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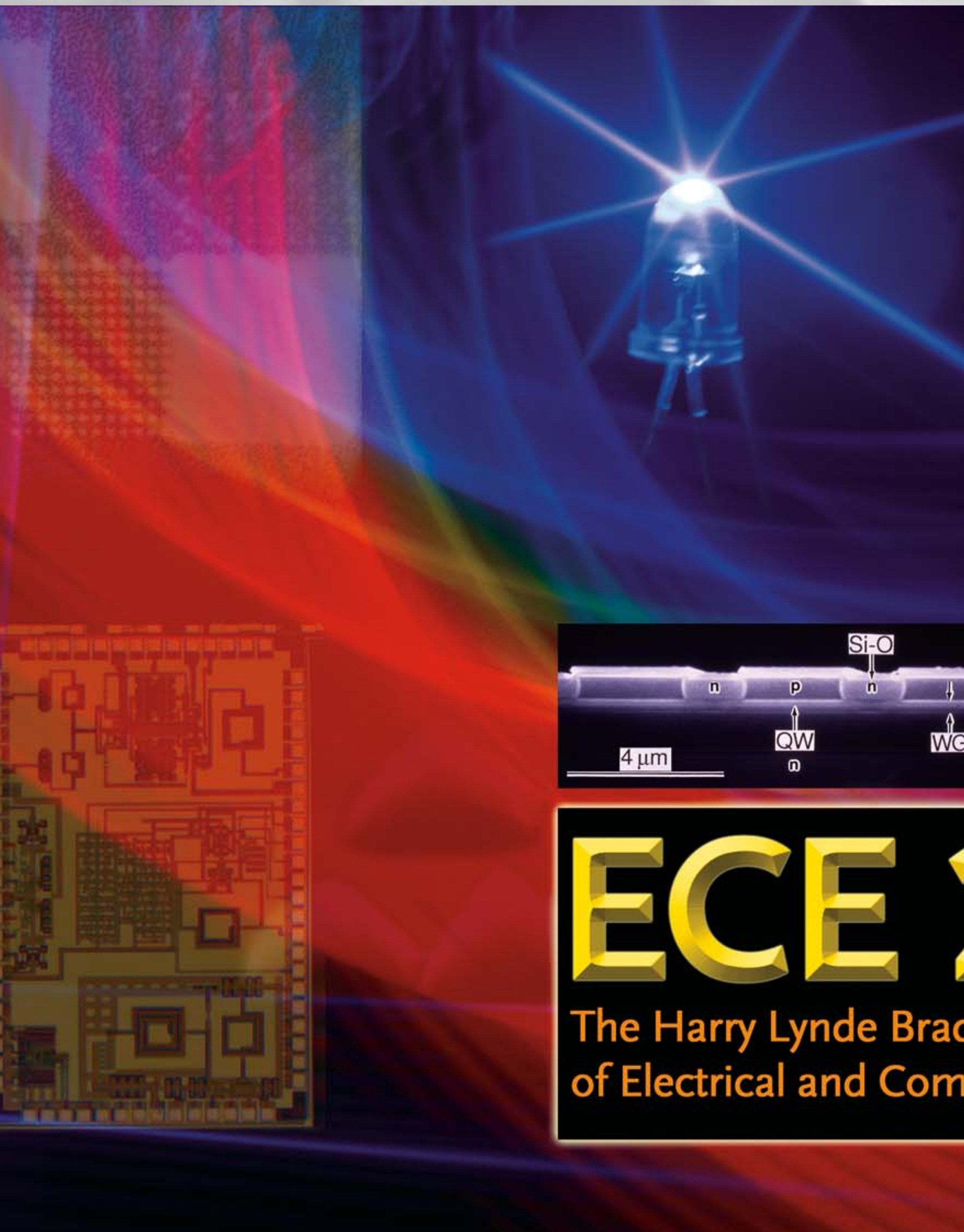
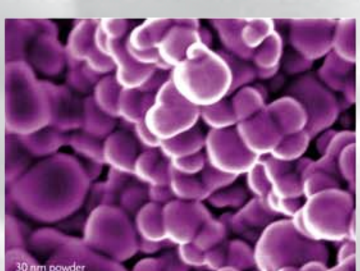
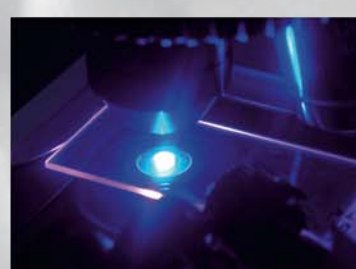


ECE 2005

The Harry Lynde Bradley Department of Electrical and Computer Engineering





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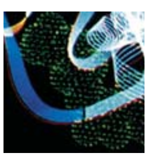

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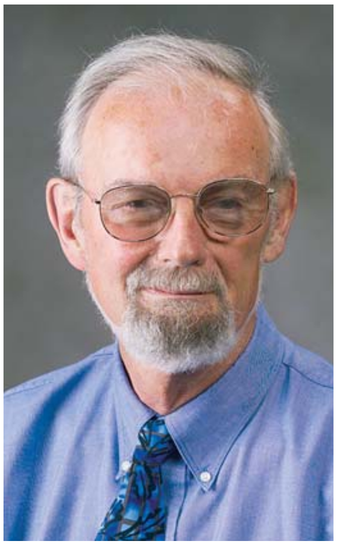


'Electrical and computer engineering as fields have always been on the cutting edge of new technology, and the pace continues unabated at Virginia Tech...'

Since arriving at Virginia Tech eight months ago, I have come to know a vibrant, accomplished ECE department of exceptional breadth. You will see in this report that we have nine general areas of endeavor, each providing distinct perspectives on the applications and problems facing technologists today. You will read of super-bright LEDs (p. 5), cancer research (p. 35), metal rubber (p. 23), software radios (p. 20), and a lab-in-a-box (p. 18) to mention a few.

Electrical and computer engineering as fields, have always been on the cutting edge of new technology and the pace continues unabated at Virginia Tech. Today's hot topics are bio-related and use nano-scale technology. You will read that in almost every area in our department, biologists are tapping ECE expertise and skills for imaging, computation, systems analysis, and more. Their efforts require manipulation of light, energy, and information—all ECE skills.

In other endeavors, ECEs lead the way in tapping new energy sources, such as fuel cells (p. 24), and in energy transmission (p. 26). ECEs are active in homeland security, applying communications, power, computation and sensor skills. Farther afield, Wayne Scales and colleagues have received funding for an initiative to study upper atmospheric space physics. Their NSF grant was one of only three such awards given nationally.

The vibrancy I find flows from the energy and minds of my new colleagues. Their expertise and contributions to society are recognized by the many honors they earn.

Rick Claus was named one of Virginia's Outstanding Faculty for 2005. He has led more than 550 research efforts totaling more than $40 million and authored 1,000 papers. In April, Fred Lee will receive the 2004 Ernst-Blickle Award from the SEW-Eurodrive Foundation. The award is made biannually and includes a prize of EUR 100,000.00. Of the 11 previous recipients, only one other was from the United States.

Sandeep Shukla received the Presidential Early Career Award for Scientists and Engineers (PECASE) at a White House ceremony. Our other young faculty members are also earning national attention. Thomas Hou, Allen MacKenzie, and Tom Martin have received NSF CAREER awards, bringing to 10 the number of ECE faculty members so honored. Anbo Wang's team received one of this year's *R&D 100* Awards. Jeff Reed became the department's latest IEEE Fellow. The department's 19 fellows represent nearly one-third of our faculty.

We continue to grow and strengthen our graduate program, emphasizing the Ph.D. An ECE team has developed one of the country's few online graduate application systems, which will be available to the whole university by fall 2007. We welcomed three new faculty members in January and are searching for six more. Our new colleagues are: Yong Xu (Ph.D. '01 CalTech), Paul Plassmann (Ph.D. '90 Cornell), and Fred Wang (Ph.D. '90 University of Southern California).

My thanks to Doug Juanarena, who completed his term chairing the ECE Advisory Board. Wayne Snodgrass ('61) was elected chair and his comments, at right, reflect the involvement of our alumni and the partnership of our board.

These are challenging times. Pressure to expand the graduate program and enhance our research ranking conflicts with our limited resources. ECE is desperately short of space. Our space-per-faculty member is well below those of competing programs and the shortage of quality lab space makes it difficult to recruit faculty. Finding solutions to these problems is vital to achieving university and department long-term goals. However, the dedication and energy of the ECE faculty have helped Virginia Tech gain national prominences and I am convinced that with proper support, we can take the next step.

James S. Thorp
Department Head

From the Advisory Board Chair

The Great Potential

There is no burden like the great potential. Fulfilling great promise requires great commitment, innovation, resources, and performance. When we were graduated from Virginia Tech, we were well prepared to begin our professional journeys in search of opportunity and service.

Each year, this report highlights the innovations from basic science to applied technology resulting from the efforts of ECE faculty members and students. We review curriculum changes, technological advances, research achievements, and faculty who are nationally recognized. The next page discusses work to be done in a new laboratory that ECE and Materials Science Engineering have developed that will help researchers across the university move forward in microelectronics, nanotechnology, and biotechnology. ECE is enhancing their strengths in power electronics and systems, wireless communications and electromagnetics, optical sensors, devices, configurable computing and networking. ECE is also developing the emerging areas in embedded computing, nanomaterials, biomedical engineering, complex systems and networks, energy and the environment.

Virginia Tech is currently updating the university and college strategies. The new goals still include advancing in the ratings, expanding our research, and continually improving our performance. ECE will play an important role in any strategy, as it has built the largest multi-discipline research program in the College of Engineering, which, in turn, has the largest research program at Tech. The consistent performance and growing success of ECE faculty and students reveals their commitment and innovation. However, our department goals in a constrained investment environment create special short-term needs that alumni and their industries/agencies can support. ECE, along with its research stakeholders within and outside the university, is focusing on pursuits that create growth opportunities and impact our ratings. Although we are fortunate to have the experience and wisdom of Department Head Jim Thorp leading a great faculty team, ECE alumni input is critical at this time.

The ECE Advisory Board is working with Thorp and the faculty to develop and execute the ECE strategy. The Board has established four committees that focus on research, undergraduates, graduates, and special projects. The Research Committee, working with alumni, will identify areas where industry and government agencies expect to boost research expenditures. The Undergraduate and Graduate Committees, also working with alumni, will suggest performance improvements based on experience, observations, and data from ECE's new formal assessment program. The Special Projects Committee will support the requests and priorities set by the department head.

We hope to encourage an environment where ECE faculty, the Advisory Board, and the alumni act together in this "great potential" to become one of the top departments in the country. As public universities in other states have shown recently, it can be done – but only with alumni involvement.

Wayne Snodgrass
Chair, ECE Advisory Board

Courtesy of Northrup Grumman, Frank Bocianowski photographer

'There is no burden like the great potential. Fulfilling great promise requires great commitment, innovation, resources, and performance. ...'

SOLID STATE LIGHTING

BUILDING a BETTER LIGHT BULB

MOLECULE BY MOLECULE BY MOLECULE

Louis Guido and G.Q. Lu are trying to build a better light bulb by combining an unconventional approach to the architecture and packaging of light emitting diodes (LED) with nano-technology developed at Virginia Tech. Their effort is now possible with the new ECE/MSE metal-organic chemical vapor deposition (MOCVD) laboratory, which begins operation in June.

Guido and Lu hope to create a white LED lamp with thermal capabilities that are three to five times better than current state-of-the-art. Their efforts support U.S. Department of Energy (DOE) goals of developing solid-state lighting technology that competes with conventional incandescent and fluorescent lamps and is fully integrated into the lighting market by 2020.

DOE statistics for 2001 indicate that lighting accounts for 21 percent of U.S. electric energy generation. Since today's illumination technology for residential applications still relies on the century-old incandescent lamp developed by Thomas Edison, more than 85 percent of the electrical energy spent on residential lighting is wasted in heating the environment, according to Guido. "This is because incandescent lighting is based on the principle of black-body radiation, which uses electricity to heat a tungsten filament to glow, thus providing light, but also heat," he explained. "Although fluorescent lighting is about three-to-five times more efficient than incandescent, it has not been widely used in residential markets because of the perceived poor quality of light and higher initial costs."

By switching to white LEDs, which are efficient and long-lived, national electricity demand for lighting can be reduced by about 167 billion kW hours per year, or the equivalent of about 29 600-MW power plants. The cost savings of $12 billion/year would be augmented by the accompanying reduction in pollution associated with electricity generation.

The p-n junction LED is a nearly perfect electrical-to-optical energy conversion device; that is, it can convert input electrical energy, in the form of the bias voltage applied across the p-n junction multiplied by the current flowing through the

Left: More than a century old, the Edison light bulb, based on black-body radiation, is still the technology to beat for general lighting purposes. Opposite page: Thanks to recent developments in blue LEDs, the technology is now capable of producing a white light. Researchers at Virginia Tech are using a new nanopaste and new design to boost the brightness and lower cost.

device, into output optical energy, consisting of photons created by electron-hole recombination across the energy band-gap of the semiconductor, with an efficiency approaching 100 percent.

The first practical red LED was invented more than 40 years ago, by Nick Holonyak, Jr., who was Guido's Ph.D. thesis advisor at the University of Illinois. Single-color LEDs are highly efficient and are now used extensively in automobile brake lights, outdoor TV screens, and traffic signals. The challenge for future LEDs in general lighting applications is to generate a "high quality" white light spectrum with the best possible electrical-to-optical energy conversion efficiency. "In principle, the white light output from an LED lamp could be tailored to mimic the solar spectrum over the visible spectrum while eliminating the unnecessary ultraviolet and infrared radiation," Guido said.

Single-color LEDs used in signaling and display applications now constitute a $2 billion/year industry and the market is expected to grow to $10 billion/year over the next 10 years, he indicated. If white LED lamps could fully penetrate the general illumination market then overall LED sales would double in size beyond this estimate. However, for white LED lamps to successfully compete with incandescent and fluorescent lighting, significant cost improvements are needed. "To meet the roadmap for LED lighting, we need an eight-fold increase in performance, plus a 12-fold decrease in cost," Guido noted.

"There are two ways to lower the fixed cost of LED based solid-state lighting," Guido explained. "You can increase the power, or you can lower the cost. It's hard to increase the power without increasing the cost. A big fraction of the cost is the semiconductor itself, measured in $/square cm. If you double the power by doubling the area, you have doubled the cost."

Guido and Lu's solution is to design the semiconductor nano-scale active region for improved efficiency, then to run more current through, increasing the brightness. Increasing the current will raise the operating temperature, and they are developing the packaging to withstand high temperatures.

"This is a nice collaborative project at the interface between electrical and materials engineering," said Guido, who, like Lu, has a joint appointment in ECE and Materials Science and Engineering (MSE). "This project involves materials, device design, and packaging."

Their new design involves removing the sapphire substrate that supports the junction in conventional LEDs so that current can flow directly across the junction. They also plan to use mesh electrodes for optimal light extraction and flexibility, a reflective silver coating, and direct-bond-copper heat sinks.

Increasing the current will yield brighter light per unit area of device, but it will also raise the junction temperature. Conventional packaging materials, such as solder, cannot withstand higher temperatures. The team's solution is a nano-scale silver paste developed by Lu's research group working with the Center for Power Electronics Systems (CPES) for attaching power devices. The paste, which looks black at room temperature, turns silver at high temperatures and has excellent thermal and electrical conductivity.

"Our new material works at high temperatures, such as 500-600°C," Lu said. "However, it can be processed or sintered at the lower 200 to 300°C temperature of solder. Using our paste, manufacturers do not need to retool, which is important for being useful in the marketplace." He explained that nano-scale materials have a "large surface area," so the nano-scale paste contains more surface energy than commercial materials and does not need high temperature to attach devices. The sintered silver is also porous, which makes it more malleable, giving devices improved reliability compared to devices attached by conventional means. "With its porosity, the attachment does not transfer stresses from substrate to device," Lu said.

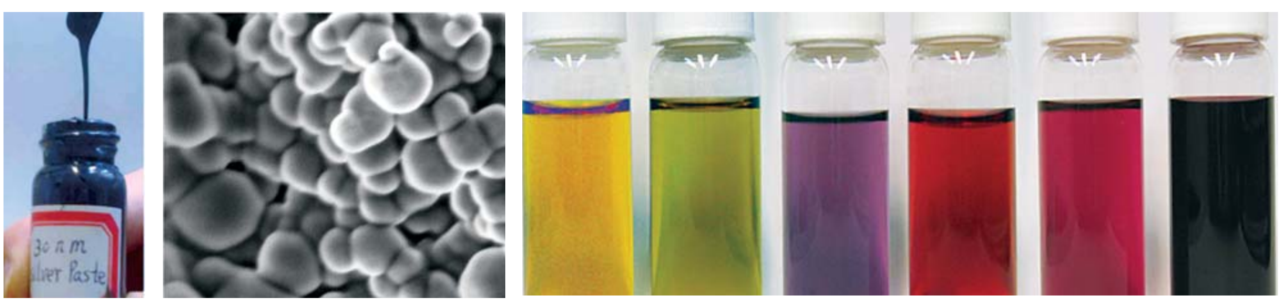
New MOCVD Laboratory enables atomic-level precision

The third partner on the team to develop a brighter LED is the new ECE/MSE metal-organic chemical vapor deposition (MOCVD) laboratory. The $2.5-million facility, which begins operation June, will enable researchers to build semiconductor materials with precise control of thickness and composition at the atomic level. "We can build very complex structures out of individual layers," said Guido, who serves as director of the laboratory.

The Aixtron MOCVD system, which is the centerpiece of this new laboratory, can be used to synthesize semiconductor alloys and heterostructures containing elements from column III and column V of the periodic table. These semiconductor materials can be used to construct a variety of devices including electronic amplifiers operating at high power and high frequency and lasers and photodetectors covering the entire ultraviolet-to-infrared portion of the electromagnetic spectrum.

The MOCVD laboratory is the newest addition in the college's microelectronics capabilities. "The ECE and MSE departments have made a large commitment to microelectronics at Tech," Guido said. "The capabilities of this laboratory, combined with the soon-to-be-completed upgrade of our cleanroom microfabrication facility, will put Virginia Tech researchers in a position to compete and do research at a new level." These experimental facilities will enable research along the entire "food chain" from molecules-to-devices in important areas such as chemical and biological sensing, electronics and photonics, and energy and environmental systems.

Louis Guido (left) and G.Q. Lu (right) discuss sapphire crystal substrates in the new laboratory for metal-organic chemical vapor deposition (MOCVD). The new laboratory gives Virginia Tech researchers the capability of building semiconductor materials with precise control of thicknesses and composition at the atomic level.



Left: A metal paste made of silver nano-particles has been developed at Virginia Tech for interconnecting high-power electronic devices. The paste looks black, but turns silver when heated. The nano-scale silver paste can be processed or sintered at low temperatures used for reflowing solder materials; but, the sintered silver allows devices to operate at temperatures as high as 600°C. Center: A scanning electron micrograph of silver nano-particles undergoing densification, providing excellent thermal and electrical properties to device attachment. Right: A series of other nano-materials developed at Tech by Lu's group. The yellow and green solutions are suspensions of silver nano-particles, and the rest are suspensions of gold nano-particles. The nano-metal suspensions are under development for biological sensing applications and for control of harmful bacteria.

Formality rules

As computing systems grow increasingly complex and integrated into all aspects of life, verification, testing, and debugging have taken the biggest role in product design.

Most system houses and chip design firms report that 70 percent of their total cost comes from checking to be sure their design is correct, according to verification expert Michael Hsiao, a computer engineering professor. For large software projects, verification can run 90 percent of cost, he added.

"Verification and debugging are difficult problems with today's complex systems," Hsiao said. He pointed to the many hardware and software products that require continual modifications both before and after being released. He believes the answers lie in better tools — specifically formal verification algorithms — and a new focus in engineering education.

He is taking action in both directions. He has built one of the university's largest research teams, with 15 graduate students

(14 Ph.D.), that recently improved the performance and capacity of verification tools by one to two orders of magnitude. Based on the breakthroughs, he is leading a faculty team to build course modules and a curriculum to integrate verification throughout the ECE curriculum.

Why formal?

"The most naïve way to check a large, complex design is through simulation," he said. "People use it because it is easy to understand, but most systems are too complex for simulation to be effective. The search space is just too big." He described how simulating with 100 million input patterns is still significantly less than one percent of the possibilities in many designs. "Some companies spend months, simulating 24/7. After a time, when nothing bad happens, they think it is probably OK for release. But they have no guarantee."

More effective tools are found in formal techniques, what Hsiao called "the opposite of simulation." Formal techniques are algorithms based on theorems and proofs. "Like other methods, in formal techniques, you are trying to prove that you hold a property or that two different designs hold the same property," he explained. He gave the simple example of a traffic control system being tested to ensure that there are never green lights in all directions at the same time. Comparing different designs for similar properties, or an equivalence check, is useful when a newer, or improved version is developed. "For instance, whatever the Pentium 3 was able to perform, the Pentium 4 should be able to do."

Expanding the bottleneck

Although formal techniques have been researched for decades, there is no good method for large and complex problems, according to Hsiao. The research follows two general tracks: binary-decision-diagram (BDD) and satisfiability-based. Both methods try to solve all the billions of solutions very quickly.

"In general, BDD tries to exploit memory space: if I have infinite memory, I can solve this." On the other hand, the satisfiability-based track, including automatic test pattern generation (ATPG), says, "for these methods, I don't need infinite space, but if I have infinite time, I can solve this."

Without infinite time or space, the question becomes how to reduce the space requirement AND the temporal, or time requirement. Hsiao's answer is to enhance learning capabilities. "Our breakthrough was in formal learning," he explained. "If we solve certain parts of the problem, can we use that knowledge to help with other unsolved parts? The answer is 'Yes'. Essentially, if we have found 1 million solutions so far and want to reach 1 billion, we don't have to spend 1,000 times more, we can take advantage of what we solved so far." The Virginia Tech technique is called "generic term static and dynamic learning" and allows formal verification of much greater complexity than ever before, according to Hsiao.

Even with his recent advances, formal verification has a long way to go, he said. "Now, we need to develop better learning mechanisms. How do we reason in a complex system? How do we learn from a given set of facts? How do we accelerate the learning process? How do we make the algorithms that learn most efficiently?"

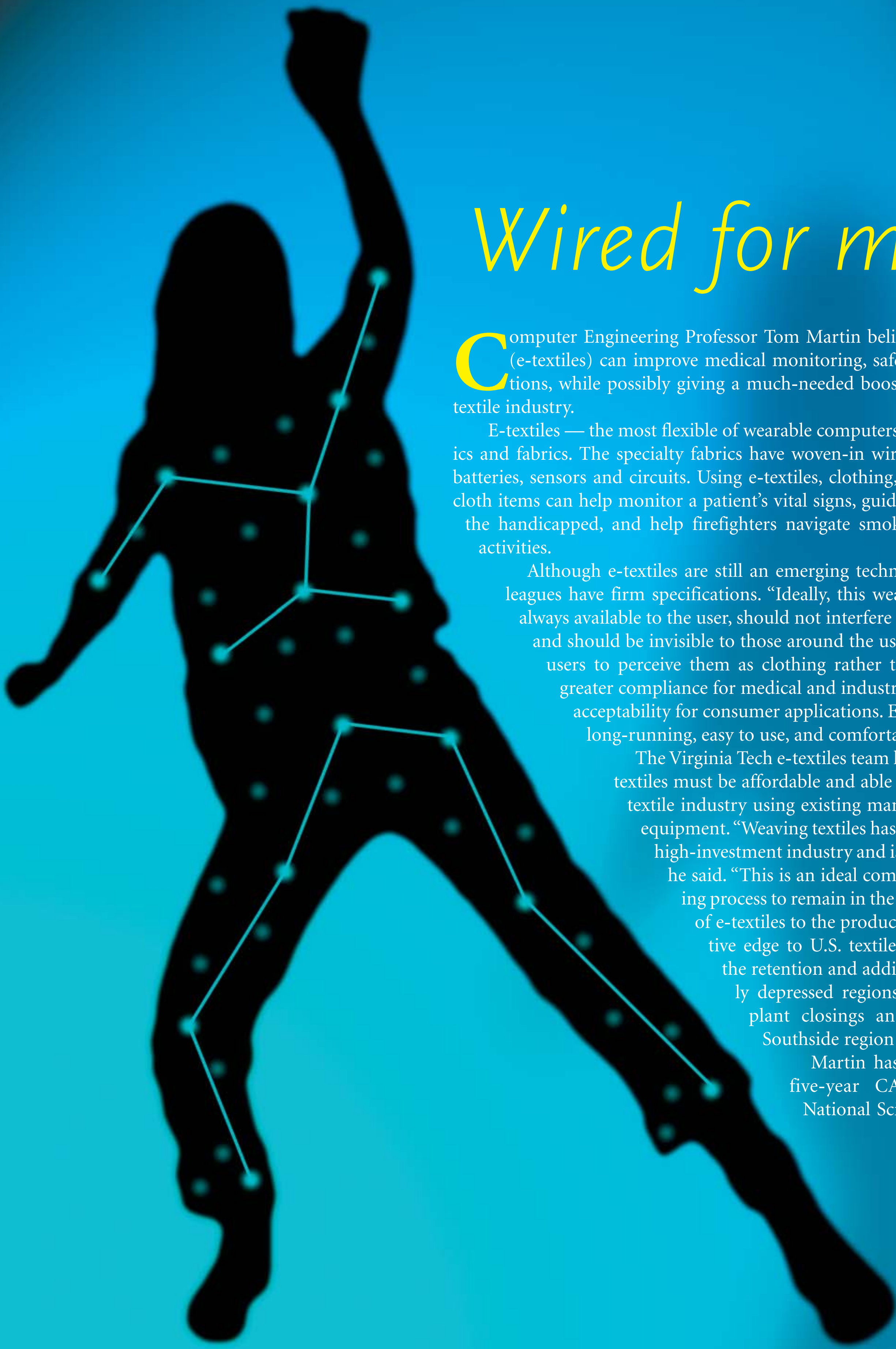
Verification-centricity

Advancing the verification tools is only part of the answer in reducing time and costs of product development, according to Hsiao. He is interested in changing the design culture to incorporate verification, starting with the education of engineers. Funded by the National Science Foundation, Hsiao, Sandeep Shukla, Dong Ha, and Joseph Tront are building course modules and a curriculum to integrate verification at all levels of ECE education. Instead of "design conception and implementation…becoming mere preludes to the main activity of verification," as described in a recent industry report, the team wants to instill verification-centric design and introduce formal verification skills.

The goal is for students to be able to envision the verification tasks before the design begins, write properties and transactions to be checked, and know how to embed design-for-verifiability into the process. After the design stage, students would be able to select the appropriate verification approaches for a design task, and apply formal and semi-formal verification techniques. The project complements Hsiao's other efforts. He has been funded by six separate NSF projects, along with industrial support from companies such as Intel, Fujitsu Labs, and nVidia.

"The companies want to reduce this verification cost," said Hsiao. "Now they need designers who know how to verify and debug."

Michael Hsiao believes that formal verification tools and a new focus in engineering education will help companies reduce the costs to testing their designs. Companies report that 70-90 percent of development costs are spent in verification, testing, and debugging.



Wired for motion

Computer Engineering Professor Tom Martin believes that electronic textiles (e-textiles) can improve medical monitoring, safety, and consumer applications, while possibly giving a much-needed boost to the region's struggling textile industry.

E-textiles — the most flexible of wearable computers — are a blend of electronics and fabrics. The specialty fabrics have woven-in wiring and can accommodate batteries, sensors and circuits. Using e-textiles, clothing, draperies, tents and other cloth items can help monitor a patient's vital signs, guide or measure movement of the handicapped, and help firefighters navigate smoky buildings, among other activities.

Although e-textiles are still an emerging technology, Martin and his colleagues have firm specifications. "Ideally, this wearable computer should be always available to the user, should not interfere with the user's movements, and should be invisible to those around the user," he explained. "We want users to perceive them as clothing rather than computers, leading to greater compliance for medical and industrial applications and greater acceptability for consumer applications. E-textiles should be durable, long-running, easy to use, and comfortable," he added.

The Virginia Tech e-textiles team has two more conditions: e-textiles must be affordable and able to be processed by the U.S. textile industry using existing manufacturing techniques and equipment. "Weaving textiles has become a high-technology, high-investment industry and is no longer labor intensive," he said. "This is an ideal combination for a manufacturing process to remain in the United States. The addition of e-textiles to the product line could give a competitive edge to U.S. textile manufacturers, leading to the retention and addition of jobs in economically depressed regions that have suffered textile plant closings and cut-backs, such as the Southside region of Virginia."

Martin has recently won a $400,000, five-year CAREER award from the National Science Foundation (NSF) to pursue advances so that e-textile garments can function robustly in applications for people of all ages, plus meet his manufacturability and affordability goals.

The project builds on recent prototype successes from the E-Textiles Laboratory, co-directed by Martin and Mark Jones. Their team has developed a 30-foot fabric acoustic array to detect the location of vehicles, a glove to demonstrate typing without a keyboard, a garment for mapping a building using ultrasound, an acoustic beamformer shirt to localize sound, a software simulation system for designing electronic fabric, and a vest-and-pants outfit to monitor heart rate, and motion.

The CAREER project goals include improving the technology so that e-garments can be mass-produced instead of custom-designed. Martin's team is also developing the ability for e-garments to sense their own shapes as well as the positions and locations of their sensing and processing elements. "We want the garment to track the location of the electronics so that it can configure itself and adapt to changes in how the user is wearing the garment," Martin said. "When a user rolls up her sleeves, the electronics should adapt." He described how garments should not have to be skin tight to accomplish their tasks and that eventually, he hopes to solve the difficult problem of accounting for the draping and flowing clothes.

The first tasks include determining the types and placement of sensors that will be used for determining the shape of the garment, location of the elements, and activity of the wearer. Then, the team plans to create software services for the electronics to automatically identify their own location on the body and balance the power and computational loads. Martin hopes this will lead ultimately to the ability to produce e-textiles in bulk, with the electronic sensors and computation devices built in. The garments would then be constructed as though made of conventional fabric and the function programs installed like firmware.

Martin plans to implement the technology on two test-bed applications. The first is a prototype garment for indoor navigation that not only uses ultrasonic sensors, but also dead reckoning. The garment would sense the direction and distance traveled and compare it to a preinstalled map. The second prototype would be an automatic activity diary that could determine the activities of the wearer and monitor environmental conditions such as temperature. The diary garment would help with medical diagnoses as most patients are notoriously bad at self-reporting their activities, according to Martin.

E-textile garments should be easier to use and more versatile than similar mobile systems using wireless technology, Martin explained. E-textiles will use much less battery power than wireless systems. "Wireless transmission costs more energy," he commented. "The technology is at the point where a wireless sensor node can be the size of a thumb, but it requires a camcorder battery to power it for 20 minutes. With interconnections in the fabric, a 9-volt battery will power the system for hours." He cited the 30-foot-long beamformer fabric that runs for 20 hours nonstop on a 9 volt battery with no power management.

Martin also said that consumers may have concerns about being surrounded by wireless fields and that privacy is also an issue with wireless. "Eavesdropping and interference are a problem for wearable wireless devices. If I'm sitting next to you on a bus, I don't want you to be able to control my devices or to snoop on their communications. With e-textiles, all the communication is in the wires, so eavesdropping isn't an issue," he said.

E-textile researchers are not alone in their enthusiasm regarding the technology. A textile manufacturer in the region supported the CAREER proposal and offered to weave the e-textile fabric for the prototyopes in their mills without cost. "E-textiles could give domestic textile makers an opportunity to create a product with a high-tech advantage over imports," Martin said. "So as we develop e-textiles we are trying to stay as close as possible to existing manufacturing techniques in the textile and garment industries."

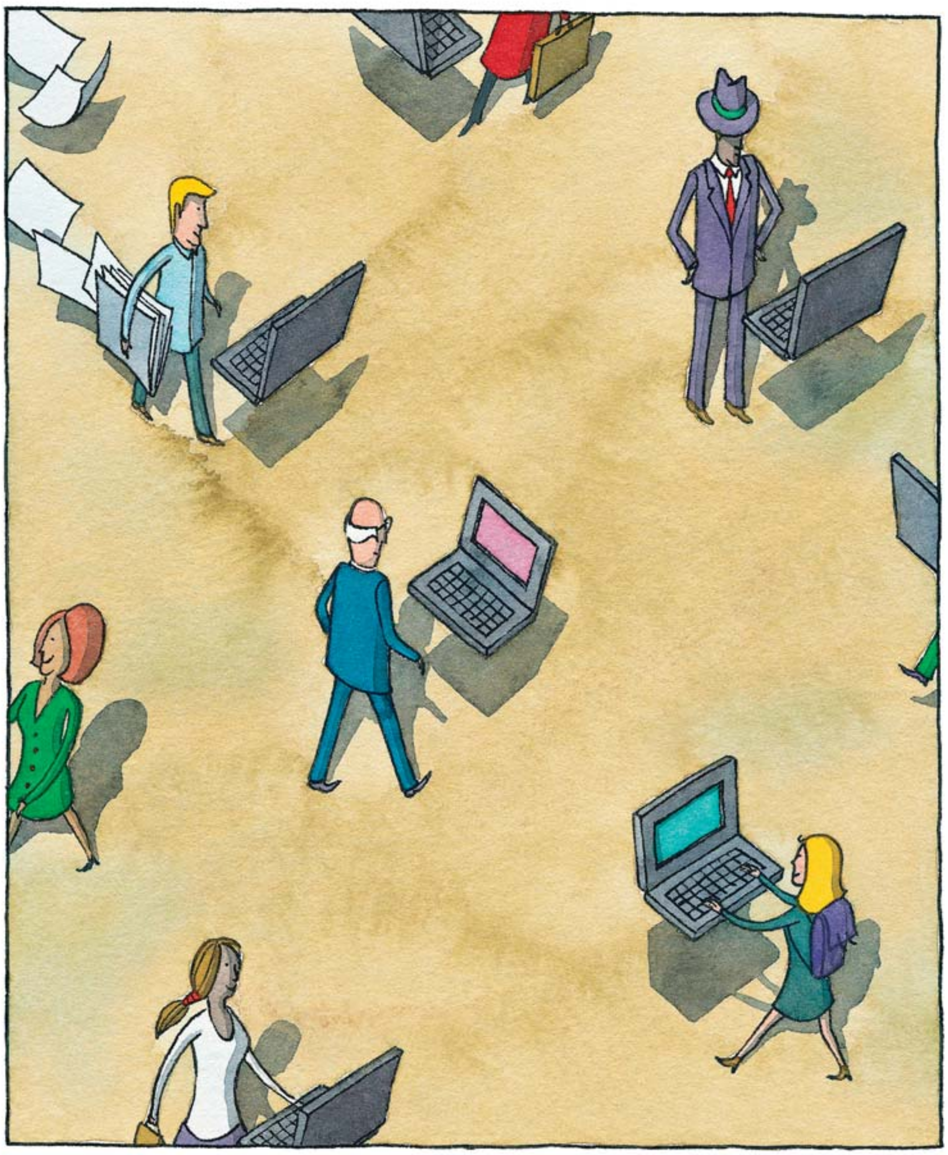
Every CAREER project has an educational component and Martin plans to go beyond research/education integration. He is developing instructional models to help students improve their debugging skills.

After participating in a faculty study group sponsored by Tech's Center for Excellence in Undergraduate Teaching that focused on student learning styles and theories of learning, Martin has concluded that poor debugging skills are the result of more than inexperience. "Debugging requires a different form of thinking than what students are used to exercising for most of their courses," Martin said.

Most courses present general principles, then derive particular facts, he explained. "Most of the time students use this deductive thinking and so they tend to be better at it than inductive thinking. Good debugging, however, is an inductive process." He described how the programmer observes a system's response, then abstracts from those observations to form a hypothesis about what is causing an error. Then the programmer devises a test for the hypothesis and observes whether the test supports the hypothesis. Students, on the other hand, tend to make a change to a program, see if the changes fixes the problem, and then make another change, without stopping to consider how the change should have affected the program or what makes sense to be changed next.

The modules will be available on the internet for instructors at all levels.

Wireless networking



Can we make it a game?

Wireless communications research is in crisis, according to Allen MacKenzie. Researchers and engineers tend to focus on point-to-point access and signals, however, the biggest issues are quickly becoming dynamic and complex wireless networks. "We have no unifying theory of how they work, and we need this theory to be engineers," he said. "We need analytical tools so we can build and operate these complex systems."

MacKenzie, who joined ECE last year as an assistant professor, recently won a $400,000 National Science Foundation (NSF) CAREER Award to develop analytical tools that can be applied to controlling the power, interconnections, and interference avoidance in wireless networks. The CAREER Awards are NSF's most prestigious awards for new faculty members.

Much of the work in wireless communications is heavily reliant on simulation and heuristics (rules of thumb), with a growing emphasis on experimentation, he explained. "Unfortunately, unlike many other parts of electrical and computer engineering, we do not have a deep understanding how these networks work. We cannot write formulas and equations to solve networking problems."

Complex, dynamic systems

Today's internet is said to have about 317 million hosts. Wireless networks are smaller, but with the proliferation of devices beyond cell phones, PDAs, and laptops, wireless networks are expected to become as ubiquitous as the internet, according to MacKenzie. Further complicating wireless networks is the mobility factor, as shown by a recent New York City proposal to design a wireless safety network that could accommodate tens of thousands of mobile devices moving at speeds up to 70 mph. "Not only do we have size to contend with, but it's possible they may all be moving around at high speed."

MacKenzie and other researchers believe that game theory, which has revolutionized economics, may provide greater understanding of wireless systems. "The global economy, with 6.4 billion participants, is the most complex dynamic system developed by people," he said. "If game theory can help us understand that system, maybe it can help us provide fundamental insights into the growing complexity of wireless systems."

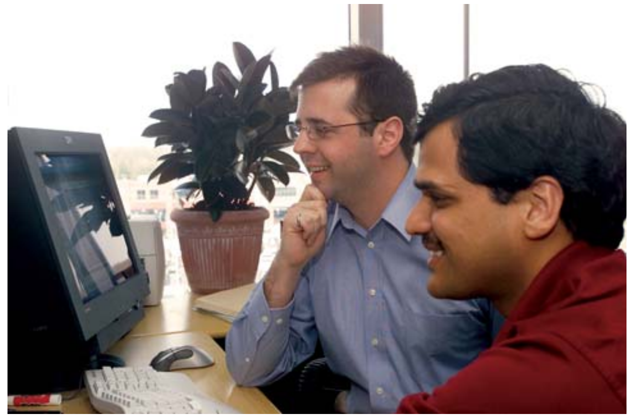
Applying economic theory to engineering

Game theory focuses on the interactions between players or agents in a changing environment, rather than the actions of a single player in a static environment. There are three elements to a game: players, preferences, and actions, which are the choices of the players.

When applied to wireless engineering, the players can be either human decision-makers or software controlling the devices. The actions can be decisions such as increasing power, or switching channels. Preferences become the player's objective, or utility. "Potential games are particularly attractive for engineering applications," MacKenzie said. "A game is a potential game if there is a single function that can express the preferences of any player when the actions of all other players are fixed."

Although game theory seems to fit the wireless network situation, it is not directly applicable without significant adaptations for engineering, according to MacKenzie. He described two properties of preferences that are important to engineering and sometimes ignored by the economic theorists. "First, as a player, I must be able to measure my utility," he said. "If I can't, it's not my utility. Second, the happiness of the player is different from the happiness of the designer." A designer might want to maximize average node throughput, for example, whereas a player just wants to maximize her own throughput. The designer's preferences do not typically play a role in traditional game theory.

Other differences involve cooperation. Most game theory models are based on noncooperating players, where each individual makes decisions for maximum personal benefit. In wireless networks, however, the designer can program the devices to consider the welfare of the whole network. Devices can be programmed to cooperate.



Allen MacKenzie (left) and graduate student Ramakant Komali review a presentation on game theory for wireless networking.

Cooperative games involve the formation of coalitions and the ability of players to negotiate and make binding agreements. "Nobel laureate John Nash suggested that all cooperative games should be studied by reducing them to non-cooperative form," MacKenzie explained.

"Yet a fundamental question remains unaddressed: How can players with common objectives but differing information and limited means of communication cooperate to achieve a common goal?" This brings up another difference in that the economic models typically assume full knowledge of all the other player's preferences and actions, whereas in wireless networks, decisions are made with limited knowledge and communications. Gaining more knowledge of each other's situation requires more control traffic, which reduces network capability.

Controlling power

Working with colleagues in ECE and Economics, MacKenzie is applying game theory to understanding the tradeoffs in power control. In a cell system or wireless LAN where a single base provides access to several connections, any individual device that increases its power will get a higher signal-to-noise ratio, faster throughput, and fewer errors. The downside is that increasing power drains batteries faster and increases interference to other users on the network. "Using game theory, we can identify both problems and potential solutions," MacKenzie said. "However, using the Nash equilibrium all the players end up increasing their transmit power and draining their batteries. So some researchers have proposed added pricing to the equation: charging individuals for creating interference to others."

MacKenzie has proposed solving the power control problem by considering it as a repeated game. "Make the players responsible for enforcing the social welfare, or network quality," he explained. "If you raise your power too much and interfere with all of us, the next time, we'll punish you. If you know you will be punished, you might not misbehave in the first place." For the CAREER project, he is applying the repeated-game-group-enforcement scenario to ad hoc networks.

The power control problem is directly related to topology control, or control of the network links in an ad hoc network. "If the user increases power, he can talk farther away, but that affects the topology of the network," he said. "All these properties cost extra power and are the users willing to trade battery life for that?" He also described an extensive literature in the social sciences regarding network formation, where people are connected to those with whom they do business. "Perhaps it contains elements that can be connected with wireless topology control."

Avoiding interference

MacKenzie is also applying game theory to analyzing interference avoidance and control the spreading code. In communications, the goal is for the spreading codes of different nodes to be maximally orthogonal (perpendicular) to each other, which generates the least interference. "Right now, spreading codes are chosen by the base station, but in the future, it would be nice if individuals could do it themselves and control what they see as interference," he said. "That would also work best for ad hoc networks. What happens when you increase the signal-to-noise ratio, then choose the most orthogonal spread? The individual is better off and so is the entire network, since each individual is doing its best to avoid the others."

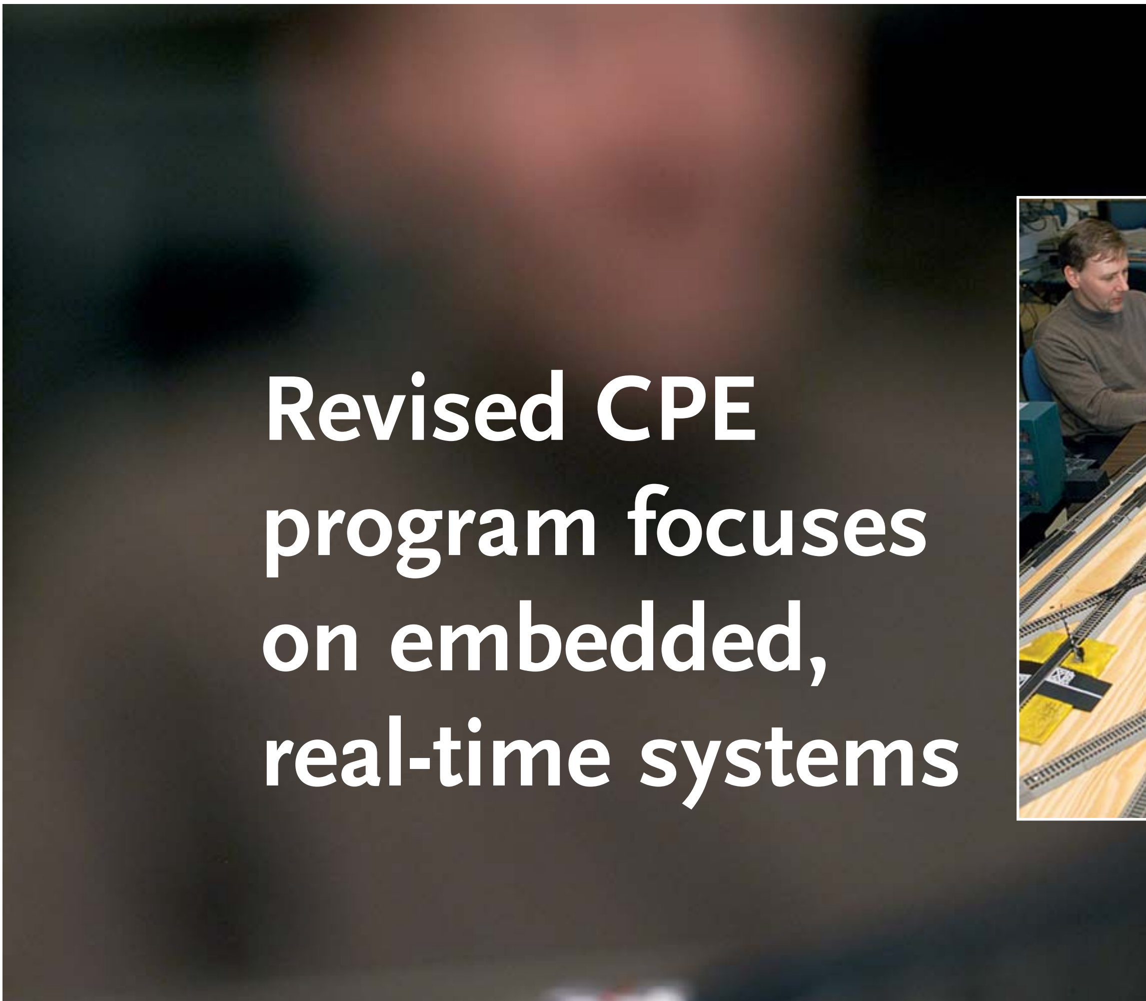
Whether it is in controlling power, topology, or interference, MacKenzie is working to alter or extend game theory so that he can develop analytical tools for wireless communications. "Game theory was developed to understand systems that already exist. We engineers want to design what does not exist," he said. "We need a deeper understanding of mechanism design: How can you design a game with specific outcomes? We need tools that focus on cooperation, not just conflict…We need to explicitly model information in games and acknowledge that each player has little information…"

He believes these analytical efforts may be applicable beyond wireless networks. "If you are an electrical or computer engineer today, you are going to have a hard time not encountering extremely complex dynamic systems in your work. It will happen in power, wireless, or circuits with multiple decision-making entities. Increasing complexity demands new, more powerful analytical tools."

Increasing exposure to EE: Allen MacKenzie has a special interest in boosting the representation of women and minorities in ECE. As part of his NSF CAREER Award, he is working to increase exposure to electrical engineering among middle- and high-school girls. His team plans to develop a series of active, hands-on, modular education units to introduce students to communications engineering. Anticipated units include the mathematics of AM Communications, the Science of AM Communications, Simulation of an AM Communication System, Build a Crystal Radio, and Build an AM Transmitter.

The modules will first be introduced at the Virginia Tech College of Engineering summer camps for middle and high school students: C-Tech2 (photo) and Imagination. The modules will also be available on the web and MacKenzie expects to teach modules to groups of interested high school science and mathematics teachers in Southwest Virginia.

Revised CPE program focuses on embedded, real-time systems



Embedded systems and real-time operations dominate the work of most computer engineers and Virginia Tech's CPE faculty has revised the curriculum to emphasize that focus.

Beginning with the graduating class of 2008, CPE students will no longer be required to take computer science classes, but will study system architecture, operating systems, and data structures in the ECE department with an engineering focus. Computer engineering is a relatively new field and the curriculum revision reflects a natural evolution of focus, according to Nat Davis, who oversaw the curriculum revision.

In the past, CPE students took a mix of computer science, computer engineering, and electrical engineering

Previous page: Mark Jones assembles the HO scale model train testbed for this spring's Embedded System Design (ECE 4534). Jones is revising the design-heavy course to incorporate embedded systems and higher-level programming. Each student team of three will select a project with real-time functions, either relating to the trains or their environment.

courses, separating the hardware from the software. The new curriculum provides a stronger integration of hardware and software that is more appropriate to computer engineering.

With the new curriculum, students still will get strong exposure to programming and data structures with Engineering Problem Solving with C++ (ECE 1574) and Introduction to Data Structures and Algorithms (ECE 2574). In addition, all students will be required to take Software Engineering (ECE 3574), which is currently offered as an elective.

A new sophomore-level course is being developed called Computer Organization and Architecture (ECE 2500). The course will provide an understanding of the processor-level components of computer systems, their design and operation, and their impact on operating systems. The current course in Computer Organization (ECE 4504) will be revised to become a senior-level processor design course.

Updated design

The new curriculum keeps the strong design focus that has been a hallmark of the program. In addition, two of the upper-level design courses are being updated to reflect the new focus: Microprocessor System Design (ECE 3534) and Embedded System Design (ECE 4534). For ECE 3534, teams of students used to check out a suitcase with an integrated microcontroller board, power supply, and protoboard to develop their projects. Beginning this semester, students will buy their own microcontroller boards instead of a textbook. They can take it home and play with different concepts at their leisure. The new board has more memory than the old suitcases, which enables more complicated software projects and less wiring. Students use C in addition to assembly, which more closely reflects how embedded systems are programmed in industry.

The senior-level Embedded Systems course will now be required of all CPE students and will satisfy the Capstone Design requirement for EE students wishing to focus on computers. As in the other courses, the hardware has been updated to accommodate embedded systems and real-time processing. This semester, students are using new 4x6 printed circuit boards with an ARM processor and peripherals, such as serial ports, analog to digital converters, lights, and buttons.

The course starts out with a series of homework projects in which the teams build compiler tools for the board, then compile a mini operating system for the board, then generate an application for the board. "All of the programming is done in C at a very high level, instead of assembly," said Mark Jones, who is revising the course. Once the students had worked with the basics, they embarked on a semester-long project that

Bob Lineberry, an ECE tech support engineer, demonstrates the new microcontroller board that students now purchase for ECE 3534, Microprocessor System Design. The new boards' functions enable students to design more complicated software projects while getting less tangled in wiring issues. The boards connect directly to student laptop PCs. Lineberry managed a team of student programmers, including Troy Berg and Dan Nash, who developed the PC user interface that controls the board.

comprises 50 percent of their grade.

The teams are assigned to reflect a mix of experience in skills, according to Jones. “This more closely resembles the industrial environment, where you work with people of different backgrounds who are not necessarily your friends,” Jones said.

Training

The projects relate to an HO-scale model train layout designed by Jones. The layout is composed of switches, a turntable, and several engines and cars, all under remote, digital control. Each team selects its own project, but must adhere to electrical and data standards. The designs must be power aware and each must include a real-time aspect. Teams are to write specifications, determine formal testing objectives, and specify how they are to be evaluated. As in real-world efforts, teams must supply documentation, a formal proposal, and interim reports. Beginning next year, at the end of the semester, teams will present formal poster sessions to judging teams.

The variety of requirements and parameters for the project does not limit the possibilities, according to Jones. “Teams have many options. They can take scenery and figures and make them react in a certain way to specific trains as they pass. They can set a camera in the train yard and create a system to sort trains by color or identity. They can develop a system for a train to react to another train on the track; or a system that generates sound in speakers as it tracks a train. All these projects have a real-time component,” he said.

The projects include a fair amount of interfacing to the real world and responding instantly in reasonable ways. “But these are senior computer engineering students,” he said. “This is a class to pull together all their skills in a complex project with embedded systems operating in real time.”

Where have all the red squirrels gone?

Students in James Armstrong’s Design of Systems on a Chip (ECE 5524) class jumped into bio-mathematical computation last fall when they designed hardware accelerators for a “competition between species” model. Until some Americans introduced gray squirrels into parts of England in the early 20th century, red squirrels had been the only species of squirrel in the country. The gray squirrels were larger and bred faster and successfully competed for resources. Within a couple years of overlap in an area, the red squirrels disappeared.

“There is enough data on the red squirrel/grey squirrel competition in England that it is an excellent introduction to computation for biological modeling,” Armstrong said. Using an ARM processor and a field programmable gate array (FPGA), student teams were challenged to develop a hardware/software accelerator that could beat a Matlab standard for the model. Students were able to choose their strategy as long as the final system was a partitioned model between software and hardware, running on the ARM ASIC development platform. The teams found challenges ranging from serial transfer bottlenecks to memory storage.

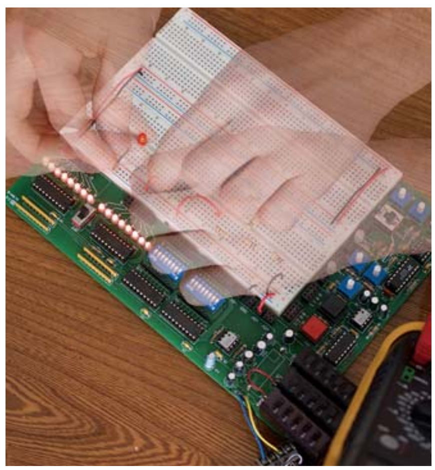
The students enjoyed whole-system design approach. “I enjoyed working with a bunch of different things that all work together,” said Brian Marshall.

Patrick La Fratta agreed, saying, “I’ve had classes on just FPGAs and others on just software. This involved the interaction of both types of components and was challenging and fun.”

Personal Laboratories

In a move to encourage personal exploration and experimentation throughout the curriculum, the ECE department has developed portable laboratories for students to purchase and use at home that support a sequence of four required courses.

Called “lab-in-a-box,” the main unit contains a powered protoboard, plus switches, a logic probe, potentiometers, clocks and LEDs and fits in a container about the size of a textbook. In addition, the kit includes a digital multimeter, some basic tools, and various wires and resistors. Software that allows the student to use the sound card of a PC as an oscilloscope for simple measurements is also included. For each class that uses the lab-in-a-box, students purchase a bag of course-specific components, such as resistors, capacitors, inductors, digital ICs and op amps. “This kit gives students the major measuring equipment and tools that once were restricted to laboratory benches,” said Robert Hendricks, faculty lead on the effort.



Beginning with the sophomore-level courses in Electric Circuit Analysis (ECE 2004) and Introduction to Computer Engineering (ECE 2504), students use the laboratories for homework and project assignments. The kits’ special functions enable them to be used again in Digital Design (ECE 3504), required for CPEs and AC Circuit Analysis, (ECE 3004), required for EEs.

“Students are coming to college with less hardware experience than in the past. This makes sense when we consider that most digital and analog technology is integrated onto one miniature board for most applications. But it makes the introductory material in ECE seem very abstract to the students,” Hendricks said.

“We wanted to find a way to give them the experience and opportunity to explore on their own. After exploring many options, we decided to expand on the ‘Lab-in-a-Box’ concept first proposed by Rich Christie at the University of Washington.”

The biggest advantage is that students can now try out circuits and designs without needing to go to a special room or take a special course, according to Hendricks. “In laboratory courses, time is restricted and if students want to try something different from the assigned projects and experiments, they cannot always get that opportunity. With lab-in-a-box, students can wire up a design any time of day.” The personal laboratories are part of a curriculum overhaul designed to incorporate more experiments and research with ECE theory. The curriculum revision has been funded by a grant from the National Science Foundation (NSF). Working with Hendricks are Kathleen Meehan, William Tranter, William Baumann, Nathaniel Davis, and Lynn Abbott.

For Introduction to Computer Engineering and Digital Design, the new laboratory kits replace older pencil-box kits that were assigned to students each semester. The new lab-in-a-boxes provide expanded capabilities for projects and designs. The circuit analysis courses, however, never had hands-on components, and the team developed assignments to help make them more concrete.

The initial projects, developed by Kevin Lai (EE ’05) and Brac Webb (EE ’05) under the auspices of an NSF REU grant, include about a dozen simple experiments designed to help the student understand the introductory materials taught in the lecture pat of the courses and culminate in a pair of introductory engineering design experiments where the students build an analog voltmeter or develop a traffic signal with a blinking arrow. Lai and Webb also were involved in developing new projects in the electronics laboratory course that relate to technology students use every day.

The lab-in-a-box projects were first used by a Circuit Analysis class this past fall, and this spring all the sophomore circuits classes incorporated the projects, using older pencil-box kits. The custom-made lab-in-a-box kits will be available for students beginning fall 2005.

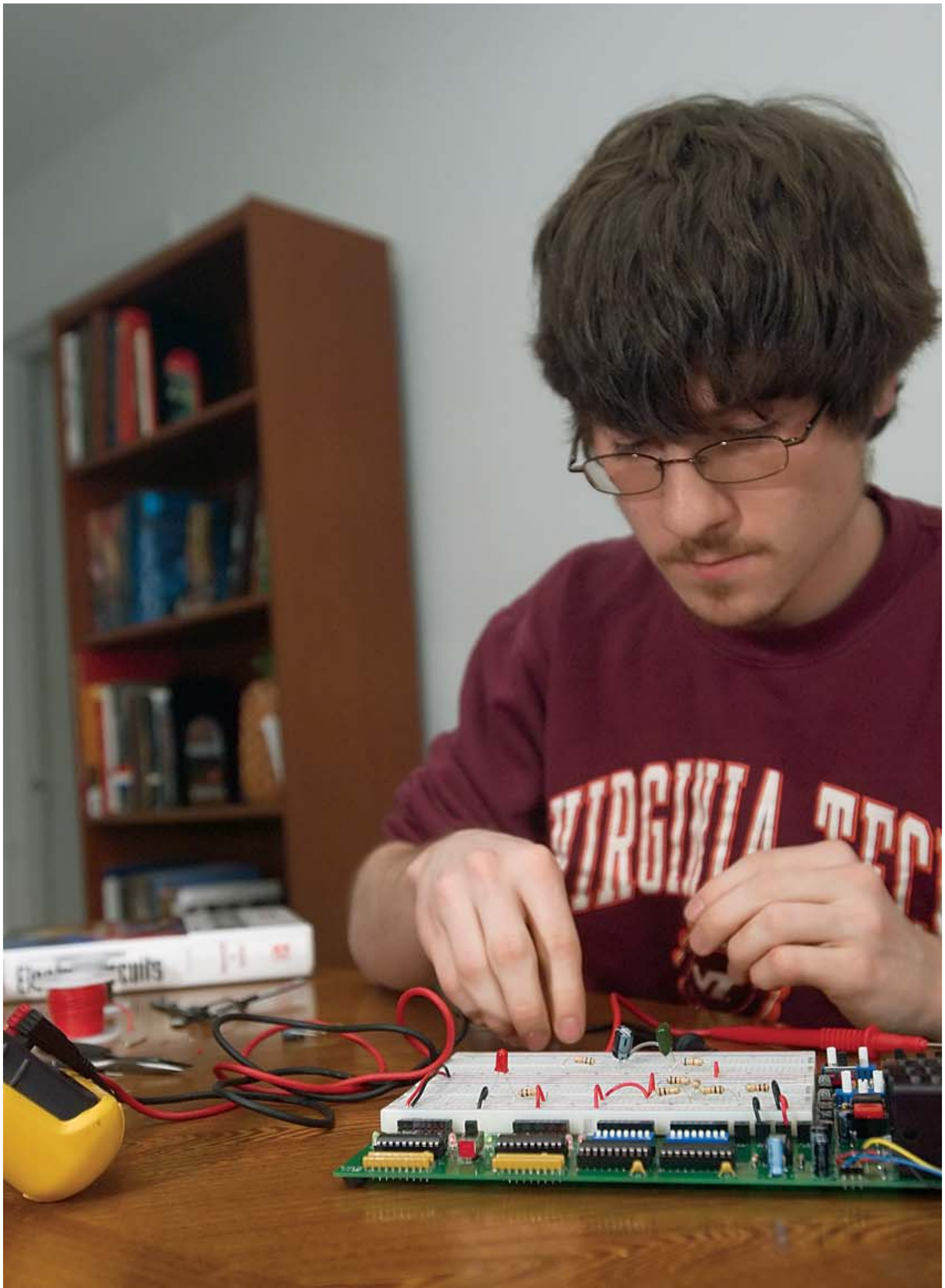
Students in the test class appreciated the flexibility the kits offer as well as the opportunity to see first-hand the concepts discussed in class. “The boxes were great,” said Chris Headley (EE ’06). I could carry it around on campus, do them in Torgersen, or work in my apartment. I could leave a circuit, close the box and finish later.” He described the difference when he took an electronics laboratory course, where the time was limited and students were required to turn in their designs. “With the lab-in-a-box, we had a week to do the projects, so we could toy with them.”

Elizabeth Goldberg (EE ’07) enjoyed being able to do the projects at home. “I could do it any time I wanted, like 2 a.m.” She also mentioned appreciating being able to discuss and troubleshoot the projects with other students, within the confines of the Honor Code. The disadvantage she mentioned was getting questions answered as she worked on the projects. Both students agreed on the advantage of building the projects themselves. "It's neat to build it on your own and figure it out on your own," Golberg said. "Even in a lab course, you have a partner. It's always good to know you can do it yourself; it builds your confidence in applying the concepts with the actual wires and components…One of the best parts was seeing what the components actually look like," she added.

Headley said that working with the circuits being studied helped him visualize the concepts. "We were able to see that things are not as simple as the schematics make them look," he said. "On the bread boards, we have bus lines and connection lines and had to make sure we were grounding the circuits and that we measured the voltages in parallel and the currents in series. That isn't evident by looking at a simple schematic."

They learned from their mistakes: Goldberg by blowing a fuse on her multimeter and Headley by using a 2-ohm instead of a 2,000-ohm resister. "I burned myself pretty badly," Headley said, "but I really learned to double check my circuit before turning it on."

Goldberg she realized in later courses how the concepts taught in the introductory circuits course were truly a foundation. "After just a semester, I can tell how important the course was. The following courses assume you know that material...Looking back, I'd advise any students taking the course to make sure they can do everything on their own because it's skills and knowledge they will use for the rest of their career."


Chris Headley tries out the new 'lab-in-a-box' that will be available to ECE students beginning this fall semester. The personal, portable laboratories enable students to take the time to experiment and explore outside of classes.

Communications

Faculty

Wireless
Annamalai Annamalai
Charles Bostian
Michael Buehrer
Allen MacKenzie
Timothy Pratt
Jeffrey Reed
William Tranter
Amir Zaghloul

Fiber Comm
Ira Jacobs

DSP
A.A. (Louis) Beex
Amy Bell
Jeffrey Reed
Lamine Mili

Networks
Luiz daSilva
Nathaniel Davis
Thomas Hou
Yao Liang
Scott Midkiff
Amitabh Mishra
Jung-Min Park

VLSI Circuits
Peter Athanas
Dong Ha
Michael Hsiao

Propagation
Gary Brown
William Davis
Steven Ellingson
Sanjay Raman
Sedki Riad
Ahmad Safaai-Jazi
Warren Stutzman

Optics
T.-C. Poon

Tech releases world's first open-source software radio tool

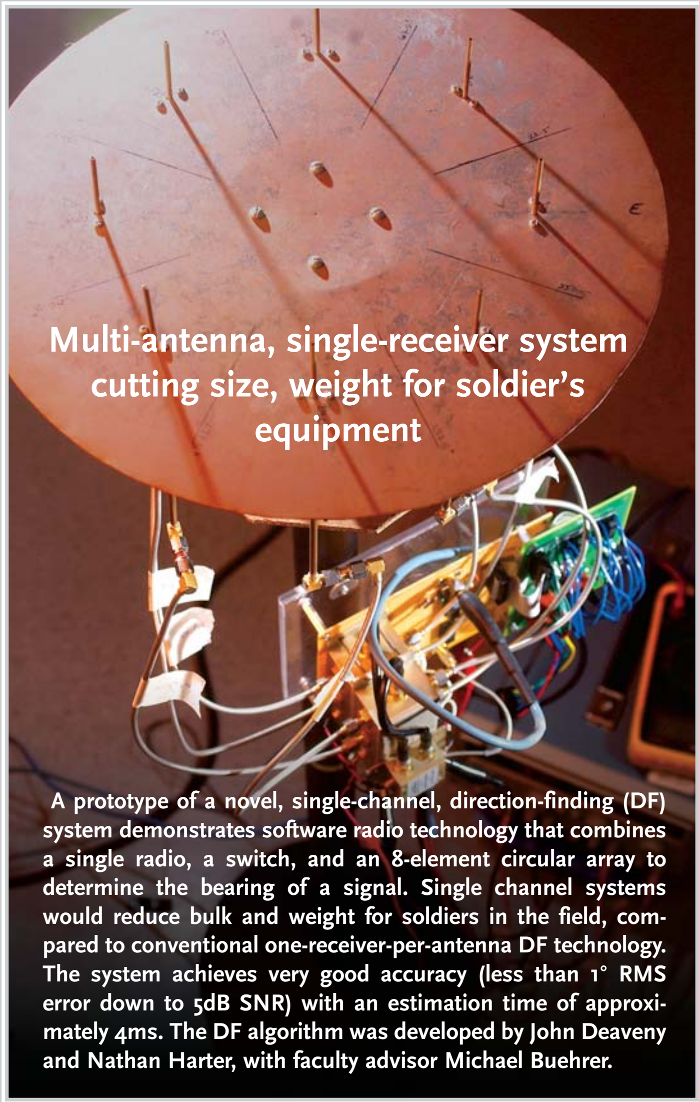
ECE wireless communications researchers have released the world's first open-source implementation of the defacto industry standard for software radio design. The open-source tool lowers the barriers to entering software radio research and should boost software radio education as well as research innovations, according to industry experts.

Called OSSIE (Open-Source SCA Implementation: Embedded), the MPRG tool is written in C++ and is currently available for the Windows 2000 and Linux platforms with MATLAB® installed. OSSIE is an implementation of the Software Communications Architecture (SCA) developed by the U.S. Department of Defense Joint Tactical Radio Systems (JTRS).

The SCA describes the framework that is used to establish, maintain, and tear down waveforms in a radio system. With much of the software radio research driven by Department of Defense needs, the SCA has become the working standard in the field.

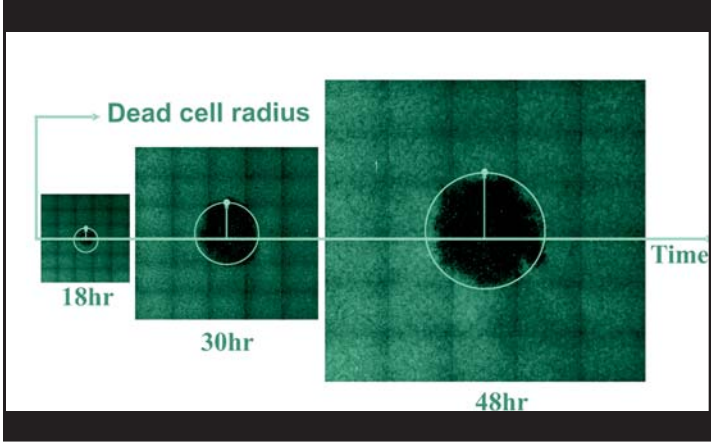
The ability of a software framework that is free, easy to use, and written in a language common to most wireless developers has been a significant barrier to entry into the software-radio research arena

Under the direction of faculty advisor Jeff Reed, post-doctoral fellow Max Robert led a mostly-volunteer team of students to develop OSSIE.

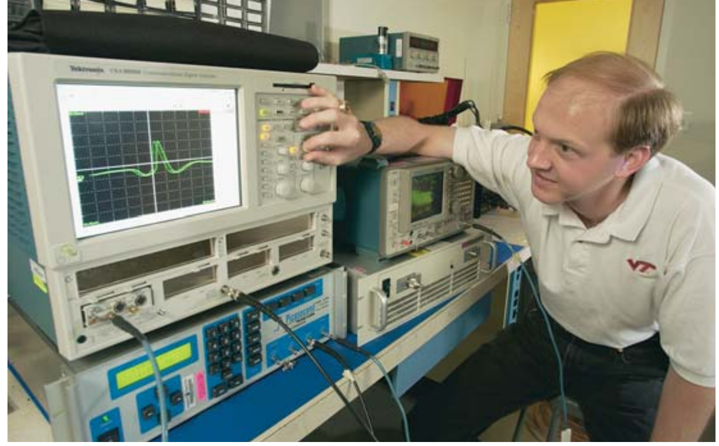


Multi-antenna, single-receiver system cutting size, weight for soldier's equipment

A prototype of a novel, single-channel, direction-finding (DF) system demonstrates software radio technology that combines a single radio, a switch, and an 8-element circular array to determine the bearing of a signal. Single channel systems would reduce bulk and weight for soldiers in the field, compared to conventional one-receiver-per-antenna DF technology. The system achieves very good accuracy (less than 1° RMS error down to 5dB SNR) with an estimation time of approximately 4ms. The DF algorithm was developed by John Deaveny and Nathan Harter, with faculty advisor Michael Buehrer.



Applying signal and image processing to virus/cell interactions: Amy Bell is using signal and image processing to denoise microscope images in a study of how cells react to viruses. She is working with Karen Duca of the Virginia Bioinformatics Institute (VBI). Above: Images showing the cells that have died after being infected.



New UWB Lab: Bradley Fellow Chris Anderson examines an ultrawideband (UWB) pulse in the department's new multidisciplinary UWB laboratory. Anderson is developing a testbed for evaluating different UWB modulation, multiple access, and coding schemes and that will support raw data rates up to 100 Megabits/second.

Communications Overview

Communications research is inherently interdisciplinary, and often coupled with device, circuit and networking technologies. It is common for interests to span multiple areas and for multidisciplinary teams to tackle major topics.

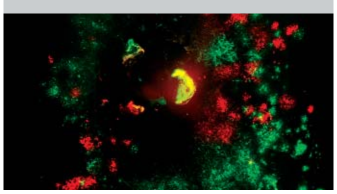
In general, communications research aims to understand the basic limitations on communication system performance; analyze, model, and characterize performance; devise, implementi and evaluate new techniques to improve performance; and contribute to a range of communications applications.

Wireless Communications: Research has progressed from a long-standing involvement in radio technology to propagation and antenna studies for satellite communications, to wireless networking across distances and applications. Wireless researchers today model mobile communications channels, develop multiuser modulation and detection techniques, and devise techniques and applications for new spectral bands, even across spectral bands. New efforts involve developing ultra wideband techniques and cognitive radio systems. Research on antennas, RF ICs, digital ICs, and wireless networking protocols contribute to wireless efforts.

Digital Signal Processing: An important component of wireless research involves implementing functions in DSP chips to boost efficiency and functionality. DSP research reaches well beyond software radios, and covers investigating efficient signal representation, compression, and interference cancellation, for applications in imaging, speech recognition, sonar detection, medical diagnosis, and spatial beamforming. New efforts apply signal processing to microscope signals in biomedical research.

Fiber Optic Communications: Fiber communications work probes the interrelation between technology, system architecture, and applications. Recent activities include modulation techniques to counter the effects of dispersion and non-linearity in long distance systems, subcarrier multiplexing and coding for extending bit rate limitations of multimode fiber systems, information theoretic limits on capacity, and architectures for survivable communications. Current efforts involve broadband access and interfaces between wireless and fiber systems.

Signals & Images



Digital Signal Processing & Communications Laboratory
www.ece.vt.edu/fac_support/DSPCL/
Conducting research in the general areas of signal processing and image processing with applications to systems biology and digital communications. Director: Amy Bell

Wireless

Mobile & Portable Radio Research Group
www.mprg.org
Investigating the interplay of propagation, receiver design, signal processing, networking, and applications in cellular phones, personal communications, land-mobile radio, wireless data networks, and high-speed data links. Facilities include ECE UWB lab. Director: William Tranter

Center for Wireless Telecommunications
www.cwt.vt.edu
Develops technology and designs and builds hardware and software for wireless applications. CWT specializes in fully tested and operational prototypes, which are ready for production. Facilities include ECE Bluetooth Lab. Director: Charles W. Bostian

ElectroMagnetics

Faculty

Charles Bostian	William Davis	Ira Jacobs	T.-C. Poon	Ahmad Safaai-Jazi	Daan van Wyk
Gary Brown	Steven Ellingson	Kathleen Meehan	Sanjay Raman	Wayne Scales	Anbo Wang
Richard Claus	Louis Guido	Hardus Odendaal	Sedki Riad	Warren Stutzman	Amir Zaghloul

Fiber optic oilwell sensor Wins R&D 100 Award

Fiber optic sensor systems developed by the Center for Photonics Technology (CPT) for down-hole oilwell applications was named one of the top 100 inventions of 2003 by R&D Magazine. The oilwell sensor can measure temperature, pressure, flow, and acoustic signals in the harsh environment of oilwells, where traditional electronic components fail.

The CPT sensor systems can reach depths exceeding 10,000 feet and provide real-time, long-term measurements of oil reservoirs. The packaged size of the sensor head is less than 1 mm in diameter – about 1/20 the size of competing technology. According to the U.S. Department of Energy (DOE), two-thirds of oil discovered in the United States remains in the ground, largely because of lack of such data.

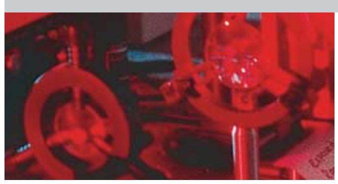
Anbo Wang shows an oil sensor developed at Tech that was named a top invention of 2003.

Tech wins $3+ million contract For wireless IT navy network

The Office of Naval Research (ONR) awarded a $3.26 million grant to Virginia Tech for information technology research. The Advanced Wireless Integrated Navy Network (AWINN) project follows the five-year, Navy Collaborative Integrated Information Technology Initiative (NAVCIITI) project. The AWINN and NAVCIITI programs together have total funding of $16 million.

AWINN supports Navy requirements in wireless secure communications, wideband multifunctional and smart antennas, visualization tools using the CAVE environment, computer networking, digital ships, real-time resource allocation and management, simulation of virtual scenarios, and ultra wideband (UWB) communications.

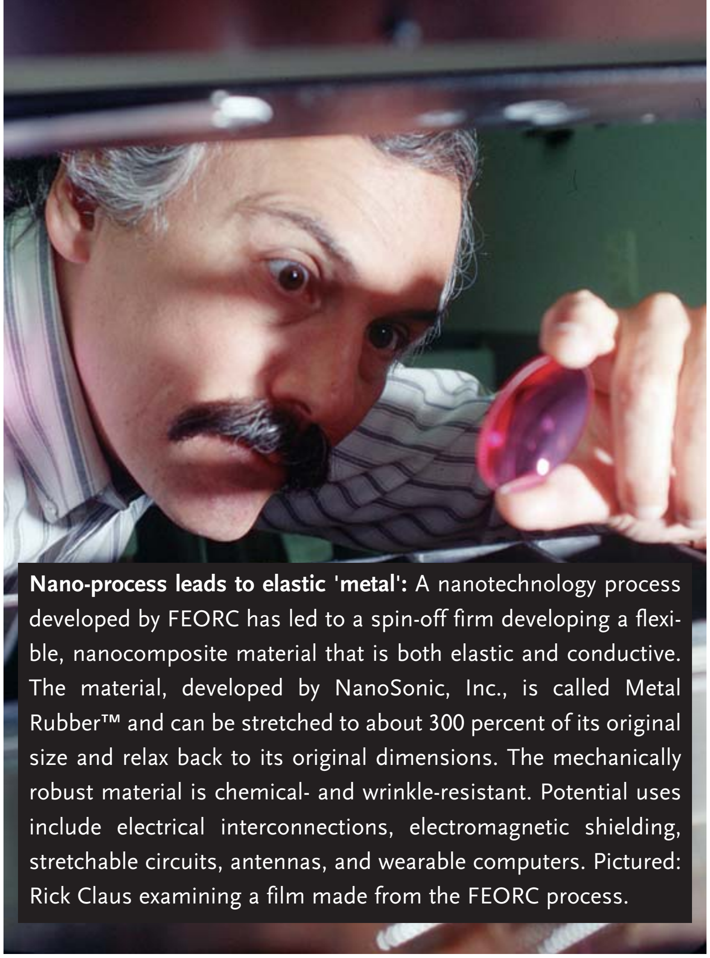
Photonics & Optics



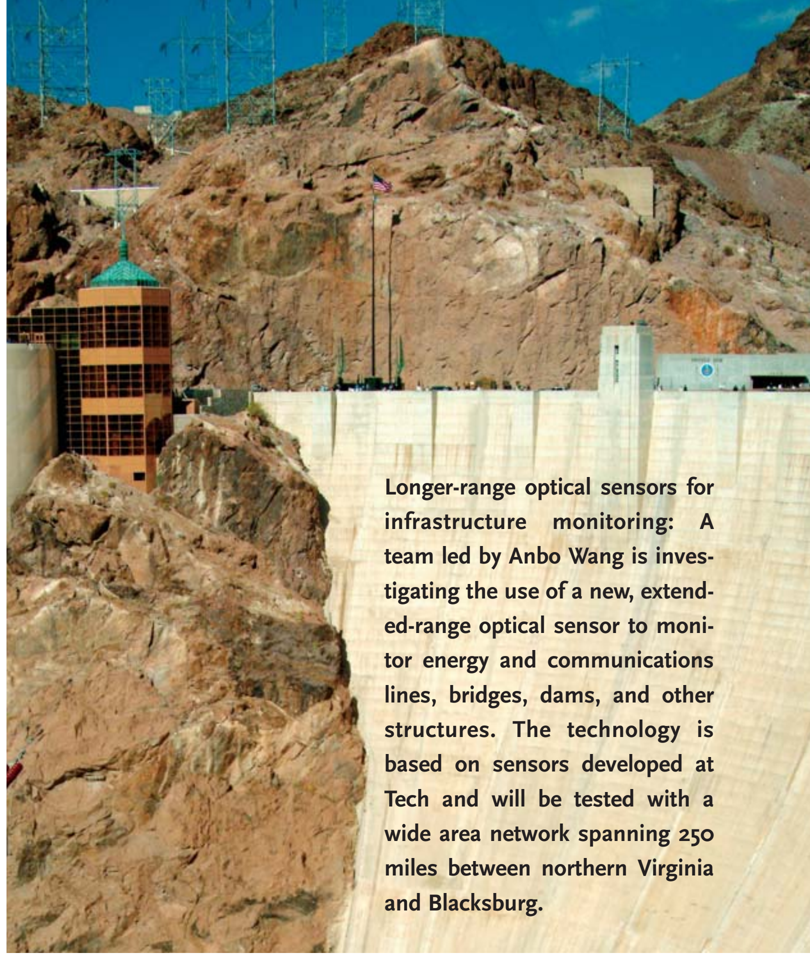
Optical Image Processing Laboratory
http://www.ee.vt.edu/~oiplab
The laboratory studies all aspects of hybrid (optical/electronic/digital) information processing technology, including 3-D display, microscopy and recognition, optical scanning holography, optical scanning cryptography, and acousto-optics.
Director: T.-C. Poon

Fiber & Electro-Optics Research Center (FEORC)
http://www.ee.vt.edu/~feorc/
The Fiber & Electro-Optics Research Center is a high-tech center for the study of fiber optics, electro-optics, optical materials, thin films and other highly advanced technologies. Director: Richard Claus

Center for Photonics Technology
http://www.ee.vt.edu/~photonics/
CPT investigates all facets of photonic sensors, including new sensing mechanisms, materials, thin films, fiber modifications, advanced packaging, optoelectronic signal processing, and instrumentation systems. The center is noted for developing innovative photonic sensors for use in harsh environments. Director: Anbo Wang



Nano-process leads to elastic 'metal': A nanotechnology process developed by FEORC has led to a spin-off firm developing a flexible, nanocomposite material that is both elastic and conductive. The material, developed by NanoSonic, Inc., is called Metal Rubber™ and can be stretched to about 300 percent of its original size and relax back to its original dimensions. The mechanically robust material is chemical- and wrinkle-resistant. Potential uses include electrical interconnections, electromagnetic shielding, stretchable circuits, antennas, and wearable computers. Pictured: Rick Claus examining a film made from the FEORC process.



Longer-range optical sensors for infrastructure monitoring: A team led by Anbo Wang is investigating the use of a new, extended-range optical sensor to monitor energy and communications lines, bridges, dams, and other structures. The technology is based on sensors developed at Tech and will be tested with a wide area network spanning 250 miles between northern Virginia and Blacksburg.

ElectroMagnetics Overview

Research in electromagnetics ranges from the highly theoretical to the very applied. Efforts include atmospheric science, antennas & microwaves, fiber optic communications, numerical methods/simulation, material characterization, time-domain measurements, random media, focused waves, propagation, remote sensing, and photonics. Photonics encompasses acousto-optics, image processing, holography, fiber optic processes, and fiber-optic sensors and devices.

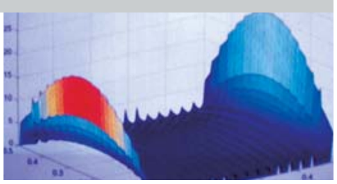
UWB Propagation & Applications: The Time Domain Laboratory (TDL) is collaborating with communications researchers in ultra wideband (UWB) propagation studies and applications.

Radio Astronomy: Radio astronomy investigations include interference mitigation for radio astronomy and remote sensing; high dynamic range, very-wideband FPGA-based digital receivers; and design of large antenna arrays for radio astronomical imaging and transient detection.

E&M Interactions

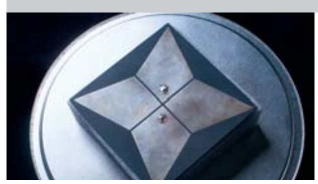
JPL Image

Dusty Plasma Lab
www.ee.vt.edu/~gchae/research.html
The study of dusty plasmas has a broad range of applications including interplanetary space dust, comets, planetary rings, dusty surfaces in space, and aerosols in the atmosphere. Director: Wayne Scales



ElectroMagnetic Interactions Lab
www.ee.vt.edu/~randem/emil/emil
EMIL is devoted to computationally intensive analysis involving the interaction of electromagnetic fields with the natural environment. Current focus: modeling fields through foliage for target detection/location; predicting wave propagation in caves and tunnels; and mine detection and mapping. Director: Gary Brown

Measurements & Devices



Virginia Tech Antenna Group
http://antenna.ece.vt.edu
VTAG aids industry with research and development in propagation, antennas, and communication systems. Of special note are small antennas; wideband antennas/arrays; antennas for unlicensed bands; smart, personal, vehicular, and UWB antennas and systems; and application specific systems. Director: William Davis

Time Domain & RF Measurement Lab
http://www.ee.vt.edu/~tdl/
The main interest of the Microwave Characterization Group at Virginia Tech is in the area of wideband measurements and characterization problems using time domain and frequency domain techniques.
Director: Ahmad Safaai-Jazi

Electronics

Faculty

Dushan Boroyevich
Richard Claus
Louis Guido
Robert Hendricks
Jason Lai
Fred C. Lee
G.Q. Lu
Kathleen Meehan
Hardus Odendaal
Sanjay Raman
Anbo Wang
Daan van Wyk
Fred Wang
Sedki Riad
Amir Zaghloul
Kwa-Sur Tam
Krishnan Ramu
Douglas
Lindner
Joseph Tront
Yong Xu

Electromagnetic armor runs on vehicle battery alone

A power electronics team has developed high-voltage, distributed-power technology so a standard military vehicle battery can provide enough instantaneous energy for electromagnetic armor to repel an incoming projectile. The high-performance system dramatically reduces weight and thickness of the vehicle armor and enhances survivability and mobility.

The technology, developed at the Center for Power Electronics Systems (CPES), passed U.S. Army Research Laboratory testing and is undergoing vehicle testing.

Electromagnetic armor uses an intense electrical discharge to create a powerful, pulsed magnetic field on the intercepting plate to destroy incoming projectiles. Using a pulsed power system, the CPES technology converts 24V battery input to charge the armor to 10 kV, which is more than 410 times higher than the input. The system takes five to 10 seconds to recharge the armor for respective events. In each charging cycle, 100 kJ of energy is delivered in a two-stage step-up. First, front-end converters boost voltage to 600 V, then load converters raise the voltage to 10 kV.

The front-end converters use a high-frequency, soft-switching technique and a newly developed, amorphous magnetic material. Power density is 45W/cubic inch with 91.3 percent efficiency and the switching frequency of 200 kHz is two to four times higher than state-of-the-art. The amorphous material helps cut the magnetic size by 80 percent of conventional transformers. The load converter also achieves greater than 90 percent efficiency and 35 W/cubic-inch power density. CPES Director Fred Lee served as lead on the project.

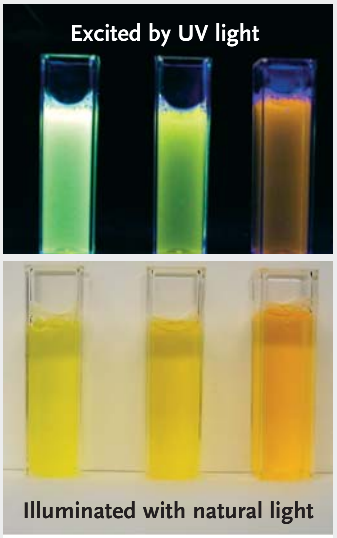
Fuel cells gain power with 97% efficient converter

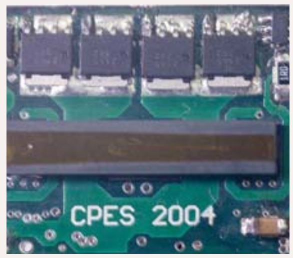
Jason Lai's team at the Future Energy Electronics Center (FEEC) has developed a highly efficient converter that takes the unpredictable, slow DC output of solid oxide fuel cells and produces the high-quality, high-power AC voltage needed by household and business devices. The converter boosts net power output and helps downsize both the fuel cell stack and its supporting electronics. The development is a significant step toward the U.S. Department of Energy (DOE) goal of 40-60 percent overall fuel cell efficiency at a cost of $400/kW by 2010.

The FEEC technology converts 22 V to 400 V at 97 percent efficiency, while reducing 120 Hz ripple current to 2 percent—eliminating the need for the costly, bulky capacitors or additional converters that are customarily used.

The research was funded by DOE's Solid State Energy Conversion Alliance (SECA) Program. SECA studies indicate that each 1 percent improvement in inverter efficiency can reduce fuel cell stack costs by $5-$10 per kW.

Optical biosensors: Kathleen Meehan's team is working with materials, environmental, and life scientists to develop robust optical biosensors for studying living cells. Goals are real-life monitoring of cell response to drugs, viruses, and chemicals, plus identifying intracellular pathways via functionalized probes. The probes are semiconductor quantum dots tailored to detect chemicals through the attachment of biochemical ligands to their surfaces. Photos: CdSe quantum dots in aqueous suspension. Dot diameter influences color.





More power to telecomm devices: Bradley Fellow Douglas Sterk developed a technique that allows the integration of three transformers and two inductors onto a single magnetic core, outperforming standard technology that requires one core for each transformer and inductor. His prototype power supply (shown above) increases the load current more than 30 percent above today's state-of-the-art eighth brick power supplies. With more power delivered in a smaller package, Sterk's converter can replace more expensive quarter brick converters used by today's telecommunications devices.

Electronics Overview

ECE electronics research ranges from investigating physical concepts, new materials and processes, to developing devices and systems using electronics components. This work includes: developing nanotechnology processes; investigating new electronic materials and novel designs; developing microscopic systems that incorporate sensors, actuators, transceivers, and computation technology; and revolutionizing the electronics that convert power.

Microelectronics Materials & Processes: Areas of investigation include microelectronic materials, such as wide-bandgap materials and electronic ceramics; novel devices, including power devices, high-frequency/high-speed devices, optoelectronics; MEMS; and organic light-emitting devices. Additional investigation areas involve: process technologies, such as nanotechnology, advanced lithography, plasma-aided processing, and micromachining, and circuits, systems, and design work.

Semiconductor Devices: Researchers are investigating advanced solid-state devices for RF and power conversion applications. The latest initiatives involve developing advanced RF and power switching devices.

Electronic Systems: Investigations range from microscopic applications to large power converters for utility companies. Microelectronic systems research focuses on IC design of integrated microsystems that incorporate micro-mechanical structures, multi-functional materials, and micro-/optoelectronic circuits on the same semiconductor substrate. In power electronics, researchers are developing standardized integrated power electronics modules (IPEM) to replace expensive, custom-designed technology that is used in power conversion today.

Energy & Power Electronics

Future Energy Electronics Center
www.feec.ece.vt.edu
The mission of the newly established Future Energy Electronics Center is to explore and promote energy efficiency in power electronics technologies. Current efforts include developing technology for small, efficient fuel cells. Director: Jason Lai

Center for Power Electronics Systems
www.cpes.vt.edu
A consortium of 5 universities and 75+ industry partners, is an NSF ERC. The $10+ million program is developing a modular, integrated system approach with semiconductor devices, ICs, packaging, controls, sensors, design methods, distributed power systems, and motor drives for a wide range of applications. Director: Fred C. Lee

Microelectronics

Microelectronics, Optoelectronics and Nanotechnology
MicrON Group facilities include a micro-fabrication cleanroom, as well as packaging, materials analysis, device characterization, materials synthesis, device fabrication, laser ablation, and MOCVD laboratories. The facilities support work in process technologies and electronic devices and systems. Director: Louis Guido

Wireless Microsystems Laboratory
www.ece.vt.edu/wml
Exploring integrated microsystems, notably those communicating wirelessly with the information infrastructure: RF/Microwave/mm-wave ICs, antennas; high-speed interconnects, packaging; mixed-signal ICs; MEMS/NEMS, solid-state/nanotechnology; wireless communications; sensors. Director: Sanjay Raman

Power Engineering

Faculty

Robert Broadwater	Jaime de la Ree	Lamine Mili	Kwa-Sur Tam
Virgilio Centeno	Yilu Liu	Saifur Rahman	James Thorp

Tech deploys 1st-ever network monitoring U.S. power grid

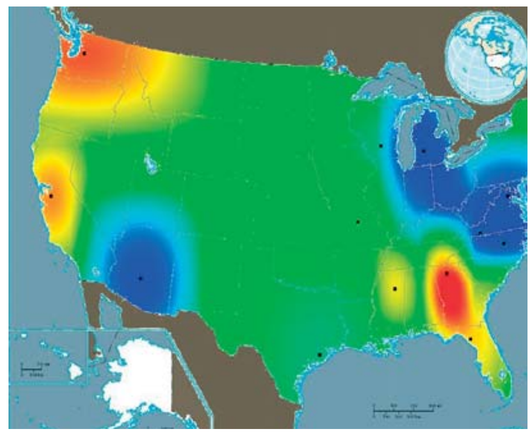
Virginia Tech has launched the first network ever deployed to monitor the entire U.S. power grid as well as the world's first frequency monitoring system using the internet and the Global Positioning System (GPS). The system uses inexpensive frequency recording units (FRU) that are plugged into standard 110V outlets at various university and office locations nationwide.

Called FNET (frequency monitoring network), the real-time, wide-area, synchronized measurement system is based on the concept that system frequency remains constant regardless of voltage level. However, when a significant disturbance occurs, the frequency varies in time and space exhibiting identifiable wave characteristics. As a result, by constantly measuring frequency, system operators can monitor system status and detect disturbances.

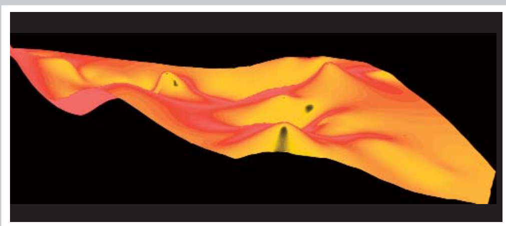
FNET uses the internet for wide area data gathering and transmission, and taps GPS time synchronization for precise data analysis. The system is based on the phasor measurement unit technology (PMU) developed at Virginia Tech by Arun Phadke.

FNET's unique feature is its ability to provide accurate measurements without needing to be installed at high-voltage substations. By eliminating the time and high costs involved with substation deployment, FNET costs a small fraction of what would be required to get global dynamic frequency information using other technology. The installed cost of one PMU last year was more than $80,000 according to the Tennessee Valley Authority (TVA), whereas an FNET unit was only 1-3 percent of that amount.

Since the units do not need to be installed at substations, FNET provides an independent observation system of the US power grids and can contribute to the homeland security monitoring system. FNET can be used for operational and research purposes. The system can provide information for analyzing the underlying causes of cascading events. System operators can detect system disturbances, and researchers can use FNET to verify system models for better understanding the theory of system oscillations. Yilu Liu has led development of the project, assisted by Richard Conners, Phadke, Virgilio Centeno, and Lamine Mili.



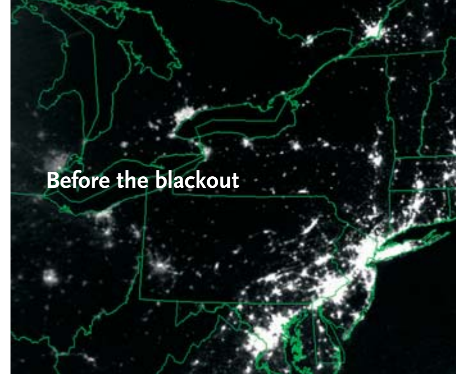
An on-line dynamic frequency map provided by the Virginia Tech FNET system, helps researchers, operators, and students understand, monitor, and measure the power grid in real time.



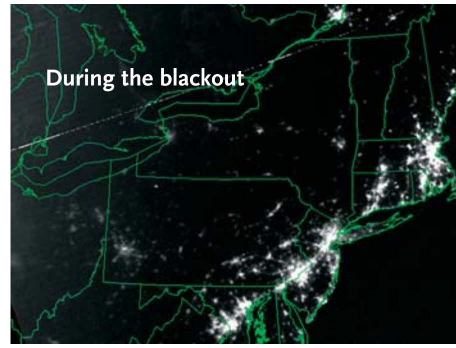
Modeling the power grid as a continuum with geographic data is providing researchers with new understanding of how disturbances propagate throughout the system in a electromechanical wave dispersion. The technique, developed by James Thorp's team when he was at Cornell, provides global behavior analysis not available with conventional discrete system modeling.

The Alexandria Research Institute has developed the Critical Infrastruture Modeling and Assessment Program to assess critical infrastructure issues in Northern Virginia

New York City:
the Blackout of August 2003



Before the blackout



During the blackout

Left photo by AP WideWorld Photos: Mike Derer - Right images: NOAA

Wide area measurements and power blackout prevention

In its final report on the Blackout of 2003, the National Energy Research Council (NERC) put partial blame on inadequate system protection and a lack of adequate tools for operators to visualize system conditions. Its recommendations included installing additional time-synchronized recording devices, which use technology developed at Virginia Tech in the 1980s. Tech's phasor measurement unit (PMU) was the the first such device for wide area measurement. Tech researchers improved the technology and this year deployed the world's first national frequency monitoring network.

Power Overview

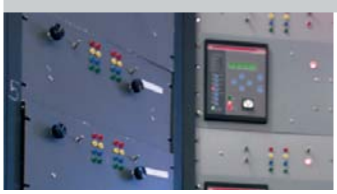
Power research involves delivering electricity and converting it for use at its final destinations. Power systems in many industrialized countries rely on decades-old equipment, creating unique challenges in blending state-of-the-art technology with working equipment that can be half a century old. At Virginia Tech, researchers work to design, improve, and protect the world's power grids and equipment; understand and design distributed and alternative power systems; store electricity for later use; and develop equipment that increases function with less energy.

Much power research integrates and utilizes IT, and, like other areas in ECE, advances involve other technologies, including communications, controls, electronics, and electromagnetics.

Ongoing activities

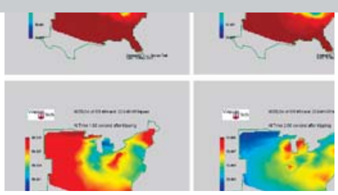
- Equipment monitoring and diagnosis via transformer dissolved gas analysis and fiber optic sensors
- Alternative energy: wind and solar electricity and mitigation of emissions
- Modeling and assessment of critical infrastructure
- Power quality
- Power system monitoring and protection
- FACTS and energy storage technologies, such as battery, super capacitors, and superconducting magnetic energy storage (SMES)
- In-system electrical distribution and control
- Distributed power systems
- Power market modeling and forecasting
- Homeland security

Power Engineering Group



Center for Power Engineering

Research ranges from power system issues to equipment diagnosis and monitoring. Efforts include a comprehensive system information network; the use of SMES in stabilizing power system oscillations; hidden failures in protection; and software for designing and analyzing distribution systems.
Director: Yilu Liu



Power IT Lab

www.powerit.vt.edu

A Center for Power Engineering lab, Power IT addresses the development and implementation of effective computer and network strategies to meet new challenges in the deregulated power industry. Research includes real-time information display, on-line transformer diagnosis and a grid monitoring network. Director: Yilu Liu

Center for Energy & the Global Environment

www.ceage.vt.edu

Focuses on environmentally compatible methods of power generation for supporting the critical infrastructure, including the necessary manpower training. Current efforts involve the internet infrastructure, alternative energy sources, and an online digital library. Director: Saifur Rahman

Systems & Controls

Faculty

William Baumann
A.A. (Louis) Beex
Pushkin Kachroo
Douglas Lindner
Krishnan Ramu
Daniel Stilwell
Chris Wyatt

Underwater robots: Virginia Tech's small, low cost, fully field-deployable underwater robot is being used for testing multi-vehicle control, estimation, and adaptive sampling algorithms.

Underwater and surface robots to monitor lakes, rivers, for biological, chemical agents

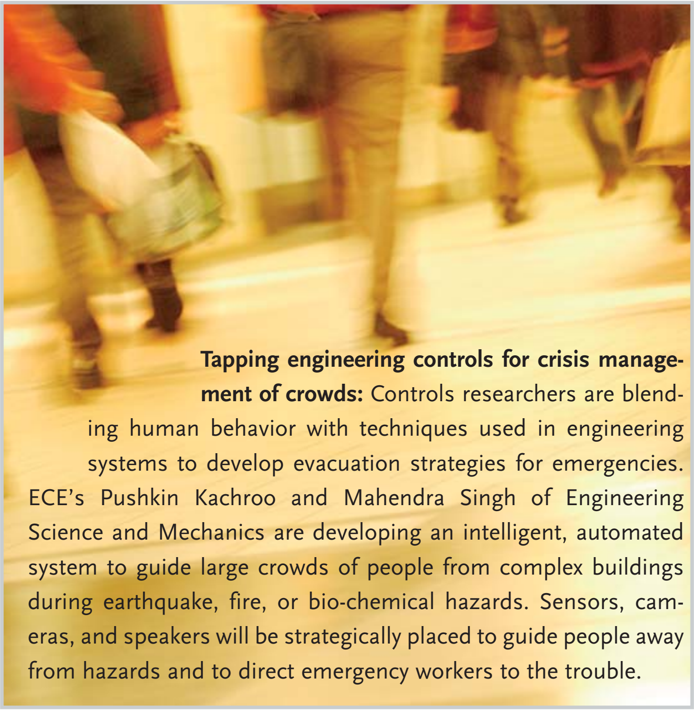
Controls researchers are developing underwater robots and robotic boats to monitor lakes, rivers, and coastal waters for biological and chemical agents.

The mobile, robotic biochemical sensors will support military and homeland security efforts, with potential additional applications in industrial and environmental monitoring.

The Virginia Tech researchers have teamed with the Center for Bioenvironmental Research (CBR) at Tulane and Xavier universities on the project.

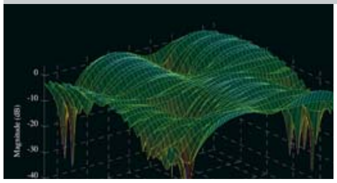
The team is pushing existing technology to enable the biosensing platforms to cooperate as a group without human supervision and to autonomously navigate dynamic and unknown environments such as rivers and estuaries, according to ECE's Dan Stilwell, the principal investigator for the project.

"Currently, autonomous marine vehicles are limited to operating with preprogrammed paths in static and open waters," he explained. "They cannot operate in unknown or dynamic environments where they must make decisions during a mission without human supervision. Autonomous marine vehicles are also incapable of operating effectively in groups," he said.



Tapping engineering controls for crisis management of crowds: Controls researchers are blending human behavior with techniques used in engineering systems to develop evacuation strategies for emergencies. ECE's Pushkin Kachroo and Mahendra Singh of Engineering Science and Mechanics are developing an intelligent, automated system to guide large crowds of people from complex buildings during earthquake, fire, or bio-chemical hazards. Sensors, cameras, and speakers will be strategically placed to guide people away from hazards and to direct emergency workers to the trouble.

Associated Groups and Laboratories



Digital Signal Processing Research Laboratory (DSPRL)
http://www.ee.vt.edu/~dsprl/
Investigating the use of non-Wiener effects in adaptive filtering for narrowband interference mitigation. Other efforts include direction of arrival estimation, speech coding, accelerating convergence of adaptive algorithms, and EEG modeling. Director: A. A. (Louis) Beex

Virginia Active Combustion Control Group (VACCG)
http://www.combustion.me.vt.edu/
Interdisciplinary studies of the interaction of combustion and acoustics often found in power generation turbines and aircraft engines. Goals are to reduce thermoacoustic instabilities and minimize emissions of combustors. ECE Lead: William Baumann

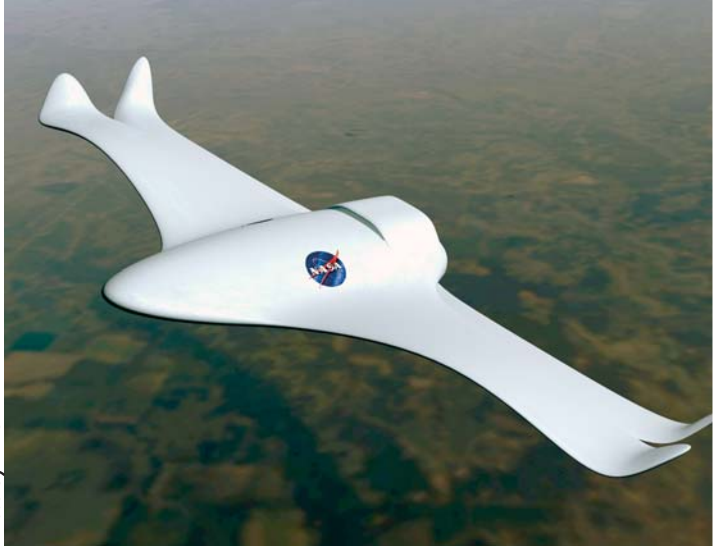


Photo by NASA

Morphing wings for bird-like flight: Douglas Lindner is on a multidiscplinary team to develop optimization methods for morphing wings that consider structural, actuation, and changing aerodynamic loading issues simultaneously. Smart materials and technology are expected to help air vehicles configure themselves during flight. Shown at left is an artist's rendering of NASA's 21st Centeruy Aerospace Vehicle, nicknamed the "Morphing Airplane."

Systems & Controls Overview

Research in the area is geared towards understanding and improving the performance of systems through the use of feedback and advanced signal processing algorithms. A broad range of systems is under investigation, including autonomous vehicles, land-based gas turbines, computer networks, magnetic levitation transportation, interference mitigation, and brain-computer interfacing.

Autonomous vehicles: A number of researchers are involved in the design and construction of autonomous vehicles, both land-based and sea-based. While work has continued in applying advanced control techniques to land-based vehicles and intelligent transportation systems, a new thrust has involved the development of miniature underwater robots and small robotic boats. The target application of this effort is to use platoons of such robots for rapid and adaptive environmental sensing in the Chesapeake Bay and nearby coastal waters.

Motor drives and magnetic levitation: The major thrust in this area is the design of a commuter system for the Virginia Tech campus based on linear propulsion and magnetic levitation technologies. In addition, work continues on high performance motor drives for military, aerospace and consumer applications. A new application area involves the design of variable-speed motor drives for weapons elevators.

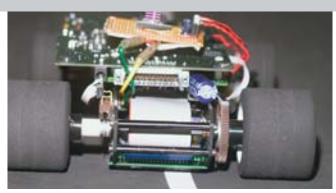
Communication networks & computer systems: Work in this area focuses on applying new developments in nonlinear feedback control and the control and verification of hybrid systems to problems in real-time computer operating systems and the performance of computer communication networks.

Advanced signal processing algorithms: Major progress has been made in understanding the causes of the enhanced performance — above the steady-state optimal value — of certain adaptive filtering algorithms. Work is now underway to exploit these effects in applications involving interference mitigating noise cancellation, equalization, and adaptive prediction. Research is continuing in the areas of speech coding, direction-of-arrival estimation, and EEG modeling for brain-computer interfacing.

Active combustion control: Recent work has involved modeling and determining the performance limits of proportional modulation of the main fuel stream to control thermoacoustic instabilities in liquid-fueled combustors. The development of models to predict instabilities and lean blowout from first principles and empirical data continues.

Motion Control Systems Research Group
www.crts.vt.edu
Developing quiet, electric machines and drives particularly with switched reluctance technology. Also developing innovative, energy-efficient environmentally friendly applications based on the PERTS linear propulsion technology with electromagnetic controls. Director: Krishnan Ramu

Autonomous Systems & Controls Lab
www.ascl.ece.vt.edu
Investigating advances in decentralized estimation and control, sensor networks, and adaptive sampling of the environment. ASCL's AUV is being used to test multi-vehicle control, estimation, and adaptive sampling. New efforts include a robotic boat for long-term deployments in unstructured environments. Director: Dan Stilwell



Intelligent Control Group
Developing a scale model platform for the rapid prototyping and testing of ITS systems and technologies related to the small scale intelligent vehicle project. Other goals include developing future technologies that will help the public adapt to rapid automotoive changes, such as autonomous vehicles. Director: Pushkin Kachroo

Computer Systems

Faculty

Lynn Abbott	Nathaniel Davis	Tom Martin	Paul Plassmann	Chris Wyatt
James Armstrong	Michael Hsiao	Jung-Min Park	Binoy Ravindran	
Peter Athanas	Mark Jones	Cameron Patterson	Joseph Tront	

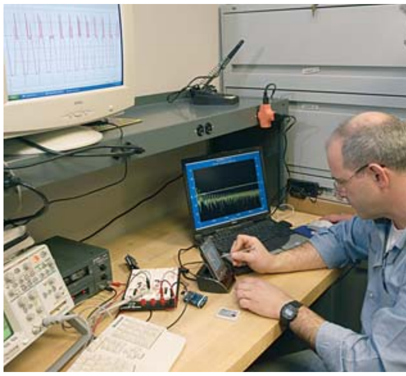
Battery-based detection gives warning of attacks on mobile devices

Virginia Tech computer engineers have devised an early-warning system to protect mobile electronic devices and their networks from malicious attacks. The system, which works on equipment such as cell phones, PDAs and handPCs, is based on the behavior of a battery when a mobile device is under attack.

"A new generation of hackers is emerging who specialize in disrupting and hijacking wireless communications of PDAs and smart phones, which, by default, are not configured to be secure," said Grant Jacoby, who developed the system with his Ph.D. advisor Nathaniel Davis.

He described how some worms deplete batteries by constantly scanning for Bluetooth-enabled devices, and how other attacks can be targeted specifically to consume resources which, in effect, drain batteries and compromise performance. "In the commercial and military sectors, these accelerated battery depletion activities can trigger mission failure and loss of revenue" he said.

The Tech system operates through a host intrusion detection engine (HIDE) that monitors power behavior and notes consumption irregularities. A scan port intrusion engine (SPIE) determines the IP source address and port, as well as the energy signatures of the attack. The system then correlates and compares the data to a variety of the most common attacks. This process could also alert security administrators earlier of an ongoing attack than current means by using mobile devices in this fashion as sensors.



Grant Jacoby tests a battery-based intrusion detector for mobile devices.

The goal of any detection algorithm for mobile computing is to identify attempts before they are successful and not tap too much performance or memory in the process, according to Jacoby. "The question becomes how much power to expend in the effort to protect the device. This is why we developed a software-based solution, since embedded systems are not only expensive, but also make significant energy constraints on these small devices."

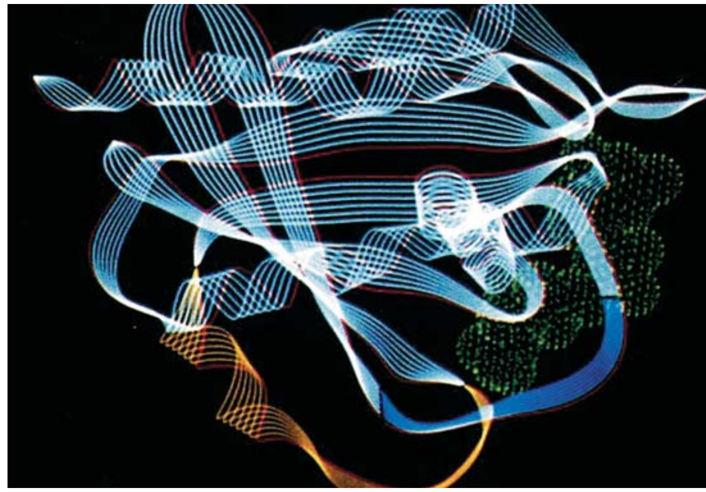
Exploring the hardware/software boundary

Computer engineers work at the interface of hardware and software — and Bradley Fellow Neil Steiner wants to define that interface; its boundaries, properties and behavior; and ultimately identify a unified model. Just as electromagnetics relies on boundary conditions, Steiner questions whether boundary conditions influence hardware/software interactions.

He defines hardware as tangible and able to function on its own — whether it is digital, quantum, biological, or optical. Software is a form of information: intangible, structured, but unable to function on its own. He is intrigued by the energy/information relationships described by IBM researcher Rolf Landauer, and the possibility that a larger structure awaits below the surface.

Steiner proposes that hardware and software may be interchangeable, paralleling each other and sharing similar topologies. "Is an FPGA configuration hardware or software? Or perhaps, potential hardware?" Software emulation of hardware also blurs the boundaries, he acknowledged. "What do we really know about this interface and its boundaries? Do we know what 'forces' come into play? Are the boundaries fixed? Smooth? Malleable?" The questions are important because "engineers are great at finding ways to exploit new properties and behaviors," he says.

Speeding up supercomputers to study human viruses: Mark Jones and Paul Plassmann have developed a toolbox of scalable algorithms and software for complex simulations that reduce CPU time on massively parallel computers, such as Virginia Tech's System X. The toolbox, which has been successfully used in large-scale combustion calculations, has obtained computational speed ups of 1,000 times. Working with Karen Duca of the Virginia Bioinformatics Institute, the team is applying the toolbox to understand the Epstein-Barr Virus (EBV) in humans. The team is linking simulations representing the interaction of EBV and lymphocytes (B and T cells) with the underlying biochemical reactions networks regarding the body's tonsil system.



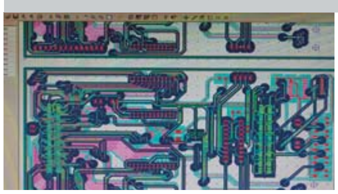
U.S. Department of Energy Human Genome Program

Reconfiguring for bioinformatics: Public production of genomic sequence data has been doubling annually for the past decade, presenting a challenging puzzle to unravel. Peter Athanas and researchers at the Virginia Bioinformatics Institute are investigating relationships that exist between multiple sequences of amino acids to detect variability in a family of proteins and as a step in understanding relationships between organisms. The computing time for multiple sequence alignment can be lengthy, yet can be reduced by orders of magnitude using specialized tools created in the Configurable Computing Lab. By providing dramatic speedup, tools like this may enable researchers to better understand protein construction and evolutionary factors. Shown above is the construction of a Ras protein — a molecular switch — built from amino acid components.

Computer Systems Overview

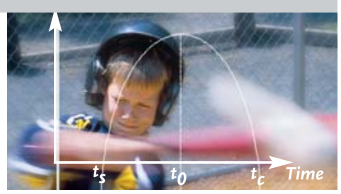
Computer systems research includes the development of parallel high-performance architectures, reconfigurable systems, real-time operating systems and middleware, ubiquitous computing, wearable computers, and e-textiles. Applications of this work include secure communications, acceleration for bioinformatics, embedded systems, and command and control systems.

Computer Systems Group



Configurable Computing Laboratory
www.ccm.ece.vt.edu
Researchers are pursuing advances in configurable computing technology and FPGAs, along with related applications, such as secure communications, wireless medical communications, bioinformatics acceleration, high performance/low power VLSI, and e-textiles. Director: Peter Athanas

Virginia Tech E-Textile Group
www.ccm.ece.vt.edu/etextiles/
Researchers are involved with developing theory and technology for wearable computers and large-scale sensor networks using fabrics that have electronics and interconnections woven into them. Contacts: Mark Jones & Thomas Martin

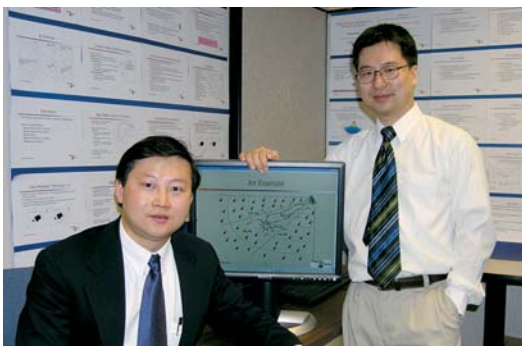


Real Time Systems Laboratory
www.ee.vt.edu/~realtime
The laboratory conducts research in real-time scheduling and resource management (uniprocessor and distributed systems), real-time operating systems and middleware, real-time networking, and systems engineering of real-time systems. Director: Binoy Ravindran

Networking

Faculty

Luiz DaSilva	Thomas Hou	Allen MacKenzie	Amitabh Mishra	Jung-Min Park
Nathaniel Davis	Yao Liang	Scott Midkiff	Jahng Park	Binoy Ravindran



Thomas Hou (left) and research scientist Shiwen Mao (right) have developed a new approach to sensor network design by exploiting capabilities at network edge. This approach is expected to reduce storage, processing, and communication requirements on a sensor node, while offering improved routing, code distribution, and network programmability, compared to conventional core-based approaches.

Limits, trade-offs for wireless sensor networks

Last spring, Thomas Hou won a 2004 five-year, $449,295 National Science Foundation (NSF) CAREER Award for research on Fundamental Performance Limits and Trade-offs in Wireless Sensor Networks. Hou's research will focus on wireless sensor networks operating under a set of unique constraints and requirements.

His main interests in this project are to study some fundamental performance limits and trade-offs that are inherent to wireless sensor networks, with the aim of laying a theoretical foundation for future protocol design and algorithm implementation.

Hou plans to pursue three thrust areas under the overarching theme of energy constraints and network lifetime: maximizing network lifetime through optimal power-controlled flow routing; understanding performance limits and the trade-offs between relay node placement and energy provisioning; and uncovering the inherent properties associated with the energy-constrained rate allocation problem..

Cognitive networks

Luiz DaSilva and Jeffrey Reed have recently received funding from Booz Allen Hamilton for research on software-defined radios and application areas. The group is developing a vision for cognitive networks, where cognitive radios are capable of adapting their behavior to benefit network-wide performance.

Advanced Wireless Integrated Navy Network

The networking area participates in several tasks in the AWINN project, including: the development of integrated routing, security and quality of service solutions for mobile ad hoc networks; real-time resource management, communication, and middleware for secure and robust networks; and adaptive and dynamic cross-layer optimization of physical, data link and network functions in ad hoc networks.

ECE's wireless network testbed provides a network between Northern Virginia and Blacksburg for researchers to test concepts and designs ranging from cognitive networks to game theory.

Left photo: U.S. Forest Service

Radio over IP helps Forest Service with mixed bag of radios, networks

When the U.S. Forest Service wanted its incompatible radio systems to be able to communicate and share information nationwide, it turned to an industry/university team that included Catalyst Communication Technologies of Lynchburg, Virginia and ECE's Scott Midkiff.

The team is leveraging Catalyst's Radio over IP (ROIP) system that allows high quality, critical voice communications from two-way radios to be routed across computer networks. The Catalyst and Virginia Tech team is investigating new techniques that allow voice calls to be routed between incompatible land mobile radio systems that operate on different bands and include a mix of digital and analog technology. The team is also working to ensure that calls can be sent over networks that are saturated with other traffic and can successfully traverse firewalls and other computer network security components. Michael Buehrer has recently joined the team to investigate advanced methods to further improve the quality of the voice calls.

Left: The Monongahela National Forest served as a radio over IP test site where creating a link from the field without a dispatcher was first demonstrated. Right: When crews from different regions meet to fight a fire, communications coordination is critical.

Networking Overview

Research in networking includes aspects of protocols, security, wireless networks, management, support for mobile and pervasive computing, sensor networks, quality of service, and performance evaluation. Some specific research topics include multimedia delivery over wireless and video sensor networks, policy-based network management to provide quality of service in mobile networks, design and analysis of routing protocols for mobile ad hoc networks, security in ad hoc and mobile networks, network traffic prediction and dynamic bandwidth allocation, cross-layer design of multiple access protocols and routing for wireless networks, service discovery and service location for pervasive computing environments, and voice over IP for land mobile radio systems.

Networking Laboratories and Groups

Integrated Research and Education in Advanced Networking (IREAN)
www.irean.vt.edu
IREAN provides students with multidisciplinary, team-based research and learning experiences. Topics include broadband wireless access, pervasive computing, wireless ad hoc networks, wireless multimedia, and network security. Director: Scott Midkiff

Laboratory for Advanced Networking
www.irean.vt.edu/lan
www.lan.ece.vt.edu (Northern Va.)
An affiliation of networking groups with expertise in wireless networks, quality of service, network management, sensor networks, network support for mobile and pervasive computing, networked application, and network simulation. Contact: Scott Midkiff. Northern Va: Luiz A. DaSilva

Wireless Internet Networking Group
www.wing.ece.vt.edu
WING (a subgroup of LAN) research ranges from wireless networking in WANs (3G/4G), LANs (IEEE 802.11) and personal area networks (PAN), to wireless ad hoc and sensor networks. WING focuses on networking protocols, platforms, and application architectures. Director: Amitabh Mishra

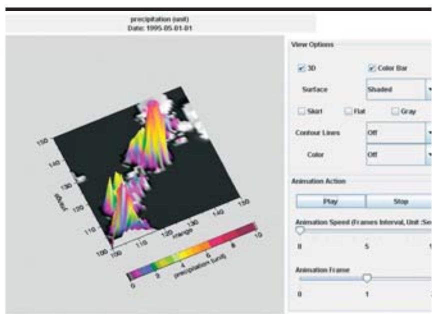
Complex Network and System Research Group
www.ece.vt.edu/~thou/CNSR.html
Focuses on algorithmic design and analysis, and cross-layer optimization for emerging networks systems. The current research area of the group includes wireless ad hoc networks, sensor networks, and video over dynamic ad hoc networks. Director: Thomas Hou

Software & Machine Intelligence

Faculty

Lynn Abbott, Mark Jones, Paul Plassmann, Yue Wang, Robert Broadwater, Pushkin Kachroo, Binoy Ravindran, Chris Wyatt, Walling Cyre, Yao Liang, Sandeep Shukla

Web-based hydrological information and analysis



What was the distribution of rainfall around the world last year? What are the weather trends on the Asian subcontinent? Although these questions seem reasonable given today's computing, communications, and monitoring tools, getting answers requires scientists to collect and analyze huge amounts of data from geographically widespread, dissimilar datasets that have different data structures, organizations and formats.

The problem is complicated by the relative autonomy of the organizations collecting the data. Although the organizations, such as national weather bureaus, provide user-friendly access to their data, the interfaces are all different.

Yao Liang and graduate student, Nimmy Ravindran, have been working with a multi-university team funded by the NSF and the NOAA (National Oceanic and Atmospheric Administration) to develop a hydrological integrated data environment (HIDE) system that synthesizes data from diverse sources, provides analysis and visualization tools, and links to external modeling and software systems.

The Virginia Tech team has developed a web-based integration, data analysis and management system using a novel DataNode tree model, which provides a virtual information space supported by flexible query evaluation. The model combines the semantic aspects of the hydrology domain and the logical organization of datasets.

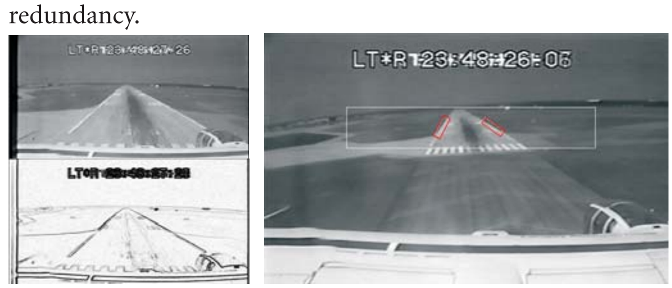
Although the architecture can be applied to many scientific endeavors, their prototype incorporates data from the U.S. Geological Survey (USGS), Germany's Global Precipit-ation Climatology Centre (GPCC), Canada's HyDRO, and the Australian Antarctic Automatic Weather Station.

Each module is developed as a Java package with an open interface for flexibility and extensibility. Any additional features required in a module can be easily plugged in without affecting others.

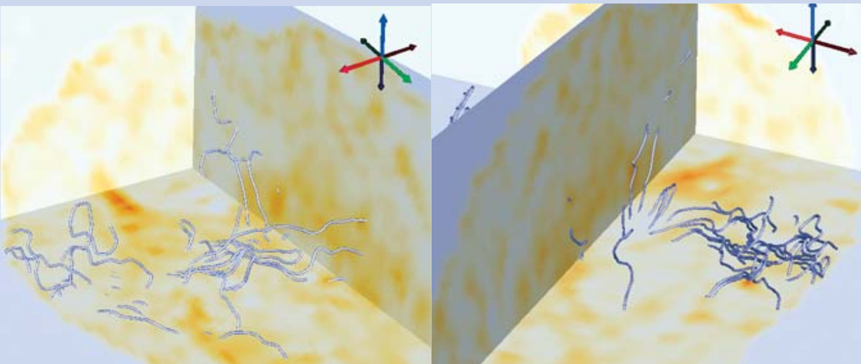
Small plane landing challenges computer vision systems

With today's low-cost cameras and fast CPUs, computer vision shows promise for autonomous and machine-assisted landing of air vehicles, according to computer vision expert Lynn Abbott. Abbott's team has explored two promising methods for semi-autonomous computer-vision-based landing systems. The left images depict edge-based line detection, which assumes that runway edges correspond to sudden changes in image intensity. The image to the far right is an area-based matching system, which uses the concepts of a 2–D matched filter. After locating the runway in the image, the next step is to track the runway during an approach, and guide the aircraft to a safe landing.

"Although the vision-based approach seems simple at first, it is quite challenging for several reasons. Lighting variations caused by clouds and position of the sun must be addressed. Shadows, seasonal changes, wear and tear of runway surfaces, and lack of uniformity in runway appearance create special challenges." Although Abbott's work was sponsored by NASA's now-cancelled Personal Air Vehicle program, computer vision systems have the potential to provide a good alternative for the many small airports that do not have ground-based radar and as an alternative system for planned redundancy.

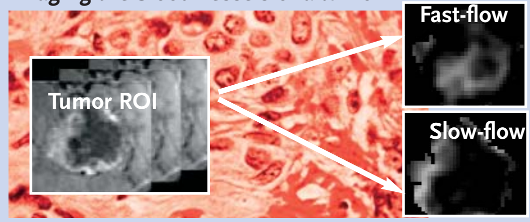


Left: edge detection. Right: area detection.

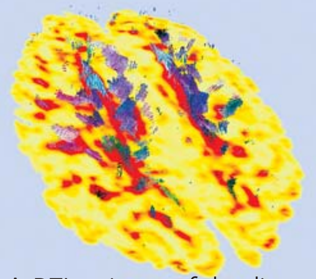


Diffusion Tensor Tractography (DTI): Left and right DTI tractography images of the brain from a patient with asymmetric white matter damage from a stroke.

Imaging the blood vessels of a tumor



Color: Microscopic magnification of a tumor blood vessel. Greyscale: Dynamic contrast-enhanced magnetic resonance image (DCE-MRI).



A DTI estimate of the direction and density of white matter connections in a brain.

BioImaging Technology for medical advances

Algorithms for imaging how the brain works: (Left images) Chris Wyatt is developing algorithms for studying the functioning of the brain via diffusion tensor imaging (DTI), which tracks water diffusion in the brain. DTI helps image the brain's white matter, the nerve fibers that transmit signals within the brain. Nerves in the white matter are surrounded by a layer of fat, which restricts the diffusion of water differently than in other brain regions, giving rise to DTI contrast. DTI provides 3-D analysis of the white matter structure, but its output has significant distortions and noise. Wyatt's team is developing distortion correction and multi-variate analysis algorithms to help speed the technology into medical practice and basic research.

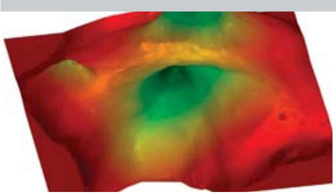
Algorithms to dissect the blood vessels in a tumor: (Top right) Yue Wang's team developed a novel image processing algorithm for dynamic contrast-enhanced MRI (DCE-MRI) to dissect the microscopic blood vessels that a tumor develops. The process is used to characterize the functions (e.g., perfusion, permeability) of tumor induced microvasculature. Scientists hope to stop cancerous growths by cutting off their blood supply.

Software & Machine Intelligence Overview

Research in this area includes software engineering, artificial intelligence (AI), computer vision, and biomedical computing. Software engineering has been applied to large-scale projects, such as monitoring and control of power distribution systems over wide geographic regions and reconfiguration for restoration analysis of interdependent, critical infrastructures. Research in AI has included aspects of pattern recognition, machine learning, genetic algorithms, natural language processing, and autonomous vehicle navigation. Some of this work focuses on automatic synthesis of digital systems directly from English language descriptions. Work continues on automatic extraction of knowledge bases from documents for simulation models and decision support.

Computer vision refers to the analysis of images and video sequences, often with an emphasis on the interpretation of 3-D scenes. Current efforts include image compositing, human face recognition, industrial inspection, and content-driven image compression. Biomedical research includes the development of specialized sensors, imaging systems, and image-analysis techniques for the modeling and detection of internal organs and tissue. One emphasis of this work is to assist with clinical evaluation.

Vision & Automated Design



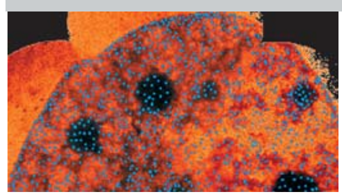
Computer Vision Laboratory
http://vision.ece.vt.edu/

Computer vision involves extracting information from digital images through such tasks as object recognition, visual tracking, depth perception, or 3-D shape estimation. Applications include defect detection for factory automation, autonomous vehicle control, and human face recognition.
Director: Lynn Abbott

Automated Design Research Group
www.ee.vt.edu/~adrg/Members.html

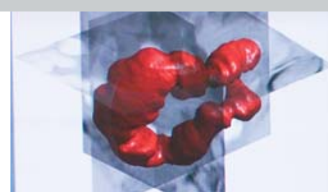
ADRG constructs behavioral models of digital systems automatically from specifications expressed in controlled English. Model extraction is the automatic construction of behavioral engineering models from natural language descriptions, such as U.S. patents and product descriptions.
Director: Walling Cyre

Bioimaging & Bioinformatics



Computational Bioinformatics & Bioimaging Laboratory (CBIL)
www.cbil.ece.vt.edu

Seeking technological advances and discoveries for analyzing and treating diseases, such as cancer, diabetes and brain disorders. Methods include neural networks, computer vision, microarray gene expression analysis, gene regulatory networks, and systems biology. (ARI) Director: Yue Wang



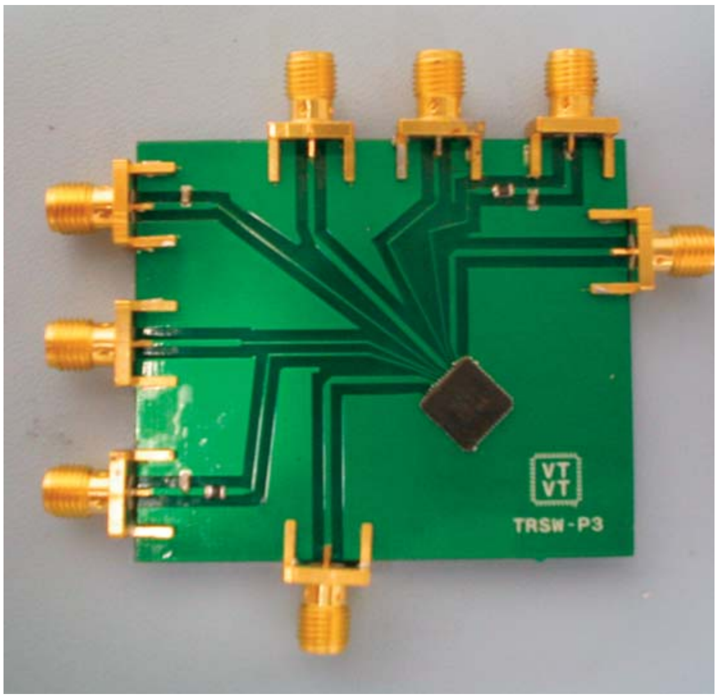
BioImaging Systems Laboratory

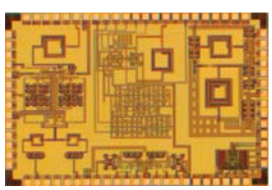
Seeks to develop technology to accelerate the use of imaging and image analysis in biomedicine, including computer-aided diagnosis, neuroimaging, and image-guided interventions. Methods include computer vision, pattern recognition, differential geometry, and scale-space analysis. (Blacksburg campus)
Director: Chris Wyatt

VLSI & Design Automation

Faculty

James Armstrong	Walling Cyre	Michael Hsiao	Sandeep Shukla
Peter Athanas	Dong Ha	Tom Martin	Joseph Tront





Test fixture for a CMOS UWB radio being developed by a Virginia Tech team aiming to build the world's first CMOS single-chip UWB radio. Commercial UWB devices are manufactured with standard SiGe bi-polar technology. Implementing UWB in CMOS would save power and cost, allowing both digital and analog circuits on a single chip. Right: The die photo shows the four key building blocks of a UWB radio.

Aiming for world's first CMOS UWB radio

VTVT successfully fabricates and tests key blocks

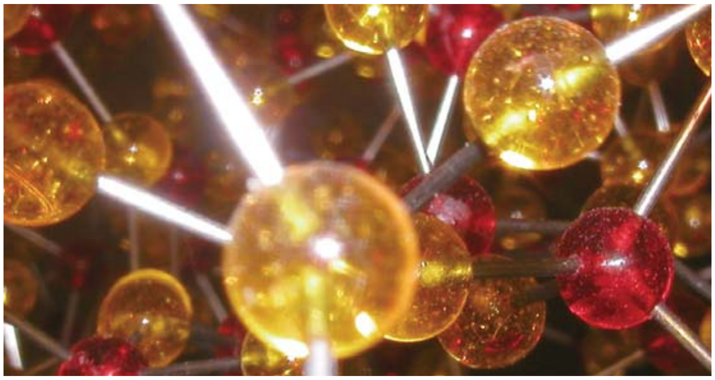
Virginia Tech researchers have successfully implemented analog ultra-wide band (UWB) radio components in a CMOS process, which typically accommodates only digital circuits. The CMOS process allows low-cost implementation and low-power dissipation. The radio components are a major milestone toward the goal of producing the world's first CMOS single-chip UWB radio.

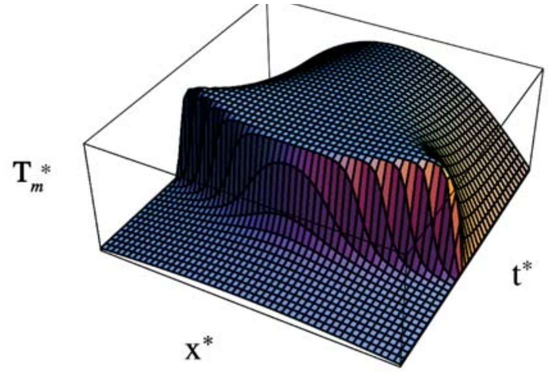
Compared to traditional narrowband radio communication systems, UWB uses narrow pulses that occupy a wide bandwidth. The technology has both communications and radar potential in a variety of applications including wireless personal area networks (WPANs), home networking, sensor networks, through-wall imaging, and ground penetrating radar.

Several research groups worldwide are pursuing development of a CMOS UWB radio however, the wideband nature of UWB pushes the physical limits of CMOS. As a result, commercial UWB radios to date have been implemented in SiGe, a more expensive, higher power process. In order to include digital features, UWB radios typically employ two chips: a CMOS chip for digital functions and a SiGe chip for analog functions.

The Virginia Tech VLSI for Telecommunications (VTVT) group recently became one of the first groups to successfully fabricate and test key blocks of UWB radios in CMOS. The group hopes to develop the world's first complete CMOS UWB solution by the close of the year. The target data rate is 220 Mbps at a 10 meter distance. The effort is sponsored by the Electronics and Telecommunications Research Institute (ETRI).

The group uses an innovative iterative design and testing process because of the inadequacy of current simulation models for UWB implementation. Dong Ha, VTVT director, explained, "SPICE simulations are insufficient to estimate the performance of CMOS in this high-frequency region. Since we cannot accurately predict performance, it is essential to measure the performance of fabricated chips." He continued, "We fabricate test chips about every six months, which is a rare opportunity for a university research team. We are very fortunate to collaborate with ETRI, which not only pays for the fabrication cost, but also provides great assistance from the design review to the final testing."





Design verification tools for the nano-scale: An increase in nano-scale products will introduce greater uncertainty and unreliability into circuit and system design, according to ECE's Sandeep Shukla. Shukla is working to develop reliability techniques for defect-tolerant architectures at the nano scale. "With uncertainties being rampant in nano-technology, we can only rely on the measures of the probability that a transistor will behave correctly, or a logic gate function correctly," he said. Engineers will have to build redundancy in the design, but increased redundancy may lead to reduced reliability. His team is using formal methods applied to probabilistic models and their verification. The goal is to build tools for designers to model the probabilistic nature of defects and automatically evaluate the reliability-redundancy trade-offs.

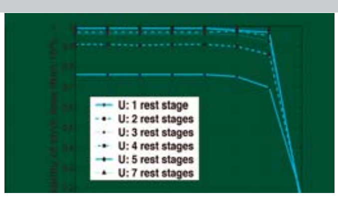
Building scientists their own acceleration pedal: James Armstrong is developing automatic acceleration tools for scientists who are not computer experts and need to model complex physical and biological processes. Working with researchers in mechanical engineering, he has implemented a cascading cellular automata algorithm that they developed by using FPGAs to speed up scientific modeling and simulation. Shown above are results from modeling the chemical reactions in a curing process in a material consisting of a matrix with embedded, separated particles. "Most approaches to acceleration with physical equations rely on super computers," Armstrong said. "Our technique enables a scientist to formulate model equations on a PC and have the solution accelerated locally on a low-cost attached platform."

VLSI & Design Automation Overview

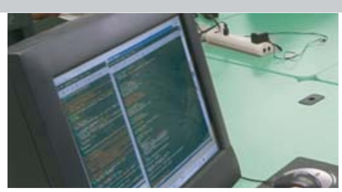
Research activities encompass the design, modeling, testing, and analysis of computational machines at all levels, including logic gates, integrated circuits, systems-on-a-chip (SoC), micro-architectures, and network architectures. Particular emphasis is on high speed and low-power VLSI design for software defined radios, analog, mixed-signal and RF design for ultra wideband radios, bio-microelectronics sensor design, nanotechnology architecture and design for computing, modeling of SoC, reliability and testability of digital hardware, computer-aided design for VLSI, and design methodology for embedded systems.

VLSI & Design Automation

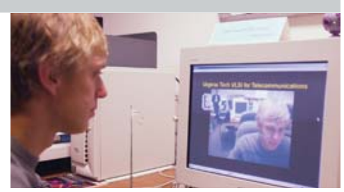
Center for Embedded Systems in Critical Applications (CESCA)
http://www.ee.vt.edu/~cesca/
The multidisciplinary center develops enabling technologies to support distributed decision-making among hundreds or thousands of networked computing nodes. Applications in healthcare, environmental monitoring, transportation, and business are the main focus of the Center. Director: Dong Ha



Formal Engineering Research with Models Abstraction, and Transformations Laboratory
http://fermat.ece.vt.edu
FERMAT investigates embedded system design methodology, verification, low-power design of embedded systems, high level modeling and synthesis, and CAD.
Director: Sandeep Shukla



Proactive Research on Advanced Computer-Aided Testing, Verification, and Power Management Techniques
http://www.proactive.vt.edu
PROACTIVE focuses on state-of-the-art CAD algorithms for automatic testing, verification, and power management of large, high-performance system-on-a-chip (SoCs) and VLSI circuits. Director: Michael Hsiao



Virginia Tech VLSI for Telecommunications (VTVT)
www.ee.vt.edu~ha/research/research
VTVT laboratory focuses on low-power VLSI design for software defined radios and multimedia applications, analog, mixed-signal and RF design for ultra wideband radios, nanotechnology design for computing, and bio-microelectronics sensors.
Director: Dong Ha

2003-2004 Ph.D. Degrees Awarded

Bai, Yuming
Optimization of Power MOSFET for High-Frequency Synchronous Buck Converter
Committee Chair: Huang, A. Q.

Barts, Robert Michael
The Stub Loaded Helix: A Reduced Size Helical Antenna
Committee Chair: Stutzman, W. L.

Biedka, Thomas Edward
Analysis and Development of Blind Adaptive Beamforming Algorithms
Committee Chair: Reed, J. H.

Canales, Francisco
Novel DC/DC Converters for High-Power Distributed Power Systems
Committee Chair: Lee, F. C.

Chongburee, Wachira
Digital Transmission by Hermite N-Dimensional Antipodal Scheme
Committee Chair: Pratt, T.

Cuadros Ortiz, Carlos
On the Circuit Oriented Average Large Signal Modeling of Power Converters and its Applications
Committee Chair: Boroyevich, D.

Cummings, Nathan P.
Active Antenna Bandwidth Control Using Reconfigurable Antenna Elements
Committee Chair: Stutzman, W. L.

Dong, Wei
Analysis and Evaluation of Soft-Switching Inverter Techniques in Electric Vehicle Applications
Committee Chair: Lee, F. C.

Harper, Scott J.
A Secure Adaptive Network Processor
Committee Chair: Athanas, P. M.

Hicks, James Edward
Novel Approaches to Overloaded Array Processing
Committee Chair: Reed, J. H.

Huang, Liling
Electromechanical Wave Propagation in Large Electric Power Systems
Committee Chair: Phadke, A. G.

Kim, Jeong IL
Analysis and Applications of Microstructure and Holey Optical Fibers
Committee Chair: Safaai-Jazi, A.

Lahouar, Samer
Development of Data Analysis Algorithms for Interpretation of Ground Penetrating Radar Data
Committee Chairs: Brown, G. S.; Al-Qadi, I. L.

Lin, Tao
Mobile Ad-Hoc Network Routing Protocols: Methodologies and Applications
Committee Chair: Midkiff, S. F.

Nakad, Zahi
Architectures for e-Textiles
Committee Chairs: Martin, T. S.; Jones, M. T.

Phanse, Kaustubh
Simulation Study of an ADSL Network Architecture: TCP/IP Performance Characterization and Improvements using ACK Regulation and Scheduling Mechanisms
Committee Chair: DaSilva, L. A.

Qiu, Qun
Risk Assessment of Power System Catastrophic Failures and Hidden Failure Monitoring and Control System
Committee Chair: Mili, L. M.

Ransbottom, Jeffrey Scot
Mobile Wireless System Interworking with 3G and Packet Aggregation for Wireless LAN
Committee Chair: Davis, N. J.

Sirisukpasert, Siriroj
The Modeling and Control of a Cascaded-Multilevel Converter-Based STATCOM
Committee Chair: Lai, J. S.

Takamizawa, Koichiro
Analysis of Highly Coupled Wideband Antenna Arrays Using Scattering Parameter Network Models
Committee Chair: Stutzman, W. L.

Xiao, Xiangyu
A Multiple Sensors Approach to Wood Defect Detection
Committee Chair: Conners, R. W.

Xu, Zhenxue (Aaron)
Advanced Semiconductor Device and Topology for High Power Current Source Converter
Committee Chair: Huang, A. Q.

Yang, Bo
Topology Investigation of Front End DC/DC Converter for Distributed Power System
Committee Chair: Lee, F. C.

Yao, Kaiwei
High-Frequency and High-Performance VRM Design for the Next Generations of Processors
Committee Chair: Lee, F. C.

Zhang, Po
High-resolution Photon Counting OTDR Based Interrogation of Multiplexing Broadband FBG Sensors
Committee Chair: Wang, A.

Zhang, Yibing
Novel Optical Sensors for High Temperature Measurement in Harsh Environments
Committee Chairs: Wang, A.; Safaai-Jazi, A.

Bradley Fellows 2004-2005

Christopher R. Anderson
BSEE '99, MSEE '02, Virginia Tech
Advisor: Jeffrey Reed

Research: Developing a software-defined UWB communication system testbed. The system is based on software/reconfigurable radio concepts, and implemented using off-the-shelf components. It will support raw data rates of up to 100 Megabits/second.(See p. 21)

Nathaniel August
BSCPE '98, MSEE '01 Virginia Tech
Advisor: Dong Ha

Research: Developed a system design, MAC protocol, and supporting hardware to apply UWB radio technology to ad hoc and sensor network applications, such as inventory control, environmental monitoring, or RFID.
Honors: Cunningham Fellow.

Jeffrey R. Clark
BS '01, University of Richmond; MSEE '03, Virginia Tech
Advisor: Ahmad Safaai-Jazi

Research: Studying the inclusion of negative refractive index metamaterials in dielectric waveguide configurations. Seeking propagation modes unavailable in positive refractive index waveguides.
Honors: Pratt Fellow; Rappaport Wireless Scholarship.

Stephen D. Craven
BSE '99, University of Tennessee, Chattanooga; MSECE '00, Georgia Tech
Advisor: Peter Athanas

Research: Reducing design time and complexity of custom hardware for accelerating computationally intensive applications by first mapping them to parallel soft processors inside a programmable logic device, then optimizing those processors.

Alumni Bradley Fellows and Scholars 1991-2005

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

Robert Adams (Ph.D. '98)
Assistant Professor, ECE
University of Kentucky
Lexington, Ky.

Shawn J. Addington (Ph.D. '96)
Professor and Head, ECE
Virginia Military Institute
Lexington, Va.
Addington was recently promoted to Department Head and awarded the Jamison-Payne Institute Professorship. He continues to develop the microelectronics program.

Sarah S. Airey (BSCPE '01)

Christopher R. Anderson (BSEE '99)
Ph.D. Student
Virginia Tech

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

Brian Berg (Ph.D. '01)

Ray A. Bittner, Jr. (Ph.D. '97)

Kirsten Brown (BSEE '94)

Steven E. Bucca (BSEE '87, MSEE '90)

Mark Bucciero (BSCPE '01, MSCPE '04)
Arlington, Va.

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

Charles F. Bunting (Ph.D. '94)
Associate Professor, ECE
Oklahoma State University
Stillwater, OK

Carey Buxton (Ph.D. '02)

Scott Cappiello (BSCPE '94)

Matthew Carson (BSEE '98)
Engineer, Engine Dept.
Joe Gibbs Racing
Huntersville, N.C.

Ricky Castles (BSCPE '03)
Graduate Student
Virginia Tech

Eric Caswell (Ph.D. '02)

Kevin Cooley (BSEE '02)
Industrial Automation Specialists Corp.
Hampton, Va.
Cooley is enjoying working with small teams on embedded systems in his new position at this contract R&D firm.

Bradley Fellows

Nathan Harter
BSEE '03, St. Louis University
Advisor: Michael Buehrer

Research: Analysis and implementation of an algorithm for single channel direction finding. Current work focuses on adapting the algorithm for use with a 16 element antenna array, as well as improving performance in multipath channels.

Keith McKenzie
BSEE '01, MSEE '04, University of Tennessee
Advisor: Yilu Liu

Research: Preliminary research has begun involving wind energy, specifically power quality problems associated with wind turbines.

Jamie Riggins
BSEE '04, BSCPE '04, Virginia Tech
Advisor: Daniel Stilwell

Research: Preliminary research on vision, sensor integration, and navigation schemes for an autonomous boat. The principle goal is to create a network of autonomous sensors capable of dynamic reconfiguration, optmization, and navigation.

Mark A. Lehne
BSEE '94 Seattle Pacific; MSME '98, MSEE '00, Oregon State
Advisor: Sanjay Raman

Research: Developing RF/mixed signal integrated circuits with ultra low power consumption for self-organized reconfigurable wireless sensor network nodes.
Honors: TriQuint Semiconductor President Award for IC design.

Justin Rice
BSEE '02, BSCPE '02, MSECE '04, University of Florida
Advisor: Cameron Patterson

Research: Preliminary research on techniques to unify the design process for hardware software co-design. This could allow programmers to create and implement hardware designs without requiring hardware knowledge.

David Gray Roberson, Jr.
BSEE '92, MSEE '00, University of Virginia
Advisor: Daniel Stilwell

Research: Decentralized control and estimation algorithms for severely limited bandwidth conditions for environmental mapping using platoons of AUV.
Industrial experience: GE, Carlen Controls, PrairieComm, Inc.

Alumni Bradley Fellows and Scholars 1991-2005 (continued)

Cass Dalton (BSCPE '03)

Phillip A. Danner (BSCPE '91)

Bradley A. Davis (Ph.D. '01)

Daniel Davis (BSEE '03)

Scott Davis (BSCPE '00)

Joel A. Donahue (MSEE '94)
Ph.D. Student
Virginia Tech

Thomas H. Drayer (Ph.D. '97)

Bradley D. Duncan (Ph.D. '91)
Professor, University of Dayton
Dayton, Ohio

Gregory Durgin (Ph.D. '00)
Assistant Professor
Georgia Tech
Atlanta, Ga.

W. Ashley Eanes (BSEE '95)

Brian Flanagan (BSEE '97, MSEE '98)

Kevin P. Flanagan (BSCPE '00, MSCPE, '01)

Todd Fleming (BSEE '94, MSEE '96)

Ryan Fong (BSCPE '01)
EVI Technology
Columbia, Md.

Jayda B. Freibert (BSEE '98)

Bradley H. Gale (BSEE '97)

Daniel J. Gillespie (BSCPE '95)

Brian Gold (BSEE '01)

Jonathan Graf (BSCPE '02, MSCPE '04)
Research Engineer
Luna Innovations
Blacksburg, Va.
Graf leads projects related to reconfigurable computing on FPGAs.

Timothy Gredler (BSCPE '03)
Project Electrical Engineer
Lutron Electronics
Coopersburg, Pa.

Christopher R. Griger (BSCPE '02)

Alex Hanisch (BSCPE '03)
Graduate Student
George Washington University

Jennifer J. Hastings (BSEE '96)

Ian Schworer
BSCPE ’03, Virginia Tech
Advisor: Pushkin Kachroo

Research: Investigating motor control, navigation, and path planning for autonomous vehicles with the objective of designing a robust and practical autonomous lawn mower.

Douglas Sterk
BSEE ’00, MSEE ’03, Virginia Tech
Advisor: Fred Lee

Research: Developing voltage regulator modules for advanced microprocessors targeting Intel’s 2010 specs. Previously he developed a technique that allows the integration of three transformers and two inductors on a single magnetic core. (See p. 25)

Ethan Swint
MSECE ’02, Baylor, MSME ’05, University of Texas, Austin
Advisor: Krishnan Ramu

Research: Development of novel electrical topologies and control systems for switched reluctance machines with the goal of reducing the number and cost of electrical components required to produce them.

Neil Steiner
BA ’98, Wheaton; BSEE ’98, Illinois Inst. of Technology; MSEE ’02, Virginia Tech
Advisor: Peter Athanas

Research: Investigating the fundamental interactions between hardware and software, with particular interest in the nature of the interface between them, as well as possible boundary conditions and their consequences. (See p. 30)

Juan E. Suris
BSEE ’96, Puerto Rico; MSCPE ’98, Northwestern; MS Statistics ’99, Chicago;
Advisor: Luiz DaSilva

Research: Networking cognitive radios that adapt to new situations and learn from previous experience with high level coordination to boost power efficiency, route stability, and QoS.
Honors: NSF Minority Fellow ‘98.

Daniel Tebben
BS Physics, Secondary Education, ’94, MSEE ’98, Kansas,
Advisor: Ira Jacobs

Research: Investigating new techniques and applications of optical subcarrier multiplixed systems, including sending them over fiber optic networks.
Honors: Cunningham Fellowship.

Dwayne A. Hawbaker (MSEE ’91)

Matt Helton (BSEE ’01)

Jason Hess (MSEE ’99)

Benjamin E. Henty (MSEE ’01)

Eric Hia (MSCPE ’01)

James Hicks (Ph.D. ’03)

Hugh E. Hockett (BSCPE ’03)

Janie Hodges (BSCPE ’01)

Russell T. Holbrook (BSCPE ’03)

Andrew Hollingsworth (BSCPE ’02)

Spencer Hoke (BSCPE ’03)
Graduate Student
University of Illinois-Urbana Champaign

Ryan Hurrell (BSEE ’03)

Todd Hutson (BSEE ’93)

Madiha Jafri (BSCPE ’03)

Daniel A. Johnson (MSEE ’01)

Adam Kania (BSEE ’01)

David A. Kapp (Ph.D. ’96)

Dimos Katsis (Ph.D. ’03)

Paul A. Kline (Ph.D. ’97)

Gregory Kozick (BSCPE ’03)

William B. Kuhn (Ph.D. ’95)
Associate Professor ECE
Kansas State University

Jeff D. Laster (Ph.D. ’97)
Product Specialist
Mentor Graphics
Richardson, TX
Laster works on mixed-signal, analog, and RF products.

Charles Lepple (BSEE ’99, MSEE ’04)

Jason Lewis (BSEE ’99)

Joseph Liberti (Ph.D. ’95)

Zion Lo (BSEE ’94)
Consultant
Highlands Ranch, CO
Lo contacts out software services to Breakthrough Management Group and NetRegulus, a firm specializing in web-based regulatory management software.

Daniel L. Lough (Ph.D. ’01)

Cheryl Duty Martin (BSEE ’95 Ph.D University of Texas at Austin)

Michael Mattern (BSEE ’02)
Senior Control Systems Engineer
Cummins, Inc.
Columbus, Ind.

Christopher Maxey (BSCPE ’02)

Eric J. Mayfield (BSEE ’97)

Patrick McDougle (BSEE ’03)

Brian J. McGiverin (BSCPE ’96)

John McHenry (Ph.D. ’93)
Senior Electronic Engineer
Department of Defense
Odenton, Md.

Bradley Scholars 2004-2005

Daniel Hager, CPE '08
High Point, N.C.
Robert Byrd Scholar; Automotive Engineers Scholar.

Why ECE: "Appears to be the field that will experience the most dynamic development."
Why Virginia Tech: "Best balance of academics and social life, as well as professors and staff who genuinely care."

Benjamin Beasley, EE/Music '08
Kernersville, N.C.
Symphonic Wind Ensemble; Horn Ensemble; Sinfonietta; J.B. West Scholar (music); Robert Byrd Scholar.
Why Virginia Tech: Tech's flexibility "allows me to pursue majors in both of my strongest interests, something I could have done at very few other universities."

David C. Craven, CPE '08
Winston Salem, N.C.
Pratt Engineering Scholar

Most memorable experience: "'Breaking' the Math Emporium. The quiz server froze absolutely and completely after I plugged my mouse into a terminal."

Edward A. Jones, EE '07
Richmond, Va.
Tau Beta Pi; Vice President, Engineers Without Borders.

Research: MACN Lab Group, and design projects including a compressed air racquetball cannon and a simple ALU.
Fun experience: "Representing Tech at the Sustainable Resources Conference in Boulder."

Alumni Bradley Fellows and Scholars 1991-2005 (continued)

David McKinstry (MSSEE '03)
Radar Engineer
Associate Professional Staff
Johns Hopkins University
Applied Physics Laboratory
Baltimore, Md.

Garrett Mears (BSCPE '00)
Software Engineer
DoubleClick, Inc.
Cary, N.C.

Vinodh Menon (BSCPE '02)

Michael Mera (BSEE '03)

Carl Minton (MSCPE '99)

John Morton (MSEE '98)

Stephen Nash (BSCPE '03)
Lockheed Martin Integrated Systems and Solutions
Clarksburg, Md.
Nash is a certified FAA Private Pilot and will soon begin assembling a kit-built Zenith Zodiac airplane.

Troy Nergaard (MSEE '00)

Michael Newkirk (PH.D. '94)

Paul E. Nguyen (BSCPE '98, MSCPE '99)

Eric Nuckols (BSEE '97, MSEE '99)
Chantilly, Va.

Anne E. Palmore (BSEE '91)

Neal Patwari (BSEE, '97, MSEE '99)
Ph.D. Student
University of Michigan
Ann Arbor, Mich.
Patwari's research is in the intersection between statistical signal processing and networking, including applications in wireless sensor networks, and internet anomaly detection.

Joseph A. Payne (BSEE '00)

W. Bruce Puckett (MSEE '00)

Yaron Rachlin (BSEE '00)
Ph.D. student
Carnegie Mellon University
Pittsburgh, PA
Rachlin's research concerns

Brian Kalb, CPE ’07
Aldie, Va.
Engineering Senator in SGA. Co-founder Wallyball Club

Internship: Defense contractor doing research on sonar including acousting and thread detection software.
Work experience: InterCom Network, developing software for AutoCAD users.

David Schroder, EE ’05
Charlotte, N.C.

Career aspirations: Systems engineer for a wireless or satellite communications firm.
Research: Cognitive radios.
Why ECE: “I had been studying electronic music equipment before college, and the electrical aspect fascinated me.”

Jacob Simmons, CPE ’08
Smithfield, Va.
Hillcrest Honors Community.

Why ECE: “To be a part of some idea of invention that will change people’s lives forever. The scope of ECE technology is constantly widening and having great impact on the world.”

Linh Pham, CPE ’07
Annandale, Va.
Hillcrest Honors Community; Argentine Tango.

Research: Autonomous surface vehicles.
Why ECE: “To develop cutting edge microchips by combining this with physics.”

Adam Shank, CPE ’08
Stuarts Draft, Va.
Marshall Hahn Scholar; Gilbert L. & Lucille C. Seay Scholar.

Co-op: Software engineer at IBM.
Most memorable experience: “Creating a racquetball launcher in a team design project in the second semester of Engineering Fundamentals.”

Jerry A. Towler, EE ’08
Greer, S.C.
Student Technology Council; Macintosh Users Group; intramural soccer

Project: Testing engineering software on PowerBooks to determine if students could use Macintosh computers for their coursework.

information theory and sensor networks.

Steve Richmond (MSEE ’01)

Pablo Maximiliano Robert (Ph.D. ’03)
Postdoctoral Researcher
Virginia Tech

Thomas W. Rondeau (BSEE ’03)
Graduate Student
Virginia Tech

Thomas M. Rose (MSEE ’96)
Boeing Company
University City, MO
Rose is working on advanced radar upgrades for the F-15 fighter aircraft.

Jonathan Scalera (MSCPE ’01)

Amy Schneider (BSCPE ’03)

Steven Schulz (MSEE ’91)

Jeff Scruggs (MSEE ‘99)

Kashan Shaikh (BSCPE ’02)

Raymond Sharp (BSE ’02)

Roger Skidmore (Ph.D. ’03)

Jeff Smidler (BSEE ’98)

Graham Stead (BSCPE ’93)

Scott M. Stern (BSEE ’93)

Sam Stone (BSCPE ‘03)

Seema Sud (Ph.D. ’02)

David L. Tarnoff (M.S.E.E. ’91)

Christian Twaddle (BSCPE ’01)

Matthew Valenti (Ph.D. ’99)
Assistant Professor
West Virginia State University
Morgantown, WV

Wesley Wade (BSEE ’93)’

Kristin Weary (BSEE ’03)

Michael L. Webber (MSEE ’03)

Jason Wienke (BSEE ’02)

Thomas Williams (BSEE ’00)

William J. Worek (BSCPE ’99)
SAIC
Arlington, VA
Worek is involved in research and development in biometric recognition and verification, as well as network communications systems.

Kai Xu (BSEE ’95)

Jason Yoho (Ph.D. ’01)

Gregory A. Zvonar (MSEE ’91)

Donors to ECE During Fiscal Year 2004

Although every effort has been made to ensure the accuracy of this report, we acknowledge that errors may have occurred. If your name was omitted or listed incorrectly, please accept our sincere apologies and send corrections to the Office of University Development at (540) 231-2801.

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Stanley C. Ahalt '79
Cary J. Ahrano '68
Christopher R. Anderson '99
William D. Barnhart '00
Michael J. Batchelder '74
Andrew Beach '80
Thomas G. Beazell '79
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Robert C. Bertin '91
Vikram Bhatia '93
James R. Bodkin '65
Rodney H. Bonck '72
James H. Bowen '70
William J. Boyer '50
Robert F. Bruce '65
Edwin A. Bullard '64
Ryan L. Bunch '99
David W. Chandler '82
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Leslie H. Christian '58
Kenton L. Clark '91
James K. Cook '81
Kenneth E. Cutler '85
George S. Davis '69
James M. Deatherage '76
Steve O. Dixon '64
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Steve Estes '96
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David C. Finch '63
Amy R. Flax '86
William E. Fravel, Jr. '66
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Michael S. Fulk '77
James K. George, Jr. '64
Jane A. Gilbert '84
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Jeffrey G. Hadley '89
Paul S. Hamer '72
Edgar D. Harras '67
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Jill S. Herbold '85
Daniel J. Hibbard '02
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Hsien L. Huang '68
Kenneth B. Humm '86
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Bradley S. Jackson '82
Susan J. Jackson '84
William A. Johnson '57
Kenneth L. Johnson '79
Marvin L. Johnson '64
Randall R. Jones '88
John L. Joynes '62
Paul J. Kauffmann, Jr. '71
Davie L. Key, Jr. '84
Joel E. Keys, Jr. '87
Joseph E. Kusterer '82
Jason C. Lang '00
David S. Lehnus '84
Maja M. Lehnus '84
John K. Loftis, Jr. '77
Ronald L. Marsh '77
Claus D. Marzen '73
Joanna N. McMurray '83
James C. Morizio '82
Charles A. Moses, Jr. '71
Constance W. Moses '71
Christopher Munk '90
Forrest E. Norrod '86
Sheila A. O'Brien '83
Walter E. O'Brien '83
Jeffrey T. Olson '81
Robert C. Patterson, III '91
Trevor A. Paul '98
David T. Perdue '75
Milton A. Pilcher '38
Frank M. Pilewski '90
Kurt A. Pilgrim '83
Casimir A. Potyraj, Jr. '85
Michael J. Ratway '88
Danny G. Rhudy '69
Arnie J. Riisen '66
John J. Rinehart '60
Denise Rosenthal '99
Osie M. Sawyer, Jr. '65
James F. Schooler '85
Wayne T. Sink '72
Stephen V. Smith '90
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Michael E. Sockell '81
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Joseph R. Tauchen '91
Paul T. Thurneysen '88
Edward G. Tiedemann, Jr. '75
Michael L. Tolbert '97
Russell J. Torrisi '86
Clifton H. Tucker '56
Robert F. Virostek '87
Robert C. Wagner '80
Donald J. Waltman, Jr. '65
William B. Webber '34
Robert E. Wilber, Jr. '60
Garland R. Williams '58
Jerome A. Zadnik '84
Yibing Zhang '03

ECE Friends Who Contributed to ECE

Steven D. & Julia S. Adams
Glenn M. Allen
Phillip W. & Gwendolyn L. Beauchamp
Arnold Berman
Edward C. & Monica Bischof
F. D. & Louise Bloss
Steven & Yolanda A. Canales
Stephen R. & Rosemary P. Cole
Robert M. & Ruth S. Dell
James A. Eder
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Jackson Joe
Susan A. Johnson
Paul D. Klingenberg
Maryann W. Kusterer
Charles A. Lindberg
David M. Lofe
Dick Man
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Scott F. Midkiff
Michael L. Miles
Jo Ann L. Newell
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George S. Powley
Virginia K. Ratway
Sheila B. Rinehart
Karen Seargeant
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James D. & Carol M. Thompson
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Texas Instuments

Honors & Achievements

Honors & Awards

Rick Claus earned the Virginia Outstanding Faculty Award. He has also been named a Fellow of the Institute of Physics.

Anbo Wang and his colleagues at the Center for Photonics Technology received a R&D 100 Award for their development of optical fiber oil well sensors.

Yue (Joseph) Wang was named the University of Maryland's Alumnus of the Year in Engineering and Information Technology.

Gary Brown received a Distinguished Alumnus Award for 2004 from the University of Illinois ECE Department.

Sandeep Shukla received the Presidential Early Career Award for Scientists and Engineers and gave the keynote speech at the International Forum on Design Languages in Lille, France.

Tom Martin, **Thomas Hou**, and **Allen MacKenzie** received NSF CAREER Awards.

Jeff Reed was named an IEEE Fellow for his work in software defined radio.

Shiwen Mao, a post-doctoral associate working with **Thomas Hou** received the IEEE Communications Society Leonard G. Abraham Prize Paper award for his paper "Video Transport over Ad Hoc Networks: Multistream Coding With Multipath Transport."

Roger Stolen won the 2005 John Tyndall Award for sustained seminal contributions to the fundamentals of the nonlinear optical properties of fibers.

Fred C. Lee received the Outstanding Alumnus Achievement Award from the National Cheng Kung University in Taiwan. He also was the keynote speaker at the International Power Electronics Components, Systems Applications Conference and at the International Power Electronics and Motion Control Conference.

He also won the 2004 Ernst-Blickle Award from the SEW-Eurodrive Foundation and was named an Honorary Professor from Jiaotong University.

Krishnan Ramu is serving as an IEEE Distinguished Lecturer of the Industrial Electronics Society.

Dushan Boroyevich was honored with the Award for Outstanding Achievements and Service to the Profession by the European Power Electronics Association Power Electronics and Motion Control Council (EPE-PEMC).

James Thorp was named the Hugh P. and Ethel C. Kelly Professor of Electrical and Computer Engineering.

Louis Guido was named a Faculty Fellow for his research and contributions in microelectronics.

Tim Pratt was named one of three Virginia Tech Wine Award winners for excellence in teaching. He also receieved awards commending his efforts in service and off-campus programs.

Jaime de la Ree received a Virginia Tech Sporn Award for excellence in teaching introductory subjects. The Sporn Award is selected entirely from student input.

Scott Midkiff along with Sheryl Ball and Catherine Eckel of the Economics Department received the university's Excalibur Award for their Wireless Interactive Teaching System project.

Thomas Hou received the Oak Ridge Associated Universities (ORAU) Ralph E. Powe Award.

Amir Zaghloul and Ph.D. student **Minh Nguyen** won the Best Paper Award in the CNS Networks Track at the 23rd IEEE Digital Avionics Systems Conference (DASC) in Salt Lake City, October 2004.

Editorships

Daan Van Wyk is editor-in-chief of the *IEEE Transactions on Power Electronics*.

Dong Ha is editor-in chief of *Smart Materials and Structures*.

Rick Claus is editor-in-chief of *Smart Materials and Structures* journal.

William Tranter is senior editor of the *IEEE Journal on Selected Areas in Communications*.

T.- C. Poon served as lead guest editor of the "Digital Holography" issue of *Applied Optics*.

Sandeep K. Shukla is an associate editor for the *IEEE Design and Test Magazine*. He served as guest editor for the special issue on "Advanced Technologies and Reliable Design of Nanotechnology Systems."

Thomas Hou is an associate editor for *IEEE Transactions on Vehicular Technology* and an associate editor for *ACM/Kluwer Wireless Networks Journal* and *Elsevier Ad Hoc Networks Journal*.

Yue (Joseph) Wang is an associate editor for *IEEE Signal Processing Letters*.

Amy Bell is an associate editor of *IEEE Signal Processing Magazine* and *IEEE Signal Processing Letters*.

Michael Buehrer is an associate editor of *IEEE Transactions on Wireless Communications*.

Michael Hsiao is on the editorial board of the *Journal of Embedded Computing* and the *Journal of Electronic Testing: Theory and Applications*.

T.-C. Poon serves on the editorial boards of *Optics & Laser Technology* and the *Journal of Holography and Speckle*.

National & International Service

Dushan Boroyevich was a visiting professor at the University of ROMA TRE.

Jeffrey Reed is serving on the Samsung Technical Advisory Board.

Saifur Rahman is a program reviewer and external examiner for Nanyang Technological Institute and Kokej Universiti Teknikal Kebangsaan Malaysia.

Luiz DaSilva and **Scott Midkiff** headlined the Curriculum Development Workshop for Wireless Networks in Hsichu, Taiwan.

Hardus Odendall serves as chair of the IEEEIAS Power Electronics Devices and Components Committee.

Amitabh Mishra has been elected secretary of the IEEE Internet Technical Committee.

Krishnan Ramu was elected vice president (publications) and a senior AdCom member of the IEEE Industrial Electronics Society.

William Tranter is on the Board of Governors and director of education for the IEEE Communications Society.

Conference Chairs

Tom Martin was General Chair of the IEEE International Symposium on Wearable Computers, October 2004.

Daan Van Wyk chaired the VDE/IEEE 3rd International Conference on Integrated Power Electronic Systems, June 2004.

Fred C. Lee was General Chair of the 4th International Power Electronics and Motion Control Conference, August 2004.

Luiz DaSilva will serve as General Chair for the 14th International Conference on Computer Communications and Networks, October 2005.

Anbo Wang chaired the Sensors for Harsh Environments, SPIE OpticsEast, October 2004.

Peter Athanas will co-chair the IEEE International Conference on Rapid System Prototyping, June 2005.

Dong Ha is chairing the International SOC Conference, September 2005.

Saifur Rahman chaired IEEE's "Hydrogen Economy: Its Impact on the Future of Electricity," April 2004.

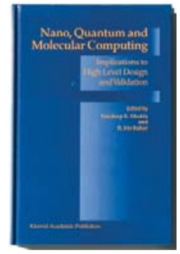
Sandeep Shukla co-chaired the 2nd International Workshop on Formal Methods for Globally Asynchronous and Locally Synchronous Designs, July 2004

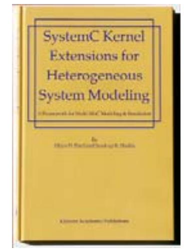
Technical Program Chairs

Thomas Hou served as co-chair of the technical program committee of BroadNets 2004, October 2004.

Anbo Wang co-chaired a SPIE conference "Advanced materials and devices for sensing and imaging" as part of Photonics Asia, November 2004.

Yue (Joseph) Wang is on the program committee for the IEEE International Symposium on Biomedical Imaging, April 2005.





Books Published

Pushkin Kachroo published *Mobile Robotic Car Design*; McGraw-Hill, 2004.

Sandeep K. Shukla with Hiren D. Patel published *SystemC Kernel Extentions for Heterogeneous System Modeling: A Framework for Multi-MoC Modeling and Simulation*; Kluwer, 2004. He also co-edited *Formal Methods and Models for System Design* and *Nano, Quantum and Molecular Computing: Implications to High Level Design and Validation,* both published by Kluwer, 2004.

Patents Awarded

"Hardware configuration, support node, and method for implementing general packet radio service over GSM," Amitabh Mishra.

"Wireless position location system and method using differential global positioning system information and general packet radio switching technology," Amitabh Mishra.

"Line card for supporting circuit and packet switching," Amitabh Mishra.

"Independent component imaging," Yue (Joseph) Wang.

"Twin-image elimination apparatus and method," S. Shinoda, T.-C. Poon, M. Wu, Y. Suzuki.

"Improved emitter turn-off thyristers and their drive circuits," Alex Huang, Bin Zhang.

"Integrated voltage sensor for dead time control," Yuming Bai, Nick Sun, Alex Huang.

"Matrix-transformer phase-shift buck converter," Jia Wei, Fred C. Lee.

"New concept for no body diode in current doubled synchronous rectifier," Ming Xu, Fred C. Lee.

"Self-oscillating electronic discharge lamp ballast with dimming control," Fengfeng Tao, Fred C. Lee.

"The active-clamp couple-buck converter — a novel high efficiency voltage regulator module," Peng Xu, Kaiwei Yao, Fred C. Lee, Mao Ye, Jia Wei.

"Self-driven circuit for synchronous rectifier DC/DC converter," Ming Xu, Fred C. Lee, Yuancheng Ren.

"A wideband compact PIFA antenna," Minh-Chau Huynh and W. L. Stutzman.

"*Fourpoint antenna*," S-Y Suh and W. L. Stutzman.

"Cellular communications systems and related methods," R. M. Buehrer, S. Nicolso, R. A. Soni, D. Uptegrove.

"Methods and apparatus for optically measuring polarization rotation of optical wavefronts using rare earth iron garnets," Richard Claus.

Software Lcensed: "*ANNEPS: a power transformer DGA based diagnosis tool,*" Yilu Liu.

ECE Faculty 2004/2005

A. Lynn Abbott
Associate Professor
Illinois '89

Annamalai Annamalai
Assistant Professor
Victoria '99

James R. Armstrong
Professor
Marquette '75

Peter Athanas
Professor
Brown '92

William T. Baumann
Associate Professor
Johns Hopkins '85

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

Amy E. Bell
Associate Professor
Michigan '97

Dushan Boroyevich
Professor
Virginia Tech '86

Charles W. Bostian
Alumni Distinguished Professor
NC State '67

Robert P. Broadwater
Professor
Virginia Tech '77

Gary S. Brown
Bradley Distinguished Professor of Electromagnetics
Illinois '67

Michael Buehrer
Assistant Professor
Virginia Tech '96

Virgilio Centeno
Assistant Professor
Virginia Tech '95

Richard O. Claus
Lewis A. Hester Professor
Johns Hopkins '77

Walling R. Cyre
Associate Professor
Florida '73

Luiz DaSilva
Associate Professor
Kansas '98

Nathaniel Davis, IV
Professor
Purdue '85

William A. Davis
Professor
Illinois '74

Jaime de la Ree
Associate Professor
Pittsburgh '84

Steven Ellingson
Assistant Professor
Ohio State '00

Louis Guido
Associate Professor
Illinois '89

Dong Ha
Professor
Iowa '86

Robert Hendricks
Professor
Cornell '64

Thomas Hou
Assistant Professor
Polytechnic Univ. '98

Michael Hsiao
Associate Professor
Illinois '97

Ira Jacobs
Professor
Purdue '55

Mark Jones
Associate Professor
Duke '90

Pushkin Kachroo
Associate Professor
UC Berkeley '93

Jason Lai
Professor
Tennessee '89

Fred C. Lee
University Distinguished Professor
Duke '74

Yao Liang
Assistant Professor
Clemson '97

Douglas Lindner
Associate Professor
Illinois '80

Yilu Liu
Professor
Ohio State '89

G. Q. Lu
Professor
Harvard '90

Allen MacKenzie
Assistant Professor
Cornell '03

Tom Martin
Assistant Professor
Carnegie Mellon '99

Kathleen Meehan
Assistant Professor
Illinois '85

Scott F. Midkiff
Professor
Duke '85

Lamine Mili
Professor
Liege '87

Amitabh Mishra
Associate Professor
McGill '85

Hardus Odendaal
Assistant Professor
Rand Afrikaans '97

Jung-Min Park
Assistant Professor
Purdue '03

Cameron Patterson
Associate Professor
Calgary '92

Paul Plassmann
Professor
Cornell '90

T.-C. Poon
Professor
Iowa '82

Timothy Pratt
Professor
Birmingham '68

Saifur Rahman
Professor
Virginia Tech '78

Sanjay Raman
Associate Professor
Michigan '97

Krishnan Ramu
Professor
Concordia '82

Binoy Ravindran
Associate Professor
UT Arlington '98

Jeffrey H. Reed
Professor
UC Davis '87

Sedki Riad
Professor
Toledo '76

Ahmad Safaai-Jazi
Professor
McGill '78

Wayne Scales
Associate Professor
Cornell '88

Sandeep Shukla
Assistant Professor
SUNY Albany '97

Daniel Stilwell
Assistant Professor
Johns Hopkins '99

Kwa-Sur Tam
Associate Professor
Wisconsin '85

James S. Thorp
Department Head;
Hugh P. and Ethel C. Kelly Professor
Cornell '62

William H. Tranter
Bradley Professor of Communications
Alabama '70

Joseph G. Tront
Professor
SUNY Buffalo '78

J. Daan Van Wyk
J. Byron Maupin Professor
Eindhoven '69

Anbo Wang
Professor
Dalian '89

Fred Wang
Associate Professor
USC '90

Yue (Joseph) Wang
Associate Professor
Maryland '95

Chris Wyatt
Assistant Professor
Wake Forest School of Medicine '02

Yong Xu
Assistant Professor
Caltech '95

Amir Zaghloul
Professor
Waterloo '73

Research Faculty & Instructors

Carl B. Dietrich
Research Assistant Professor

Abdul Habayeb
Information Technology Research Professor

James Hendry
Instructor

Jahng Park
Research Assistant Professor

Leslie K. Pendleton
Instructor

Arun G. Phadke
University Distinguished Professor (Emeritus)

Gerald Reid
Instructor

Roger Stolen
Research Professor

Warren L. Stutzman
Thomas L. Phillips Professor (Emeritus)

Dennis Sweeney
Research Assistant Professor

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Instructor

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