ECE RESEARCH ON THE CUTTING-EDGE OF CIRCUIT DESIGN

FUTURE CURRENT: ECE RESEARCH ON THE CUTTING-EDGE OF CIRCUIT DESIGN

CONNECTIONS
Alumni gifts provide critical financial assistance for our students. In today’s economy, more students and their families are faced with economic hardships. We remain unwavering in our commitment to admit outstanding students who demonstrate intellectual potential, strength of character, and a love of learning, regardless of their ability to pay. We endeavor to make a Cornell experience affordable to all admitted students. It is alumni like you who help to make this possible.

Alumni gifts also help us attract the finest faculty. We must compete with other top engineering schools to attract and retain these outstanding individuals. Your gifts help to equip modern research labs and support our outstanding graduate students, making Cornell a top contender when competing for the best and brightest faculty.

Alumni gifts are essential in providing top-notch facilities. The importance of well-equipped labs for teaching cannot be underestimated. Such labs are where students gain their hands-on experience, giving them an edge in the job market. Every little bit matters—even a few hundred dollars can put a piece of equipment on a lab bench featuring the donor’s name. Likewise, ECE faculty and students depend upon technology to enable effectiveness and efficiency, as well as adequate meeting spaces, which facilitate collaboration to generate and grow ideas. For example, we now offer our students an M.Eng lounge, which fosters key interactions, and other meeting places for students are being designed. You, our ECE alumni, are critical in supporting these facilities.

Whether you are able to make a large gift or a small one, we need your support for our students, faculty and facilities. Every gift matters. Individually and collectively, you are instrumental in making Cornell ECE a strong, vibrant school that produces fine engineers and essential knowledge.

For more information about supporting ECE:

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DIRECTOR'S REFLECTIONS:
CLIF POLLOCK

This summer, I went backpacking with a group of 16-year-old boy scouts. We went rim to rim across the Grand Canyon and then over 100 miles in northern New Mexico. It was intense, because it’s no secret that I am not 16 anymore. But what struck me most about the hike was the different expectations: I went for the journey, the boys went for the destination.

Even as we hiked through spectacular scenery, the boys’ goal seemed to be to get to the next campsite as quickly as possible. I mostly recall breathing hard as I was looking at the boots on the trail in front of me, trying to keep up with these young men.

I often visit other schools to review their programs, and what I usually see, metaphorically speaking, is the same rush to the destination. Their graduates seem thoroughly trained in the latest design tools and can probably be productive at their first job within 30 minutes. But a few years later when technology changes, these poor people are doomed to management!

Cornell students are different. Our graduates may not be as conversant with the latest versions of a CAD suite, but they do understand the timeless fundamentals of the tools and can quickly learn and adapt as technology advances. We take our students on the journey. They end up at the destination, but the richness of our trip is what sticks with them.

In the alumna article on Page 2, Sarah Fischell B.S. ’78, M.Eng ’79, concisely summarizes the experience:

“Cornell totally prepared me to ask the right questions, to absorb new technical knowledge and to work with a group to define problems and find solutions to those problems. These skills were key to success in my engineering career.” Those are the skills each of you learned, that came from the long and often arduous journey of discovery through tough homework, ambitious design projects, endless labs and the constant sense of gasping for air as each professor pushed your class to particular new heights.

A good curriculum makes graduate students look forward 20 years, and ensures undergraduates see nothing older than 20 years. Of course, things like Maxwell’s equations are 160 years old and are still taught, but we put them in context of today’s applications such as terahertz radiation sources, fiber optic waveguides or high-k dielectrics. This requires constant discussion and updating of the curriculum. When I arrived here, every student was required to take quantum mechanics. At that time solid state electronics was changing the world as we knew it, devices like lasers were being employed in lots of new situations and nanotechnology was a new emerging field. Today, quantum mechanics still serves students who want to master solid-state electronics or quantum electronics, but it is no longer required of all.

As a field matures, the level of abstraction increases. This moves detail behind an interface, and allows wider use with less specific knowledge. For example, instead of using assembly language to program the microcontroller like we did in 1980, today almost any high school student can download an “IDE” (integrated development environment) to program a microcontroller and within minutes have LEDs blinking to all sorts of input. Does the high school student understand the device as well as we did? Not even close! But abstraction has increased the overall productivity surrounding the tool.

We constantly discuss where the field is going, adjusting our research and our curriculum. The last 50 years have been a spectacular success for our field. The integrated circuit is the enabling tool of high tech, making everything from smart phones to autonomous devices possible. Our cellular networks, which use everything from lasers and fiber optics to information theory, now support the Internet, e-commerce and social networks that are changing the way people interact. The world is entering unexplored territory on the social science domain. How should we prepare the next generation of ECE students to participate and lead in this new domain?

This brings me back to the journey. Cornell students have always mastered the ability to ask and be asked tough questions, tackle tough issues in a logical way and debug problems. I am not worried about their destination. They will go out and influence the world in ways we have never predicted.

I’d enjoy hearing your thoughts on where you think the future of ECE will be, and what you think we should be teaching students today. Please send me an email at crp10@cornell.edu if you’d like to suggest some new legs to this journey.

Sincerely,

Clif Pollock
When Sarah Fischell B.S. ’78, M.Eng ’79, first stepped foot inside Bell Labs—one of the world’s foremost technology research institutes—she knew she was in a place of legend. It was 1979 and the young Cornell graduate had just been offered a job with an organization that today is credited with the development of the transistor, the laser, the solar cell, several computer program languages, 14 Nobel Prize Laureates and even a GRAMMY Award winner in sound technology.

Fischell had been hired as a systems engineer to improve voice and data communications services for business customers of the AT&T Network. “I was able to play a key role in the network implementation of many obscure network capabilities and a few recognizable ones, including caller ID and number portability,” said Fischell.

Fischell also served as one of AT&T’s on-campus recruiters, often recruiting students from Cornell. She used the same One Year On Campus program she participated in as a tool to attract prospective employees, and she says it was an important development tool for Bell Labs. “As a manager, I’d rather have a newly minted engineer who just completed a bachelor’s degree go away to school and get that one year of experience than take them into my operation while we were trying to actually get stuff done,” said Fischell. “It was worth it to me to pay to have somebody else get them through their first big project and help them build some engineering intuition.”

Fischell spent 20 years at Bell Labs and AT&T. Over the course of that time, the research lab and the overall corporation went through many structural changes to adapt to a changing regulatory framework, competitive landscape and technology market. “It was a good place to work—challenging technically and intellectually, with great colleagues. I was reasonably successful and happy there,” said Fischell. “By the mid to late 1990s, it was a tough industry to be in. While it was an interesting engineering challenge to continually increase capacity while continually decreasing unit cost, the pressure on cost-cutting was no fun.”

After leaving Bell Labs in 1998, Fischell became a telecommunications consultant before joining her family’s biomedical engineering enterprise. She served as co-founder, CFO and director of Afmedica, Inc., a medical device company that focused on pharmaceuticals and devices to prevent complications that occur following surgery.

Fischell retired in 2008 but stays busy with various volunteer activities. She also remains heavily involved with her alma mater as director-emeritus for the Cornell Engineering Alumni Association, member of the Engineering College Council and member of the Cornell University Council. She and her husband, David Fischell ’75, M.S. ’78, Ph.D. ’80, are also passionate supporters of the Big Red Marching and Pep Bands. The couple spearheaded and was a lead donor for the bands’ new 6,400-square-foot facility behind Schoellkopf Crescent.

Attributing her professional success to her electrical engineering education, Fischell says Cornell provided a foundation for her work ethic and critical thinking skills. “Even in the early years of my career, it was a rare day at work when I could apply the specific analytical and modeling techniques I had learned in class. However, Cornell totally prepared me to ask the right questions, to absorb new technical knowledge and to work with a group to define problems and find solutions to those problems,” said Fischell. “These skills were key to success in my engineering career.”

—Syl Kacapyr
Over the past several years, Senior Research Associate and Lecturer Carl Poitras has taught and co-taught several different ECE courses including ECE 3030: Electromagnetic Fields and Waves, ECE 3100: Introduction of Probability, ECE 3250: Mathematics of Signals and Systems, and ECE 4300: Lasers and Optoelectronics. This fall he taught ECE 4110: Random Signals in Communications and Signal Processing.

In the spring 2014 semester, Poitras began teaching ECE 3400: ECE Practice and Design, and in spring 2015 implemented changes to the syllabus to include engineering design contests and teamwork components. With David Albonesi, ECE professor and associate director, and under the expert guidance of Bruce Land, senior lecturer, Poitras launched a new hands-on project to make the course more engaging and challenging. Bruce Land worked closely with ECE M.Eng and undergraduate students Olivia Gustafson, Scott Zhao, Alex Jaus, and Jay Fetter to create a prototype for a maze-mapping robot that eventually evolved into a complex robot with multiple functionalities. In the course, students produce a robot and use design process strategies and teamwork to design a system that meets specific requirements and electrical and computer engineering constraints. The project tests the students’ knowledge, skills and teamwork capabilities.

“This spring’s course was the first to include the robot project, and we learned a lot that will carry over into the future,” said Poitras. “The course was very well received, a huge hit really. The students especially relished the ability to show off their robots during the competition in Duffield Atrium on ECE Day. And they really enjoyed dunking Bruce Land and me in the dunk tank after they competed.”

Visit the links below to watch videos of the course and ECE Day.

http://www.ece.cornell.edu/ece/news/spotlights.cfm?s_id=542

http://www.ece.cornell.edu/ece/news/spotlights.cfm?s_id=541

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— Carl Poitras
“It was a no-brainer.” That’s how several electrical engineering majors reacted 50 years ago when they found out they could opt to earn a master’s of engineering degree (M.Eng EE) in only one semester.

They were the beneficiaries of a sweeping change the College of Engineering made after the fall of 1960. The college replaced the five-year bachelor program with a heavier, pre-professional four-year curriculum, and began offering a separate master’s degree that could be completed with 30 credits.

For the class caught in the transition, the administration made an exception: Students could earn an M.Eng EE by applying 15 credits from their fifth year to the degree and taking 15 more credits the subsequent semester. For many, it was an easy decision. Seventy-eight students opted in.

“It was a no-brainer to get a master’s degree for 15 credits,” remembers Arthur Levitan BEE ’65, M.Eng EE ’66.

“Whereas other master’s programs might have taken a year or two years, we had paid our dues by being there for five years,” recalls Robert Gray BEE ’65, M.Eng EE ’66.

“The transition was totally seamless. The familiarity of the campus, the faculty and the courses were a big plus,” said Tom Pazis BEE ’65, M.Eng EE ’66.

Fifty years later, some 3,258 engineers have earned an electrical and computer engineering M.Eng degree from Cornell. They include key industry players such as Justin Rattner B.S. ’70, M.Eng ’72, former CTO of Intel, and Lee Wang B.S. ’97, M.Eng ’98, COO of WeddingWire and co-founder of Blackboard, Inc. Although the M.Eng program’s curriculum and student population have shifted significantly over time, the degree still prepares engineers for work in industry and gives them a leg up in the job market. “The original intent was to increase the depth of knowledge of people who went into industry,” said Peter Jessel BEE ’65, M.S. ’66, director of the M.Eng program. “And that’s still what it is today.”

The M.Eng was and still is a rare beast in engineering higher education, says Clif Pollock, ECE director and the Ilda and Charles Lee Professor of Engineering. Many universities offer a master’s of science degree as a stepping stone to a Ph.D., but no Cornell peer has a one-year, 30-credit terminal degree that offers students a master’s project and the freedom to choose courses to fit their needs, Pollock says.

From the beginning, M.Eng coursework was customizable and cutting-edge. Bruce Wagner BEE ’65, M.Eng EE ’66, remembers taking courses in the new field of digital logic with the famed electrical and computer engineering professor, Hwa C. Torng M.S. ’58, Ph.D. ’60, who would later go on to develop high-speed microprocessors. When Wagner visited Bell Labs for an interview during January of his master’s year, he saw researchers working on the same projects he was learning about in Torng’s class. “When I told them I was learning all about it, they were excited. Coming from Cornell, with that right-up-to-date education, was big for them,” Wagner said.

Decades later, Meg Walraed-Sullivan B.S. ’03, M.Eng EE ’04, tailored her M.Eng program to take mostly computer engineering classes—a move that helped in her decision to get a Ph.D. in computer science. She credits Associate Professor David Delchamps and Senior Lecturer Bruce Land with encouraging her to stay in the field, she said. “They really looked out for me and were in my corner. You’d expect that at any school, but they went above and beyond.”

Like customizable, state-of-the-art courses, the master’s project has been a bedrock component of the M.Eng since its inception. Students work alone or in groups during the three- to seven-credit required course to define an unstructured technical problem and create and execute a solution. Through the mid-1970s, candidates with sufficient design experience in industry at the time they entered the M.Eng program could convert three credits of a design project...
for three credits of additional advanced course work. “By the late ’70s that idea lost favor,” said John Belina B.S. ’74, M.Eng EE ’75, former M.Eng program director.

Today, 80 percent of the projects stem from faculty research. Recent projects have ranged from real-time face detection and tracking to a wearable, wireless motion-sensing system for hip rehabilitation and a portable micro-hydro system aimed at providing inexpensive power for rural India.

Master’s projects give students a chance to demonstrate their ability to think on their feet. “Recruiters just love it,” Pollock said. “On a project, something breaks or doesn’t arrive, a piece of technology fails, your teammate gets sick. It’s real life. In a homework assignment, those things aren’t going to happen.”

The projects also often help graduate students figure out a career path. In her project, Sarah Fischell B.S. ’78, M.Eng EE ’79, worked with geology faculty to do unattended data recording for earthquakes in New Guinea’s mountains. At the time, the state of the art was low-capacity digital tape. She analyzed the options for data compression and detection, rather than simply what recorder they should use. “That experience taught me I was happy at this more macro level, where I was deciding the approach we were going to use,” she said. Fischell went on to use that big-picture thinking while working in systems engineering at AT&T and Bell Labs (see Page 2 for Fischell profile).

The M.Eng became so valuable to corporations that several began programs...
in the late 1960s and early 1970s through which they paid employees to get the degree. “They wanted to scoop up smart people out of the best engineering colleges,” said Fischell, who was hired as an undergraduate by Bell Labs, which offered to pay for her to stay at Cornell and receive her M.Eng. “The program was a tremendous incentive. I was dying to take all these computer engineering classes that just didn’t fit into my undergraduate program. And I got to take them,” Fischell said.

She wasn’t among the first women to earn the degree, but female M.Eng students were still a rarity in the 1970s. “Professors didn’t quite know how to deal with girls—not that there was any special way to deal with girls—but they didn’t know that at the time,” Fischell remembers. Today the gender landscape is much different. This fall, more than one-third of the M.Eng class is female, with 70 women and 127 men enrolled.

The student population has changed even more dramatically in terms of nationality and undergrad background. Back in 1966, all M.Eng EE students were men who had graduated from Cornell. Today, about 80 percent of M.Eng students come from other universities, and about 70 percent are foreign students, most from China and India.

It’s an inverse proportion to the economy, said Jessel. When the economy is strong, Cornell graduates can get a good job after receiving their bachelor’s degree. On the other hand, the M.Eng offers the cachet of a Cornell engineering degree and the quality year of post-

M.Eng students with Senior Lecturer Bruce Land at ECE Day 2015

“WHEN I TOLD [BELL LABS] I WAS LEARNING ALL ABOUT IT, THEY WERE EXCITED. COMING FROM CORNELL, WITH THAT RIGHT-UP-TO-DATE EDUCATION, WAS BIG FOR THEM.”

— Bruce Wagner BEE ’65, M.Eng EE ’66

M.Eng students present their project during ECE Day 2011
suggestions or critiques for our projects,” he said. M.Eng students also get the benefit of learning from their international peers, noted Ding, whose lab partners came from India and had worked in industry prior to enrolling in the M.Eng. “We complimented each other’s knowledge base. I learned a lot about what their jobs were like and what they think of the industry, and we got to know each other’s cultures,” he said.

In 2005, the department took a hard look at curriculum and, based on industry demands, decided to further emphasize professional issues such as communication, team work, project planning and management and deadlines, on top of the rigorous courses. Some courses, such as “Managing and Leading in Organizations” and “Managing Operations,” are offered through the Johnson Graduate School of Management. The updated curriculum catalyzed a significant increase in applications, which has continued to grow annually, Pollock said. This year’s class numbers 143 students, nearly twice the enrollment in 1966. An additional 54 students are staying for a third semester, an increasingly common practice.

Thanks to this combination of technical and practical skills, the placement rate among M.Eng graduates has remained high since the early years. Even in 2013, when the job market was rough, about 75 percent of M.Eng graduates had jobs before they left Cornell. The fact that most were foreign nationals makes that rate even more impressive, Pollock said, because it means their employers were willing to manage visas and other documentation required to allow them to work. “The fact that they’re getting jobs means they’re a pretty good product,” Pollock said.

During the next 50 years, the M.Eng program will continue to evolve with technology, Jessel said. For example, an increasing number of students are taking classes online, and the M.Eng could shift toward more distance-learning. But much would be lost, Jessel said. “One of the objectives is to teach graduate students the problem solving skills and group skills that you don’t teach undergraduates, and if it’s only through online courses, that won’t be delivered.

“What we teach now is very different, how we teach is very different” compared to the first classes in 1966, Jessel said. “But why we’re doing it has remained pretty much the same.”

—Susan Kelley

“The original intent was to increase the depth of people who went into industry. And that’s still what it is today.”

—Peter Jessel, director of the M.Eng program
The endless objective of producing a more powerful and efficient microchip grows more challenging as electrical engineers reach new limits in key design features. At Cornell Engineering’s School of Electrical and Computer Engineering, faculty are looking at electronic circuits in a different way, not only to improve performance, but to create new devices that can make life more healthy, productive and enjoyable.

ANALOG CIRCUITS

Electronic circuits have grown so powerful, miniature, and in many cases, affordable, that they are creating what is known as the Internet of Things—a network of “smart” devices that can communicate and exchange data with each other. Everything from mobile phones and televisions to light bulbs and coffee makers can be programmed wirelessly and collect data about usage and user preferences. In order for humans themselves to become part of this network, circuits must be able to sense analog information such as a heartbeat, a step or a breath, and convert it into meaningful, digital data.

While devices like smart watches have been successful in wirelessly tracking our movements and even basic vital signs such as heart rate, Professor Alyssa Apsel is building circuits that can track something much more difficult: neurochemicals. The ability to monitor neurochemicals such as dopamine can give researchers new insights into social behaviors and the ability to regulate neurodegenerative diseases such as Parkinson’s.

A common neurochemical sensing technique in rats—fast-scan cyclic voltammetry—allows for real-time collection of neurodata, but requires biosensors that are tethered to a computer system that can translate and digitize the data. This restricts the animal’s movement and dictates when and where data can be acquired. The solution being developed by Apsel and Carlos Dorta-Quinones Ph.D. ’14 is a low-cost, low-power chip that can be implanted in a rat’s brain and allows it to move freely while transmitting data wirelessly.

The challenge lies in the performance of the chip, which must be able to read dopamine levels while still having enough power to communicate the data to a remote system. In order to improve the range in which the circuit can transmit data, Apsel and Dorta-Quinones developed a new compressive analog-to-digital converter that was able to ignore unwanted data and focus on the small amounts of dopamine being produced by the rat. “With this we could decrease the amount of data being sent wirelessly during neurochemical monitoring experiments. We paired this with our existing radio technology that let us build a full system that was about 10-times more power-efficient than previously published work and did the same thing,” said Apsel.

The implications are easy to imagine. One day, doctors may be able to monitor a patient’s neurochemical balance noninvasively and in real-time, without the patient ever leaving her home. “I think circuits will continue to blend with our environment and actually become less obvious in our daily life. Our devices will become better and better at adapting to us and our needs,” said Apsel, on the future of circuit design in general.

Similarly, Associate Professor Ehsan
Afshari is thinking about analog circuit design in an entirely new way in order to more effectively monitor human health. Afshari has developed a method of generating terahertz signals on a silicon microchip with the goal of one day replacing large and expensive machines designed to produce X-ray and terahertz signals. Medical imaging devices, such as body scans that can detect skin cancer, may one day be a hand-held technology for consumers, and could even be embedded in smartphones.

The challenge of producing a terahertz signal on a silicon metal-oxide semiconductor—the common transistor found in many microprocessors and data converters—is that the transistor’s maximum oscillation is below the terahertz frequency band. In other words, the transistor can’t exchange electrons fast enough to generate a terahertz signal that can be tuned by the circuit.

To address this problem, Afshari has designed a circuit with multiple oscillators that can harmonize together and combine their power to create a higher-quality signal within a narrow band of the terahertz range. It’s a task that’s easier said than done, but using this method, Afshari and his team of researchers have managed to produce a 180-milliwatts signal at 0.32 terahertz and a 50-milliwatts signal at 0.34 terahertz, both “with the ability to change the frequency and steer the direction of the radiation,” said Afshari.

Using this research, the team has created the first fully-integrated, coherent terahertz imaging system. “That means the transmitter and receiver are phase-locked. In simple terms, we not only detect the intensity of the signal, but we have its phase information. This results in a much higher sensitivity compared to the incoherent systems before us,” said Afshari. “So not only do we have great sources and individual components, we now have a complete coherent imaging system in our lab.”

To advance the technology, Afshari is using the same design to construct chips from materials that can handle higher frequencies, such as gallium nitride. He was recently able to generate a world-record 1-milliwatt signal at 0.22 terahertz—the most powerful signal ever from this type of integrated system. Such materials are significantly more expensive than silicon, so Afshari is also experimenting with adding more oscillators to his silicon-based circuits.

Aside from medical imaging, microchips that can produce the right terahertz frequencies could also be used for mobile security scanning and wireless transfer of large amounts of data. “With this kind of technology, we can easily envision adding terahertz imaging and communication technology to mobile phones. This means everyone can scan for certain medical issues or find certain materials,” said Afshari.

**DIGITAL CIRCUITS**

The invention of the transistor in 1947 set off a digital revolution that has seen integrated circuits continue to grow exponentially more powerful. Transistors are one of the most important elements of circuits found in all electronic devices, controlling the flow of electricity and amplifying the current. When engineers wanted more performance, the common solution has been to leverage technology scaling by integrating faster transistors in greater numbers onto a single chip.

But as today’s transistors approach near-atomic sizes, that solution is beginning to reach its limitations. Christopher Batten, assistant professor, says the performance-energy tradeoff reached a breaking point for monolithic general-purpose processors around 2005. As a result, engineers like Batten have been developing new and creative methods of providing more performance for less energy.
One of those methods is parallel computing. "The idea is instead of making a single-core processor more and more complicated, what we’ll do is go back to a simpler core and integrate two onto a chip. Theoretically, you would get twice the performance at the same energy," said Batten. But there hasn’t been an exponential growth in the amount of processors on chips. Even high-end servers typically have only 16 processors or less because it’s difficult for them to work cooperatively. “You can have 100 workers building a house,” Batten analogizes, “but you would have guys sitting around waiting or they don’t know what to do.”

So instead, Batten says to think about only 16 workers building that same house, but they work together to build small sections at a time. First the floors, then the walls, then the roof. Processors are now performing the same tasks on different data, in parallel. Add to that specialized accelerators that are specifically designed to speed the performance of each task, and you have a very powerful chip.

But to make parallel computing and specialized accelerators work, there are serious challenges, the most complex of which is where the hardware meets the software. Because the hardware is so specialized, programmers writing software code must learn how each element of the chip communicates with the rest to ensure the software’s compatibility.

Batten is working on creating new hardware-software abstractions—essentially mediators that help the software communicate with the hardware—that are clean and elegant, but still give some kind of specialization benefit.

Another researcher addressing these challenges is Christoph Studer, assistant professor, who possesses a rare mix of expertise in communication theory (methods of transmitting and decoding data) and integrated circuit design that allows him to think about the full design process and its complex symbiosis, all at once. “The engineers that just implement, they’re limited by the algorithms given to them. They cannot change the algorithms because they don’t understand the theory behind them,” said Studer, who adds that it can take years for the industry to pick up on new theoretical results. That’s opposed to the instantaneous circuit implementation of novel theoretical results.
that can occur in Cornell’s Computer Systems Laboratory.

“The key point is that the biggest saving, if you want to reduce power consumption, is by implementing the right algorithm,” said Studer. A common example is the Fourier transform—an algorithm first developed in the early 1800s as a method for analyzing the frequency contents of signals. In 1965, a much faster version of the algorithm was developed to perform the same task, and it revolutionized the STEM field. The fast Fourier transform, or FFT, is now used to transmit data wirelessly and to compress files to take up less space, among its many other applications.

Studer says efficient algorithms are becoming more important as future communication systems demand methods that require more battery power. “We’re looking at a 5G standard [for cellphones] in about five to 10 years. Unfortunately, the batteries won’t be significantly better in 10 years,” said Studer, who adds that the scaling of battery technology is much slower than that of integrated circuit technology.

Analog engineers like Apsel and Afshari, who rely on tiny, low-powered sensors and signal-processors to read and decode data from the human body, also rely on engineers like Studer, who can develop suitable algorithms that make sense of the data generated by their devices.

“Cornell is getting really good at [circuit design] because we cover the full spectrum,” said Studer, who says the research being done at the School of Electric and Computer Engineering provides a lot of potential for startup companies to form, especially with the emergence of Cornell Tech.

Batten says chip startups have great potential to contribute innovations to the circuit industry because they don’t have the luxury of working off years of built-up intellectual capital. Instead, they rely on exploring new concepts, such as field-programmable gate arrays—circuits made of reconfigurable fabrics that can be manipulated by consumers after being manufactured.

“It’s an exciting time to get into the field because industry seems open to try new things to address these challenges. Everyone is looking for ways to deal with and manage this complexity,” said Batten.

—Syl Kacapyr
In the three years that the Cornell Maker Club has existed, it has amassed a collection of useful tools and equipment, including a 3-D printer, a soldering station, a function generator, an oscilloscope, assorted hand tools and power tools and a small library of technical manuals and books. It has greatly increased the number of people participating in club activities, and has secured official status as a student-run club. The only thing it had been lacking, until now, is a permanent home.

ECE Director Clif Pollock worked with the group during the 2014-15 academic year to secure permanent space in Phillips Hall. “This new room is something we really needed,” says Club President Alex Jaus ’15. “Our original space in 211 Phillips got pretty cramped. If we wanted to cut a large piece of plywood, we had to do it at somebody’s house because there was no space in the room.”

The new space, which recently underwent a major renovation to make it better suited to the needs of the club, is much larger than the old space. “Clif Pollock and ECE have been very supportive of the club ever since day one,” says Jaus. The student that founded the Cornell Maker Club, Hanna Lin M.Eng ’14, was a biological engineer, but much of her work relied on electronics. She spent a lot of time in Phillips Hall and when she started the club, ECE Senior Lecturer Bruce Land agreed to be the faculty advisor.

Land has shown a deep commitment to hands-on projects in his own teaching and advising, and he believes in the mission of the Maker Club. “Projects are an essential part of engineering education, and they help the students understand why they are taking all the theory courses,” says Land. “The Maker Club is a social context for people to share ideas and techniques in a free-form way that is hard to provide in a class setting.”

Jaus and the current members of the Maker Club have a vision for the group: they want it to be a place where people of all levels of ability can come and everyone can learn. “People should not feel embarrassed about not knowing how to do something,” says Jaus. “We want to be a place where people can come and learn whatever it is they need to learn to get
better at the skills their projects demand. People don’t get grades for coming to Maker Club and they certainly don’t get paid. They come for the joy of making things and learning.”

The learning is not solely technical. Jaus highlights the many non-technical skills that grow through project work and membership in a club. “People learn communication and leadership skills through their interactions in the club,” says Jaus. “We also hope they’ll learn from their failures. Projects are an iterative process and if people give up as soon as they fail, they don’t learn. We want to be a safe place to fail.”

The safe place to fail (as well as succeed) will soon be open for business. The timing is good, because they’ve been busy recruiting new members at ClubFest, as well as raising excitement through their first annual Maker Workshop, which was held on Sept. 19. Membership in the Cornell Maker Club is free and interested students can join any time throughout the year. “A lot of our most active members have come to us on their own, independent of ClubFest,” says Jaus. “They come because they have a need to learn something. We do some recruiting, but often it works the other way around—people come looking for us because we have something to offer them.”

If you are interested in Maker Club, contact Alex Jaus at cornellmakerclub@gmail.com or visit www.cornellmakers.wordpress.com for more information.

— Chris Dawson
Professor Michael Spencer recently met with ECE Director Clif Pollock to discuss the devaluation of hardware and how a software-focused generation is changing the way students learn. They also discussed the ways in which the department can contribute to research improving high voltage electronics.

Pollock—I’m impressed with what you’re doing inside your Advanced Materials and Devices Lab in Phillips Hall, in particular how you and the school have discussed and chosen a path in electronic materials and devices.

Spencer—Hardware currently goes against the grain of where many people are investing. The conversation we’ve been having inside and also outside of Cornell is about the role of physical electronics in a world which is dominated by software. There’s a lot of short-term gratification because you do some interesting things with software and create an app that will define something new. But it doesn’t have the permanency of a physical electronic. It doesn’t often change the paradigm.

Pollock—Yeah. Software development doesn’t require anything close to the investments needed in time and capital that go into device development.

Spencer—I’m reading this really interesting book by Howard Gardner and Katie Davis called “The App Generation.”
They’re asking: Are these apps a boon for us to move to the next level, or are they somehow restraining creativity? One of the suggestions is that students from this App Generation take fewer risks, and they think all of the answers are on the Internet. It explores this idea of Googling everything, and I think it’s interesting when you start thinking about what that means for engineering students.

**Pollock**—You’ve mentioned software and apps. We use CAD software all the time but it’s like your apps, it can do a certain task and nothing more. Does that constrain us?

**Spencer**—To the extent that the software forces you to use the package by creating standard constructs, I think it does place constraints upon us. If you’re analyzing a laser, you have to have a multi-level system. It has population inversion, reflectivity at the end and then the software is going to crank out efficiencies and so forth. But you’ve already said that the only way you’re going to make a laser system is with a multi-level system with reflectors at the end. It precludes you from thinking about the possibility that it might be a Plasmon laser or something that doesn’t use a multi-level system. It potentially constrains you in one specific direction because it boxes you into this way of thinking.

**Pollock**—Things have changed in the span of our collective careers. When I walk down the hall today I see students sitting in front of a computer. When we were students, our desk was where we stored our books and we spent our time in the lab. Now it’s reversed.

**Spencer**—When I was a student, we would spend a lot of time in the library stacks. We would look things up. But it also became a kind of place where you could run into people and have interactions. The very act of looking things up required you to physically move from place to place. And so, I think there was more of a forced social engagement rather than now when you can put on a pair of headphones, sit down at a computer, and access almost any document you need.

**Pollock**—So are we better or worse off? In spite of all the hands-on experience I developed, today’s students do a lot more design work than I ever did. With computers, they can design with a thousand times more complexity than I ever could.

**Spencer**—Yeah, we’re getting a lot of really clever designs. But how much stuff is really shifting the paradigm? There are some very fundamental things happening, but the questions is: Are there more or less fundamental things happening now than before? Is it constrained by something else or is it truly the way people are approaching things?

I have a question for you, Clif: What is your vision for the department? I know one time you said people were always questioning you about what we’re doing in energy. Where do you see the impact?

**Pollock**—One ECE area in energy that intrigues me is high voltage electronics. You can’t buy an analog chip nowadays that isn’t programmable because it’s full of switches, which are cheap and easy to make. So, when the power network becomes switchable, I think all the smart grid stuff is going to expand dramatically. But, until we have the technology to switch and do it quickly and cheaply, I’m not sure it’s going to happen.

**Spencer**—The question about the grid—Cree* now has demonstrated a silicon carbide at 20-kilovolt device and it costs a lot of money. If you have a grid device, even if you make it work, how many are you going to need?

**Pollock**—Not too many. Maybe a dozen in a town like Ithaca?

**Spencer**—Maybe a little more than that. But it’s not like an automobile or solar
inverter where there are a lot of them. What company is going to go into that market? And that’s at the highest energy.

My first grants were in solar cell technology. Solar cell power nowadays is really coming from standard silicon devices. The price of solar energy is now dependent upon the cost of polycrystal silicon and China is controlling the cost. They’ve made it artificially low.

There’s not a lot of fundamental research, in my opinion, in an area that’s going to make an impact on something that is so cost driven. It’s almost getting to be a commodity. In terms of cell technology, I just don’t see us being able to do much to move the needle.

In terms of grid technology, that’s also an interesting question. Cree has been doing higher and higher voltage devices, slowly. It’s a slow development. The big market where they’re now finally producing devices is in silicon carbide. The big market has always been automotive, where the industry has never really been committing.

“Cree, Inc. is a multinational manufacturer of semiconductor light-emitting diode (LED) materials and devices, with its headquarters in Durham, North Carolina. Most of its products are based on silicon carbide.”

**Pollock**—You’re referring to the electric car?
**Spencer**—Yeah, that’s the big one. The power device market is in two places—600 volts and 1,200 volts. Twelve-hundred volts is right about what you need to power an electrical car. That’s where the high-power switches really have an advantage of silicon. The problem is the automotive market place is incredibly difficult to penetrate. So the only place where the power switches have been able to survive is solar inverters. That’s it so far.

**Pollock**—So this is a DC to AC conversion?
**Spencer**—DC to AC, so the power company buys back your energy. The other one that may save them is downloading power to quick-charge cars. For those remote stations, you need a high-power semiconductor device to be able to charge many amps very quickly.

But probably the biggest energy efficiency argument is this one: In our computers there’s an energy cost of going from zero to one. The switching cost. Our brain switches about two to three magnitudes of order less than that. Where do you see this anywhere else?

So if you actually go to the Google server, the power required for that is a building about the size of The Statler Hotel. It’s all wasted heat. So if you can solve the switching problem, you actually make a huge contribution to the energy situation.

**Pollock**—And that’s by just reducing the power. There’s a lot of opportunities for us. ECE could have as big of an impact there as anyone.
Average salaries right out of college 2014

$65,000
National average for CE & EE graduates

$78,826
Cornell ECE graduates

Undergraduate starting salaries

27% of Cornell ECE undergars are female

EMPLOYERS OF CORNELL ECE UNDERGRADUATES

Computer Industry: Intel, Facebook, Apple, Google, Hewlett-Packard, Microsoft, Oracle, IBM
Networking & Telecom: Cisco Systems, Verizon, Caviun, Alcatel-Lucent, Qualcomm
Data Analytics: Cataphora, Sentrana, Applied Predictive Technologies
Financial Services: Goldman Sachs, BlackRock, JP Morgan, Capital One, Deutsche Bank, Deloitte, UBS
Aerospace, Defense & Information Security: Boeing, Raytheon, Lockheed Martin, Northrup Grumman, BAE Systems, Booz Allen Hamilton
Automotive: General Motors, Toyota
Manufacturing, Technology & Semiconductors: Altera, LG Electronics, General Electric, Garmin, Analog Devices, Nvidia
Lighting: Lutron Electronics
Energy & Power: Con Edison, Southwest Power Pool
Research & Development: Sandia National Labs, Draper Labs, Jet Propulsion Lab, MITRE, Semiconductor Research Corporation, USAF
Health Care: Arcadia Solutions, Siemens AG, Athena Health
Media Services: Bloomberg, ESPN
Law: Ropes & Gray
Batten recognized with Cornell Engineering Research Excellence Award

Christopher Batten, assistant professor, has been recognized as one of seven winners of the Cornell Engineering Research Excellence Award for 2015. The award is given in recognition of his research contributions and leadership. Nominated by the school, Batten was selected by a committee of recognized senior researchers within the college. Batten leads a research group focusing on energy-efficient parallel computer architecture for both high-performance and embedded applications.

Albonesi, Delchamps, Wagner win Excellence in Teaching Awards

David Albonesi, professor and associate director of ECE, David Delchamps, associate professor, and Aaron Wagner, associate professor, have each received Excellence in Teaching Awards from Cornell Engineering. The respective awards are among the highest for teaching within the college. Nominated by faculty from the school, the recipients were selected by committees comprised of former teaching-prize winners from within the college.

Albonesi won the Ralph S. Watts ’72 Excellence in Teaching Award. His current research interests include adaptive and reconfigurable multi-core and processor architectures, power- and reliability-aware computing and energy-efficient smart buildings.

Delchamps won the Michael Tien ’72 Excellence in Teaching Award. He is interested in applying techniques from dynamical systems theory, game theory and stochastic processes to the modeling, analysis and design of natural and artificial complex multi-agent systems.

Wagner won the Douglas Whitney ’61 Excellence in Teaching Award. He studies problems at the intersection of information theory and other fields including networking, statistics, queuing theory, security, computational linguistics and learning.

Suh and Cornell team to work with NSF on cybersecurity program

Ed Suh, associate professor, and Andrew Myers, professor of computer science, have received a share of grants totaling more than $3 million as part of the National Science Foundation’s Secure and Trustworthy Cyberspace program. Suh and Myers will combine their expertise in hardware and software, respectively, to create a system in which both work together to create security using software to track information flow through hardware. As part of the project they will design a new high-performance microprocessor with verified-secure information flow. Their work could have a significant impact on how computing systems are designed and could make the next generation of computing devices and platforms inherently more secure.

Blackburn earns 2015 Frank and Rosa Rhodes Scholarship

Brecken Blackburn (ECE) was selected as a 2014-2015 Frank and Rosa Rhodes Scholarship recipient from Cornell Engineering. She was selected for this award based on her contributions to the college through academic achievement and leadership.

Bose named Atkinson Postdoctoral Fellow in Sustainability

Subhonmesh Bose, ECE Postdoc, has been named to the inaugural class of Atkinson Postdoctoral Fellows in Sustainability. We can’t control when the wind blows or when the sun shines, which makes renewable resources like wind and solar a challenge to integrate into the power grid.
When the supply side is highly variable, how do we reliably procure and pay for power? Bose’s research will develop a mathematical framework and simulation platform to answer this fundamental question.

**Manohar named Weiss Fellow**

Rajit Manohar, professor of electrical and computer engineering, along with Nina Bassuk, professor of horticulture and Marie Caudill, professor in the division of nutritional sciences, are the newest recipients of Stephen H. Weiss Presidential Fellowships in recognition of their teaching of undergraduate students. Former university President David Skorton announced the Weiss Fellows on Jan. 30 at a meeting of the Cornell Board of Trustees.

**Nwana receives Bouchet Research Award**

Amandy Nwana, a Ph.D. candidate in ECE and a Cornell Sloan Fellow, won the Bouchet Graduate Honor Society’s Research Award in the Sciences for his research presentation at the Bouchet Conference in April.

**Xing, Jena promoted to full professors**

Huili Grace Xing and Debdeep Jena have been promoted to full professors with indefinite tenure. Both faculty members joined Cornell in Jan. 2015 as Richard E. Lunquist Sesquicentennial Faculty Fellows with dual appointments in ECE and MSE.

**Delchamps receives 2015 Tau Beta Pi Excellence in Teaching Award**

Cornell Engineering students have elected ECE’s David Delchamps, associate professor in ECE, as the Tau Beta Pi Excellence in Teaching Award for 2015, recognizing him as one of Cornell Engineering’s most outstanding teachers.

**2015 ECE Innovation Competition Award**

The winners of the 2015 ECE Innovation Awards are:

- **Dogstar** (Michael Karp, Cornell Tech MBA ’15, Yannis Tsapalalis, Cornell Tech MBA ’15 and Li Guo BS ECE ’11, Cornell Tech MBA ’15) invented a happiness tracker for dogs. Their technology measures dog emotions based on detailed tail positions and movements.

- **Rapid Circuit Plotter** (Feiran Chen CS/ECE ’15 and Connor Archard ECE ’15) invented a functional and inexpensive desktop circuit printer that the team developed during ECE 4760, Designing with Microcontrollers. The team also won two prizes during the 2015 BOOM showcase.

**Ma places in IEEE student paper competition**

Yunfei Ma, Ph.D. candidate, won third place in the student paper competition at the 2015 IEEE MIT-S International Microwave Symposium for his paper entitled “Passive Ranging by Low-Directivity Antennas with Quality Estimate.”

**Air Force awards grants to Batten**

Christopher Batten, assistant professor, has received an Air Force Office of Scientific Research (AFOSR) Young Investigator Research Program grant. Batten won for his proposal titled “Exploiting Amorphous Data Parallelism Through Software and Architecture Co-Design.”

**Han honored as Merrill Scholar**

Sang Min Han ’15 was honored as a Merrill Scholar recipient during an award ceremony on campus in May. Highlighting the importance of teacher-mentors in the lives of students, the Merrill Presidential Scholars Program allows each student to
recognize one high school teacher and one Cornell faculty member who has influenced them. Han of Fairfax, Va., honored Dennis McFaden of Thomas Jefferson High School of Science and Technology and Bruce Land of ECE.

**Lal honored as the Robert M. Scharf 1977 Professor of Engineering**

ECE Professor Amit Lal has been recognized as the Robert M. Scharf 1977 Professor of Engineering by Cornell Engineering.

**Apsel promoted to professor**

Alyssa Apsel has been promoted to the rank of professor. Among other accomplishments, Apsel has received the National Science Foundation CAREER Award, and was selected by Technology Review Magazine as one of its Top 100 Young Innovators. She has served as associate editor of various journals including IEEE Transactions on Circuits and Systems I and II.

**Jayasuriya receives Qualcomm Fellowship**

Suren Jayasuriya, a Ph.D. student in ECE under the direction of Associate Professor Alyosha Molnar, recently received the Qualcomm Innovation Fellowship for his joint proposal with Achuta Kadambi, a Ph.D. student of Dr. Ramesh Raskar at the MIT Media Lab’s Camera Culture group. Their proposal, “Nanophotography: Computational CMOS Sensor Design for 3-D Imaging” is focused on creating robust platforms for 3-D imaging.

**Strait earns fellowships to work for CNST and NIST**

Jared Strait Ph.D. ’15 received a two-year postdoctoral fellowship from the National Research Council’s Research Associateship Program to work in the Center for Nanoscale Science and Technology (CNST) at the National Institute of Standards and Technology (NIST) in Gaithersburg, M.D. There he will be developing new measurement techniques using ultrafast lasers to investigate the properties of novel electronic and optical materials.

**Alireza Vahid receives ECE Outstanding Thesis Research Award**

Alireza Vahid Ph.D. ’15 was recently honored with the 2015 Outstanding Thesis Research Award from ECE. Vahid’s research has focused on feedback, which plays a central role in many engineering systems, in particular control and communications. In the context of wireless communication systems, feedback provides wireless nodes with vital information about the network state such as connectivity, channel statistics and channel gains.

**Zhang receives 2015 IEEE CEDA Early Career Award, NSF Career Award, 2015 DARPA Young Faculty Award**

Zhiru Zhang, assistant professor and member of the Computer Systems Laboratory, has been selected as the recipient of the IEEE Council on Electronic Design Automation (CEDA) Early Career Award for 2015 for outstanding contributions to algorithms, methodologies and successful commercialization of high-level synthesis tools for FPGAs.

Zhang also received the DARPA Young Faculty Award for his proposal on “Scale-Out Design Automation for Highly Productive Hardware Specialization.”

**ECE welcomes Zhao**

ECE has welcomed Professor Qing Zhao as its newest faculty member. Zhao comes from UC-Davis where her work focused on mathematical formulations of, and solutions to, engineering problems. Some of the challenges she has looked at come from communication networks, social economic networks, infrastructure networks such as cybersystems and the electric power grid. Zhao returns to her alma mater after earning her Ph.D. in electrical engineering from Cornell in 2001.
NEW MEMBERS INDUCTED INTO HKN, ECE HONOR SOCIETY

The Cornell ECE chapter of Eta Kappa Nu (HKN), the national honor society dedicated to electrical and computer engineering, recently inducted 13 new members for the fall 2015 semester. They are Yawen Wang, Lisa Zhu, Nellie Wu, Sally Yu, Brian Ritchken, Ian Briggs, Ricardo Stephen, Alex Rucker, Alex Parkhurst, Nathan Lambert, Fred Kummer, Erissa Irani and Qingyun Xie.

HKN students serve as a model for others in the ECE department. Members demonstrate ideals of scholarship, character and attitude, and students must be in the top fourth of their junior class or top third of their senior class to be eligible. Inductions are held twice each year.

The chapter organizes social events, runs tutorial sessions for lower-level ECE classes and connects members to a large and prestigious ECE network.

HKN AND IEEE INTRODUCE STUDENTS TO COMPUTER ENGINEERING

The Cornell ECE honor society Eta Kappa Nu and Cornell IEEE recently participated in Splash! Cornell where they taught “Computers Don’t Byte—an Introduction to Digital Logic” to middle and high school students.

The class included a short lecture introducing students to a history of computing, teaching the basics of logic gates and showing them how to count and do simple addition in binary. Students then participate in a hands-on lab, building “half-adder” circuits using integrated circuits, wires, LEDs and batteries. At the end, the students’ half adders were chained together to show how to create a complex, multi-bit adder.

Splash! is a one-day event where high school and middle school students come to Cornell’s campus to discover that learning is fun. Splash teachers, administrators and volunteers are all Cornell students. Find out more at www.cornell.learningu.org/teach/index.html.

SPOTLIGHT: ETA KAPPA NU HONOR SOCIETY

Members of Cornell HKN and Cornell IEEE pose during the Splash! Cornell event.

HKN RECENTLY LAUNCHED A NEW WEBSITE AND HAS HELD NUMEROUS EVENTS THIS SEMESTER.

www.hkn.ece.cornell.edu