CornellEngineering
Electrical and Computer Engineering

ECE CONNECTIONS

2019/2020

BUILDING THE NEW COMPUTER USING REVOLUTIONARY NEW ARCHITECTURES

Page 16

DIRECTOR'S REFLECTIONS: ALYSSA APSEL

Robyn Wishna

As I write this, our Cornell community is adapting to the rapidly evolving conditions resulting from the COVID-19 pandemic. My heart is heavy with the distress, uncertainty and anxiety this brings for so many of us, and in particular seniors who were looking forward to their last semesters at Cornell.

I recognize that these are difficult times and many uncertainties remain, but I sincerely believe that by working together as a community, we will achieve the best possible results for the health and well-being of all of Cornell. Although we are distant from each other, our work in ECE continues.

Around 1965 Gordon Moore, the co-founder of Intel, predicted exponential increases in computer performance which amounted to doubling of processor speeds every two years. This prediction was astonishingly accurate for approximately the next 45 years, only starting to break down in the last decade.

The field of Electrical and Computer Engineering developed around supporting and benefiting from Moore's Law. We engineers worked on scaling down devices, lithographic solutions, modeling and scaling up new processes, and architecting and building faster machines. We utilized these exponentially faster machines to support telecommunications and ever more complex algorithms and systems.

Recently it has become apparent that these assumptions no longer hold, and scaling alone isn't the answer to more powerful and more efficient computers. We can build chips with upwards of four billion transistors in a square centimeter (such as Apple's A11 chip), but when attempting to make devices any smaller the electrical properties become difficult to control. Pushing them faster also bumps up against thermal issues as the predicted temperatures on-chip become comparable to that of a rocket nozzle.

Does that mean the end of innovation in electronics? No, it's just the beginning.

Instead of investing in manufacturing that matches the pace of Moore's law, major manufacturers have realized that it is cost effective to pursue other approaches such as graphics processors, innovative computing architectures, novel devices, new materials, hybrid chips, AI, and quantum computing. Cornell ECE is at the forefront of many of these new technologies.

Our faculty and students are conducting groundbreaking research in new hardware accelerators with "brain-like" functions that enable machines to learn and make fast associations. Others are understanding what makes a machine learning algorithm work and how to optimize it. Still others are exploring how to improve computing with new heterogeneous platforms made up of different types of devices.

In this issue of *Connections* we explore a small part of what Cornell ECE faculty are doing to revolutionize computing by rethinking the way memory and logic interact. ECE researchers are changing the very nature of computation by building memory devices, algorithms, circuits, and devices that directly integrate computation even at the cellular level. The work highlighted in this issue is exciting in that it breaks the traditional separation between switches and gates, between memory and computing functions, all the way down to the device level.

This new way of thinking is not only fascinating research, but it also flows into how we teach our students. By injecting examples from research and cutting-edge design into the classroom, students understand technology and engineering as an evolution instead of a static, unchanging set of principles. In this way, Cornell ECE is again at the forefront of designing better systems, and giving our students the opportunity to be change leaders.

As the next era of electrical and computer engineering unfolds, we celebrate the exciting and innovative work of Cornell ECE's amazing students, faculty and staff.

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HOW WILL YOU MAKE AN IMPACT?

Nobody knows better the impact a gift can make than a former Cornell student. You walked these halls, you studied in these classrooms, you worked in these labs. You've seen the names on the signs and plaques that remind us of the contributions people have made to the educational experience and research excellence in Electrical and Computer Engineering. How will you make an impact?

Graduate Student Support

Research funding for our faculty often requires matching funds for graduate student support. These graduate students are the future leaders of our technology economy, so it is critical for the nation, and for Cornell's ranking, that we attract and recruit the right students to our program.

Revitalize Office Space

Phillips Hall was built in 1955 with three floors of identically sized offices. We want to modernize the second and fourth floors, as we did the third, to be aligned on the beams of the building, yielding 200 square foot rooms to better accommodate center administration, graduate students and TA meeting rooms for class support. The upgrades will also allow better power and HVAC upgrades and eliminate less efficient window air conditioners. Offices will be constructed with some form of window to enliven the hallways with natural lighting and activity.

Robotics Lab

Robotics is a top priority for the future of the school. Support for our growing robotics lab will ensure our students have the resources needed to excel in this challenging interdisciplinary field.

Graduate Student Seminars: Electronic Devices Society (EDS) and ECE Colloquium Series

These events regularly bring our faculty and students together to stay on top of developments inside and outside of our field and create a continued sense of community across the school.

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Visit ece.cornell.edu/ece/alumni

INSIDE THIS ISSUE

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ECE NEWS

ECE alumna leads NSF Directorate for Computer and Information Science and Engineering

Margaret Martonosi '86

The National Science Foundation (NSF) has selected Margaret Martonosi '86 to serve as head of the Directorate for Computer and Information Science and Engineering (CISE). Martonosi received her bachelor's degree in electrical engineering from Cornell University before moving on to Stanford for her Ph.D.

"I am honored to have been selected to take this CISE leadership role. My time as an undergraduate at Cornell ECE helped me see the excitement and importance of deep, curiosity-driven explorations of computer systems and of the broader world," said Martonosi. "I look forward to working at NSF and with the community to catalyze further generations of CISE researchers."

CISE supports research across all areas of computer and information science and engineering. Describing Martonosi's selection, NSF Director France Córdova said, "Her experience as an innovative researcher and a leader who has worked to improve STEM education and the workforce make her ideal for this role."

As one of Cornell's Andrew D. White Professors-at-Large she is considered a full member of the Cornell faculty, and visited campus two years ago to deliver a talk entitled "Science, Policy, and Services: Some Thoughts on the Way Forward."

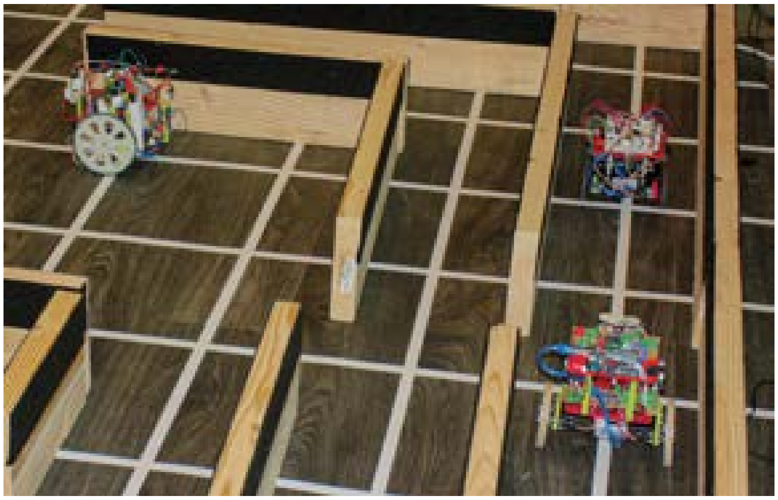
Currently, Martonosi is the Hugh Trumbull Adams '35 Professor of Computer Science, Department of Computer Science at Princeton University.

ECE robotics teams thrill crowds at annual event

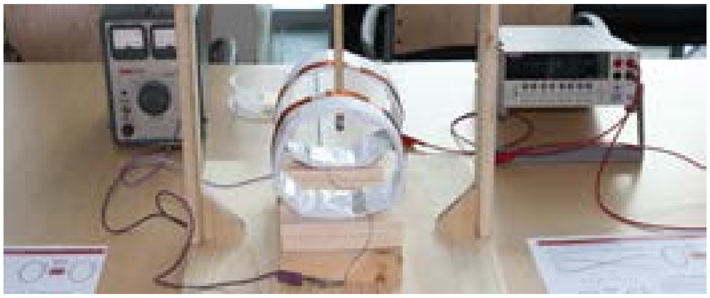
Crowds filled the Duffield Atrium to cheer student teams under the direction of ECE lecturer and senior research associate Carl Poitras, who oversaw the maze competition as part of his Intelligent Physical Systems (ECE 3400) course.

More than one hundred engineering students let off some end-of-semester steam and tried not to blow any gaskets at the annual Robotics Day competition Dec. 10 in Duffield Hall atrium.

The day kicked off with the "Robotic Maze Runners" morning competition. Each round featured four robots equipped with sensors and navigation algorithms that were placed in a 9-by-9-foot maze. Over the course of six minutes, the robots attempted to map the maze by following a grid of white lines while avoiding walls and other robots. The information each robot recorded was then transmitted wirelessly to a base station, which decoded the transmission and visualized the map.



A boistrous crowd followed the action broadcast on large viewing screens in Duffield Atrium. Student-made robots attempted to map a maze by following a grid of white lines while avoiding walls and other robots.



Graduate student projects demonstrate magnetism concepts to visiting high schoolers

At the Magnetism Exploration Fair, youth from Lehman Alternative Community School (LACS) and Ithaca High School experienced hands-on demonstrations with the students of ECE Assistant Professor Amal El-Ghazaly's ECE 5970 course, Applied Magnetism.

The fair was organized by El-Ghazaly along with Kurt Sarsfield, Assistant Director of Cornell's Science & Technology Entry Program (STEP), a program of the NYS Department of Education designed to promote postsecondary degree programs in scientific, technical, health-related fields, and the licensed professions to middle and high school students.

The event, which took place Saturday December 7 in Duffield Hall Atrium, invited curious and eager students to experience magnetism concepts through working magnetics demonstrations built by Cornell graduate students. El-Ghazaly had challenged her class to create protoype devices or machines that operate on magnetic principles with the question, "What magnetic device intrigues you?"

The Cornell scholars demonstrated a number of intriguing devices, including a magnetic "train" which moved through a copper-coil tunnel, a so-called "Farraday Flashlight" which illuminated when shaken, and a pendulum made to oscillate by magnetic fields. Other prototypes demonstrated on Saturday included macroscopic illustrations of nanoscale phenomena involving the magnetic "spin" of an electron. These included illustrations of "spin waves" using magnets rotating on fidget spinners and the concept of spin accumulation on a surface using magnetic marbles.

ECE fusion researcher educates members of Congress

Fusion Day on the Hill is a science advocacy event aimed at educating members of Congress about the state of fusion research throughout the country. In February, Cornell partnered with the University of Rochester and New York University to visit New York's delegation.

Cornell was represented by Sophia Rocco, Ph.D. student in the Laboratory of Plasma Studies.

Sophia Rocco

"Professors, researchers, students and representatives from start-ups come together in Washington, D.C.," Rocco explained, "to meet with policymakers and get them excited about the importance of fusion energy and how vital it will be to the energy security of the planet."

Specifically, they asked for a $715 million increase to the budget of the Office of Fusion Energy Science (FES), a branch of the Department of Energy. While over the past three years that budget has been steadily increased, the current proposed national budget slashes the FES allocation by 30%.

"The best thing we can bring is enthusiasm for our research and excitement about fusion energy," Rocco said.

Cornell's Office of Federal Relations coordinated Rocco's meetings with policymakers, including the offices of Rep. Paul Tonko (D-NY-20), Rep. Joe Morelle (D-NY-25), Rep. Tom Reed (R-NY-23), Rep. Grace Meng (D-NY-06), Senator Kirsten Gillibrand (D-NY), and Senator Chuck Schumer (D-NY).

"Everyone was very enthusiastic to speak with us," Rocco said. "They had lots of questions about the research being done at each of the universities." The hope was to get members of Congress to sign a letter asking for the increased fusion budget.

Rocco came away from the day feeling very optimistic about both the impact the group made and the state of fusion energy research as it is today. Fusion energy start-ups have been attracting more investors in recent years, and along with the research being done, fusion is finally getting the kind of resources it needs to be successful.

Discovery in gallium nitride a key enabler of energy efficient electronics

by David Nutt

Gallium nitride, a semiconductor that revolutionized energy-efficient LED lighting, could also transform electronics and wireless communication, thanks to a discovery made by Cornell researchers.

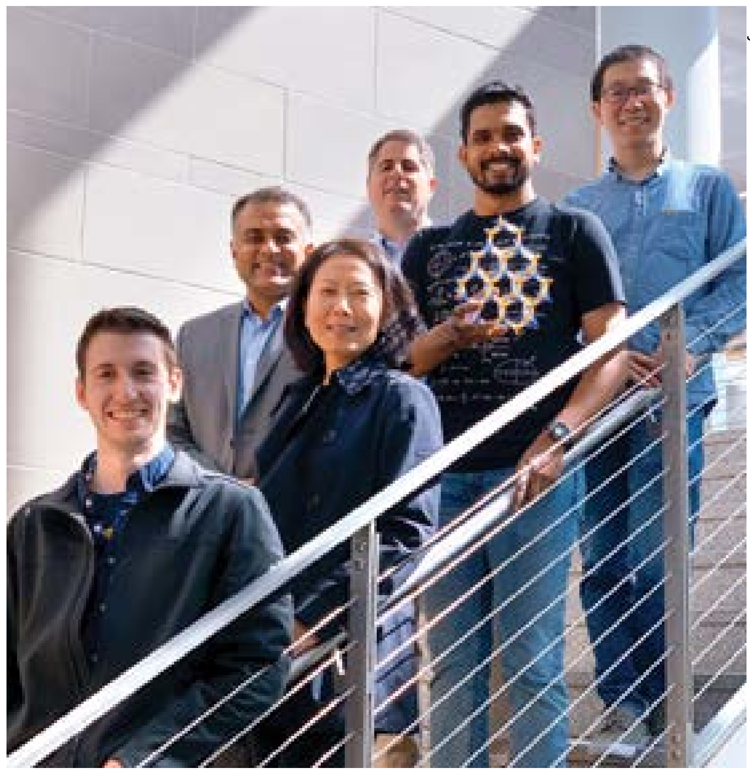
Their paper, "A Polarization-Induced 2D Hole Gas in Undoped Gallium Nitride Quantum Wells," was published September 26 in *Science*.

Silicon has long been the king of semiconductors, but it has had a little help. The pure material is often augmented, or "doped," with impurities like phosphorus or boron to enhance current flow by providing negative charges (electrons) or positive charges ("holes," the absence of electrons) as needed.

In recent years, a newer, sturdier family of lab-grown compound semiconductor materials has emerged: group III-nitrides. Gallium nitride (GaN) and aluminum nitride (AlN) and their alloys have a wider bandgap, allowing them to withstand greater voltages and higher frequencies for faster, more efficient energy transmission.

"Silicon is very good at switching off and on and controlling electrical energy flow, but when you take it to high voltages it doesn't operate very well because silicon has a weak electric strength, whereas GaN can sustain much higher electric fields," said co-senior author Debdeep Jena, the David E. Burr Professor in Electrical and Computer Engineering and in Materials Science and Engineering. "If you're doing very large amounts of energy conversion, then wide-bandgap semiconductors such as GaN and silicon carbide are the solutions."

Since the 1990s, researchers have doped GaN by adding magnesium impurities to create holes, but the process is highly inefficient. For every hundred magnesium atoms introduced into the crystal, only three or four holes might appear at room temperature, and even fewer at low temperatures.



Jimy Encomendero

From left, Ph.D. student Samuel J. Bader; Debdeep Jena, professor of electrical and computer engineering and materials science and engineering; Huili Grace Xing, professor of electrical and computer engineering and materials science and engineering; David Muller, professor of applied and engineering physics; Ph.D. student Reet Chaudhuri; and postdoctoral associate Zhen Chen.

Rather than using impurities, Ph.D. student Reet Chaudhuri stacked a thin GaN crystal layer—called a quantum well—atop an AlN crystal, and the difference in their crystal structures was found to generate a high density of mobile holes. Compared with magnesium-doping, the researchers discovered that the resulting 2D hole gas makes the GaN structures almost 10 times more conductive.

"In 1992, researchers discovered that when aluminum nitride is deposited on top of gallium nitride, you get free electrons at the interface. Having electrons conduct inside GaN makes what we call n-type electronic devices," said Chaudhuri, the paper's lead author. "The polarization theory that explains why we get mobile electrons in this structure, which in fact was conceptualized and validated by Cornell researchers in late '90s, also predicts that we should expect holes when the structure is flipped. But to date, there had not been any report of holes in an undoped III-nitride semiconductor structure. And that's what we have found in this work."

Using the new material structure created by Reet, co-author and Ph.D. student

Samuel James Bader recently demonstrated some of the most efficient p-type GaN transistors in a collaborative project with Intel. Now that the team has the capability to make hole-channel transistors—which are called p-type—they plan to pair them with n-type transistors to form more complex circuits, opening up new possibilities in high-power switching, 5G cellular technology and energy efficient electronics, including phone and laptop chargers.

"It's very difficult to simultaneously achieve n-type and p-type in a wide bandgap semiconductor. Right now, silicon carbide is the only other one that has both besides GaN. But the mobile electrons in silicon carbide are more sluggish than those in GaN," said co-senior author Huili Grace Xing, the William L. Quackenbush Professor in Electrical and Computer Engineering and in Materials Science and Engineering. "Using these complementary operations enabled by both n-type and p-type devices, much more energy efficient architecture can be built."

Xiang Li

Ph.D. student Reet Chaudhuri takes measurements on the 2D hole gas.

Another advantage of the 2D hole gas is that its conductivity improves as the temperature is lowered, meaning that researchers will now be able to study fundamental GaN properties in ways that haven't been previously possible. Equally important is its ability to retain energy that would otherwise be lost in less efficient power systems.

"Gallium nitride caused a revolution in the lighting industry," Jena said. "It enabled the white lighting that is in our cellphones, laptops, and LED bulbs that are replacing the incandescent bulbs in our homes. With a regular 100W incandescent light bulb, which is about 4% energy efficient, you might get 4 watts of light and the rest is heat. You know this very well if you touch the bulb when it is on. LEDs on the other hand can be almost 80% efficient, and only 20% is heat. A similar change in energy-efficiency of electronics has not yet happened. And maybe this finding is a step in that direction."

"IF YOU'RE DOING VERY LARGE AMOUNTS OF ENERGY CONVERSION, THEN WIDE-BANDGAP SEMICONDUCTORS SUCH AS GaN AND SILICON CARBIDE ARE THE SOLUTIONS."
— Debdeep Jena

A patent application has been filed through the Cornell Center for Technology Licensing for the discovery. Other contributors included David Muller, the Samuel B. Eckert Professor in Applied and Engineering physics; and Zhen Chen, a postdoctoral researcher in Muller's lab.

The research was supported in part by Intel, the Air Force Office of Scientific Research, the National Science Foundation and the Cornell Center for Materials Research.

ECE research drives NYSEG electric car charging pilot

by Melanie Lefkowitz

Owners of electric vehicles tend to come home in the evenings and plug in their cars—straining the grid because they're demanding a lot of power at peak times.

Even with plans offering off-peak discounts, most electric car owners still charge their cars at the same time to take advantage of lower prices—also straining the grid, though at different hours.

NYSEG, in collaboration with Eilyan Bitar, associate professor of electrical and computer engineering, is piloting a new approach to coordinate electric vehicle power use by encouraging owners to delay charging times in exchange for lower prices. The project, OptimizEV, will engage 35 participants in Tompkins County for a year to better understand consumer charging preferences, and how these might align with the overall power grid.

"When most people plug their vehicles in, they don't always need them to be charged immediately, and even though they won't need them until the following morning, they're plugged in for the rest of the night," said Bitar, also a fellow with the Cornell Atkinson Center for Sustainability.

Participants in the pilot will use smart chargers that can communicate to NYSEG their energy usage minute by minute. Electric vehicle owners will indicate how long they plan to leave their cars plugged in, choosing from a menu of options that offers larger discounts the longer they're willing to delay.

Once customers make their selections, an optimization algorithm—developed by Bitar with Polina Alexeenko, a doctoral student in electrical and computer engineering—will consider their deadlines, their energy usage and the wider demand on the power grid in order to determine the optimal charging pattern for every vehicle being managed.

"That will allow us to both monitor electric-vehicle charging and to transmit control signals that let us adjust the power they're drawing in real time," Bitar said. "We'll reshape the electric vehicle power load patterns to minimize strain on the grid, while still respecting customers' charging preferences and personal deadlines."

Power demand for electric vehicles is growing as more consumers use level two chargers, which are faster and more powerful than level one chargers, but can double a household's peak power demand. The popularity of these chargers, combined with the increased adoption of electric cars, could jeopardize the utility's ability to deliver power cheaply and reliably.

"Our grid infrastructure has limited capacity," Bitar said. "Transformers can only accommodate so much demand at any given moment. Exceeding a transformer's capacity to serve demand can severely reduce its lifetime, requiring more frequent replacements—which is not cheap."

Experts consider plug-in electric vehicles a step in the right direction for sustainability, but most electric cars are still powered by fossil fuels, if indirectly. Understanding consumers' willingness to delay their charging patterns, Bitar said, will help relieve pressure on the power grid; it also has long-term implications for integrating renewable energy into the grid.

Renewable sources of energy, such as wind and solar, remain impractical for widespread use in part because they are intermittent, making it difficult to ensure that power will be available when needed. Since electric vehicles are essentially batteries on wheels, they could potentially serve as storage buffers for intermittent energy sources—adding

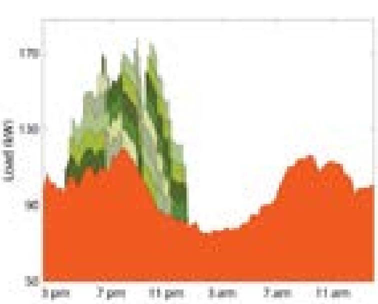


Figure A

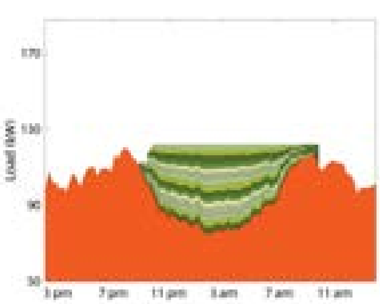


Figure B

Figure (a) *depicts the impact that uncoordinated EV charging will have on peak electricity demand.* ***Figure (b)*** *illustrates the extent to which optimized EV charging is able to reshape the aggregate EV demand profile to flatten the resulting demand peak, while still respecting customer-specified charging deadlines. In each figure, the orange curve depicts the existing electricity demand profile, and the different green curves represent individual EV charging profiles. In the absence of coordination, customers charge their EVs at the maximum power rate upon arriving home and plugging their EVs into the grid, resulting in a peak system load of approximately 178 kW. With optimized charging, the rates and times at which different EVs charge are coordinated in real-time to fill the load "valley", resulting in a substantially smaller system peak of approximately 122 kW.*

power back to the grid when they're not being used.

"Such coordination could create a symbiotic relationship, where the flexibility of electric vehicles is used to smooth the variability of renewables, and renewables directly supply clean power to the vehicles," Bitar said. "The OptimizEV project could help lay the groundwork for more sophisticated experiments that look at the possibility of coordinating electric vehicles not only to mitigate peak demand, but perhaps also to mitigate the intermittency effect of renewables."

Smart chargers have been installed in the homes of the 35 participants, and preliminary monitoring will continue through the end of the year. The pilot is expected to be completed in late 2020.

OptimizEV is part of NYSEG's Energy Smart Community Initiative in Tompkins County, and was developed in partnership with Kitu Systems of San Diego, California; Taitem Engineering in Ithaca; and supported in part by the New York State Energy Research and Development Authority, the National Science Foundation and the Cornell Atkinson Center for Sustainability.

New publication introduces a circuits model for a proposed spin-based device

Olalekan Afuye and Xiang Li , both Ph.D. students in ECE, are the lead co-authors of a paper titled "Modeling and Circuit Design of Associative Memories with Spin Orbit Torque FETs (SOTFET)."

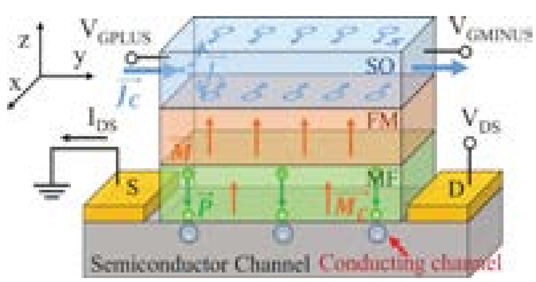
The paper is published in the *IEEE Journal on Exploratory Solid-State Computational Devices and Circuits*, which supports research in solid-state circuits using exploratory materials and devices for energy efficient computation beyond standard CMOS (Complementary Metal Oxide Semiconductor) technology.

Physics Professor Daniel Ralph and ECE professors Debdeep Jena, Alyosha Molnar, Alyssa Apsel and Huili Grace Xing, along with undergraduate research assistant Felicia Guo, are co-authors.

Afuye works in ECE Director Alyssa Apsel's research group investigating new approaches to cost-effective designs that achieve improved performance while reducing power consumption.

"In the paper," Afuye said, "we explore building associative memories (CAM/TCAM) using the built-in logic functionality of SOTFETs, which are a new kind of transistor/memory being developed by multiple materials engineering groups at Cornell."

"Essentially, we are trying to extend what we can do with CMOS," he continued. "This paper introduces a circuits model for SOTFETs and verifies associative memories functionality using the developed model."



Device structure and working principle of the SOTFET. SOTFET resembles a MOSFET with unique gate stack composed of a spin orbit (SO) layer, a ferromagnet (FM) layer and a multiferroic (MF) layer stacked on a semiconductor channel. Charge current flows through the SO layer and spins accumulate on the surfaces of the SO layer. The spins switch the magnetization of the FM through SOT, which in turn switches the polarization P in the MF due to exchange coupling. Effectively switching P gates the semiconductor channel.

The paper states: "The SOTFET utilizes a FET structure with a ferromagnetic-multiferroic gate stack that enables read/compute and write functions to be isolated. This is achieved by a combination of a ferromagnetic layer that is programmable via spin orbit torque coupled to a multiferroic layer that also couples into the gate of a traditional FET."

"Using such a device we demonstrate MRAM, CAM, and TCAM functionality with 3 to 5 transistors, a significant decrease over the CMOS alternative circuits, showing that such a device can enable low cost and compact associative memories not currently feasible with CMOS devices."

When asked about future applications, Afuye spoke about the possibilities that might emerge for low-power devices. "The SOTFET combines both memory and logic functionality into one device, opening up new possibilities in low-power applications," he said. "For example, you can imagine incorporating AI in low-power devices which would not traditionally use AI because of the high energy consumption associated with standard CMOS approaches."

This research is supported in part by the Semiconductor Research Corporation and by the National Science Foundation.

AMAL EL-GHAZALY

Growing up in Arizona, Amal El-Ghazaly used to take things apart. And her parents used to get a little upset with her because the things she took apart wouldn't always work properly once she reassembled them. "But then they realized it was a thing they should encourage," says El-Ghazaly. "My father is an electrical engineering professor and my mother has a computer science degree, so I think they recognized that I might be heading for a STEM career."

El-Ghazaly certainly was heading for a STEM career. In July 2019 she joined the faculty of Cornell's School of Electrical and Computer Engineering (ECE) as an assistant professor. El-Ghazaly's research combines magnetism, ferroelectricity, and optics to create tunable, versatile systems for telecommunications, sensing, and actuation.

When she was 14 years old, El-Ghazaly's family moved to Tennessee. In high school she was active in mathematics competitions and also ran track and cross-country competitively. Her interests were broad. When it came time to choose a college and a major, El-Ghazaly says she considered everything from architecture to zoology, eventually opting for electrical and computer engineering at Carnegie Mellon. "I also seriously considered going to Georgia Tech," says El-Ghazaly, "but CMU felt like the right fit. It was much smaller than Georgia Tech and its athletics were Division 3, so I could still compete as a runner while focusing primarily on academics." To relax, El-Ghazaly still likes to run. She also bicycles and will sometimes pick up her guitar or cello.

After graduating from Carnegie Mellon with a B.S. and an M.S. in electrical engineering, El-Ghazaly decided to continue on to a Ph.D. "For my senior year capstone I had to make something by myself," says El-Ghazaly. "Through the entire process I kept asking the professor a lot of questions. It helped me realize that there was still so much more I wanted to learn, so I applied to grad school."

El-Ghazaly went to Stanford University, where she joined the lab of Professor Shan X. Wang. "I wanted to do magnetics research and when I applied to Stanford, he was the only one doing the sort of research I wanted to do in applied magnetic devices," says El-Ghazaly. El-Ghazaly was at Stanford for five years and earned her Ph.D. in electrical engineering. Her research at Stanford focused on radio frequency devices using magnetic and magnetoelectric thin-film composites for tunable wireless communications.

After Stanford, El-Ghazaly received a postdoctoral research fellowship at the University of California Berkeley, where she explored new possibilities for ultrafast all-electrical switching of magnetic nanodots for faster and more efficient computer memories.

At Cornell, El-Ghazaly continues her exploration of how to make tunable devices that would allow electronic systems for telecommunications, sensing, and actuation to be more versatile. "There are so many challenges when you look at the Internet of Things and at digital agriculture," says El-Ghazaly. "We want to be able to communicate with many 'things' and sense many different things all at once, but the challenge is that our electronics are not infinitely scalable. The solution may involve increasing the number of devices in an electronic system, but not only will the electronics become too bulky, they will be consuming too much energy. An alternative solution is possibly making one compact device that can do many different things."

"Cornell feels like such a great place for me to be," says El-Ghazaly. "In terms of my research, it's a great fit at the departmental level and at the university level. And on a personal level, everyone in the department feels so supportive."

"THERE ARE SO MANY CHALLENGES WHEN YOU LOOK AT THE INTERNET OF THINGS AND AT DIGITAL AGRICULTURE. CORNELL FEELS LIKE SUCH A GREAT PLACE FOR ME TO BE."

— Amal El-Ghazaly

ZIV GOLDFELD

Ziv Goldfeld, assistant professor in Cornell's School of Electrical and Computer Engineering (ECE), is working to develop new approaches, rooted in theoretical principles, to analyze and design machine learning systems. One of his main goals is to understand exactly how neural networks make their decisions because, as he says, "'I don't know' is not an acceptable answer when it comes to these sorts of applications."

Goldfeld joined the faculty of ECE in July 2019 after two years as a postdoctoral research fellow at MIT's Laboratory for Information and Decision Systems (LIDS). Before that, he earned his B.S., M.S., and Ph.D. from Israel's Ben Gurion University, where his graduate work on information theory focused on physical layer security, cooperation in multiuser information-theoretic problems, and multiuser channel and source duality.

Goldfeld was born in Uzbekistan when it was a part of the Soviet Union. His parents emigrated to Israel when he was 5 years old. "My dad was an electrical engineer both in the USSR and in Israel," says Goldfeld. "He was an old-school communications guy. I happened to be good at hard sciences in high school and grew to like them. My initial plan was to be a doctor of veterinary medicine, but I quickly realized it involved lots of chemistry, which is not my cup of tea."

So Goldfeld chose electrical engineering as his undergraduate major and he has not looked back. "I found that I loved the mathematical aspects of E.E. more than the devices," says Goldfeld. Near the end of his undergraduate studies Goldfeld had a serendipitous elevator conversation with Ben Gurion University Professor Haim Permuter, who told him about a direct Master's program he might consider.

Goldfeld was accepted into the Master's program and then almost immediately made a discovery. "I realized shortly after I began the Master's program that I wanted an academic life," says Goldfeld. "I realized that academics got me to think about the kinds of questions that kept me up at night—in the best way. I flourish when I have the freedom to go about things my own way, and academic research allows me to do just that."

"THE BACKBONE OF THE DEPARTMENT HERE IS SO STRONG. I WANTED TO BE AT A PLACE WHERE THERE IS A GROUP OF PEOPLE I COULD EXCHANGE IDEAS AND COLLABORATE WITH. AND I FOUND THAT AT CORNELL."

— Ziv Goldfeld

Permuter became Goldfeld's doctoral advisor at Ben Gurion and at first Goldfeld says he worked on "Haim-flavored" problems. "Then he introduced me to Professor Gerhard Kramer from the Technische Universitat Munchen," says Goldfeld. "That's when I learned about Information-Theoretic Security. I loved the idea and it has some beautiful math to it." This became the topic of Goldfeld's doctoral thesis. In his postdoctoral years at MIT Goldfeld diversified his areas of expertise by working with Professor Yury Polyanskiy. "Working with Yury was great for me," says Goldfeld. "It gave me the opportunity to learn more about statistics and machine learning."

At Cornell, Goldfeld's research interests include optimal transport theory, statistical machine learning, information theory, high-dimensional and nonparametric statistic, applied probability and interacting particle systems. In his work, he seeks to understand and design engineering systems by formulating and solving mathematical models.

"Professionally, I started to evolve into new directions which are non-orthodox for an information theorist during my postdoc," says Goldfeld. "I felt that my work would fit best in a flexible research institution in the U.S., at a place like Cornell. The backbone of the department here is so strong. I wanted to be at a place where there is a group of people I could exchange ideas and collaborate with. And I found that at Cornell."

NILS NAPP

Nils Napp joined the faculty of Cornell's School of Electrical and Computer Engineering (ECE) as an assistant professor. His research focuses on design and control strategies for systems that operate in uncertainty. More specifically, he applies biological guiding principles to develop algorithms and build robots that can operate reliably in messy and unstructured real-world environments. Most recently, Napp was an assistant professor in the Department of Computer Science and Engineering at the State University of New York (SUNY) at Buffalo.

Napp's father is from Germany and his mother is from Hawaii. Napp grew up in Germany and then when it came time to go to high school, he did what many people probably wish they could do: He studied abroad in Hawaii. "I got to stay with members of my mom's family and after that I never really went back to Germany," says Napp. While he was in high school in Hawaii in the late 1990s Napp used the internet to teach himself about electronics and robotics.

Napp continued his education in the U.S. and studied Engineering and Mathematics at Harvey Mudd College in California. For graduate school, he moved to Seattle and started a doctoral program in electrical engineering at the University of Washington. Napp's focus was on control and robotics. "Halfway through my program, my advisor decided to become a synthetic biologist. I was his last robotics advisee," says Napp. "In an odd way, this gave me a lot of freedom to follow my own research interests."

Napp graduated with his Ph.D. in 2011 and then began a three-year position as a computer science postdoctoral fellow at Harvard's famous Wyss Institute for Biologically Inspired Engineering. In a very productive stint at Wyss, he worked on a 3D terrain acquisition system for biological fieldwork; developed hardware, models, and control strategies for amorphous robotic construction; developed a valve and a strategy for underactuated control of soft robots; and applied machine learning algorithms to the area of molecular machines.

"HAVING SUCH AN INTERDISCIPLINARY GROUP HERE CAN HELP SPARK NEW IDEAS. IT GIVES ME READY ACCESS TO PEOPLE WHO ARE EXPERTS IN MANY DIFFERENT AREAS THAT OVERLAP WITH MY WORK."
— Nils Napp

From Wyss, Napp joined the faculty at SUNY Buffalo, where he taught from 2014 to the end of 2019. At Buffalo, Napp and his students took some of the theoretical work at the Wyss Institute and made it a reality. They built several robot systems that could reliably build structures in unstructured terrain using a variety of specialized and found materials.

When Napp moved to Cornell in January, two of his doctoral students from Buffalo joined him. "This has been amazingly helpful," says Napp. "They know me and our research and they know how to set up a lab. I feel lucky to have them here." Napp is excited to be part of a larger robotics group at Cornell. "Having such an interdisciplinary group here can help spark new ideas," says Napp. "It also gives me ready access to people who are experts in many different areas that overlap with my work."

Napp's work at Cornell will focus on pushing algorithmic development even further, examining the complex problems we want robots to solve and then figuring out the right level of complexity to include in the robot's representation of the world.

"Evolved biological systems reliably work in cluttered, unstructured, and fluctuating environments, and often…with a lack of global information, planning, and communication," writes Napp. "Their approaches seem to focus on self-organization, managing noise created by many interacting components, and using distributed reactive behaviors as feedback to adapt their strategies." Napp looks to these biological systems to inform the algorithms his robots will use to interpret and interact with the world.

When asked what he likes to do in his free time, Napp said simply, "I am the parent of a new baby. That is a full-time thing."

Faculty Profiles by Chris Dawson

TWENTY YEARS OF ECE

Twenty years ago this July, Cornell's School of Electrical Engineering formally changed its name to the School of Electrical and Computer Engineering. The change was an effort to better describe the work the department was already doing, and the direction in which it was moving. The result was an almost immediate boost in enrollment.

The 1999 Electrical Engineering Advisory Committee agreed with those faculty who suggested the name change in order to attract students who might be unaware that EE was active in the computer field. After some discussion, the faculty voted overwhelmingly in favor. The associate director at the time, Paul Kintner, summarized the rationale in the Spring 2000 issue of *ECE Connections*:

"We live in an age when electrical and computer engineering is primarily characterized by change and innovation. Rapid evolution in materials, devices, communications, information systems and the impact of these advances on our social and environmental fabric, demand that students be grounded in basic knowledge that they adapt throughout their lives The School of Electrical and Computer Engineering will deliver these concepts through a broad program of courses that consider the latest technological developments, the processes by which they arise, and the foundations upon which they rest."

Professor Clifford Pollock, who became director of ECE a year after the change, said the aim was "to make students aware that our field was broader than just the transistor. And it worked! Almost overnight our enrollment doubled."

"Long before the name change," Pollock said, "we were organized into four areas—semiconductors, plasma, communications and computers—but with most emphasis on the physics and mathematics of electrical engineering."

As breakthroughs in personal

"WE WANTED TO MAKE STUDENTS AWARE THAT OUR FIELD WAS BROADER THAN JUST THE TRANSISTOR. ALMOST OVERNIGHT OUR ENROLLMENT DOUBLED."

— Clifford Pollock

computing, peripheral devices, and the internet began to revolutionize the field throughout the 1990s, world-wide interest in computers grew. Pollock recalled that the department realized: "We've got to hire more people in this area, and we've got to build it up because digital technology is clearly becoming the new way to do things."

Rajit Manohar and Mark Heinrich joined Cornell as assistant professors in July 1998 and created the Computer Systems Laboratory soon after. "They were two brilliant guys," said Pollock. "They put in their own network, helped hire two more computer systems faculty, and pretty soon the computer systems areas were growing. They were leading us."

Professor Clifford Pollock, circa 2000.

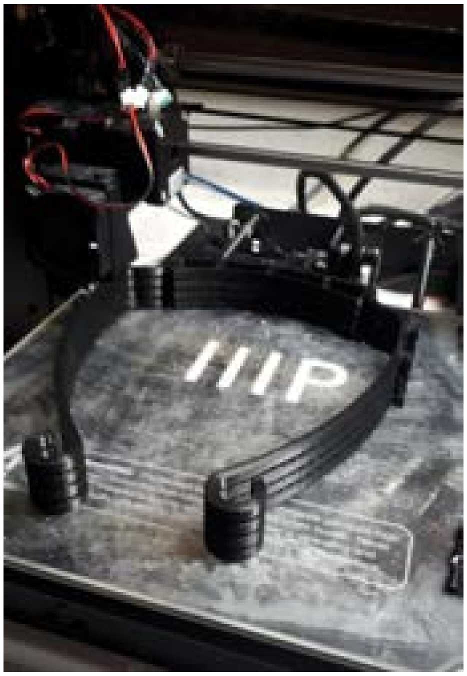
The strength of the rebranded School of Electrical and Computer Engineering was its expansive view. Building from foundations in physics and signals, ECE is concerned with all aspects of computer engineering: algorithms, devices, chips—the entire stack. The response from students was overwhelmingly positive.

In the Fall of 2000, the first semester after the name change, 21 sophomores were affiliated with ECE. In Spring 2001, that number had grown to 148. "It was huge," said Pollock. "Everyone wanted to be ECE."

ECE COMMUNITY WORKS THROUGH A CHALLENGING SEMESTER

As the COVID-19 pandemic began to disrupt our normal practices, the people of ECE responded with remarkable community spirit. Faculty and staff worked together to adapt to daily changing conditions with the single goal of creating the best possible experience for students when classes resumed on April 6.

ECE faculty quickly mobilized to develop strategies and resources to establish effective communication channels with students, put course materials on-line and assess student learning. Cornell's Center for Teaching Innovation McCormick Teaching Excellence Institute have been critical partners, assembling an array of tools to help move instruction on-line, engage students in distance learning, and meet course learning objectives.



One team is 3D printing protective visors.

At the same time, the Cornell community has worked to donate crucial medical supplies to local health care providers who face a shortage in protective gear. The push to collect supplies began after Deputy Provost John Siliciano emailed college deans to ask if any research labs had extra viral specimen swabs or personal protective equipment (PPE) that could be sent to Cayuga Medical Center.

Professor Aaron Wagner responded with an unopened box of N95 face masks he had purchased for a home improvement project. Professor Grace Xing helped organize donations to Cayuga Medical Center from the Cornell NanoScale Science and Technology Facility (CNF). Assistant Professor Kirstin Petersen helped lead, along with AAP, an effort to use our 3D printing labs to make visors for protective face shields requested by Weill Cornell Medical in New York City.

These are just a few stories we learned about as we were finalizing publication of this issue of *ECE Connections*. Undoubtedly, there are many more efforts which have since been realized. It's been inspiring to see our faculty and staff making time to help others in need, even while meeting the challenge of moving an entire semester of ECE education on-line for hundreds of graduate and undergraduate students.

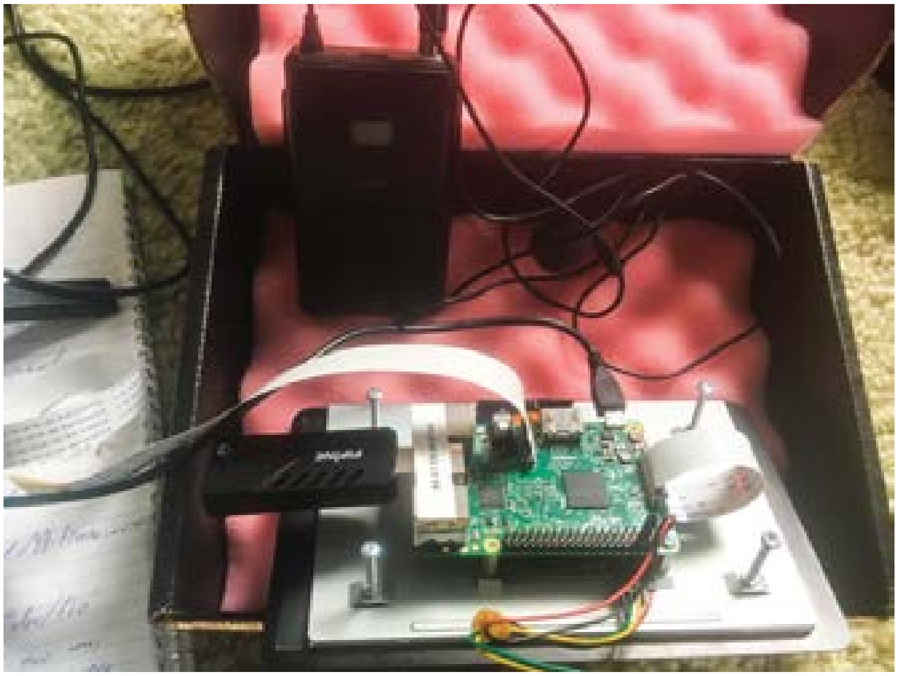
Assistant Professor Francesco Monticone sees some benefit in the upheaval, giving faculty reason to experiment with alternate learning methods. "Just thinking about these challenges and opportunities certainly pushes the instructor to innovate and explore different teaching approaches," he said, "which may prove useful even after the end (hopefully soon!) of the current crisis."

"JUST THINKING ABOUT THESE CHALLENGES AND OPPORTUNITIES PUSHES THE INSTRUCTOR TO INNOVATE AND EXPLORE DIFFERENT TEACHING APPROACHES."

— Francesco Monticone

Senior Lecturer Joe Skovira started the semester with a desire to record classes for students to reference later. "I was going to ask about setting up a recording system," Skovira said, "but then I thought: I've got Raspberry Pi's and cameras, so I started to build."

Skovira's portable recording system, which he calls ClassCam, includes a touchscreen and camera designed to



This is the system with the screen face down. That's a Raspberry Pi connected to the little screen; it runs the app and the software that records video and audio. The 'Fifine' USB dongle is the USB connection for the wireless mic. The white cable on the left side goes to the 8 Pixel camera. The white cable on the right goes to the display.

mount on a tripod and record video in class. "I use it to record PowerPoint slides on the screen, writing on the board, and myself lecturing," he said. "It saves audio and video to an MP4 file which I upload to Cornell Box for the students to reference."

Over the semester he made various prototypes, sharing improvements with students who were also working with Raspberry Pi's. "When the virus hit," he said, "I was just moving to prototype 5, a completely autonomous, battery-powered system."

Other faculty members have expressed interest in building versions of Skovira's system to use themselves. "I'm still working on improvements," Skovira said. "I want to make it as bulletproof as possible and control all actions with just a few button hits."

In the photos Skovira sent from his home lab, the camera sits on a test tripod. "The system can be controlled from the little screen," he explained. "There is a video preview on the left hand side of the screen. A little app I wrote has 'start' and 'quit' functions. In the back of the box is the wireless mic." He's using WiFi to mirror the display and controls on his laptop.

The ClassCam system eliminates the drawbacks of livestream systems; there's no network congestion and students can access the recordings at the time that best suits them. It's portable, self-contained, autonomous and costs less than $200 in parts. In short, it's a classic example of how electrical and computer engineers approach a challenge with ingenuity and innovation.

ENGINEERING ETHICAL STUDENTS

Engineering ethics is concerned with the study of ethical issues involved in engineering practice. It explores the engineer's role in technical decision-making within organizations, and considers the engineer's relationship to the uses of technology in society.

The Bovay Program in the History and Ethics of Engineering seeks to be a catalyst for consideration of social and ethical issues in Cornell Engineering. Dr. Park Doing, lecturer in electrical and computer engineering, guides the program to introduce ethical concepts to engineering students using real world case studies and current topics.

"Usually these issues come up when things go wrong," said Doing. Examples include the recent Boeing 737 Max disaster, along with historical catastrophes such as the Columbia and Challenger Space Shuttles and accidents at the Three Mile Island and Chernobyl nuclear plants. "But we also have another mode," he continued. "What happens when things go right?"

Engineers are tasked with developing technologies, techniques and devices to be taken up and used by the world. Even when functioning as designed, these technologies have social and ethical implications to consider. "How engineers deliberate these questions is definitely worth exploring," said Doing.

Recently, civil liberties groups as well as the general public have raised concerns about bias in algorithms and data sets, especially those used in corporate hiring practices, medical diagnoses, and law enforcement procedures.

"Algorithms can identify subtleties and correlations within data that a person might not see," Doing said. "The use of an algorithm in some kind of screening process might well mitigate the bias of any individual human being who is performing the screening."

For example, a human screener of job applicants might exhibit biased behavior in dismissing resumes from graduates of certain universities or any number of other prejudices. An algorithm could identify well-suited candidates by highlighting characteristics linked to successful employees already working for the company. "It's possible that helps the underdog," Doing said. "It's not automatic, but it's possible."

Park Doing

"USUALLY THESE ISSUES COME UP WHEN THINGS GO WRONG. WHAT HAPPENS WHEN THINGS GO RIGHT?"
— Park Doing

"Of course people are very concerned with biases that are built into the data sets that algorithms use," he continued, "as well as the lack of transparency in the neural net-based decision-making process."

Consequences of bias exhibited by algorithms or the data sets they work with can also be quite impactful in the areas of security and law enforcement. Tools like facial recognition, deployed with the best of intentions, can nevertheless provoke concern and even outrage from the public as biases are revealed.

When tested by the National Institute of Standards and Technology, facial-recognition algorithms from 99 different developers falsely identified African-American and Asian faces 10 times to 100 times more frequently than Caucasian faces from a database of photos used by law enforcement agencies in the U.S.

ECE Professor Stephen Wicker, who writes and teaches about data security and privacy, describes the ethical complexity of facial-recognition algorithms. "If we're capturing a face and comparing it to a database of known faces for identity—Which person is this? Do we have a match?—that's one thing," said Wicker. "But if we want facial recognition to figure out whether a crime is likely to be under way, and it's in a public situation, how are we going to write this algorithm? Are we going to focus on people looking nervous, or hiding things? Are we going to look at particular types of people congregating? Then it becomes problematic."

Both Wicker and Doing want their students to consider the downstream implications of their design decisions. What is the role of engineering in society and whom do we hold accountable when malevolent effects emerge?

"Most engineers would say: I just build stuff—how people use it is a different realm," Doing said. "I think it's an open question. Can you really absolve yourself of all responsibility?"

"WE ACCEPT THE PLAUDITS AND RENUMERATION FOR OUR WORK. WE MUST ALSO ACCEPT THE RESPONSIBILITY FOR SUBSEQUENT PROBLEMS."
— Stephen Wicker


Stephen Wicker

Wicker argues that we cannot. "We accept the plaudits and renumeration for our work—we must also accept the responsibility for subsequent social and legal problems."

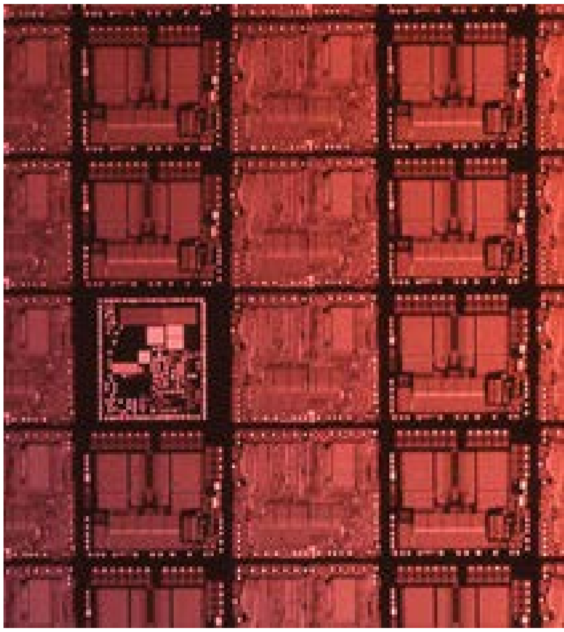
Engineers must challenge their assumptions at every stage of development. Independent review panels within organizations could analyze software for potential bias before deployment, and government regulation could help to promote transparency and allow people to have more control over their personal data.

"The Accreditation Board for Engineering and Technology (ABET) has recognized that ethics is an important element of engineering education," Wicker said, "and we build this into our curriculum." The goal is to introduce ethics into engineering solutions as a fundamental ingredient, and not an add-on.

"It's OK to apply value judgment," Wicker reminds his engineering students, "because we each have an innate ethical sense. The important thing is to pay attention to that sense and to continue to hone it over the course of your career."

BUILDING THE NEW COMPUTER

How ECE researchers are working to realize revolutionary new architectures



Computer engineering researchers are starting to grapple with the implications of what has come to be seen as the end of, or the breaking of, Moore's law.

The observation that transistor density on an integrated circuit doubled about every two years is named after Gordon Moore, whose 1965 paper originally described and predicted this performance growth rate. Moore's law allowed the semiconductor industry to transform the world by building ever-smaller transistors with increasing density, creating the ubiquitous and relatively inexpensive computing environment we live in today.

Even though transistors exist at the nanoscale, the limit of how small they can be built and how densely they can be arranged on a chip has been found. Moore's law essentially ends here.

Historically the processor side of the industry focused on complexity and speed, while the memory side focused on density of storage. Eventually problems arose as the relative speed of processors and memory diverged. Processors were increasingly stalling, waiting for data to come from memory. Clever engineers have found ways to hide this bottleneck over the years, but something has to change.

The demands of modern computing require real-time speed and massive scalability. The delays inherent in the traditional Von Neumann architecture, the model on which most of today's computers operate, provide a fundamental roadblock in terms of the expenditure of time and energy. Computer architects are searching for ways around this roadblock, to reduce the time and energy it takes to move data between the processor and memory. One solution is to do processing much closer to, or even within the memory itself.

This requires researchers to find new computer architectures and to innovate across the system stack, from the materials and devices used to build the chips to the applications running on the computer. The old, evolutionary approach is no longer adequate. ECE researchers are working to realize revolutionary new architectures to build the next generation of computers.

"THE DELAYS INHERENT IN THE TRADITIONAL VON NEUMANN ARCHITECTURE PROVIDE A FUNDAMENTAL ROADBLOCK IN TERMS OF THE EXPENDITURE OF TIME AND ENERGY."

"For the past two decades, my research emphasis has been power-efficient computer architecture," said David Albonesi, professor and associate director of ECE. "Much of this focus has been on dynamically adapting cache architectures to fit the needs of the application programs."

One approach, for which Albonesi recently received the International Symposium on Microarchitecture Test of Time Award, is to dynamically turn off portions of the processor cache according to the present characteristics of the running application. "Figuring this out on the scale of milliseconds is extremely challenging," he said, "and our recent work adapts algorithms from other problem domains to the fine timescales of computer systems, including cache power management."

Professor Edward Suh, electrical and computer engineering, discussed the potential security benefits of in-memory or near-memory computing. "In today's computer systems, data needs to be moved

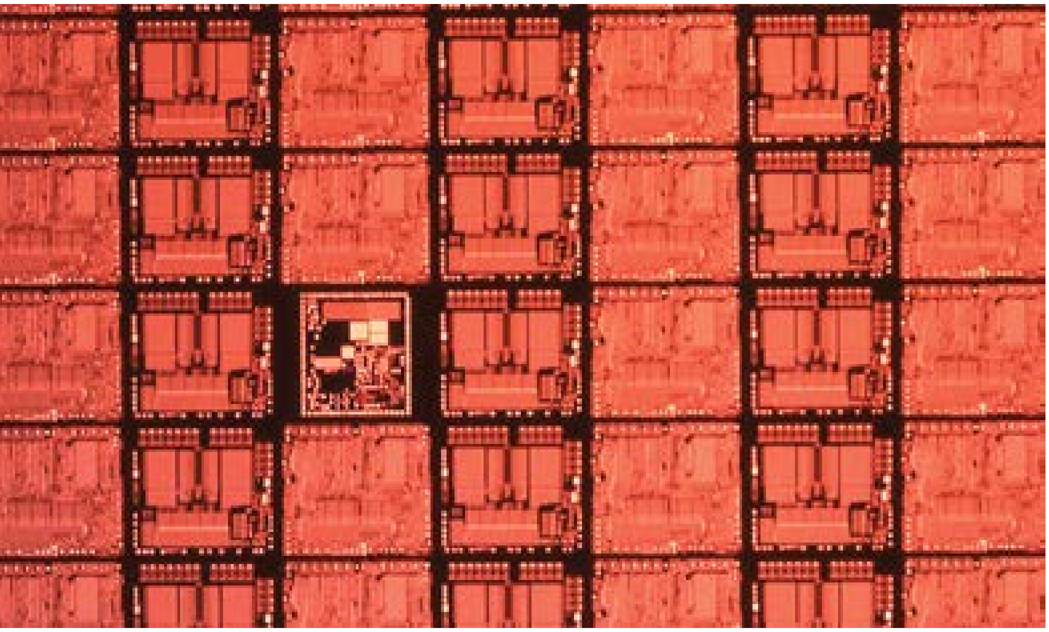


Image by Cornell NanoScale Facility (CNF), a member of NNCI supported by NSF Grant NNCI-1542081

to a processor, which is often another chip," he said. It's been shown that the data can be read, or even changed, during the transfer. "There are techniques to encrypt and protect data in memory," Suh continued, "but they come with some overhead in terms of both performance and energy consumption. If data stays inside memory, it will be quite difficult to tamper with."

Olalekan Afuye and Xiang Li, both Ph.D. students in ECE, are the lead co-authors of a paper titled "Modeling and Circuit Design of Associative Memories with Spin Orbit Torque FETs" published in the *IEEE Journal on Exploratory Solid-State Computational Devices and Circuits*. "We explore building associative memories (CAM/TCAM) using the built-in logic functionality of SOTFETs," Afuye said, "which are a new kind of transistor/memory being developed by multiple materials engineering groups at Cornell."

Several other major research initiatives currently underway focus on optimizing the memory system to improve the performance and efficiency of computer systems. The most high-profile efforts are two centers: DEEP3M and CRISP.

"ONE SOLUTION IS TO DO PROCESSING MUCH CLOSER TO, OR EVEN WITHIN THE MEMORY ITSELF."

Huili Grace Xing, professor of electrical and computer engineering and materials science and engineering, is leading an interdisciplinary team to investigate durable, energy-efficient, pausable processing in polymorphic memories (DEEP3M), where computational capabilities are pushed directly into the high-capacity memories. This center is jointly funded by the National Science Foundation (NSF) and the Semiconductor Research Corporation (SRC).

Professor José Martínez, electrical and computer engineering, is assistant director of CRISP, the Center for Research on Intelligent Storage and Processing in Memory. CRISP is part of the Joint University Microelectronics Program (JUMP, also funded by SRC) which supports creating intelligent memory and storage architectures that do as much of the computing as possible as close to the bits as possible.

DEEP3M

An ultimate memory would be suitable to all systems, with the desired features of non-volatility, low-power operation, infinite endurance, nanosecond writing time, sub-nanosecond reading time, good scalability, and more. The DEEP3M team's approach builds on recent breakthroughs in the physics of magnetic switching and advanced materials and re-imagines the memory device as a computing element itself.

The project is jointly funded by the National Science Foundation and the Semiconductor Research Corporation, supporting research by ECE faculty members Alyssa Apsel, Christopher Batten, Debdeep Jena, José Martínez, Alyosha Molnar and Christoph Studer along with Daniel Ralph in the Department of Physics and Darrell Schlom in Materials Science and Engineering (MSE). Huili Grace Xing, the William L. Quackenbush Professor of Electrical and Computer Engineering in both ECE and MSE, is DEEP3M's principal investigator.

"My focus is primarily on understanding the physics of this new device we have proposed and then converting that physical understanding into a mathematical model," Xing said.

"The official name of the device, coined by Professor Ralph, is a SOTFET." The acronym stands for Spin-Orbit-Torque Field-Effect Transistor.

The goal is to use the spin orbit torque to reorient the poles of the transistor's magnetic layer like a switch, translating the magnetic orientation into ones and zeros. This technique can be used to create memory as well as computational devices.

"The whole field of spintronics that's been developed over the last 20 years is trying to figure out if there are ways to manipulate the spins and gain new functionality that you can't get with just a charge," Ralph explained. "We take direct advantage of that. With spins you can transfer angular momentum and apply torques that can reorient magnets. The DEEP3M project is a way of trying to improve on the spin orbit torque, to use it to make a better memory for writing and for reading."

It doesn't take much electrical current to flip this magnetic switch, but two other characteristics make this approach very attractive to researchers.

"One is infinite endurance—you can write zeros and ones an infinite amount of times," Xing explained. "The other one is non-volatility, meaning when there's no power applied to this device, the ones and zeros that are stored in the device remain." Non-volatility is enormously important to energy efficiency.

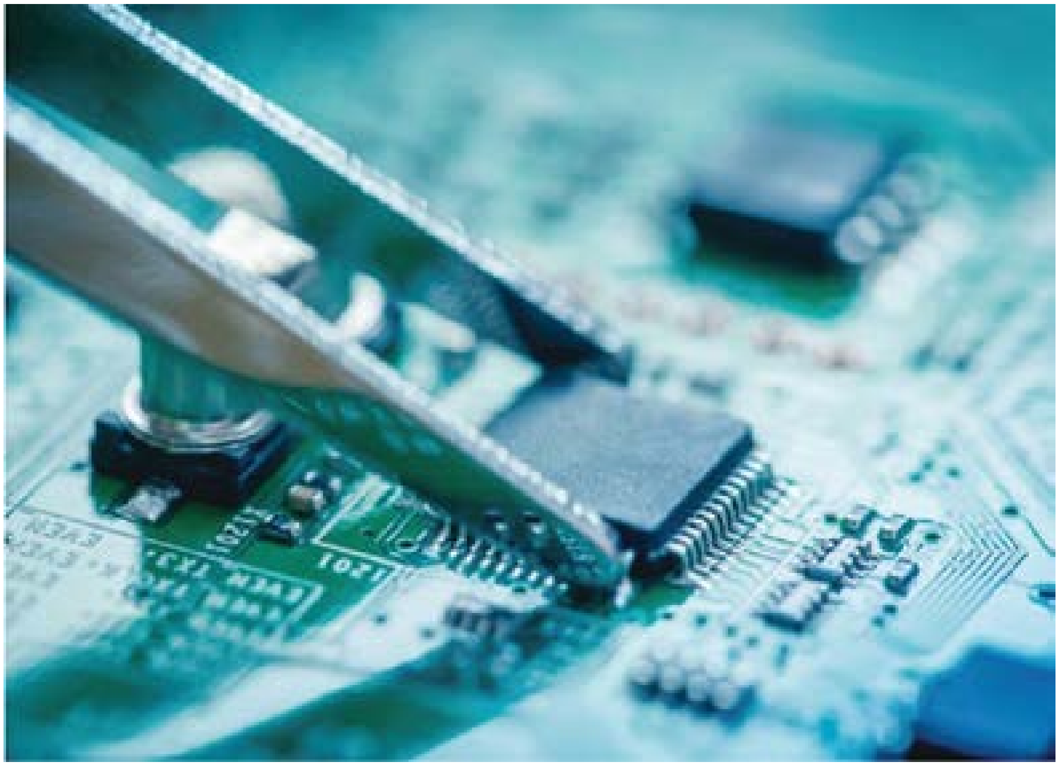
"Non-volatility is very useful, especially if you look at big data," Xing said, "because in big data not all the data will actively participate in computation, communication or decision making. The data are all there and zero energy is spent to store it."

Achieving significant benefits in performance and energy efficiency will require radically new interdisciplinary approaches spanning materials, devices, circuits, and architectures. The DEEP3M team argues that new materials and devices centered around spin-orbit torque offer compelling benefits compared to both existing and emerging memory technologies in terms of endurance, density, performance, and energy efficiency.

"ACHIEVING SIGNIFICANT BENEFITS IN PERFORMANCE AND ENERGY EFFICIENCY WILL REQUIRE RADICALLY NEW INTERDISCIPLINARY APPROACHES."

The project has the potential to impact multiple disciplines, re-weighting the cost-benefit equation of many circuit and architecture designs. It will also encourage significant interdisciplinary collaboration which will lead to further innovations.

In the emerging era of big data, search and pattern matching become critical low-level functions; the research and technology development proposed by DEEP3M will enable such functionality, with long term impacts in virtually every field of science and technology, and beyond into the broader economy. In the future, students at all levels will learn to view a larger picture of the combined



Close up on tweezers holding jumper on circuit board.

materials/devices/circuits/architectures approach to research.

"The best non-volatile memory is magnetic memory because of its infinite endurance and non-volatility," said Xing. "The best logic is the semiconductor device because it creates a huge dynamic range in terms of resistance. So now we're bringing those two elements into one device."

This means a dramatic potential paradigm shift in how we build computers in the future, with the most desired features of memory and logic in the same device.

CRISP

The "von Neumann bottleneck" is a feature-turned-problem that is almost as old as the modern computer itself.

Most modern computers operate using a von Neumann architecture, named after computer scientist John von Neumann. He proposed in 1945 that programs and data should both reside in a computer's memory, and that the central processing unit may access them as needed using a memory bus. Von Neumann's paradigm allowed processor and memory technology to evolve largely independently at breakneck pace, the former emphasizing processing speed, and the latter favoring storage density. Soon enough, however, this created a fundamental bottleneck which has become steadily worse over the years, forcing computer architects to concoct a myriad of engineering tricks such as caches, prefetching or speculative execution.

"The faster processors got relative to memory size, the more critical this problem of busing data around became," said José Martínez, professor of electrical and computer engineering. "Today's processors often find themselves waiting for data they've requested from memory so they can get something done."

Zhiru Zhang, associate professor of electrical and computer engineering, and Martínez are working to develop a radically new computer architecture through the Center for Research on Intelligent Storage and Processing in Memory (CRISP), an eight-university endeavor led by the University of Virginia. Martínez is CRISP's assistant director. The center is funded with a $27.5 million grant as part of the Joint University Microelectronics Program (JUMP). A $200-million, five-year national program, JUMP is managed by North Carolina-based Semiconductor Research Corporation, a consortium that includes engineers and scientists from technology companies, universities and government agencies.

"CRISP TAKES A VERTICAL APPROACH TO THE PROBLEM, SPANNING HARDWARE, SYSTEM AND APPLICATIONS RESEARCH."

CRISP was formed in 2018 as interest in solving the von Neumann bottleneck began to grow. The increasing use of "big data" presents new opportunities to leverage vast sets of digital information for business, health care, science, environmental protection and a wealth of other societal challenges. The center aims to develop a new type of computer architecture that considers processing and storage as one and the same mechanism, rather than two separate components. This can be achieved by building processing capabilities right inside memory storage, and by pairing processors with memory layers in "vertical silicon stacks," according to Martínez.

"Memory is deeply hierarchical, and at each level there's an opportunity for adding computing capabilities," said Martínez, who adds that consideration must be given to data structure and usage patterns. "Organizing the computation around this deeply hierarchical system is a big challenge. I could be physically very close to some stored data, but if the probability of such data being relevant to me is low, that proximity most likely does nothing for me."

The center takes a vertical approach to the problem, spanning hardware, system and applications research themes. This vertical approach allows the center to tackle another critical challenge: create a programming framework that is intuitive enough for programmers to use productively and effectively.

"We are essentially blurring the boundaries between computing and storage. This introduces a whole host of new challenges to hardware architecture design, as well as software programming. Our goal is to achieve transparent acceleration where the programmers do not have to reason about the low-level hardware details to optimize communication and data placement," said Zhang.

Zhang and Martínez both conduct their research at Cornell's Computer Systems Laboratory. As part of the project, they envision co-designing the architecture with new compiler and run-time systems that can automatically translate programs into machine code for their new architectures. "We cannot afford to determine the architecture or the run-time system before attacking the other one. We need to design both at the same time," said Martínez."

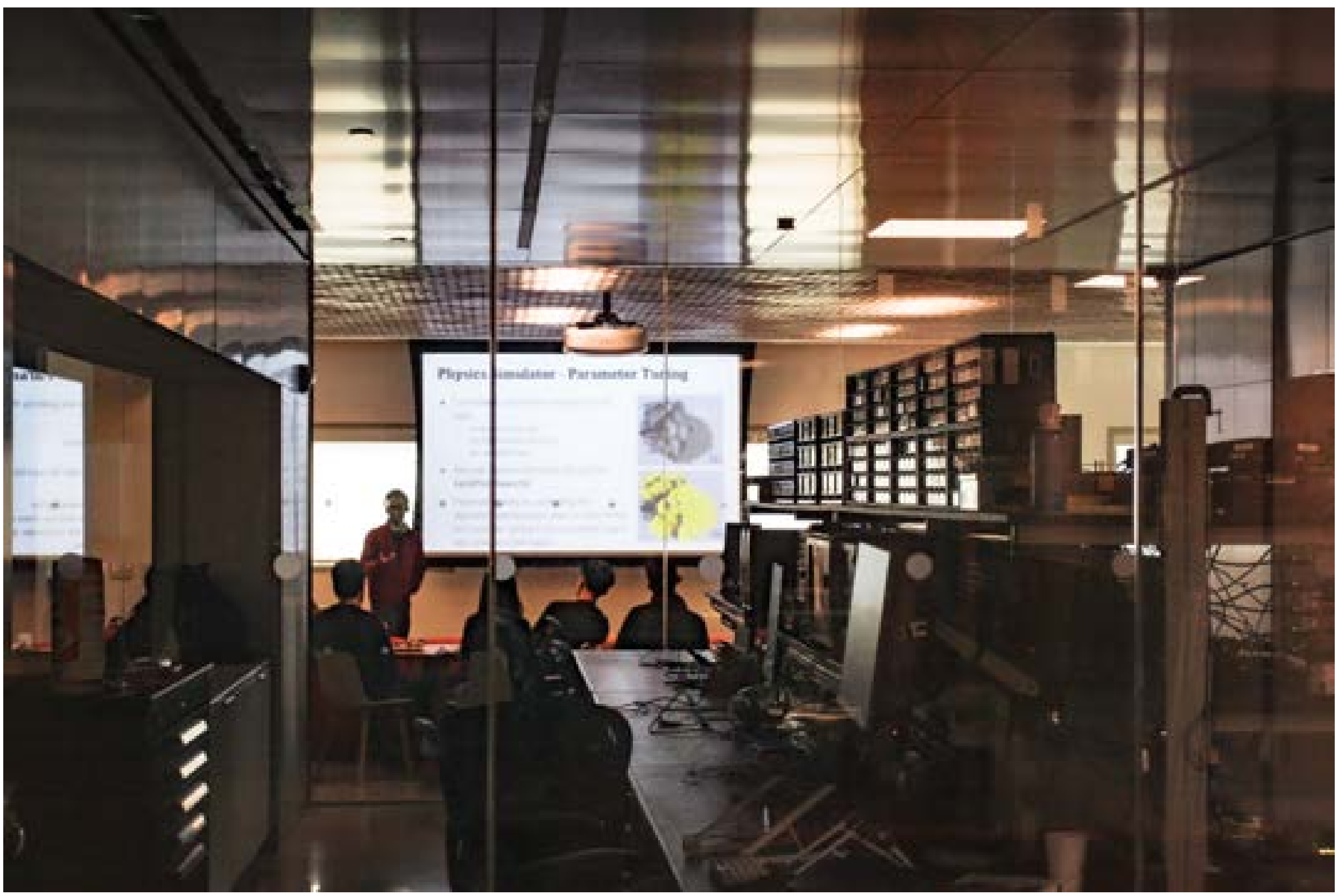
Jessica Edmister contributed to this story.

CSL: BREAKING SILOS TO BUILD COMMUNITY

The founding idea of the Computer Systems Laboratory (CSL) was the sense that community will lead to more creative thinking. The faculty and students of CSL see it as more than a way to share resources and infrastructure in a collaborative space. The CSL community is built around a fundamental sensibility about what it means to be a researcher.

Science education tends to guide students into increasingly narrow silos of specialization, often causing them to miss out on opportunities to gain different perspectives—to think like other researchers. CSL integrates alternate perspectives into the research mindset by intentionally mixing people from different research groups and different departments.

"That cross-pollination of ideas and different ways of thinking becomes second nature to the students," said ECE Professor José Martínez, "so when they are thinking about a problem, they know they are in an ecosystem that allows them to think differently, to think with an open mind



The CSL environment is designed for spontaneous interactions. The full panel glass walls encourage curiosity and engagement.

“BETTER RESEARCH COMES FROM HAVING CONVERSATIONS WITH PEOPLE WHO HAVE SIMILAR, BUT SLIGHTLY DIFFERENT BACKGROUNDS.”

— Jordan Dotzel, Ph.D. student

about integrating specialties. And this approach tends to be much more fruitful in the pursuit of creative solutions to problems.

“That’s the genesis of CSL‘s sense of community,” Martínez continued. “It’s to do better research.”

Adrian Sampson, assistant professor of computer science, supports this mission of molding students’ research practice through community. “Dialogue with other people and a shared understanding of the context that you’re in,” he said, ”That’s something you cannot get from reading any book or paper, but it’s an integral part of a person’s development from being a fresh college graduate to becoming a full-fledged independent researcher.”

ECE Professor Ed Suh emphasizes that CSL attracts genuinely collaborative people. “It’s very easy to talk to other groups. Those things happen much more organically here.”

“CSL was created right around the time EE became ECE,” said Associate Professor Christopher Batten, “and I think the fact that we’ve broadened from an EE to an ECE department has been pretty critical to our success.”

Rajit Manohar and Mark Heinrich joined Cornell as assistant professors in July, 1998. They saw the potential for creating not just a research group, but a community.

Professor Clif Pollock recalls: “They were two brilliant guys, real characters, and quite independent, who had this kind of crazy can-do attitude and they just made it happen. They put in their own network and hired two more people and pretty soon the computer systems areas were growing. They were leading us.”

Over the intervening years CSL created not just a lab, but a culture. It developed into a new way to think about how research could be done without getting locked into silos.

“Grad school can be an inherently isolating experience,” said Sampson, who joined CSL in 2015. “If you’re not careful, you end up toiling by yourself for long hours and not really interacting with anyone else.”

The shared hardware prototyping lab gets students talking with one another.

Students who work in CSL report the opposite experience. They speak of making connections, socializing, mutual emotional support, and just hanging out in the dynamic CSL space in Rhodes Hall during all hours of the day. Weekly seminars and communal lunches encourage them to stay engaged with each other, ask questions, and get to know how different people think. The environment feels more like a hip Silicon Valley startup than a stuffy academic lab.

“The numerous research, teaching, and collaboration opportunities in CSL heavily impacted my decision to come to Cornell,” said Shunning Jiang, a Ph.D. student in Batten’s group. “CSL is a diverse and cohesive community in both cultural and academic aspects. I’ve had numerous inspirational conversations with colleagues from other research groups, which gave me lots of practice in articulating my research ideas and giving constructive feedback to other people.”

“I prefer a small sized research group with a related community where I can exchange ideas with people in different subfields. I can get the latest updates from other research subjects,” said Yi Jiang, a Ph.D. student in computer science advised by Professor Martínez. “The Ph.D. path is tough sometimes,” she continued, “so support from peers who know you matters a lot. CSL provides that and makes me feel connected.”

Other students echoed this feeling of connection. “This group of people brings social benefits and research benefits, both often playing off each other,” said Jordan Dotzel, a Ph.D. student of Assistan Professor Zhiru Zhang. “A promising research idea might come out of a quick talk by the espresso machine.”

Xiaoyu Yan will complete both his

B.S. and M.Eng. in electrical and computer engineering this year, and he has been pursing research within Batten's group. He highlighted CSL's collaborative atmosphere.

"CSL has the tools for evaluating and experimenting with hardware," Yan said. "It's a good environment for collaboration between different research groups. Another undergraduate student worked in the lab to test chips our group taped out using a variety of shared bench equipment. During the summer, we had three different research groups working on the same project and we were able to quickly share information and work together."

Facilitating collaboration is part of what makes CSL unique, but it's not what Batten considers the most important aspect. "There are definitely research collaborations within CSL, but that's a small piece of it," he said. "The broader context is that our research community creates longer-lasting interactions, social interactions, growing what you know about, what you learn, and learning something new—that became our culture. That's why it's a community, not just a collaboration."

Sampson went further: "We have a culture that emphasizes independent ideas. Picking what problems to work on and deciding what makes an exciting and creative idea versus a boring, incremental next step is the key to doing good science—to understanding what good work is in the first place."

In CSL this process of development as an independent researcher is at work from the undergraduate to the postdoctoral level as students begin to envision future career paths.

ECE undergraduate Kenneth Mao '21 has been a research assistant in groups led by professors Zhang, Suh and now Batten. He said, "CSL members have helped me make industry connections that led to internship opportunities, and provided insight as to which classes would align best with my interests. It's an open and

Weekly lunch seminars provide a regular opportunity for gathering as a community.

"OUR RESEARCH COMMUNITY CREATES LONGER-LASTING INTERACTIONS — THAT BECAME OUR CULTURE."

— Christopher Batten

friendly atmosphere that allows you to share your ideas and receive valuable feedback."

Kaishuo Cheng '22, also an undergraduate research assistant in Batten's research group, is affiliated with Computer Science. "I very much appreciate the opportunity to work in CSL," he said. "It's been a valuable part of my life at Cornell. This experience allows me to get hands-on with cutting-edge technologies, to meet fantastic students and professors, and to apply what I have learned in class to real-world applications."

Though rooted firmly in electrical and computer engineering, CSL draws students and faculty from other departments and disciplines, including Computer Science and Mechanical and Aerospace Engineering. Nikita Lazarev, a Ph.D. student advised by Assistant Professor Christina Delimitrou and Assistant Professor Zhiru Zhang put it very directly: "The CSL community is a great way to share knowledge and extend our expertise beyond our main fields."

"In the end, better research comes from feeling comfortable in your environment and having conversations with people who have similar, but slightly different backgrounds," said Dotzel, chair of the CSL Student Steering Committee. "CSL is a strong model for how research communities should be structured."

Reflections from a recent CSL graduate, Mark Buckler, Ph.D. '19

Mark Buckler

One of Buckler's projects, the Amazon Scout delivery robot.

I recently graduated with a Ph.D. in Electrical and Computer Engineering from Cornell University where I was advised by Adrian Sampson, assistant professor of computer science. As an entrepreneurial engineer I quickly gravitated to both industrial and academic research. I'm currently an Applied Scientist at Amazon where I help robots see the world with fast, accurate, and energy efficient computer vision.

The Computer Systems Laboratory was the single most important factor in my decision to come to Cornell. I had been accepted to another top-ranked Ph.D. program and was settled on attending that school. But after visiting Cornell and meeting with the CSL team, I instantly changed my mind. CSL had experts on both hardware and software design, which significantly helped me to become a cross-discipline researcher.

What was most important to me at the time was the wide availability of professors who had interests similar to mine. Working with an advisor is a complex personal relationship (it has been compared to marriage) and so it can be hard to determine who exactly you would work well with. The flexibility that CSL offered was exactly what I needed to find the right advisor.

CSL is an idea, a group of professors, and a physical workspace. It is hard to exaggerate how helpful it is to your academic experience to have easy access to students and faculty from all different areas within your field.

When you attend a weekly CSL meeting you feel like you are a part of a larger goal, toward researching the next best computing machine. There is an openness that allows you to mingle with peers during the day and after talks. You learn organically what other people are working on, and when you need people to work with on any given topic, you can usually find someone.

Academia as a whole has a reputation for being very isolating—not in CSL. We were all working in the same space and attending the same group talks, so it was much easier to find someone who you would want to work with, or to find someone to be your mentor or mentee.

The CSL environment is an exciting group of people who will inspire you and support you throughout your academic career.

CIRCUIT DESIGN, PRODUCT LINES AND WINE

How Richard Hojel '88 found success chasing his passions

by Syl Kacapyr

Richard Hojel '88

Growing up in Mexico City, Richard Hojel '88 never imagined that hiding inside a library from a blustery winter storm would be an experience he would enjoy, but satisfaction and success await when one chases their passions, wherever that may take them.

Hojel is CEO of Corporacion Frigus Therme and managing director of HM International, a private holding group that acquires and operates industrial product businesses, generating more than $400 million in annual revenue. But before he discovered his proficiency for business, it was circuit design that brought him to Cornell's School of Electrical and Computer Engineering in the 1980s.

"Personal computers were just taking off and the field of integrated circuits was exploding," said Hojel. "It was a very exciting track to follow."

A family friend suggested Hojel study electrical engineering at Cornell, and soon after, Hojel found himself on campus, in the good company of his Sigma Chi brothers as well as "a fairly small, but strong Mexican community." And as he studied in Olin Library, he sometimes found himself surrounded by an unfamiliar climate.

I joke and say that it's scarred into my memory, but in fact, it's a very good memory," explains Hojel. "That very academic feeling of studying during wintery days, that's one of the highlight memories I have of Cornell."

Perhaps it was because Hojel was captivated by his studies and discovering subjects that fascinated him, not just in his circuit design courses, but in a wealth of different subjects such as physics, quantum mechanics, and psychology.

"CORNELL GAVE ME THE FOUNDATION FOR LOGICAL THINKING. THAT HAS BEEN SOMETHING THAT'S CARRIED ME THROUGHOUT MY BUSINESS CAREER."
— Richard Hojel '88

"There were a couple professors who really brought the subject matter to light. Data or topics that sometimes can be considered dry – they brought them out," said Hojel, who added that a number of other courses were naturally exciting to him, such as wine tasting.

A foundation for business

Ultimately, it would be a business education that Hojel pursued after graduating from Cornell, earning an MBA from Harvard. He imagined one day taking over his family's business and when his father passed away in 1995, that day came sooner than expected. Hojel had just turned 30 when he found himself responsible for managing the business.

His father's business partner, the late Peter Meinig '61, was instrumental in mentoring Hojel through the daunting task of managing a portfolio of complex industrial suppliers. So was his electrical engineering education.

"Cornell gave me the foundation for logical thinking and being able to break things into pieces and analyze them. That has been something that's carried me throughout my business career," said Hojel. "I never practiced as an engineer, but I use the skills to manage groups of engineers, teams of software and hardware developers, product design groups, and bring all those together and manage them towards a viable product."

Today, the investment group includes over a half-dozen companies in product and technology manufacturing, mostly in the energy and food sectors. Based in the U.S. and Mexico, the companies employ over 2,000 people and do business across the world.

Hojel describes the processes needed to drive his investments to prosperity as a personal passion.

"Long-term success driven by building organizational culture around a strong set of values and a clear common purpose – those are the things that really get me excited," said Hojel. "Pulling people together, developing a purpose and mission, and how we're going to drive to that purpose. A purpose that extends beyond the organization, that looks to have a positive impact on all its stakeholders, including our communities."

Still finding affection

Hojel's advice for today's electrical and computer engineering students is to maintain the relationships built at Cornell, and above all, grow as an individual by exploring a myriad of interests, both in and out of one's comfort zone.

"I would recommend taking courses outside of your major, especially for people who have technical majors like engineering," said Hojel. "We have a tendency as engineers to focus on the very practical courses, but courses like Psych 101 and the wine course are classes that also are very fulfilling."

The wine course Hojel remembers so fondly has become more practical than he intended. One of his group's investments, Monte Xanic, produces one of Mexico's premier wines. Hojel admits the winery, located in the Guadalupe Valley, is an outlier in the portfolio of companies, but one that is important to him.

Said Hojel of the investment: "Although not a typical investment for us, Monte Xanic has changed the Mexican wine industry and become a great source of passion and pride."

"WHAT GETS ME EXCITED IS DEVELOPING A PURPOSE AND MISSION TO HAVE A POSITIVE IMPACT ON ALL STAKEHOLDERS, INCLUDING OUR COMMUNITIES."

— Richard Hojel '88

Richard Hojel (right) with board members of Monte Xanic, which produces one of Mexico's premier wines.

EXPANDING THE CAPACITY OF COMMUNICATIONS

by Chris Dawson

Even when Zach Boynton was in high school at the Cambridge Rindge and Latin School in Massachusetts, he knew he would probably end up following a technical path. "I was in the Rindge School of Technical Arts engineering program and we did a unit on digital circuitry," says Boynton. "It was mind-blowing and eye-opening that I could construct items out of components and that those items could then do stuff and help us make sense of the world."

Boynton went to the University of Massachusetts, Amherst, where he majored in electrical engineering. While there, he was able to parlay some high school experience machining parts into an undergraduate research position in the lab of Associate Professor Joseph Bardin. Through his work in the UMass Quantum RF Group, Boynton says, "I got to see first-hand the power of what we can do using electronics as tools. I also came to appreciate the depth of my own ignorance. This helped me see that if I wanted a career in circuit design I would need to learn more." Boynton's time in the Bardin lab also resulted in two published academic papers, which is rare for an undergraduate.

This is where Cornell Engineering comes into the story. Boynton had seen some on-line lectures by Cornell Associate Professor Alyosha Molnar. "I could see that Al was very creative in his research and had expansive ideas about what is possible using electrical engineering." Boynton sought Molnar out at a conference in California and the two found a lot in common. Based on his interactions with Molnar, Boynton felt even better about having applied to Electrical and Computer Engineering (ECE) at Cornell.

He visited campus and says, "Cornell felt radically different from other schools I visited. People here were very interested in engaging with ideas and it didn't feel like big egos were an issue. I got the sense that the underlying approach at Cornell was 'Let's spend some time thinking through things together and see what kind of interesting ideas we can come up with.'"

Zach Boynton

Boynton started his Ph.D. studies at Cornell in 2015. In the five years he has been here his work has slowly shifted to reflect more of his own interests and questions. "Originally, I was working on a radio project Al and Professor Alyssa Apsel had going with Google. And now I am raising my own questions and studying them. Al has been very encouraging of me to come up with my own ideas. It is immensely motivating to be working on something that feels like it is my own."

The work Boynton does now is focused on the broad category of interference-tolerant communications systems. The picture people paint of a hyper-connected future where everything has access to the internet presents challenges at every level, from the systems themselves, to the materials used in the circuits, to the networks conveying the signals. "My work is aimed at figuring out how to push communications into the ubiquity and capacity society is shooting for," says Boynton. "I want to give people tools to change how they interact with the world around them."

Boynton is planning to graduate with his Ph.D. in August of 2020. At that point he hopes to explore what engineering might look like in the industrial realm. "I have seen research in the academic world now," says Boynton. "I want to get a sense of how researchers in industry negotiate the fact that, at the end of the day, something needs to be produced. Your work can't be driven strictly by your own curiosity and research interests."

When he is not thinking about device ubiquity and its attendant challenges, Boynton is a volunteer assistant coach for Cornell's fencing team. "Fencing is something I have been doing for fifteen years," says Boynton. "It is an absolute treat to be working with the team here. I have learned so many important lessons about how to work as part of a team, how to talk with people, and how to build culture. I love it."

PROPELLED INTO SUSTAINABLE TRANSPORTATION

Alec Wyatt '21 came to Cornell with an interest in building a more sustainable transportation infrastructure. "What brought me to engineering in the first place was based in sustainability," he said, "and it was a focus on renewable energy that brought me to electrical engineering."

He soon discovered a project team dedicated to reimagining transportation, Cornell Hyperloop. "A whole new means of transportation like the Hyperloop—that was immediately interesting to me," Wyatt said. "I saw it as an opportunity to step into the world of designing new sustainable transportation systems."

Joining Cornell Hyperloop brought Wyatt to the Emerson Manufacturing Lab in the basement of the newly renovated Upson Hall, a sprawling facility of tools, parts, and electronics where project teams set up shop.

"I very quickly realized that this was a really special part of the engineering education here. It was unlike anything I had seen anywhere else," Wyatt said, "Project teams allow you to go beyond the classroom, actually put your skills to practical use, and learn how to do things a lot more like what you're going to be doing at a job someday."

Cornell Hyperloop's goal is to build a pod ready to be entered in the SpaceX hyperloop challenge, Elon Musk's competition designed to inspire and energize development in this revolutionary transportation concept. And although this year's iteration of the challenge has likely been derailed by the COVID-19 pandemic, the team is still hard at work.

"Hyperloop will be going virtual," Wyatt said by email. "We need to shift our mindset from building the pod physically to building the pod on paper. There's a lot left to do to prepare our Final Design Review, which is what will allow us to compete the next time the competition arrives."

Alec Wyatt '21

As the electrical team lead, Wyatt manages the group responsible for powering all the systems on the pod including battery design, motors, sensors, and the software that receives and displays data in real time while the pod speeds down the track.

"There are temperature sensors to ensure the battery and motors are within safe operating limits," he explained, "and infrared proximity sensors to make sure that we're braking at the appropriate time within the tube, and an assortment of others that we will include or not include depending on what we need in our design."

The competition parameters give teams a lot of freedom in pod design. They are given the inside diameter of the tube and the specifications of the rail on which the pod rides. "How we propel the pod down that rail, how we brake at the end of it—everything we do as far as the interaction inside the tube is our design," Wyatt said.

In a fortuitous extension of his work with Cornell Hyperloop, Wyatt will be heading to Redmond, Washington for an internship at SpaceX this summer. He'll return to Ithaca for his senior year and then transition to the M.Eng. program in Electrical and Computer Engineering.

"That was part of what really brought me here to Cornell," he said. "I was really excited about the option to do a fifth year of project work and additional classwork, and the M.Eng. program looks very much aligned with what I'm interested in doing, the opportunity to get more of that hands-on practical experience."

His work with the hyperloop project team has shaped Wyatt's educational experience and given him a plan for the future. "The opportunity to work together with peers who are as excited as I am and doing something bigger than one person could accomplish is very exciting," he said. "We can be at the forefront of pushing for better, more efficient and sustainable transportation."

ECE AWARDS AND HONORS

Jayadev Acharya, assistant professor, received the Best Paper Award at the 31st International Conference on Algorithmic Learning Theory (ALT 2020). The paper, "Optimal multiclass overfitting by sequence reconstruction from Hamming queries," was co-authored by Ananda Theertha Suresh, a research scientist at Google, and provides a resolution to the problem of overfitting in machine learning.

Khurram Afridi was promoted to associate professor with indefinite tenure.

In addition, Afridi's proposal, "Dynamic Capacitive Wireless Charging System for Autonomous Material Handling Vehicles," was selected to receive funding through the Toyota Material Handling North America (TMHNA) University Research Program.

A similar proposal, "Dynamic Capacitive Wireless Charging System for Electrified Vehicles," was selected for Cornell Engineering's annual Scale-Up and Prototyping Awards, providing teams with funding to commercialize startup technologies.

David Albonesi, professor, was named Associate Director of ECE.

Albonesi's 1999 paper entitled "Selective Cache Ways: On-Demand Cache Resource Allocation" has been recognized as one of MICRO's most influential publications of the last half century, receiving the MICRO Test of Time (ToT) award presented during the IEEE/ACM International Symposium on Microarchitecture.

Albonesi also received the Ruth and Joel Spira Award for Excellence in Teaching.

Alyssa Apsel, professor and ECE Director, was named an IEEE Fellow, recognized for her research in power-aware mixed signal circuits and design for highly scaled CMOS and modern electronic systems.

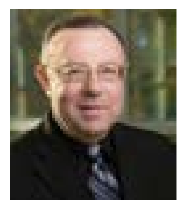
Christina Delimitrou, assistant professor, was selected as a 2020 Alfred P. Sloan Research Fellow in Computer Science. With the award, Delimitrou's team aims to explore how to apply machine learning techniques to emerging hardware and software trends in cloud computing, such as hardware accelerators and microservices.

For the second year in a row, Delimitrou received a Google Faculty Research Award to address the performance implications of new cloud programming frameworks.

DeathStarBench, an open-source benchmark suite for microservices from Delimitrou's group received an IEEE Micro Top Pick Award for the most significant papers based on novelty and long-term impact from the architecture conferences of 2019. Delimitrou's Ph.D. students Yu Gan and Yanqi Zhang were co-authors.

Delimitrou received the Douglas Whitney '61 Teaching Award from Cornell Engineering.

Ziv Goldfeld, assistant professor, received a Computer and Information Science and Engineering (CISE) Research Initiation Initiative (CRII) award from the National Science Foundation for his project titled "New Paradigms in Generalization and Information-Theoretic Analysis of Deep Neural Networks."



Zygmunt Haas, professor emeritus, was selected as a Fellow of the Institution of Engineering and Technology and a Fellow of the European Alliance for Innovation.

Debdeep Jena, professor (MSE, ECE), received one of Cornell Engineering's annual Scale-Up and Prototyping Awards for his team's proposal, "Aluminum Nitride-based Power Amplifiers for Enhanced Radar Object Detection Range." Their goal is to design and fabricate a first generation of AlN-based amplifiers at the Cornell Nanoscale Science and Technology Facility. Jena's Ph.D. students Austin Hickman and Reet Chaudhuri were co-authors of the proposal.

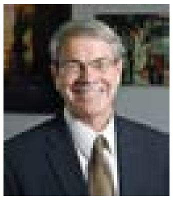
Jena also received a 2020 College of Engineering Research Excellence Award for his work exploring the fundamental limits of semiconductor devices using deep understanding of the theory of electron transport, electron-phonon interactions, light matter interactions, correlated electron behavior, and topological aspects of condensed matter physics.

Daniel Lee was promoted to professor with indefinite tenure.

José Martínez, professor, will serve a two-year term as the next Associate Dean of Diversity and Faculty Development. The position is the key diversity and faculty affairs officer in the college and oversees faculty development, the hiring process, promotions, tenure cases, and all diversity efforts at the faculty level. The position also oversees college-wide efforts to support students from historically underrepresented groups in engineering, and includes serving as a member of the College's senior leadership team.

Alyosha Molnar, associate professor, received the Mr. & Mrs. Richard F. Tucker Teaching Award from the College of Engineering.

Kirstin Petersen, assistant professor, was honored with a Packard Fellowship for Science and Engineering from the David and Lucile Packard Foundation for research involving the design and coordination of large robot collectives to achieve complex behaviors beyond the reach of a single robot. Petersen plans to use the Packard funds to design a completely autonomous collective of at least ten robots capable of constructing and maintaining a structure over many weeks.



Clifford Pollock, professor, received the Ruth and Joel Spira Award for Excellence in Teaching.

Mert Sabuncu, assistant professor (ECE, BME), received an NSF Early CAREER Award to fund the development of new machine learning-based tools to analyze brain images. The project will advance existing artificial intelligence research to address large-scale image analysis and the new tools will then be used to map genetic effects on human brain morphology in UK Biobank data.

Sabuncu received a 2020 College of Engineering Research Excellence Award for his work at the intersection of image processing and machine learning, with an application focus in healthcare and neuroscience.

Edward Suh, professor, was named an IEEE Fellow, recognized for contributions to the development of secure hardware circuits and processors.

Suh, along with professor Lang Tong, received a $1.2m award from the National Science Foundation under the Cyber-Physical Systems program for their multidisciplinary project titled "High-Fidelity High-Resolution and Secure Monitoring and Control of Future Grids: a synergy of AI, data science, and hardware security."

Christoph Studer was promoted to associate professor with indefinite tenure.

Visit the ECE website for the latest faculty and student news, awards and spotlights.

ece.cornell.edu/ece/news

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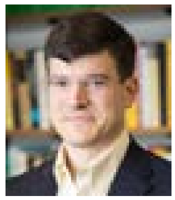
ECE AWARDS

Kevin Tang was promoted to professor with indefinite tenure.

Lang Tong, the Irwin and Joan Jacobs Professor of Engineering, received a Best Conference Paper Award at the 2019 IEEE Power & Energy Society General Meeting (PESGM) for the second year in a row. The paper, "Coordinated Transaction Scheduling in Multi-Area Power Systems with Strategic Participants," addresses market challenges arising from operating the interface between independent system operators using game-theoretic tools.

Tong, along with Professor Ed Suh, received a $1.2m award from the National Science Foundation under the Cyber-Physical Systems program for their multidisciplinary project "High-Fidelity High-Resolution and Secure Monitoring and Control of Future Grids: a synergy of AI, data science, and hardware security."



Aaron Wagner, professor, was named an IEEE Fellow, recognized for research in information theory, especially compression, feedback communication, security, and quantum information.

Wagner received a Computer and Information Science and Engineering (CISE) Computing and Communication Foundations (CCF) award from the National Science Foundation for his project titled "A Theoretical Foundation For Practical Communication with Feedback."

Huili Grace Xing, the William L. Quackenbush Professor of Electrical and Computer Engineering (MSE, ECE), was appointed to a two-year term as Associate Dean for Research, Entrepreneurship, and Graduate Studies for the College of Engineering.

Xing has been elected Fellow of the American Physical Society (APS) by the APS Council of Representatives upon the recommendation of the APS Division of Condensed Matter Physics (DCMP).

Xing received one of Cornell Engineering's annual Scale-Up and Prototyping Awards for her team's proposal, "Aluminum Nitride-based Power Amplifiers for Enhanced Radar Object Detection Range." Their goal is to design and fabricate a first generation of AlN-based amplifiers at the Cornell Nanoscale Science and Technology Facility.

Qing Zhao, the Joseph C. Ford Professor of Engineering & Director of Graduate Studies for ECE, was named to the 2020 Class of Distinguished Lecturers by the IEEE Signal Processing Society (SPS).

Zhiru Zhang, associate professor, received the Ruth and Joel Spira Award for Excellence in Teaching.

Ph.D. Student Awards and Honors

Brandon Regensburger (Afridi Lab) was awarded the Best Presentation Award at APEC 2019 on March 21. The presentation was on his paper "High-Efficiency High-Power-Transfer-Density Capacitive Wireless Power Transfer System for Electric Vehicle Charging Utilizing Semi-Toroidal Interleaved-Foil Coupled Inductors."

Kevin Lee (Jena Lab) received the best student poster award at the 77th Device Research Conference held at University of Michigan, Ann Arbor, in June 2019.

Reet Chaudhuri, ECE Ph.D, and **Samuel James Bader**, AEP Ph.D. (Jena/Xing Group) reported the first hole doping arising from symmetry breaking in GaN/AlN without impurity dopants. This phenomenon was first predicted by Cornell researchers about 20 years ago.

Wenshen Li (Xing Lab) was invited to give a talk at the ECS annual meeting on his Ga2O3 power transistors.

Aobo Chen (Monticone Lab) received an Honorable Mention at the Student Paper Competition of the 2019 IEEE International Symposium on Antennas and Propagation with the paper "Ultra-compact wave-based solvers for fractional-calculus equations."

Yingjie Bi (Tang Group) received the ECE Outstanding Thesis Research Award. His research proposes new methods to analyze the performance of algorithms for solving nonconvex optimization problems.

Xiaonan Hui (Kan Group) received the ECE Outstanding Thesis Research Award. His work work is focused on investigating the harmonic RFID system, from hardware to protocols for vital signs sensing, indoor localization and imaging.

To all the healthcare workers caring for our community

Thank You

The clinical staff members currently at the forefront of Cornell Health's fight against the spread of coronavirus urge community members to stay home. Photo by Jennifer Austin/Cornell Health.

Visit Cornell Engineering's website for Novel Coronavirus (COVID-19) Resources and Updates

engineering.cornell.edu/coronavirus

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