterostructures for Low-Power Tunnel Field Effect Transistors
Committee Chair: Hudait, M.

PATENTS AWARDED

Anti-islanding protection in three-phase converters using grid synchronization small-signal stability
Inventors: D. Dong, D. Boroyevich, P. Mattavelli, B. Wen

Three-level active neutral point clamped zero voltage switching converter
Inventors: J. Li, D. Boroyevich, J. Liu

Power inductors in silicon
Inventors: M. Wang, H. Xie, K. D. T. Ngo

Extended interior methods and systems for spectral, optical, and photoacoustic imaging
Inventors: G. Wang, Y. Xu, A. Cong, H. Shen, W. Cong, L. Yang, Y. Lu

Holey optical fiber with random pattern of holes and method for making same
Inventors: J. I. Kim, D. Kominsky, G. Pickrell, A. Safaai-Jazi, R. H. Stolen, A. Wang

Hybrid switch for resonant power converters
Inventors: J.-S. Lai, W. Yu

Multilayer packaged semiconductor device and method of packaging
Inventors: K. Rajashekara, R. Wang, Z. Chen, D. Boroyevich

Control system and method for a universal power conditioning system
Inventors: J.-S. Lai, S. Y. Park, C.-L. Chen

Use of PLL stability for islanding detection
Inventors: T. N. Thacker, D. Boroyevich, F. Wang, R. Burgos

High frequency loss measurement apparatus and methods for inductors and transformers
Inventors: M. Mu, F. C. Lee

Pulse-width-modulated resonant power conversion
Inventors: K. D. T. Ngo, X. Cao, Y. Wang

Adaptive on-time control for power factor correction stage light load efficiency
Inventors: Q. Li, F. C. Lee, M. Xu, C. Wang

Fiber array for optical imaging and therapeutics
Inventors: C. Rylander, T. A. Campbell, G. Wang, Y. Xu, M. A. Kosoglu

Apparatus and method for on-line, real-time analysis of chemical gases dissolved in transformer oil
Inventors: B. Dong, A. Wang, J. Gong

Multi-phase EMI noise separator
Inventors: S. Wang, F. C. Lee

Compact Roman lens using metamaterials
Inventors: A. I. Zaghloul, E. D. Adler

HONORS

ACHIEVEMENTS

NATIONAL / INTERNATIONAL SERVICE

Charles Clancy serves as education chair for the Information Forensics and Security Technical Committee of the IEEE Signal Processing Society.

Fred Lee serves as a member of the board of directors for the Virginia Academy of Science, Engineering and Medicine (VASEM) and is the peer committee chair of the National Academy of Engineering, Section 6, Electric Power and Energy Systems.

Tom Martin served as vice-chair of the IEEE Special Technical Community on Wearable and Ubiquitous Computing.

Saifur Rahman served on the Board of Governors of the IEEE Society of Social Implications of Technology.

Sanjay Raman was elected to the IEEE Microwave Theory and Techniques Administrative Committee.

EDITORSHIPS

William Baumann is an editorial board member of Nature's Scientific Reports.

Dushan Boroyevich is a member of the Proceedings of the IEEE editorial board.

Rolando Burgos served as associate editor of the IEEE Transactions on Power Electronics and the IEEE Power Electronics Letters. He was associate editor of the IEEE Journal of Selected and Emerging Topics in Power Electronics and served as guest editor for its special issue on "Modeling and Control of Power Electronics for Grid Applications."

Charles Clancy is an associate editor of the IEEE Transaction on Cognitive Communications and Networking.

Tom Hou served as editor of the IEEE/ACM Transactions on Networking, associate editor of the ACM Transactions on Sensor Networks, editor of the IEEE Journal on Selected Areas in Communications—Cognitive Radio Series and the IEEE Transactions on Mobile Computing. He is also an area editor of the IEEE Transactions on Wireless Communications.

Michael Hsiao served as associate editor of the IEEE Transactions on Computers and served on the editorial boards of the IEEE Design & Test of Computers and the Journal of Electronic Testing: Theory and Applications.

Luke Lester is editor-in-chief of the IEEE Journal of Special Topics in Quantum Electronics.

Allen MacKenzie is an associate editor of the IEEE Transaction on Cognitive Communications and Networking, an area editor of IEEE Transactions on Communications, and an associate editor of IEEE Transactions on Mobile Computing.

Tom Martin served as guest editor for the IEEE Computer special issue on wearable computing.

T.-C. Poon is associate editor-in-chief of Chinese Optics Letters and associate editor of the IEEE Transactions on Industrial Informatics. He is also on the editorial boards of Shanghai Jiao Tung University Press, 3D Research, the Journal of Holography and Speckle, and Optics & Laser Technology.

Saifur Rahman is editor-in-chief of the IEEE Electrification Magazine.

Walid Saad was editor of the IEEE Transactions on Communications and served as lead guest editor for the IEEE Communications Magazine, special issue on Physical Layer Security.

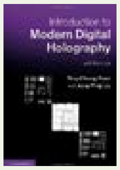
Patrick Schaumont served as associate editor for the ACM Transactions on Design Automation of Electronic Systems, the ACM Transactions on Embedded Computer Systems (TECS), the IEEE Transactions on Computers, and the Springer Journal on Cryptographic Engineering. He also served as guest editor for a special issue of ACM TECS on "Embedded Platforms for Cryptography of the Coming Decade."

Sandeep Shukla was editor-in-chief of ACM Transactions on Embedded Computing Systems and associate editor of Computing Reviews and ACM Transactions on Cyber Physical Systems. He was also book series editor for River Publishers Series on Information Science and Technology.

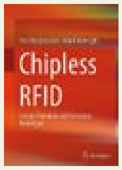
Yong Xu is associate editor of the IEEE Journal of Quantum Electronics.

Chris Wyatt is associate editor of the IEEE Transactions on Image Processing.

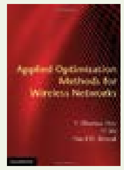
BOOKS



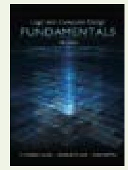
T.-C. Poon co-authored Introduction to Modern Digital Holography with MATLAB (Cambridge University Press 2014).



Majid Manteghi co-authored Chipless RFID (Springer 2015).



Tom Hou co-authored Applied Optimization Methods for Wireless Networks (Cambridge University Press 2014).



Tom Martin co-authored Logic and Computer Design Fundamentals 5th Edition (Pearson 2015).

FACULTY HONORS & AWARDS

Devi Parikh was named an Allen Distinguished Investigator in Artificial Intelligence. She also received a Google Faculty Research Award and an Army Research Office Young Investigator Program Award.

Fred Lee received the 2015 IEEE Medal in Power Engineering.

Tom Hou was named an IEEE Communications Society Distinguished Lecturer and an ACM Distinguished Scientist.

Khai Ngo was named a Fellow of the IEEE.

T.-C. Poon was named a Fellow of the Institute of Physics.

Dhruv Batra won an NSF CAREER award and an Army Research Office Young Investigator Program Award.

Binoy Ravindran was named an ACM Distinguished Scientist.

Saifur Rahman was elected to the IEEE Technical Activities Board Hall of Fame.

Tom Martin received the W.S. “Pete” White Award in Engineering Education and a Virginia Tech XCaliber Award.

Michael Buehrer received the Dean’s Award for Teaching Excellence.

Charles Clancy received the Dean’s Award for Research Excellence.

Kwang-Jin Koh was named Outstanding New Assistant Professor.

Lamine Mili received the College Award for Outreach Excellence.

Jerry Park was named a College of Engineering Faculty Fellow.

Wayne Scales received the Dean’s Award for Service Excellence.

CONFERENCE CHAIRS

Dong Ha was general chair of the Electrical, Electronics, and Communications Symposium, US-Korea Conference, San Francisco, California, Aug. 2014.

Tom Hou served as Standing Committee chair of IEEE INFOCOM, Toronto, Canada, 2014.

Michael Hsiao was program Chair of the Hardware Oriented Security and Trust Symposium, Arlington, Virginia, May 2014.

Tom Martin served as program co-chair of the International Symposium on Wearable Computers, Seattle, Washington, Sept. 2014.

Saifur Rahman served as conference chair of IEEE Smart Grid Conference (ISGT), Washington, D.C., Feb. 2015.

Sanjay Raman was technical program chair for the IEEE International Microwave Symposium, Tampa, Florida, June 2014.

Walid Saad was technical program co-chair of the 5th Conference on Decision and Game Theory for Security, San Francisco, California, Nov. 2014.

Sandeep Shukla was conference program co-chair of the ACM/IEEE International Conference on Formal Methods for System Design (MEMOCODE 2014), Lausanne, Switzerland, Oct. 2014.

KEYNOTE ADDRESSES

Dushan Boroyevich was the keynote speaker at the International Conference on Renewable Energy Research and Education, Milwaukee, Wisconsin, Oct. 2014.

Tom Hou gave the opening address at IEEE INFOCOM 2014, Toronto, Canada, April 2014 and was a keynote speaker of the 10th International Conference on Mobile Ad-hoc and Sensor Networks, Maui, Hawaii, Dec. 2014.

Michael Hsiao gave the keynote address at the Workshop on RTL and High Level Testing, Hangzhou, China, Nov. 2014.

Fred Lee was a keynote speaker at The Sustainable Development Forum on Power Electronics, Shenzhen, China, July 2014; the Power Electronics and Motion Control Conference (PEMC) Antalya, Turkey, Sept. 2014; the 2nd Workshop on Wide Bandgap Power Devices and Applications (WiPDA), Knoxville, Tennessee, Oct. 2014; and the Power Electronics Application Conference (PEAC), Shanghai, China, Nov. 2014

Saifur Rahman was a keynote speaker at the 8th IEEE GCC Conference, Muscat, Oman, Feb. 2015 and IEEE Smart Grid (ISGT) Asia Conference, Kuala Lumpur, Malaysia, May 2014.

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Head, Technologies Application Branch
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Vice President, Operations (NCR)
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BSEE '71
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BRIAN MACCLEERY
BSEE '99, MSEE '00
Principal Product Manager for Clean Energy Technology
National Instruments

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BSEE '88, MSEE '90, Ph.D. '93
Senior Electrical Engineer
Department of Defense

MICHAEL NEWKIRK
BSEE '88, MSEE '90, Ph.D. '94
Principal Professional Staff
The Johns Hopkins University Applied Physics Laboratory

NAM NGUYEN
BSEE '88
Manager – Electric Transmission Operations Engineering
Dominion Virginia Power

MICHAEL O'NEILL
BSEE '86, MSEE '87
CEO
MedicaSoft, LLC

DAVID REA
Space Products and Processing Director
BAE Systems

KENNETH SCHULZ
MSEE '84
RFIC Design Center Strategy and Research
Lockheed Martin

ROB VIROSTEK
BSEE '87
Regional Sales Engineer
RFMW, Ltd.

JONATHAN WHITCOMB
BSEE '80
Vice President, Enterprise Solution
Dynetics Inc.

TIMOTHY WINTER
BSEE '81
Vice President, Business Development, Engineering and Technology
Northrop Grumman Corp., Electronic Systems Sector

ece FACULTY

Scott F. Midkiff
Professor & Vice President for Information Technology and Chief Information Officer
Duke '85

Lamine M. Mili
Professor
Liege '87

Rosalyn J. Moran
Assistant Professor
University College Dublin '07

Leyla Nazhandali
Associate Professor
Michigan '06

A. Lynn Abbott
Associate Professor
Illinois '90

Masoud Agah
Associate Professor
Michigan '05

Peter M. Athanas
Professor
Brown '92

Scott M. Bailey
Associate Professor
Colorado '95

Joseph B. Baker
Associate Professor & Steven O. Lane Junior Faculty Fellow
Michigan '01

Dhruv Batra
Assistant Professor
Carnegie Mellon '10

William T. Baumann
Associate Professor
Johns Hopkins '85

A. A. (Louis) Beex
Professor
Colorado State '79

Dushan Boroyevich
American Electric Power Professor
Virginia Tech '86

Robert P. Broadwater
Professor
Virginia Tech '77

R. Michael Buehrer
Professor
Virginia Tech '96

Rolando Burgos
Associate Professor
Concepción '02

Virgilio A. Centeno
Associate Professor
Virginia Tech '95

Charles Clancy
Associate Professor & L-3 Communications Cyber Faculty Fellow
Maryland '06

C. Robert Clauer
Professor
UCLA '80

Jaime De La Ree
Associate Professor & Assistant Department Head
Pittsburgh '84

Harpreet S. Dhillon
Assistant Professor
UT Austin '13

Gregory D. Earle
Professor
Cornell '88

Steven W. Ellingson
Associate Professor
Ohio State '00

Louis J. Guido
Associate Professor
Illinois '89

Dong S. Ha
Professor
Iowa '86

Y. Thomas Hou
Bradley Distinguished Professor of ECE
Polytechnic Univ. '98

Michael S. Hsiao
Professor
Illinois '97

Mantu K. Hudait
Associate Professor
Indian Institute of Science '99

Mark T. Jones
Professor
Duke '90

Kwang-Jin Koh
Assistant Professor
UC San Diego '08

Jih-Sheng (Jason) Lai
James S. Tucker Professor
Tennessee '89

Fred C. Lee
University Distinguished Professor
Duke '74

Luke F. Lester
Professor & Department Head
Cornell '92

Qiang Li
Assistant Professor
Virginia Tech '11

Douglas K. Lindner
Associate Professor
Illinois '82

G. Q. Lu
Professor
Harvard '90

Allen B. MacKenzie
Associate Professor
Cornell '03

Majid Manteghi
Associate Professor
UCLA '05

Gino Manzo
Professor of Practice
Cornell MEng '76

Thomas L. Martin
Professor
Carnegie Mellon '99

Khai D.T. Ngo
Professor
Caltech '84

Willem G. (Hardus) Odendaal
Associate Professor
Rand Afrikaans '97

Marius Orlowski
Professor, VMEC Chair
Tuebingen '81

Devi Parikh
Assistant Professor
Carnegie Mellon '09

Jung-Min Park
Associate Professor
Purdue '03

Cameron D. Patterson
Associate Professor
Calgary '92

JoAnn M. Paul
Associate Professor
Pittsburgh '94

Paul E. Plassmann
Professor & Assistant Department Head
Cornell '90

T.–C. Poon
Professor
Iowa '82

Saifur Rahman
Virginia Tech '78

Sanjay Raman
Joseph Loring Professor & Associate Vice President, National Capital Region
Michigan '98

Binoy Ravindran
Professor
UT Arlington '98

Jeffrey H. Reed
Willis G. Worcester Professor
UC Davis '87

Sedki M. Riad
Professor
Toledo '76

J. Michael Ruohoniemi
Associate Professor
Western Ontario '86

Dan M. Sable
Adjunct Professor of Practice
Virginia Tech '91

Walid Saad
Assistant Professor
Oslo '10

Timothy D. Sands
President & Professor
Berkeley '84

Ahmad Safaai-Jazi
Professor
McGill '78

Wayne A. Scales
Professor
Cornell '88

Patrick R. Schaumont
Associate Professor
UCLA '04

Sandeep K. Shukla
Professor
SUNY Albany '97

Daniel J. Stilwell
Professor
Johns Hopkins '99

Dennis G. Sweeney
Professor of Practice and Director of Instructional Labs
Virginia Tech '92

Kwa-Sur Tam
Associate Professor
Wisconsin '85

Joseph G. Tront
Professor
SUNY Buffalo '78

Anbo Wang
Clayton Ayre Professor
Dalian '90

Chao Wang
Assistant Professor
Colorado '04

Yue (Joseph) Wang
Grant A. Dove Professor
Maryland '95

Chris L. Wyatt
Associate Professor
Wake Forest School of Medicine '02

Yong Xu
Associate Professor
Caltech '01

Jason J. Xuan
Associate Professor
Maryland '97

Yaling Yang
Associate Professor
Illinois '06

Guoqiang Yu
Assistant Professor
Virginia Tech '11

Haibo Zeng
Assistant Professor
Berkeley '08

Yizheng Zhu
Assistant Professor
Virginia Tech '07

INSTRUCTORS

Kristie Cooper

Dave McPherson

Leslie K. Pendleton
Director of Student Services

Jason S. Thweatt

RESEARCH FACULTY

Islam A.I.Y. Ashry
Senior Research Associate

Antonio Barbalace
Research Assistant Professor

Justin N. Carstens
Research Scientist

Kshitija B. Deshpande
Postdoctoral Associate

Carl B. Dietrich, Jr.
Research Associate Professor

Yi Deng
Research Scientist

Raymond A. Greenwald
Research Professor

Michael D. Hartinger
Research Assistant Professor

Eyosias Yoseph Imana
Postdoctoral Associate

Vincent Legout
Postdoctoral Associate

Qingqing Ma
Postdoctoral Associate

Vuk Marojevic
Research Associate

Roberto Palmieri
Research Assistant Professor

Sebastiano Peluso
Research Associate

Arun G. Phadke
University Distinguished Professor Emeritus & Research Professor

Nassim Rahimi
Postdoctoral Associate

Marina Sadini
Research Associate

Jason Snyder
Project Associate

Kevin T. Sterne
Research Associate

James S. Thorp
Hugh P. and Ethel C. Kelly Professor Emeritus & Research Professor

Brentha Thurairajah
Research Scientist

Dong Wang
Postdoctoral Associate

Daniel R. Weimer
Research Professor

Zhonghua Xu
Postdoctoral Associate

Zhihao Yu
Research Associate

TENURE & PROMOTION

Joseph Baker was promoted to associate professor

Charles Clancy was promoted to associate professor

Y. Thomas Hou was named the Bradley Distinguished Professor of ECE

THE **BRADLEY DEPARTMENT**
of Electrical & Computer Engineering

Virginia Polytechnic Institute and State University
302 Whittemore Hall
Blacksburg, VA 24061

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