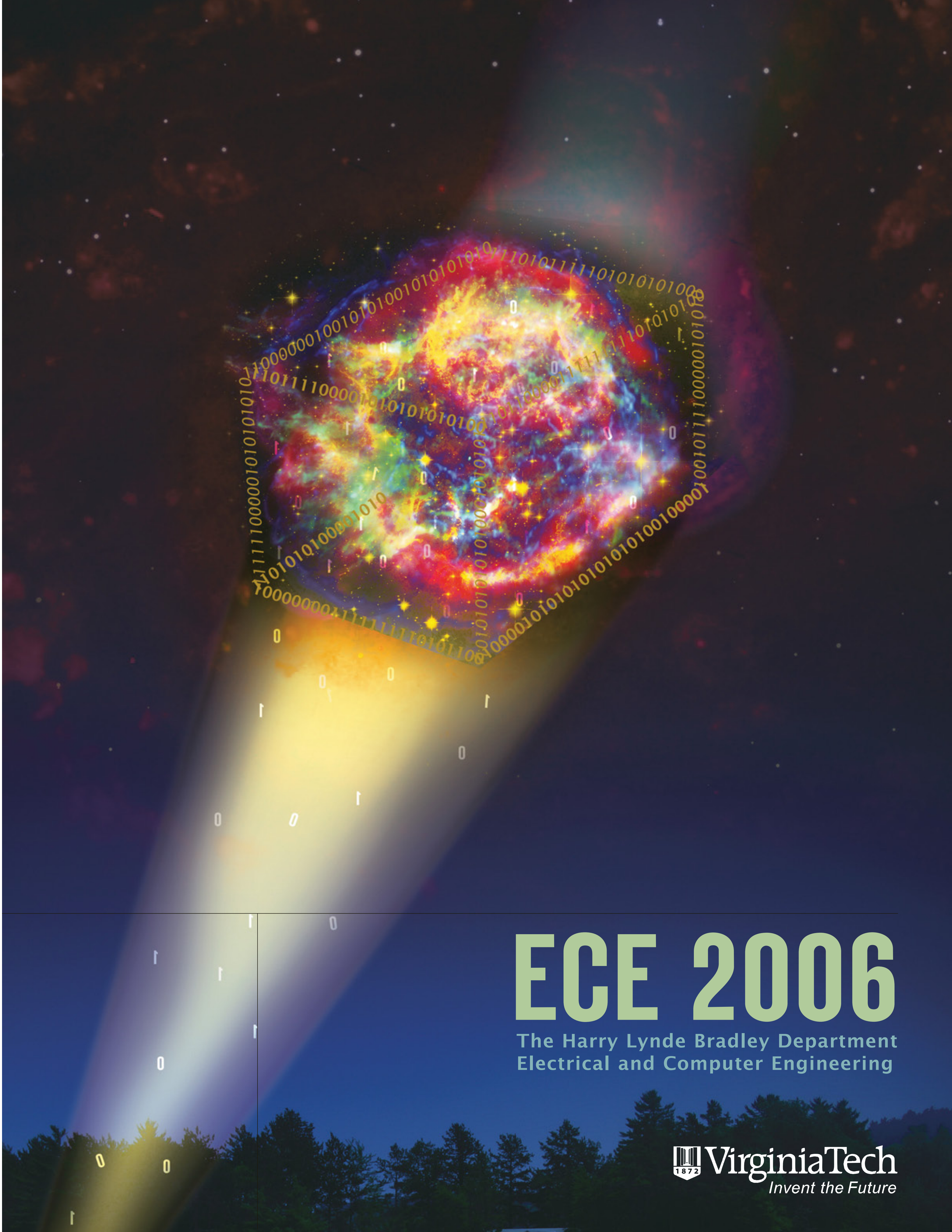


ECE 2006

The Harry Lynde Bradley Department Electrical and Computer Engineering

Virginia Tech
Invent the Future

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

CONTENTS

Inside This Issue

3 ECE Studies Beyond the ’Burg

6 Searching the Universe for Exotic Explosions

10 Radios That Think and Learn

14 Joe Tront: Teaching with Technology

16 ECE Bio-Imaging Aids Medical Researchers

18 Research Overviews

- 18 – Biomedical Applications
- 20 – Communications
- 22 – Electromagnetics
- 24 – Electronics
- 26 – Power
- 28 – Systems & Controls
- 30 – Computer Systems
- 32 – Networking
- 34 – Software & Machine Intelligence
- 36 – VLSI & Design Automation

Also Inside:

1 From the Department Head

2 From the Advisory Board Chair

38 Ph.D. Degrees

39 Bradley Fellows

42 Bradley Scholars

44 Donors

45 Corporate Affiliates

46 Honors and Awards

48 ECE Faculty

49 ECE Advisory Board

Photography by Virginia Tech Visual Communications unless noted otherwise.
John McCormick: pp 6, 12, 13, 14, 15, 16, 17, 34, 41.
Rick Griffiths: pp 1, 10, 20.
Bob Veltri: p 3

From the Department Head

From the vantage point of my sophomore year as department head, the breadth of the department continues to be impressive. In this issue, for example, you will see how our faculty and students are involved in such wide-ranging activities as exploring the universe, developing communications systems that will work in disaster zones, and developing biomedical applications

Since last year, we have added nine faculty members and are recruiting for six more this year in computer engineering, power electronics, atmospheric sciences, and bioinformatics and bioimaging. There is currently a record high of 70 tenured and tenure track faculty in the department. In January 2005, three faculty members who had been recruited the previous year joined ECE: Paul Plassmann, professor in computer engineering, Fred Wang, associate professor in power electronics, and Yong Xu, assistant professor in electronics. Last summer, six more were added: Masoud Agah, assistant professor in microelectronics; Claudio DaSilva, assistant professor in communications; Mohamed Eltoweissy, associate professor in computer engineering, Chao Huang, assistant professor in computer engineering; JoAnn Paul, associate professor in computer engineering; and Patrick Schaumont, assistant professor in computer engineering. The nine have Ph.D.s from Caltech, Cornell, Michigan, Old Dominion, Pittsburgh, Princeton, UCLA, UCSD, and USC.

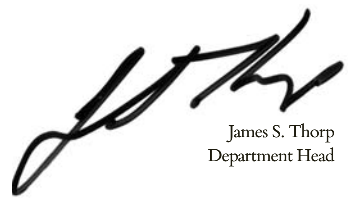
While maintaining our areas of strength, we are attempting to grow in several areas, including nano-bio and space sciences. We are renovating the Microelectronics, Optoelectronics and Nanotechnology (MicrON) cleanroom and associated support laboratories in Whittemore Hall, and expect completion by early summer. The MicrON group consists of a core team of ECE faculty, as well as faculty from MSE, ME, ESM, and physics. The renovations focus on installing a new set of plasma processing tools, including a state-of-the-art deep silicon reactive ion etcher (DRIE), an inductively coupled RIE, a plasma enhanced chemical vapor deposition system, as well as new wet chemical and lithography processing stations. These new and upgraded capabilities will enable MicrON faculty and their collaborators across the university to conduct cutting-edge research in areas such as nanostructured biological and chemical sensors, organic and molecular nanoelectronics, solid-state lighting devices, microelectromechanical systems (MEMS) for sensing and communications, microfluidics for on-chip biological assays and cooling of high-power electronic circuits, and advanced chip-level packaging strategies.

The NSF grant to Wayne Scales and colleagues mentioned last year, coupled with our proximity to thee NASA centers, several aerospace firms, aerospace subcontractors and enthusiastic support from our Industrial Advisory Board, has resulted in cluster hiring in the area. Ultimately, a Space Science Center will encompass ground-based analysis of GPS signals, development of scientific instruments for sounding rockets and satellites, and leadership of major satellite programs.

Notable faculty awards include: Dushan Boroyevich's election to IEEE Fellow for advancement of control, modeling and design of switching power converters, and Sandeep Shukla's invitation to serve as secretary of the IEEE Computer Society Task Force on Nanotechnology, Nanocomputing and Nanoarchitectures. Sandeep was also selected to attend National Frontiers of Engineering, the yearly conference of the National Academy of Engineering. Bill Stephenson has been awarded a DSc by the University of Newcastle in England.

My many thanks to Wayne Snodgrass, who has served as ECE Advisory Board chair for two years. The board has been extremely helpful in supporting the initiative in space sciences and in making connections between ECE at Virginia Tech and the University of Maryland in the nano area.

Adding faculty in these numbers and starting new programs is particularly difficult with our serious lack of space. The ICTAS A building now under construction will be home to the Advanced Materials Characterization Lab. ICTAS I construction is scheduled to begin soon and, with construction of ICTAS II, 200,000 square feet of research space will ultimately be available for the college.



James S. Thorp
Department Head

Facing a Global Change

Courtesy of Northrup Grumman, Frank Bocianowski photographer

Wayne Snodgrass
Chair, ECE Advisory Board

Charles Darwin probably said it best: "It is not the strongest of the species that survives, nor the most intelligent, but rather the one most adaptable to change." While Darwin was referring to biological organisms, the same principle seems to apply to the organizations of mankind. World economies are more competitive than ever before. As some great thinkers of today have recently published, our planet is becoming "flat" and capitalism is expanding fast while the technological leadership role of the United States is being challenged. U.S. universities have recently experienced an emphasis shift away from physical sciences, mathematics, and engineering, along with declines in graduate applications, while Asian and other emerging economies are establishing top-rated universities of their own and now produce orders of magnitude more scientists and engineers than the United States.

Following the U.S. model, these new competitors realize that leadership in technological innovation and first-to-capture markets, along with low cost, highly skilled labor will win the world's economies. The money is accelerating flow towards these emerging economies. While we hope that citizens of all nations are able to enhance their standards of living, we must be proactive to preclude these changes from detracting from the quality of life for American workers (especially the middle and lower levels). Recent trends are not favorable, as widely published. If these trends continue, by 2010 more than 90 percent of all scientists and engineers in the world will live in Asia. We are clearly in a paradigm shift. Our engineering schools and universities must change focus along with national policies if our way of life is to survive.

As our nation responds (as in State of the Union Address) and Virginia responds (with some increased funding), Virginia Tech engineering and ECE have an opportunity to participate in securing our economic future and increase their reputation among the world's top universities. I am encouraged by the effort going into the soon-to-be released Virginia Tech strategic plan that restates core values and places new focus on the scholarship domains. Please visit the Tech Provost home page, *www.provost.vt.edu*. There is a loose flow down of developing complementary policies (from national to university) that identify the goals and could result in major opportunities for ECE. What specifically can we stakeholders do to help?

1. Alumni and faculty can promote innovation. Those who are active in industry, government, or academia could seek ways to team their organizations with ECE in direct research funding and/or form partnerships for joint pursuit of grants. Business and political contacts in funding and policy organizations can be helpful. Ideas for international cooperative opportunities promote outreach opportunities (industries with international relationships). A disciplined business development approach will help win the competitions, and our Advisory Board Research Committee can help coordinate the opportunities. ECE has selected priorities in: power electronics, wireless communications, optical sensors, microelectronics / nanomaterials, networking, configurable computing, biomedical engineering, energy and the environment, and space science.

2. Alumni and faculty can promote graduate education. Active and retired alumni and friends of ECE can support graduate education through intern sponsorships, performance assessment and support, donations towards professorships, faculty part-time research opportunities within industries and agencies, and unrestricted donations to ECE. Our Advisory Board Graduate Education Committee can help coordinate the opportunities.

3. Alumni and faculty members can promote undergraduate education. Alumni and friends of ECE can support undergraduate education through intern or co-op sponsorships, assessment of performance, promoting PK-12 exposure to science/engineering and ECE, and promoting ECE in local events including e-week activities. Our Advisory Board Committee on Undergraduate Education can help coordinate the opportunities.

ECE is adapting to the changes under the effective leadership of department head, Jim Thorp and his faculty. The environment is opportune for us all to join in the dynamics of change and participate in helping our nation as well as our university.

ECE Studies

Beyond the 'Burg

From single courses to certificate programs to degree programs Virginia Tech ECE offers a variety of graduate study options for students and practicing engineers — across the state and around the world.

National Capital Region
Live Instruction and Distance Learning

Several hundred graduate students - most part-time - study at the Falls Church facility. Both master's and doctoral degree programs are offered, and students are advised by on-site faculty members as well as those from the Blacksburg campus. Admissions to degree programs are via the standard graduate school procedures.

Naval Surface Weapons Center at Dahlgren
Live Instruction and Distance Learning

Both master's and doctoral programs are available to scientists and engineers at this government research center. NSWC is now an approved site to meet the residency requirement for the Ph.D. degree.

VT-MENA
Virginia Tech Middle East and North Africa Program
Live Instruction and Distance Learning

VT-MENA is a new degree program offering Ph.D. degrees. Students are located in Alexandria, Egypt and sponsored by the Arab Institute. Students are taught by both Virginia Tech and Arab Institute faculty members. Students satisfy the same requirements as Blacksburg Ph.D. students, including one year of residency at the Blacksburg campus.

CGEP
Commonwealth Graduate Engineering Program
Distance Learning

Through a consortium of engineering programs and 15 delivery sites in Virginia, CGEP offers degrees across engineering disciplines. Students may take single courses or pursue standard degrees. Students may take up to 12 hours through CGEP, at which point, they must meet admissions standards and transfer to a degree program.

Lockheed-Martin, Vienna

Students in Lockheed-Martin's leadership training program have the opportunity to take on-site and local university classes to an M.S. degree in three years. Lockheed instructors certified by Tech teach 9 credits of coursework and the remaining 21 credit hours are taken either through Tech distance learning or at a campus site.

Lockheed-Martin, Manassas
Live Instruction

A special program at Lockheed Manassas offers two software engineering courses on-site. Students must be admitted to the graduate program and satisfy all normal degree requirements to complete an M.S. or Ph.D. degree.

VTMIT
Master of Information Technology
Distance Learning

A distance-learning graduate certificate program is offered to students anywhere in the world through cooperation between ECE, computer science, and the business college. Students may concentrate in a particular area after completing fundamental courses. Some of the eight ECE courses offered in the program are standard courses that meet ECE degree requirements, while others are for the MIT program only. Admission is handled by the VTMIT program office.

VTMIT-India
Live Instruction

Similar to the VTMIT program, VTMIT-India is offered at the S.P. Jain Institute of Management & Research in Mumbai, India. Participating faculty members from Tech travel to India to present courses in a compressed format.

Newport News Shipbuilding
Live Instruction

Non-credit graduate power engineering courses are offered to students desiring greater knowledge in the field. Students are not required to enroll as graduate students in a degree program.

Courtesy of Minh Nguyen

Northern Virginia Center, Falls Church

Part-time PhD

YOU CAN'T BEAT PERFECT

Minh Nguyen earned his Ph.D. last fall after an experience that challenges many common assumptions. He completed his coursework and dissertation on communications traffic analysis and interference cancellation for avionic systems in just three years — as a part-time graduate student holding down a full-time engineering job.

Nguyen entered the Ph.D. program at the Northern Virginia campus in September 2002 and worked with Amir Zaghloul as his advisor. When he started the program, he was a senior communications systems engineer with MITRE Corp. He had thoroughly researched his options and decided that he could pursue a Ph.D. and continue fully contributing at work.

"I was one of the youngest in my division and many colleagues had doctorates," Nguyen remembers. "MITRE is very research oriented and encourages employees to pursue advanced degrees." Nguyen had earned both his B.S. and MS degrees from Tech at the Blacksburg campus and wanted to study here for his doctorate as well.

The hardest part, he says, was the decision to pursue the degree, then to go part time. "Once we engineers start working in our professional field, it's difficult to quit for four or more years for a program that does not have a definitive end," he says. "We think that if we focus on school, we must quit our jobs."

Nguyen tried to weigh the economic cost and the benefits of getting a Ph.D. "Was the degree only for personal satisfaction, or would it help me thrive in my career? I had no answer to that." The option of keeping his job and going to school part time was intriguing. "I talked to 10 people, however, who all said the same thing: that doing a part-time Ph.D. is impossible."

In the end, he chose the job and the degree. "I could not quit a great job for a commitment that was not well defined. I continued to work at MITRE as a salaried, full-time engineer and performed advanced technology research that I really enjoyed."

He entered the program with a big advantage for Ph.D. research. He was already up-to-speed on a research topic that was related to his job. "The idea actually spun off from an internal R&D project that I had been working on. Dr. Zaghloul helped me narrow the focus for an appropriate dissertation. This gave me a jump start," he says. He also found that working in the more applied corporate environment and the theoretical academic environment cross fertilized both efforts. "My industrial work motivated my academic objectives, and what I learned in school helped with my career."

Because his academic research was related to his work at MITRE, he was fully funded to write papers and journal articles, and present his work at conferences. His work also resulted in two joint MITRE-Virginia Tech patents, which are pending. "This is a real plus for Ph.D. students."

His biggest challenge in pursuing both activities simultaneously was "heavy-duty multi-tasking. I had to balance my workloads between work, school, and family — and each one could be considered a full-time commitment." His advice for others considering a similar path: "Eliminate the word 'procrastination' from your dictionary! If you have a research idea in the middle of the night, get up and work on it immediately. Give it further thought or you might lose important ideas forever. There are many things to distract a part-time Ph.D. student and you must maintain focus."

After Nguyen completed his degree, his program at MITRE slowed down due to limitation of government funding, so Nguyen decided to pursue new opportunities. He is now at Argon ST, Inc., applying his communications system architecture signal processing, and interference cancellation expertise to sensor applications and satellite systems. "My academic and research achievements from Virginia Tech helped give me the opportunities at MITRE, and now at Argon ST, working with highly competent colleagues on interesting and cutting-edge research programs."

"My Ph.D. program was perfect: great school, great EE program, great research, wonderful advisor, while at the same time holding a fantastic job. You can't beat perfect."

Background photo by Allen MacKenzie. Left photo by Louis Beex

VT–MENA

The College of Engineering is now making it easier for graduate students in the Middle East and Northern Africa to obtain a Virginia Tech degree. Through the VT-MENA program being hosted by the Arab Academy for Science and Technology in Alexandria, Egypt, Tech is offering students the opportunity to receive master's degrees and Ph.D.s in electrical engineering, computer engineering, and computer science. The program, which has support from USAID, makes pursuing an advanced degree easier for women and working students living with families.

In its first year, 18 students are participating. The graduate engineering program is treated as an "extended campus," much like Virginia Tech's Northern Virginia campus. Classes are taught face-to-face in Egypt by visiting Tech faculty and adjunct faculty hired by Tech or through videoconference communication with faculty at Virginia Tech.

"I'm impressed with the students — they are eager to learn and participate so actively that it can be hard to cover all my material in class," said Allen MacKenzie, who taught in Egypt in the fall. Both MacKenzie and Lynn Abbott, who taught in spring 2006, agree that Egyptians aren't as tied to the clock as North Americans and may show up for class 5-10 minutes late — a habit the Tech professors are trying to change as the students prepare for their year in Blacksburg.

Both were surprised at the students' ability to speak and understand American English — even slang. "I think it's because of the U.S. movies and television shows they see," Abbott said. "Shows are aired over their television with no overdubbing, nothing removed. They learn our language and culture — at least one view of it." Abbott reported that people stopped him on the street to try out their English and welcome him to Egypt. —Su Clauson-Wicker

The VT–MENA building in Cairo, Egypt.

Promoting Undergraduate International Experiences

As academia recognizes that global perspective is crucial in today's workplace, Virginia Tech is stepping up its emphasis on international experience at the undergraduate level. The College of Engineering's strategic plan for the next six years calls for creating new international study and work experiences to grow the study abroad participation to at least 260 graduate and undergraduate students a year.

"Right now our goal is to have at least 15 percent of all undergraduate students getting some international experience before they graduate," said Sedki Riad, director of international programs for the College of Engineering. "All undergraduate programs will have at least one pre-approved study abroad option that enables students to study abroad for at least one semester or summer without delayed graduation. At some future date, we'd like to see all our undergraduate students having international experience before graduation."

At present, Tech has partnered with Darmstadt University of Technology in Germany for summer school and engineering research internships. At Darmstadt, students participate in German language and cultural studies courses, which include seminars, excursions, and visits to major industrial companies. Because Virginia Tech is a partner institution, Tech engineering students receive first-priority admission to the small, selective program.

Another formalized Virginia Tech partnership is an intensive four-week, summer study in robotics at the Arab Academy of Science and Technology in Egypt (the site of Tech's graduate VT-MENA program). Students learn about both the fundamentals of robotic systems through developing a small robot and Egyptian culture at the Alexandria, Egypt campus.

The college is working on generating more formal programs while utilizing existing programs developed by other institutions and corporations around the globe, Riad says. "Our students are somewhat limited by their ability to speak another language. We have work and study programs for them in Europe, Australia, and all around the world, but some are more formalized than others," he said. "I'm working on finding experiences especially geared for Virginia Tech's academic specialties."

ECE major Christopher Lake and 12 other Virginia Tech engineering students have been placed in paid international internships through IAESTE (International Association for the Exchange of Students for Technical Experience), an organization dedicated to developing global skills in tomorrow's technical leaders through international work and study experiences. Lake worked for STIWA in Attnang-Puchheim, Oberostereich, testing motors and designing an operating system for a handheld device. —Su Clauson-Wicker

Searching the Universe for Exotic Explosions

ECE professors Steve Ellingson (right, standing) and Cameron Patterson (seated) have teamed with physicist John Simonetti (left) to search the heavens for exotic events.

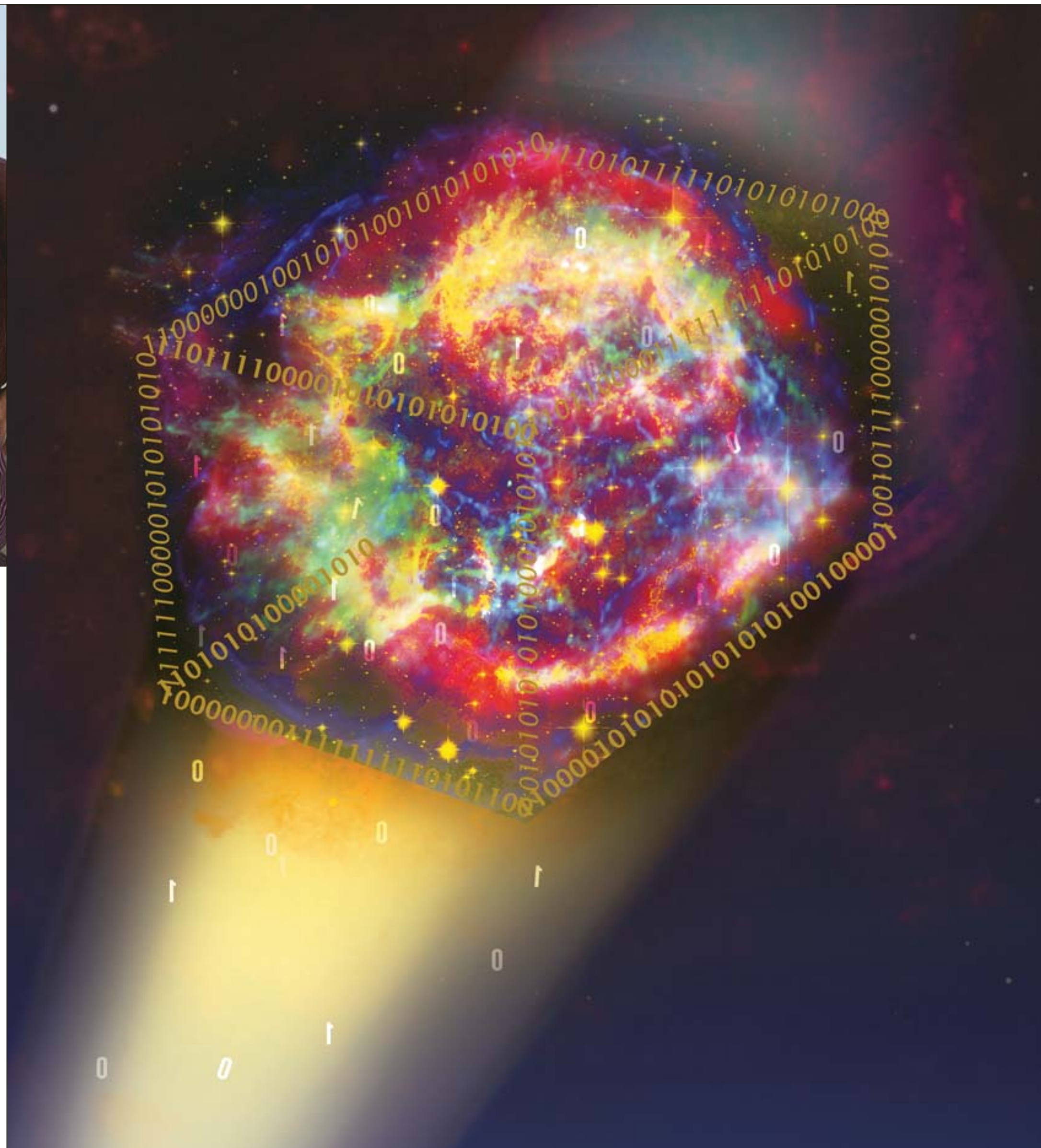


Image of Cassiopeia A by Caltech

Using aluminum pipes, low-cost equipment, and a unique, reconfigurable computing system, ECE and physics researchers have created a radio telescope to search the skies for "exotic physics" phenomena that exist in theory, but are not yet discovered. Beginning this summer, the telescope will begin its continual listening for the tell-tale radio frequency signature of transient astrophysical events such as exploding primordial black holes, gamma-ray bursts, supernovae, and more.

Called the ETA, for Eight-meter-wavelength Transient Array, the instrument represents a new breed of telescope that uses low-cost, simple antennas and receivers while taking advantage of high-performance, real-time digital signal processing and reconfigurable computing for analysis. The project is funded by a $447,000 grant from the National Science Foundation (NSF).

The telescope was designed to conduct a continuous search of the radio sky for single, dispersed radio pulses associated with the explosions of a broad class of astronomical objects called transients. Many of these transients are believed to be associated with rare astronomical events that are postulated, but not yet detected, including coalescing neutron stars and exploding primordial black holes.

"We tend to think of astronomical events unfolding over very long time scales," said John Simonetti, associate professor of physics and the project scientist. "So, discovery of astronomical events occurring over shorter timeframes tends to be a surprise," he said, referring to the unexpected discoveries of periodic emissions from neutron starts (pulsars), aperiodic "giant pulses" from pulsars, and gamma ray bursts.

"It is reasonable to expect continued detection of new sources at low radio frequencies — but only if we look," he said.

"The transient sky is mostly unexplored, since existing instruments are terrible for this," said Steve Ellingson, assistant professor of ECE, and principal investigator on the project. "Existing 'big dish' telescopes have to be pointed, and have very narrow field-of-view — like looking at the universe through a soda straw," he explained. "ETA can see the whole sky all the time, and that's a huge advantage if you are looking for rare single pulses. We would like to know what is going on in the 99.999 percent of the radio sky we aren't currently observing."

Almost belying its galactic promise, ETA is a visual surprise: it looks like 12 pipes stuck in the grass at the

Astronomical Explosions
What is ETA looking for?

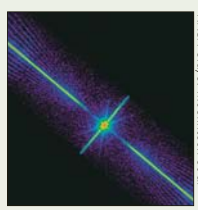
ETA is a radio telescope designed to observe the short dispersed radio pulse — the radio transient — that is expected to be produced by a number of high-energy astrophysical phenomena. The ETA will search for these transients during continuous observation of almost the entire northern hemisphere of the sky.

Giant Pulses - The Crab Pulsar


J. Hester & P. Scowen ASU, NASA

A pulsar is a pulsating radio source, with a typical period of less than one second. It is well accepted that pulsars are rotating neutron stars and that the pulse period equals the rotation period of the star. A handful of pulsars are known to emit an occasional "giant" or "nano-giant" pulses, such as the Crab Pulsar. At radio wavelengths, only the Sun appears brighter than the Crab pulsar during one of these nano-giant pulses. ETA is expected to detect the Crab's giant pulses, providing a useful diagnostic for the system.

Exploding Primordial Black Holes


NASA Cfa/J. McClintock et al

Primordial black holes may be produced as a by-product of the density fluctuations in the Big Bang. There may be as many as 10^{23} of these black holes in our Galaxy alone. Some combinations of general relativity and quantum mechanics suggest that black holes evaporate. The evaporation process quickens as the mass of the black hole decreases and the process ends in an explosion releasing 10^{30} erg or more of energy in less than one second. The resulting relativistic expansion of charged particles could interact with the interstellar magnetic field to create an electromagnetic pulse that could be detected in the low-frequency radio spectrum.

Gamma-Ray Bursts

Gamma-ray bursts are short, intense bursts of gamma radiation coming from a localized, random direction. These short duration events are undoubtedly due to high-energy events, which, in fact, are radiating in all wavelengths. Fading optical emission and even radio emission has been observed from such events, but the prompt radio emission would be very useful in pinning down the physics of the bursts, the nature of object, and possibly the medium in which it occurs.

Supernovae


Caltech

As with primordial black holes, the violent expansion of charged particles from a supernova into the ambient magnetic field would produce a pulse that might be detectable by the ETA. Approximately one supernova event per century is expected in a galaxy.

Compact Object Mergers


NASA/JPL-Caltech/Cornell Univ.

Binary star systems consisting of closely separated compact objects, such as neutron stars and/or black holes will eventually merge as a result of the emission of gravitational radiation and any other energy loss. Such mergers will potentially produce a burst of emission that could be detected in the radio spectrum. Several mergers involving a pair of neutron stars are expected per year in the observable area. Mergers of a neutron star and black hole are expected to be more common, but to generate weaker pulses.

— John Simonetti

For more information, visit www.phys.vt.edu/~jhs/eta/science.html

Pisgah Astronomical Research Institute (PARI) near Asheville, N.C. Each stand, however, is a carefully situated, dual-polarized, 38-MHz-resonant dipole antenna, individually instrumented and digitized. The complete array continually scans the entire sky using fixed "patrol beams."

The design frequency of ETA was set at 29-47 MHz because of both human and galactic considerations, according to Ellingson International short-wave broadcasting presents strong interfering signals below about 30 MHz and broadcast television interferes above 50 MHz.

"From the antenna perspective, this amounts to about 50 percent bandwidth and would ordinarily mean we should use an ultra wideband antenna," he said. "At these frequencies, however, Galactic emissions are extraordinarily strong and can easily be the dominant source of noise." Ellingson's previous studies had indicated that simple, dipole-like antennas, combined with custom preamplifiers having very high dynamic range and carefully matched to the Galactic noise spectrum, could exhibit the best possible sensitivity with such dominant Galactic noise in this case.

The inputs from the dipole feeds are analyzed by a reconfigurable computing system developed for the project by Cameron Patterson, an associate professor of ECE, who is coordinating the project's computing systems.

The system consists of 16 interconnected Xilinx evaluation boards — each incorporating a field programmable gate array (FPGA) and two PowerPC CPUs. The resulting system is a single, large "virtual FPGA" with 500,000 logic cells and 672 differential I/O signals. The virtual FPGA processes the inputs and forms the 12 patrol beams that scan the skies. The system must also estimate and remove frequency dispersion introduced by propagation through the ionized interstellar medium — an extraordinarily computationally intensive task.

"Compared to the 'stovepipe' signal processing hardware that is traditionally used for radio astronomy, this system gives us greatly increased throughput and a much lower system cost," Patterson commented.

The relatively low cost, and simple design have enabled the team to construct ETA in just months. The project was started in August and calibration begins this spring. "We would like to detect something that hasn't been detected with other instruments within the first year," Patterson said.

Detection of any new transients would have extraordinary implications for the astrophysics field, said Simonetti. "Detection of exploding primordial black holes, mergers of neutron stars, or new sources of giant and nano-giant pulses would be enormously significant — especially if they could be detected on a regular basis," he said. "Once identified, these sources become ready-made laboratories for exploring particle physics at energies unattainable in Earth-bound particle accelerators, and additionally serve as probes of the currently poorly understood structure of the interstellar and intergalactic medium."

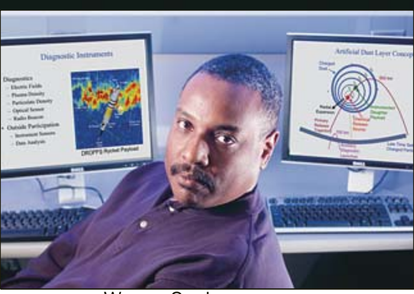
"We are building an instrument that is intended to be used — not simply demonstrated — and which will be able to do some exciting science," said Ellingson.

"Nothing compares to the thrill of building a useful working system, especially when it's the first of its kind. The fact that we are also pushing the limits of performance in wideband, high-dynamic range, direct-sampling receivers; reconfigurable real-time computing; and interference mitigation is just gravy."

For more information on ETA, visit the project website at www.ece.vt.edu/swe/eta/

Almost belying its galactic promise, ETA is a visual surprise: it looks like 12 pipes stuck in the grass at the Pisgah Astronomical Research Institute (PARI) near Asheville, N.C. Each stand, however, is a carefully situated, dual-polarized, 38-MHz-resonant dipole antenna, individually instrumented and digitized. The complete array continually scans the entire sky using fixed "patrol beams."

The aurora borealis, or northern lights, are geomagnetic storms generated by solar winds (electrically charged particles from the sun). The storms can interfere with communications and even cause surges on long-distance power transmission lines.



Wayne Scales

Exploring the Effects of Space Weather

High-altitude noctilucent, or night-shining clouds, are a relatively new phenomenon seen mostly in the northern latitudes at the boundary of space. First spotted in the 1880s, the clouds are becoming more common and can now be seen as far south as Virginia. Space scientists are seeking to understand how they form and their relationship to meteoric dust and human activity. These charged dust clouds are the subject of theoretical, computational, and experimental study in the ECE department.

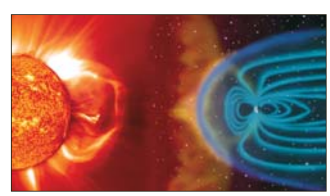
While the ETA telescope searches for exploding primordial black holes and neutron stars, another group at Virginia Tech is focusing a little closer to home — specifically our own upper atmosphere and solar system.

ECE's Wayne Scales, with Joseph Wang of the aerospace and ocean engineering (AOE) department are creating a Space Science Research Group with an $805,000 grant from the National Science Foundation (NSF). The group focuses on phenomena in the ionosphere and magnetosphere, where charged particles in the solar wind produce space weather, visibly observed as the aurora borealis and noctilucent (glowing night-sky) clouds, among other events. Solar flares and solar storms impact communications and power systems on Earth as well as satellites, other spacecraft, and astronauts.

"This is a most appropriate time for us to strengthen our space science research efforts," said Scales, the principal investigator. "Due to the strong emphasis in space exploration over the coming decades, the study of the charged upper atmosphere of the earth and other bodies in the solar system will become an even more relevant and vibrant research area."

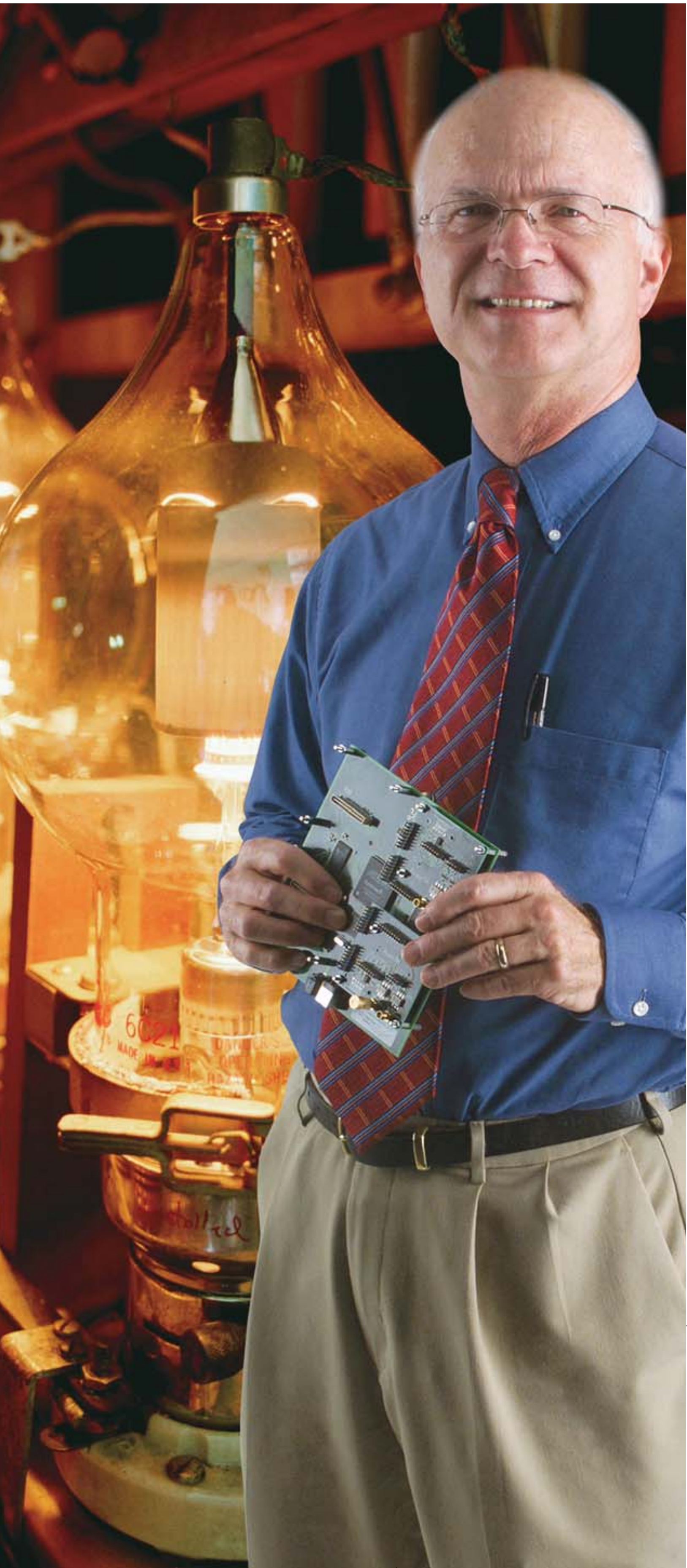
This summer, Brent Ledvina and Scott Bailey will join the ECE faculty, adding their experimental and instrumental expertise to Tech's theoretical and computational modeling research efforts. Ledvina, who holds a Ph.D. from Cornell, is currently a post-doctoral associate at the University of Texas at Austin, with experience in GPS/GNSS receivers, ionospheric physics, remote sensing, and software receivers. Bailey, currently on the faculty at the University of Alaska, Fairbanks, is deputy project director of NASA's Aeronomy of Ice in the Mesosphere (AIM) satellite mission, which launches later this year.

The group is developing a laboratory for building scientific instruments to measure electrodynamic, plasma physics, and chemical processes in the ionosphere and magnetosphere and plans to develop an interdisciplinary Ph.D. specialization in upper atmospheric space science.



NASA

Artist's conception of a solar flare and the resulting solar wind around Earth.



RADIOS
that think and learn

Like 9/11, Katrina showed how emergency response is seriously hindered when responders cannot talk to each other because of incompatible communications equipment. When police, fire, medical, and other responders arrive from different jurisdictions, they bring their own equipment. The different radios are purchased to meet the budget, geography, and political constraints of their own regions and typically use different frequencies and competing waveform standards.

An ECE-led team believes it can solve these interoperability problems — without buying new radios for every public safety organization in the country. Their goal: to build radio software that works with off-the-shelf equipment to automatically find an open, legal frequency, and establish communication with another radio and/or a base station. With grants from the National Institute of Justice (NIJ) and the National Science Foundation (NSF), the team is working to produce functional prototypes by next year.

Radios that think for themselves

"The radio must think for itself," says Alumni Distinguished Professor Charles Bostian, who serves as the faculty lead on the effort. "Emergency responders emphatically do not want a radio that requires hands-on adjustment by an expert. They need a radio that is smart enough to find the best path of opportunity, configure itself, and communicate — all with minimal human intervention."

Bostian's team believes the answer is a platform-independent cognitive radio system. A cognitive radio, according to Bostian, combines artificial intelligence with software defined radio (SDR) technology to create a transceiver that is aware of the RF environment, its own capabilities, policies that define legal operation, and its user's needs and operating privileges. Unlike adaptive radios that adapt to anticipated events, cognitive radios learn from their experience and can

Charles Bostian, holding a GNU software radio board, believes that the Virginia Tech cognitive radio project will change the very way that radio engineering is done. It was the glow of vacuum tubes, like those superimposed in the background, that first attracted Bostian to radio engineering.

function in unanticipated situations.

"A cognitive radio consists of a cognitive engine — a hardware-independent software package — controlling an SDR," he explains. "The cognitive engine sets the SDR's operating parameters, or turns the knobs, then observes the results, or reads the meters, and optimizes its operation within the governing rules."

The proprietary Virginia Tech cognitive engine is based on genetic algorithms in a network that was developed for an earlier NSF disaster communications project. The algorithms are modeled on human learning and incorporate logic, randomness, and adaptive memory. Tech's Wireless System Genetic Algorithm (WSGA) optimizes and adapts the communications system, while the Cognitive System Monitor (CSM) handles the cognitive functions, short- and long-term memory, and control.

Overcoming AI prejudice

"Our first important breakthrough was this development of a computationally efficient way of implementing rapid machine learning in a trial-and-error process based on using genetic algorithms," Bostian says. "We used a proof-of-concept prototype of our cognitive engine to control a 'dumb' legacy 'hardware' radio. The resulting cognitive radio could identify the presence of a jammer and change its modulation index, transmitter power, and FEC coding in a way that minimized the effects of the jammer. This prototype demonstrated learning, and we were off."

When he explains the cognitive radio engine and its genetic algorithms, Bostian describes his previous prejudice that artificial intelligence was all hype and little results. His students, however, were correctly convinced it was the solution and "pulled me into an entirely new area of research — at a time when I could have coasted into retirement."

Instead of retiring, he says he is having the greatest fun of his career. "We are changing the way radio engineering is done," he says. Moreover, although he has had many excellent students over the years, "this particular group of students stands out. Every single person on the team is exceptional," he says. In addition to setting much of the technical direction, the students also actively develop proposals and are pushing to commercialize the technology.

The team's two current projects will provide a large step toward commercialization. The NIJ effort involves building a radio that can recognize and interoperate with three commonly

When disaster hits the communications infrastructure


Eugenia Kir

Much of today's communications depends on small, low-powered wireless devices, like cell phones. Small, however, limits the distance and power of communications links. Small devices have short antennas, which mean high frequencies, which mean line-of-sight propagation. Small devices also have long battery life, which means low power, which leads to short range capabilities — even less than the line of sight distance. This works as long as the infrastructure exists to support it.

In a disaster like Katrina, the infrastructure is put out of operation.

- Base stations, towers, and antennas are blown down
- Base station hardware is damaged
- The power grid goes down and base stations lose power. Backup systems kick in, but ultimately run down.
- The wired infrastructure is destroyed. Calls reach the base station, but go no further.

All of these things happened in New Orleans. And on 9/11.

What happens after infrastructure failure?

- At best, cell phones reach more distant base stations. This means weaker signals and overload. Text messaging sometimes works because it requires less signal strength than voice and uses less base station capacity.
- Cell phones have no capability to talk to each other. They can only talk to a base station.
- Police radios can talk to each other on simplex or mutual aid channels. Range is limited by line of sight requirement, number of available channels (four for all of New Orleans), and everybody is on one big party line. Batteries drain quickly.

Virginia Tech solution:
Build and deploy drop-in WiFi-like systems with base stations on balloons or slowly orbiting aircraft. This concept was the key to developing the Virginia Tech cognitive radio - a radio that can automatically find and establish open channels with other radios or base stations. The cognitive radio is under development with rugged, commercial units available on the street in five to 10 years.


Stephani Phillips

used and mutually incompatible public safety waveform standards. The NSF effort extends the technology to investigate spectrum access and to study networks that contain both legacy and cognitive radios.

Public safety prototypes

The team has been working since August to develop a cognitive radio for public service use that can operate with other radios, or serve as a bridge for older radios that do not have the software capability. Funded by a $420,000 grant from the NIJ, the prototype will run on a software-defined radio that is being built by Innovative Wireless Technologies.

In addition to developing and validating the software and interfacing it to the radio platforms, the challenges include obtaining the first FCC certification for a cognitive radio and developing a user interface. "If this radio is not easy-to-use for the responder in the field, it will not be used and we will have failed," Bostian says, adding that it is his first engineering project where ease of use by non-technical people is a critical issue.

This past fall found team members tagging along with police at Hokie football games, observing the officers and their communications, and gathering data. "Interoperability is a big problem even for the Virginia Tech police," Bostian explains. "At every football game, up to 135 officers are brought in from other jurisdictions. Most of the radios from different agencies cannot talk to each other."

With human factors playing a role in the project, industrial and systems engineering professors Tonya Smith-Jackson and Woodrow Winchester have joined the team. With the further addition of economist Sheryl Ball, the team is starting work with economic theory to help create a system that can learn the user's needs based on experimental cost-modeling analysis. "This work is preliminary right now," Bostian says, "but we feel we can learn user needs as an input to the case-based optimization system of the cognitive radio."

Cognitive radio network behavior

While the NIJ effort is aimed at establishing interoperability and user needs, the team is also studying cognitive radio networks and dynamic spectrum allocation, with a $750,000 grant from the NSF NetS Programmable Wireless Information Networks program. The NSF project uses the GNU radio software, a lower-cost system than the public safety radios. Another prototype is being developed to allow WiFi-like unlicensed operation, using unoccupied TV channels as a test case.

As television broadcast completes its transition to digital TV, the issue with unoccupied channels is growing. One suggestion includes allowing cognitive radios to use the channels. A cognitive radio would know its location and know which channels were potentially available. "It would then listen in those channels and identify licensed users who might be operating there and other access points like itself," Bostian explains.

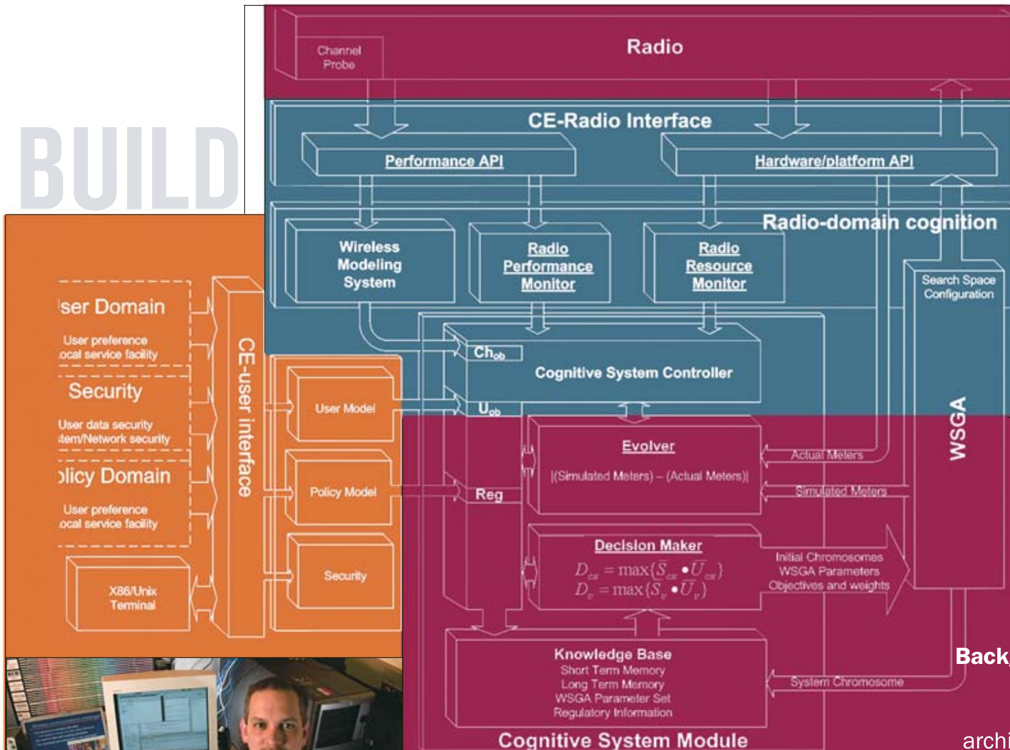
"It would configure itself to avoid causing any interference to the licensed users and negotiate with its unlicensed peers to find a way to share the channel with minimal interference."

The NSF effort is also aimed at understanding the behavior of networks that include both cognitive radios and legacy systems. "Each cognitive radio will have developed its own information. When

The cognitive radio team draws its members from many backgrounds. From left: Larissa Marple, ECE undergraduate; Woodrow Winchester, assistant professor, ISE; Bin Le, ECE Ph.D. student; Yonghseng (Sam) Shi, ECE Ph.D. student; Allen MacKenzie, assistant professor, ECE and co-investigator; Michael Hsiao, ECE associate professor and co-investigator; Akilah Hugine, ECE master's student; Adam Ferguson, economics Ph.D. student; Tom Rondeau, ECE Ph.D. student; and Daniel Friend, ECE Ph.D. student.

Building a Cognitive Radio:
ECE Technical Leads

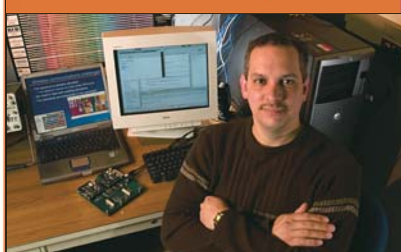
BUILD



Name: Bin Le
Alias: The designer
Background: Bell Labs China
Responsibility: Cognition at radio level; translating computer science concepts at the transistor level

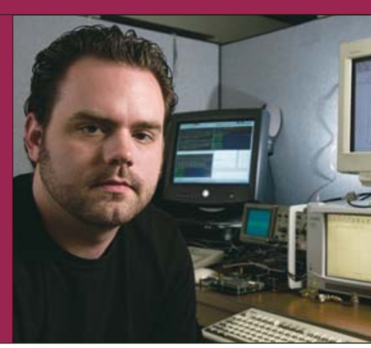
DESIGN

Name: Tom Rondeau
Alias: The philosopher
Background: Involved in project since undergraduate days
Responsibility: System architecture, learning functions and core AI abilities



Name: David Maldonado
Alias: Policy guru
Background: Sales engineering
Responsibility: Policy, regulations, marketing; policy-based reasoning

INVENT



placed in a network with other CRs, how will it share its knowledge to minimize interference and power use while maximizing network quality of service?"

1,000 points

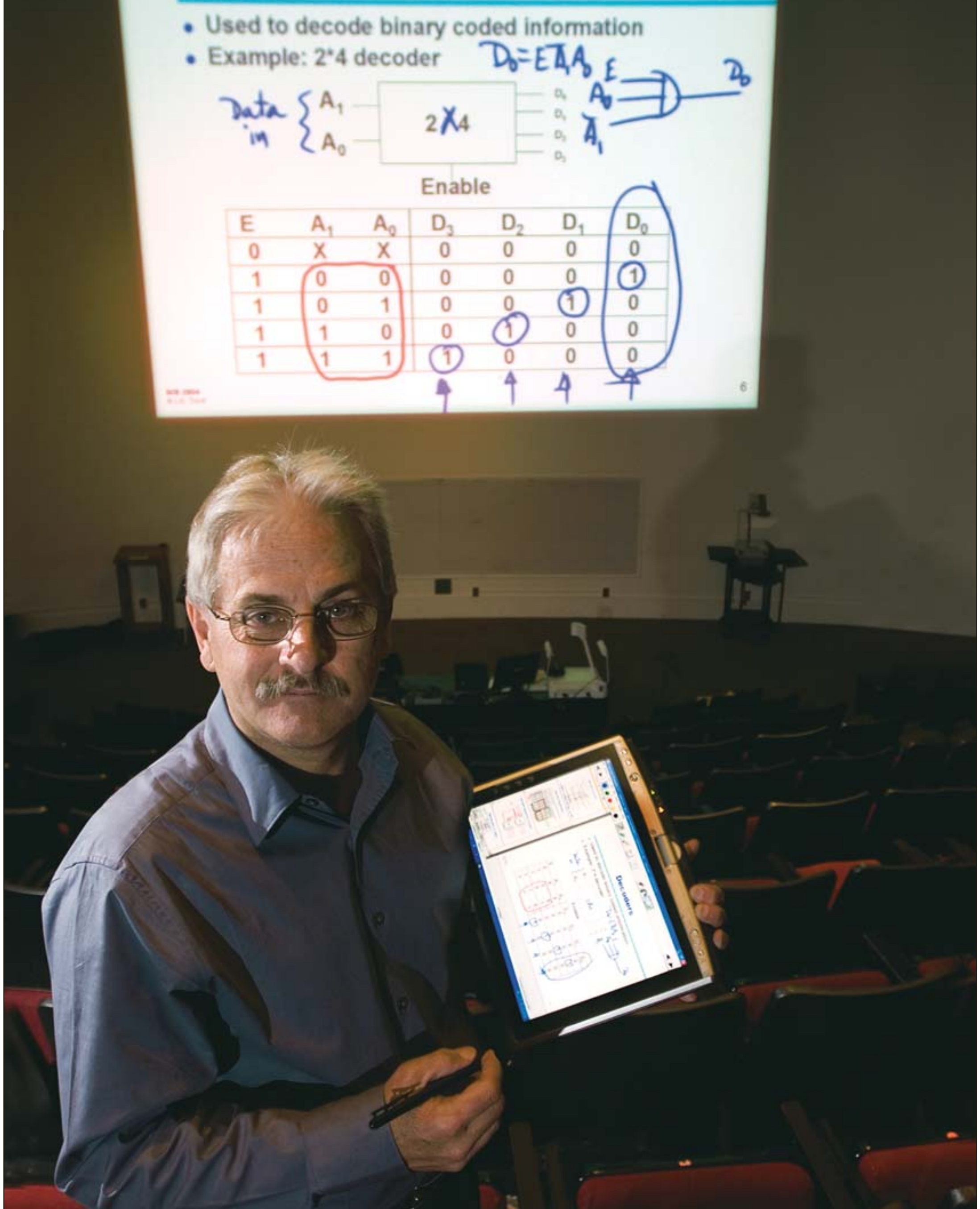
After proving interoperability and studying network behavior, Bostian's team wants to deploy the technology on a testbed with more than 1,000 nodes. "We see an opportunity to deploy our engine on more than 1,000 nodes and experiment with the largest and most intelligent wireless network testbed ever built," he says.

"Imagine a hand-held radio that offers advanced multimedia services," he continues. "Now picture more than 1,000 of these in the hands of Virginia Tech faculty, staff, and students. Think of what we can learn about network behavior, spectrum access, and human-computer interaction!"

What the team ultimately imagines, however, is five to 10 years from now, emergency response teams from all over the country being able to communicate during any situation and to minimize damage from disasters like Katrina.

TEACHING

While Tront lectures, using a tablet PC to draw diagrams, add annotations, and pose problems, students use tablet PCs donated by Microsoft to take notes and solve mathematical problems..."



Joe Tront:
Teaching with Technology

As information technology alters the practice of electrical and computer engineering, it is also constructively affecting how engineering is taught. ECE Professor Joe Tront is on the national vanguard of that movement.

Virginia Tech recently awarded Tront the 2005 XCaliber Award for excellence in teaching with technology. Under an NSF grant, he led a team from six universities who developed technology-based courseware modules to support improving teaching and learning. Tront also serves as co-editor for the Premier Award for Excellence in Engineering Education — an international competition rewarding authors of high-quality, non-commercial courseware designed to enhance engineering education. At Tech, he's using a Microsoft grant to explore how tablet PCs can facilitate active learning in engineering classes.

The real payoff, as he sees it, is in the transformation of his classroom. In the days of chalkboard computations and podium lectures, you'd find someone snoozing in the back row and maybe two or three diffident souls who weren't getting it, but wouldn't say a word. Yet the lecturer would unknowingly go on, "bombarding them with facts," as Tront likes to characterize the old style of passive learning.

Now, by teaming interactive software with Virginia Tech's wireless network infrastructure, Tront has transformed his basic computer-architecture classroom into a lively learning studio, where students ask questions and jockey for feedback. While Tront lectures, using a tablet PC to draw diagrams, add annotations to models, and pose problems, students use tablet PCs donated by Microsoft to take notes and solve mathematical problems. They wirelessly submit their work to Tront, who projects the product on a screen for all class members to view and discuss. They receive immediate feedback from each other, as well as from Tront.

"We compare and contrast digital circuit designs this way," Tront said. "They see how an expert might solve the problem, and then they ask "what if" questions. They are learning the process of solving problems, which is really important because the problems are going to change as the students move on into industry. We have a good time here. It's a participatory class now."

He also uses the tablets for in-class polls to determine whether students are absorbing the material. "I'll give them a multiple choice question, and as the answers come in electronically, I'll see whether I need to repeat the topic using a different approach," he said. "The individual responses give me a great way to gauge the information transfer, and the interactive component really invigorates the class."

Active learning is the bottom line, he says. When students are probing, discovering, testing, and applying their learning, they grasp material faster and retain it better, he says. With the help of the tablet PC, they see, hear, and act upon information all at once. By this means, students who are visual, auditory, or physical learners are all served. The software is especially good at helping students visualize engineering concepts, even when they aren't working in the lab.

Tront supported the effort in making Tech's College of Engineering the first public institution to require freshman to have desktop computers, back in 1984. Eight years later, as assistant dean for the college, he assumed the role of chief advocate for computer use and pushed to update the requirement from desktop to laptop. Now, he says, tablet PCs will soon be required.

"Having a tablet provides our students with the continual access to notes, data, applications software that they had with the laptop, as well as the add-ons of a digitized screen and writing stylus," he said. "Hewlett Packard has agreed to sell our students the new tablet PCs for the same price as the laptops — a savings of $200. This will help the transition."

The digitized screen allows users to incorporate handwritten input into Microsoft Office applications, annotate documents imported from a server or other computer, and use a stylus for pointing, clicking, selecting, and dragging. Another feature integrated into the tablet PCs is handwriting-to-text conversion.

Tront's interest in using technology to improve teaching was stimulated during his years in the Dean's Office, where he had leadership roles in such efforts to improve undergraduate education as NSF's nine-university SUCCEED Coalition where he directed the Center for Technology-Based Curriculum Delivery. He observed that the coalition played a national leadership role in showing that active, experiential approaches using technology help the learning process.

"When students are actively involved in probing, discovering, testing, and applying their learning, they grasp material faster and retain it better..."

Now Tront is pleased to see other engineering professors testing the tablet PC in their courses, particularly in the Engineering Education division where they are experimenting in freshman courses. They are already noticing how much the technology can reduce paper flow, how easy it is to annotate complicated diagrams, and how convenient it is to receive and return student assignments electronically (and receive electronic receipts). "The visualization capabilities and expressive capacity afforded by the tablet PC has great potential for stimulating freshmen engineering students studying general engineering concepts," Tront says.

"The interactive approach is especially good for presentations of dynamic material," he says. "I think we could teach all our engineering classes this way." To that end, he and his students have written a new software application for tablet PCs called WriteOn, which allows the user to annotate on top of the screen display of any operational Windows program. Using WriteOn, instructors can better describe the behavior of computer-based engineering tools or elucidate any other visual concept display on the computer screen. WriteOn also generates electronic notes of presentation sessions.

Tront is the editor for NEEDS (National Engineering Education Delivery System), a digital library of learning resources for engineering education, and also co-editor for MERLOT (Multimedia Educational Resource for Learning and Online Teaching) engineer collection. He is part of a collaboration that recently was awarded almost $3 million by the NSF to provide a comprehensive engineering portal for high-quality teaching and learning resources in engineering, computer science, information technology and engineering technology. He is involved in merging NEEDS and Teach Engineering into a unified K-Gray engineering educational digital library.

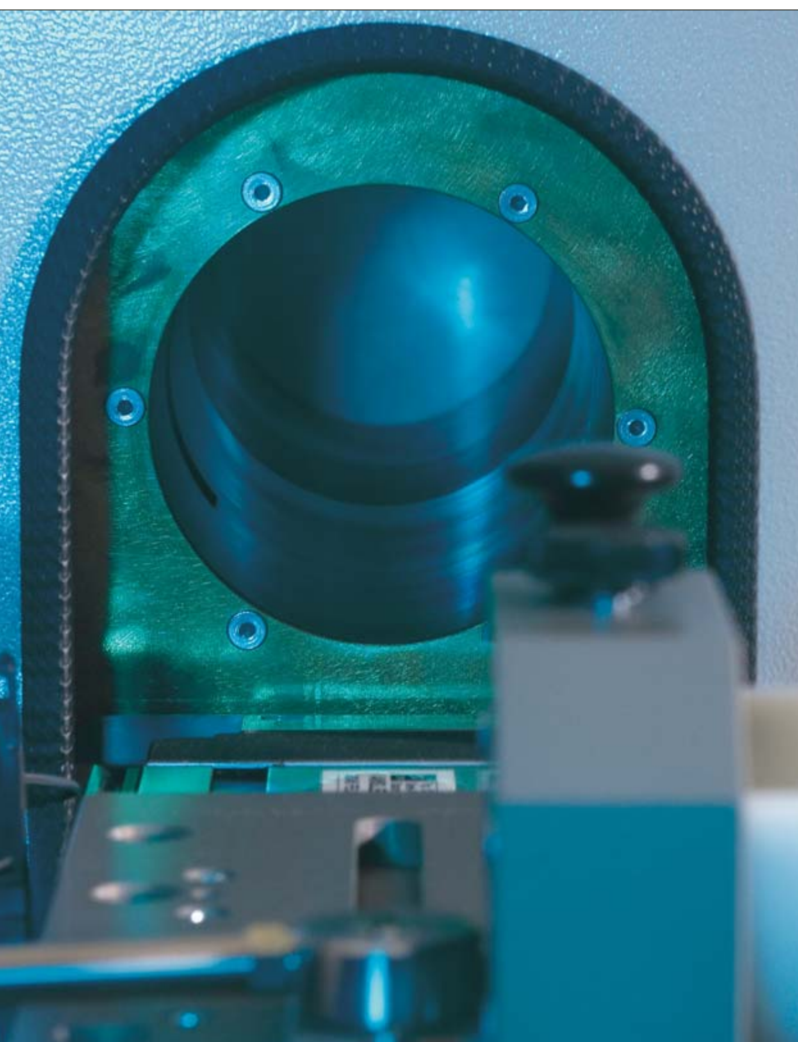
—Su Clauson-Wicker

ECE bio-imaging aids medical researchers

The purchase of a microCT scanner for computational imaging research has been a boon for Blacksburg-based biomedical studies ranging from birth defects caused by diabetes to bone strength and tissue engineering. This past fall, ECE's Chris Wyatt, director of the BioImaging Systems Laboratory, set up the new medical imaging machine for a research effort involving biomechanical modeling of bone strength. The $300,000 microCT scanner can accommodate small animals, such as rodents and small material samples.

The first of several planned imaging systems, it was purchased with funding from the State Council of Higher Education for Virginia (SCHEV) and the Virginia Tech/Wake Forest School of Biomedical Engineering and Sciences (SBES).

"Our initial purpose for the machine was to study bone development in small animals," Wyatt explained. "The soft tissue contrast is poor, but the machine is excellent at imaging hard tissue. We can see the very fine structure of bones — even the micro structure or matrix of the bone," he added.



The project involves scanning bones from different animals being treated with different drugs, and using the information to build biomechanical models of the bone strength. The models would be used to determine the effects of different drug treatments on bone. "This way, we hope to follow the course of osteoporosis, or look at calcium and see how it is metabolized in the bone," Wyatt explained.

All drug studies start with small animals, then move forward to human testing, according to Wyatt. "Medical researchers are always looking for ways to reduce the numbers of animals needed," he explained. "From microCT images, we build virtual models, so that we can simulate exactly what happens mechanically to different bones," Wyatt said. "This way, with one bone, we can do hundreds of studies, and greatly reduce the usage of animals."

In addition to the bone modeling, Wyatt has used the imaging equipment to help a variety of research projects. "We have scanned a turtle head, solid samples, chicken bones, and aggregate materials."

Another ongoing project involves a tissue engineering effort by Aaron Goldstein in chemical engineering. "We are analyzing the mechanical structures of the scaffolds that the tissue is built on," Wyatt explained. "The scanner allows us to image the actual scaffold structure. We hope to identify when the bone starts to develop and calcify on the scaffold, then image where and experimentally determine the rate at which it forms."

One of the laboratory's largest projects has been related to birth defects in mice. Soon after the equipment was set up in its home at the Virginia-Maryland Regional College of Veterinary Medicine on Tech's Blacksburg campus, Renee Prater, a research assistant professor, wanted to conduct bone scans on fetal mice. Prater, who holds a joint appointment as an assistant professor of microbiology at the Virginia College of Osteopathic Medicine, was working on a study of birth defects in babies of diabetic mothers, a syndrome called diabetic embryopathy.

The mini CT scanner has a diameter of 8 cm and fits small quantities of materials or small animals, such as mice.

ECE's mini CT scanner is helping biomedical researchers in several areas and is responsible for forming a highly experience, multidisciplinary team for studies on bone strength and bone deformities. From left: Jeryl Jones, associate professor of radiology; Renee Prater, research assistant professor of biomedical science; Chris Wyatt, assistant professor of ECE; and Cindy Hatfield, assistant professor of anesthesiology.

Mothers who have diabetes before and during pregnancy have a higher risk of birth defects. Although keeping the diabetic mother's metabolism and diabetes regulated reduces birth defects, it does not totally eliminate them. Prater was studying whether non-specific immune stimulation of diabetic mice could reduce diabetes-induced defects of the craniofacial, or head and face area, of their babies.

Instead of scanning the dead fetus, Prater was interested in being able to study pregnancies in vivo, or live, and being able to follow pregnancies throughout the process to detect exactly when different defects occur.

Prater and Wyatt soon tapped Jeryl Jones, a veterinary radiologist and associate professor at the vet school, and Cindy Hatfield, an assistant professor and expert in veterinary anesthesiology. The team is working on a system of scanning pregnant mice with the least possible discomfort. "This gives us quantitative data. We can determine how many fetuses have cleft palette, or spina bifida, without sacrificing as many animals. This experimental model gives us conclusions that are more statistically significant than the histomorphometry methods currently used," Wyatt said.

"Based on this experience, we are developing proposals for future efforts, including mouse models of osteoporosis," he said. "The big story on their side is they now have a new tool for their studies. Renee can now look at things she hasn't been able to study before and has a way to measure total bone volume. Without this equipment, the four of us would never have formed a team."

Wyatt brings his technical and engineering expertise to the team. His biggest interests with the microCT scanner are in reconstruction of images, image processing, and developing efficient image analysis systems. "The scanner takes projections of an object, like you are looking at different angles," he said. "The projections are then reconstructed into 3-D images, which is a mathematical/computer problem. We take the data from the projections and reconstruction to get images."

The scanner comes with general software for the image computation, but his team is developing computational software specific for extremely low doses of radiation. "We're trying to use the lowest dose of radiation possible, because we are imaging fetal mice and do not want to introduce problems," he said. Lower doses means more noise in the images, which they are compensating for in the reconstruction stage. "There is always a tradeoff between dose and noise. We have to rely on our clinical collaborators to monitor the animals and help us find the ideal balance," he said.

In addition to noise and quantitative issues, Wyatt is tackling one of the biggest issues in medical research today — too much data. "The good news about these scanners is they generate a lot of data," he said. "And the bad news is, these scanners generate a lot of data. If we scan at 15 microns, each mouse image is 2048 x 2048 x 600 pixels. That's about 5 gigabytes of data. Somebody must sit down and go through all that."

Whether dealing with animal studies or human drug trials, one of the biggest time and cost factors is reading and analyzing data from diagnostic images, according to Wyatt. "If you are evaluating a new drug and you scan 1,000 animals three times, you have 3,000 sets of data to process by hand. It is a difficult, time-consuming process that right now is done manually."

Wyatt's team is working to automatically extract the necessary information from the data on the fetal bone studies. "We are working on software to count ribs, estimate if any are fused or not, measure the total bone volume, or density, or just measure the skull or arms and limbs. We are trying to automate that process so it is consistent and fast." Wyatt's ultimate goal is to release the software as an open-source package so other biologists with access to such a scanner has the appropriate tools for analysis.

The microCT scanner is the first of several diagnostic imaging pieces that Wyatt hopes to have in the laboratory. "With the microCT scanner, we are able to show researchers in other areas how our expertise can further their studies," he said. Virginia Tech's associated biomedical laboratories have a number of research projects that can be helped with imaging tools, he added. "We anticipate that as the laboratory develops, we will be able to add capabilities and specialized computational tools that can help further the research of both basic scientists and clinicians, whose research impacts human and animal health."

Biomedical Applications

FACULTY

Masoud Agah
Peter Athanas
William Baumann
Amy Bell
Louis Beex
Gary Brown
Michael Buehrer
Richard Claus
William Davis
Mark Jones
G.Q. Lu
Tom Martin
Kathleen Meehan
T.-C. Poon
Joseph Tront
Anbo Wang
Yue (Joseph) Wang
Chris Wyatt

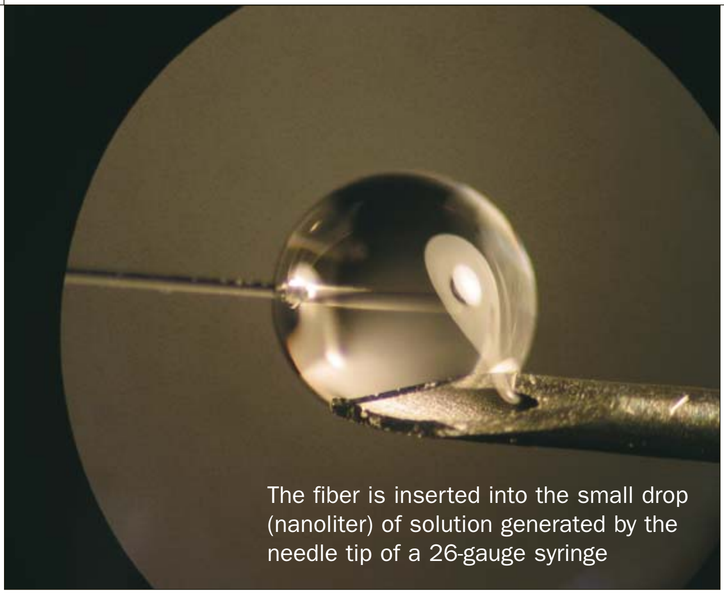
Sensor developed
for low-cost, quick DNA detection

A research team from ECE and biochemistry has developed a fiber-optic sensor for DNA sequence detection that costs 20 times less than currently available technology. The new sensor method could be used in fields such as genetics, pathology, pharmacogenetics, food safety, criminology, and civil defense, including applications such as detecting disease or biological weapons, according to Kristie Cooper, an ECE research scientist.

The new method involves immobilizing capture DNA on the tip of an optical fiber. When the probe is exposed to the target DNA, the capture and target materials bind together as a hybrid and the tip of the probe thickens and is measured by an interferometer.

The capture DNA is immobilized on the tip by a nanoscale self-assembly technique in which single monolayers of film are deposited by alternating the charge of each assembled monolayer.

Traditional DNA detection methods involve some form of labeling, such as fluorescence, to signal a binding event, according to Cooper. "Fluorescent labeling is very expensive and cumbersome," she said. "Fluorescent dyes bleach out in light and reading the arrays involves highly precise and expensive instrumentation."



The fiber is inserted into the small drop (nanoliter) of solution generated by the needle tip of a 26-gauge syringe

Advantages of the sensor method include speed of detection and ease of use. "Current methods of verifying TB, such as the TB Rapid Cultivation Detection Technique, require about 30 days to obtain definitive results," she explained. "Using a fiber sensor, based on our method, direct detection of DNA could be completed in minutes."

The team's tests show the new sensor can detect DNA quantities as small as 1.7 ng with contact times of about five minutes.

MEMS plus nanotechnology:
Building gas sensors for biomedical, food, environmental monitors

A research team from ECE, physics, and chemistry is working to blend MEMS and nanotechnology to create inexpensive, portable gas sensors that can be used in a variety of applications, including breath analysis, biomedical diagnostics, pharmaceuticals, food processing, and environmental monitoring.

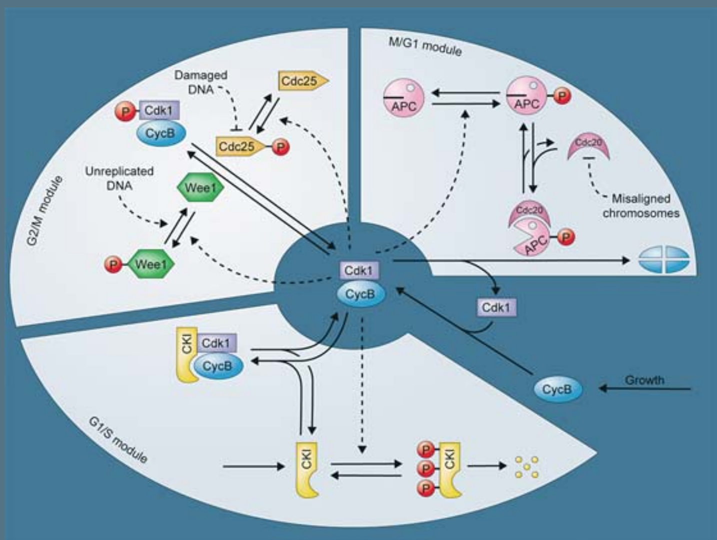
There are currently two basic methods of gas sensing: measuring in place, or first separating the gas into its constituents and analyzing them instantly, according to ECE's Masoud Agah, who is faculty lead on the effort. "Electronic noses tend to be in the first category, however, they have not been able to identify vapors in a gas mixture composed of more than five components," he said.

The second method, 50-year-old gas chromatography (GC) has become the most common approach for analyzing gas mixtures. Although GC equipment tends to be large, fragile, and relatively expensive, with high power consumption, about $1 billion worth, or 30,000 GC instruments, are sold annually, he noted.

Agah is working with Randy Heflin of physics and Larry Taylor of chemistry to develop micro-GC instruments that are less expensive and consume less power while providing faster analysis (less than five seconds) and greatly increased portability for in-field use. The team is employing MEMS technology for the first time to develop special miniaturized multicapillary columns having on-chip temperature-programming capability and to use nanotechnology to coat the column walls with nano-structured materials such as ionically self-assembled films.

Biomedical Applications Overview

Many of the advances in biological and medical applications today directly involve electrical and computer engineers. Modeling gene networks and cellular processes, development of prosthetics and drug delivery systems, diagnostic imaging, and measurement devices and sensors, are just some of the efforts that depend upon electrical and computer engineering. The use of computers in the field is essential for clinical support, databases, data-mining, and data analysis and processing. Within the human body itself, many systems — from the beating of the heart to the functioning of the brain — can be described and better understood using electrical engineering theory.



Modeling how cells divide

The "wiring diagram" (above) represents the basic components that control the cell-division cycle in a yeast cell. In collaboration with John Tyson, University Distinguished Professor of Biology, William Baumann is building models of the cell cycle that accurately capture the noise in the process due to the random nature of the chemical reactions.

The goal is to understand why cells with certain mutations divide successfully with a certain probability — something that cannot be understood with noiseless models. Being able to predict the effect of mutations is a key way to validate cell cycle models and so this work may lead to improving the knowledge of cell cycle control. Ultimately, comprehending cell-cycle control is important for understanding and treating diseases where this system has broken down, such as in cancer.

Biological research is inherently interdisciplinary and ECE researchers are increasingly teaming up with biologists, chemists, physicists and clinical researchers to develop biomedical technology and contribute to scientific discovery at the cellular and molecular level. As a result, researchers in every ECE area at Virginia Tech are involved in biomedical projects, from trying to add "smart" functionality to diagnostic imaging, to biophotonics, EEG modeling, bioinformatics, and systems biology.

Investigating how cells react to invasive viruses

Amy Bell is applying signal and image processing techniques to microscope images in an effort to understand how viral and host cells interact. The goal is to develop a procedure that will rapidly identify viruses and the illness and mortality risks that they present.

Bell is collaborating with Karen Duca, a biophysicist with the Virginia Bioinformatics Institute (VBI). The team recently received a $400,000 grant from the National Institutes of Health (NIH) to support their work in visualizing viruses spreading through cells.

When Duca introduces a virus into cells in a laboratory dish, she infects only the cell's center. As the virus moves out from the center in its attempt to infect other healthy cells, Duca indentifies and stains relevant markers from the virus and the host. Under ultraviolet lighting, the chemical stains become fluorescent, allowing Bell and Duca to capture images of the laboratory dish at regular time invervals.

Bell then works to remove the signal noise from the microscope and the fluorescent markers and other sources. The microscope cannot capture the entire well at once, so multiple subimages are taken and assembled in matrix fashion. A "montage" artifact arises from the microscope's uneven illumination, which is brighter in the center and dissipates nearer the edges of the dish for each sub-image.

Bell's team has developed a method to remove the montage artifact, based on a model that reflects the physics of fluorescent microscopy. They have also designed a novel algorithm for estimating and removing the "spectral overlap" noise that arises from using multiple fluorescent markers in the experiment. Bell's image denoising methods are critical for performing an accurate quantitative analysis of the host-virus interaction dynamics.

Ultimately, the interdisciplinary work should contribute to knowledge of what starts an immune response and even help to quickly determine the danger of a virus without waiting to identify it.

Communication

FACULTY

Wireless
Annamalai Annamalai
Charles Bostian
Michael Buehrer
Claudio da Silva
Allen MacKenzie
Tim Pratt
William Tranter
Amir Zaghloul

DSP
Louis Beex
Amy Bell
Lamine Mili
Jeffrey Reed

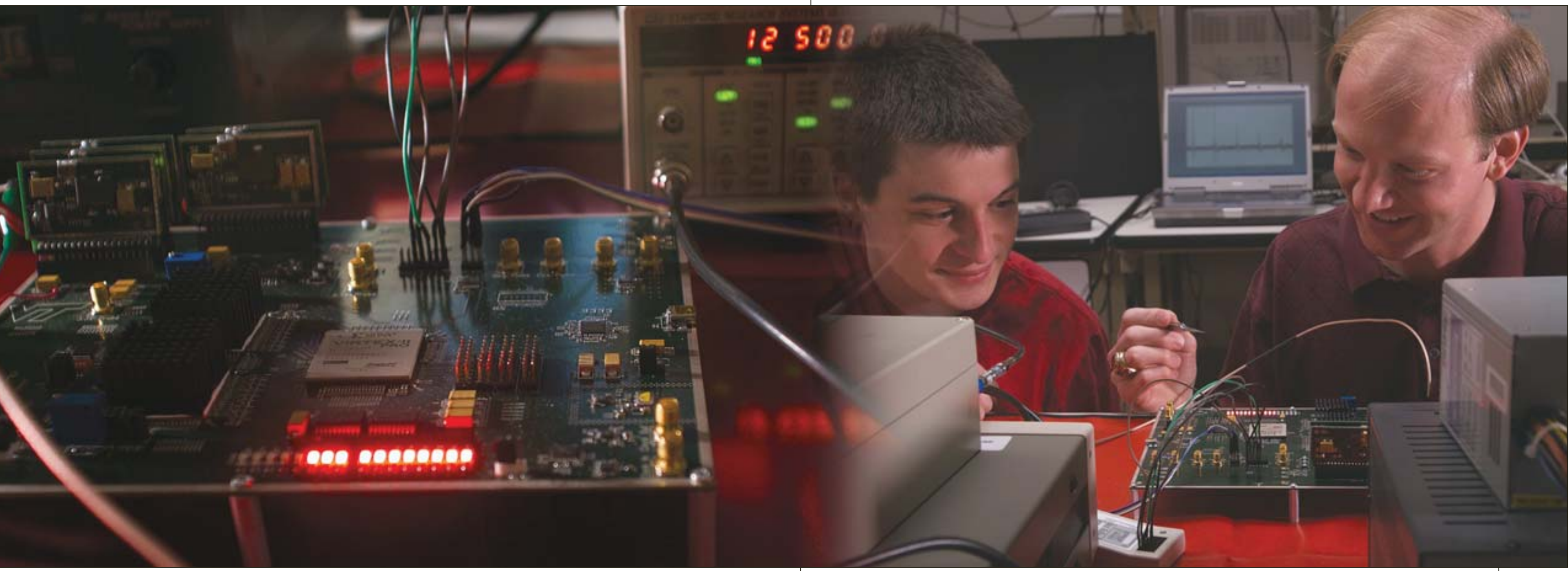
Fiber Comm
Ira Jacobs

Networks
Luiz DaSilva
Thomas Hou
Yao Liang
Scott Midkiff
Amitabh Mishra
Jung-Min Park

VLSE Circuits
Peter Athanas
Dong Ha
Michael Hsiao

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

Optics
T.-C. Poon



Matt Blanton (left) and Chris Anderson (right) test the UWB software radio initial prototype

Tech builds multi-use UWB software radio

While building a software defined radio using ultra wideband signals (UWB) for naval applications, ECE researchers have developed a flexible, high-performance testbed that can be used in applications ranging from inventory tracking to heart-rate measurements and medical imaging.

"This is no other UWB software radio with the extreme amount of flexibility this one has," said Ph.D student Chris Anderson, who serves as the student lead on the project. "Not only can the platform be used for such different applications, but it can also work with any other broadband waveform. It allows other graduate students to play with things like pulse shapes, modulation schemes, and multiple access schemes."

The radio receiver was built for the Advanced Wireless Integrated Navy Network (AWINN) project, funded by the Office of Naval Research. The goal was to build a single hardware platform that could be used for close in ranging and communications, such as ship-ship cargo container transfer, or synchronized with several other systems for longer-range communications.

The system uses off-the-shelf components and achieves a raw data rate of 100 Mbits/second at 10 meters, with a 2.2 GHz RF bandwidth and 8 GHz sampling frequency. The initial prototype uses two 1 GS/s time-interleaved analog-to-digital converters and will be scaled up to eight for the final platform. Anderson worked with Matt Blanton and Deepak Agarwal to incorporate FPGAs for fast parallel processing.

"The ultimate goal for this receiver is for it to be a testbed," Anderson said. "People could use it to play around with different UWB or other broadband signals and investigate the effects of different pulse shapes, coding schemes, etc. It gives them a tool to use in the lab or field to validate their algorithms or simulation results."

Communications Overview

RESEARCH

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.

Communications research aims to understand the basic limitations on communication system performance; analyze, model, and characterize performance; devise, implement 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. Researchers 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 UWB techniques and cognitive radios. Research on antennas, RFICs, 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.

UWB for Position Location in Harsh Environments

Many activities requiring position location — such as emergency response, urban troop deployment — must operate in a harsh communications environment with significant multipath and interference.

Current GPS systems, as well as indoor position technology based on laser, ultrasound, or narrowband RF, are severely limited in these environments, according to Michael Buehrer. Buehrer is leading a team that seeks to assist people in these situations by developing position location technology for ad hoc networks, using an ultra wideband sensor.

With a $174,000 grant from the NSF, his team is investigating four issues: UWB signals in non-line-of-sight environments; signal acquisition of the primary path in dense multipath scenarios; MAC design for UWB-based position location networks; and network position determination with a limited number of anchors. "We are hoping to address these challenges using a mixture of local signal processing methods and collaborative, network-level techniques," he said.

Extending Tech's Open-Source SDR tool

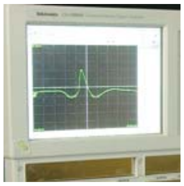
ECE's open-source software radio tool, OSSIE (Open-Source SCA Implementation: Embedded) has been downloaded over 1000 times.

The modular, reusable, software framework, libraries and tools for software defined radio (SDR) development is accelerating wireless communications development and research, according to its creators. "Even though it was created to support graduate teaching and research, companies and governments around the world have told us that they are evaluating OSSIE for inclusion into their products," said Jeff Reed, faculty advisor on the project.

With a $250,000 grant from the NSF NeTS program, the team is adapting OSSIE for use in investigating more efficient SDR design and for allowing rapid prototyping and testing of new waveform with minimal hardware dependencies.

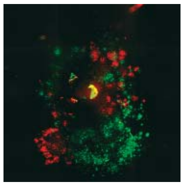
The effort will address several limitations in the SCA, on which OSSIE is based. The team plans to enhance code portability, reduce overhead, increase radio flexibility to support dynamic changes, and reduce power consumption.

Wireless @ Virginia Tech
www.wireless.vt.edu



Develops technology for wireless applications, from theory through fully tested and operational prototypes ready for production. Investigates propagation, receiver design, signal processing, networking, and usability in voice, video, and data communications. Facilities include the Antenna Group, CWT, MPRG, VTVT, and the Wireless Microsystems labs.
Director: Jeff Reed

Digital Signal Processing & Communications Laboratory
www.ece.vt.edu/fac_support/DSPCL

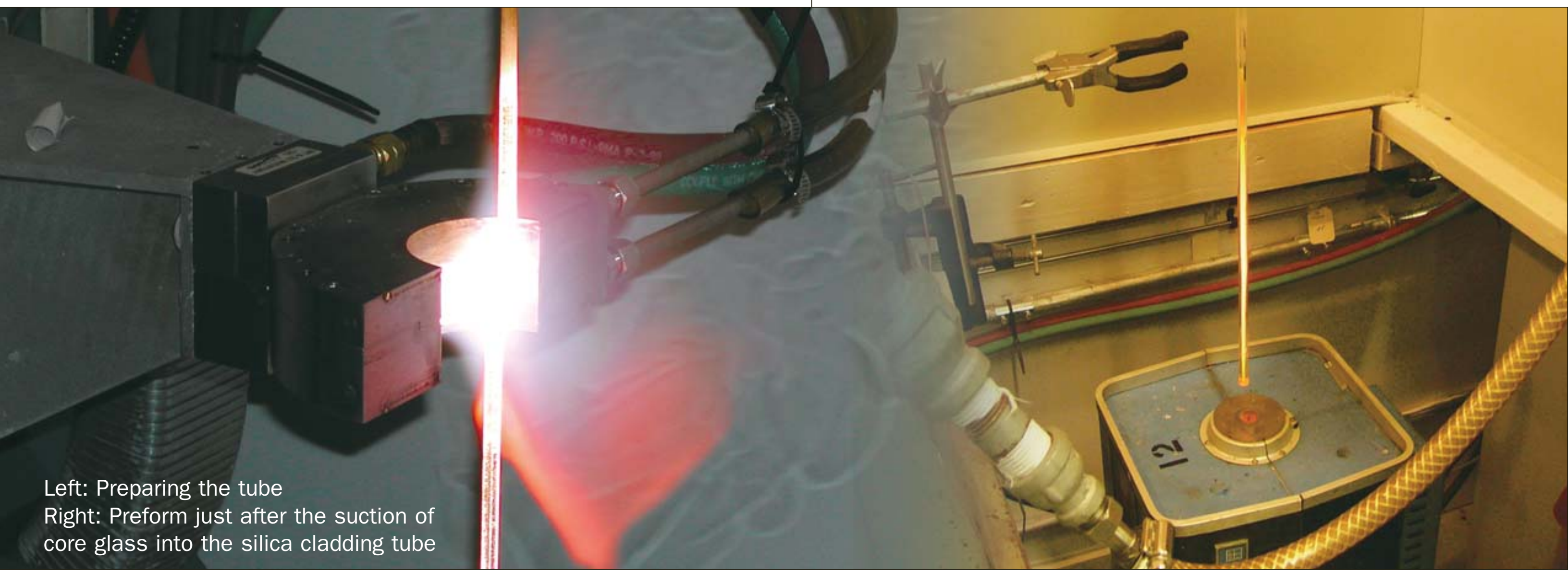


Conducting research in the general areas of signal processing and image processing with applications to systems biology and digital communications.
Director: Amy Bell

ElectroMagnetics

FACULTY

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



Left: Preparing the tube
Right: Preform just after the suction of core glass into the silica cladding tube

RESEARCH

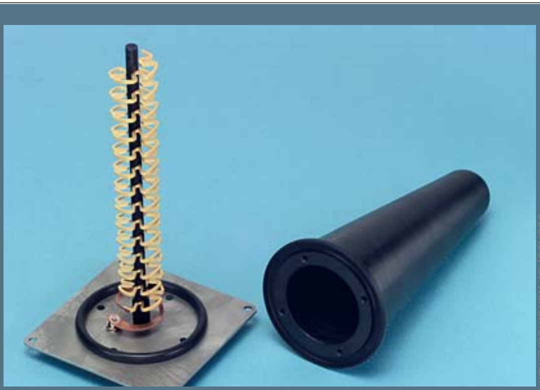
ECEs develop simple, inexpensive optical fiber preform manufacturing

Fiber optics researchers have developed a simple, inexpensive technique for making optical fibers with compound glass cores. Compound glass fibers are of current interest for their high optical nonlinearity and for transmission into the infrared spectral region in applications such as Raman amplifiers, fiber lasers, and continuum generation.

The new Virginia Tech process involved melting the glass in a conventional crucible, then drawing the molten glass into a cladding tube to form a preform. After cooling, the preform can be drawn or over-cladded. The technique relies on the melting temperatures of the core glasses being less than that of the cladding tube.

"The core-suction technique eliminates several process steps compared with other techniques, which can lead to contamination," explained Nitin Goel (Ph.D. '05) who developed the process with his advisor Roger Stolen and others.

The core-suction technique produces little waste. Its efficiency means that more expensive, high-purity materials can be used and that organizations can easily make fibers with small quantities of different nonconventional, highly nonlinear core glasses.



Courtesy of Warren Stutzman

Stub-loaded antenna considered a top tech-transfer case

The patented stub-loaded helix antenna, invented in an ECE laboratory in the 1990s, has been selected as one of 100 successful technology transfer cases in the 2006 publication of the Association of University Technology Managers. Warren Stutzman and graduate student Mike Barts developed the antenna, which is used around the world for wireless internet connections. The antenna is valued for its use in difficult applications where long distances or building penetration is needed, such as cities and hotels. FRC Corp. in Mason City, Iowa, is the exclusive licensee of the antennas and claims they are considered the best performing 2.5 GHz range antennas in the field today. The firm says sales are growing and they are geared up to produce 1 million antennas a year.

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 is collaborating with communications researchers in UWB propagation studies and applications. 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.

CPT first to prove experimentally speed of light independent of "photon age"

ECE researchers in the Center for Photonics Technology claim to be the first to prove experimentally that the speed of light is independent of the time the light has traveled.

Anbo Wang, with graduate students Bo Dong and Ming Han, used an active Mach-Zehnder interferometer illuminated by sunlight. They measured the difference in optical fibers between the speeds of light from a star (the sun) and the stimulated emission from an optical amplifier as presented by the interferomter.

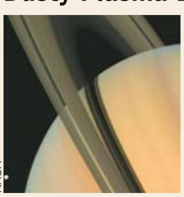
The speed difference of the stimulated emission and sunlight was obtained by measuring the phase change when the interferometric signal propagates along a span of a single-mode fiber. The test measured a constant speed with an accuracy of $1.6\text{x}10^{-11}$/year.

"The speed of light as a universal constant must be tested with ever-increasing accuracy as our applications get more sophisticated and the interpretation of the constancy of light speed is manifold," Wang said. In the past century, experiments have tested that the speed of light is independent of the motion of the observer and independent of light frequency. Recently another postulate that the speed does not vary with time and space, has drawn a great deal of attention as experiments may suggest possible variations of the fine structure constant with time, according to Wang. "However, to our best knowledge, there has been no experimental test on the constancy of light speed with respect to photon age, even though it has been universally accepted," he said.

Nitin Goel

Dusty Plasma Lab

www.ee.vt.edu/~gchae/research.html

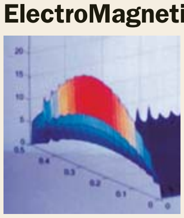


NASA

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

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 antenna 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

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

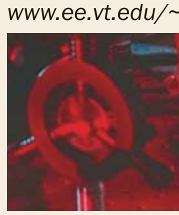
Fiber & Electro-Optics Research Center (FEORC)

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

Optical Image Processing Laboratory

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

Center for Photonics Technology

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

Electronics

FACULTY

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

Left: Fred Lee, Director of the Center for Power Electronics, which is working to reduce EMI noise in distributed power systems.
Right: Electromagnetic noise is a concern with large installations, such as Virginia Tech's Terascale Computing System.

RESEARCH

A better way to kill electromagnetic noise in distributed power systems

The growing need for a highly reliable supply of electrical energy for critical applications, such as hospitals, telecommunications, internet, and semiconductor industry, as well as many defense and homeland security applications, is spawning the development of very complex, local power distribution systems with the massive use of power electronics converters. With more and more high-frequency switching converters being widely used, the management of the resulting electromagnetic noise is becoming a major challenge.

The current practice for reducing system interference is generally to add a filter to each converter – a local, expensive, and inefficient solution. CPES has developed new technology that can eliminate the need for additional electromagnetic noise filters, resulting in considerably improved power density and simplified manufacturability of electronic power converters.

Called integrated bus filters, the technology is based on transmission line principles. The new filter is implemented as a simple, planar, low-cost, metal-ceramic sandwich structure that connects the outside power terminals with the converter inside the box. Classical filters cannot attenuate properly the noise at radio frequencies due to natural parasitic interactions with the components. The integrated planar power connection structure uses these normally harmful parasitic interactions to enhance the attenuation. Also, the attenuation at lower frequencies can be further improved by creatively utilizing interactions between the connection structure and the input power line.

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.

New packaging technology cuts thermal stress by order of magnitude

Power electronics researchers have developed technology that reduces by an order of magnitude the thermally induced mechanical stresses in integrated modules for high-temperature applications.

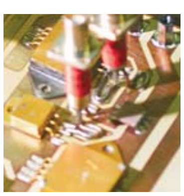
High temperature applications incur greater thermal stress on materials as they go from environmental temperature when off, to operating temperatures. The interfaces of materials with different coefficients of thermal expansion (CTE) suffer severe stresses and can have limited lifetimes, as is the case with silicon carbide (SiC) and copper. This issue has challenged researchers at the Center for Power Electronics (CPES) as they develop integrated modules for high-temperature applications.

The new high-temperature packaging technology involves electroplating a composite layer of copper, with chromium, which has an almost-identical expansion coefficient as SiC. Chromium has high electrical resistance and is unsuitable as interconnect metal. When used in the composite layer, however, its effect on electrical resistance is negligible.

The chromium provides a buffer layer between the copper and SiC that reduces the thermal/mechanical stress by half an order of magnitude. The metallized interconnects enable a mechanically balanced structure, leading to an ultimate order-of-magnitude reduction in stressed.The technology has been implemented successfully in a two die-module and operated at 250° C.

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, 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

FACULTY

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

RESEARCH

The impact of wind on the grid

While demand increases for alternative energy sources, research is needed to understand how to integrate them into the power grid, according to Bradley Fellow Keith McKenzie, who is investigating the interaction of wind energy sources with the power grid.

McKenzie is developing models that accommodate the multiple wind turbine topologies and associated power electronics that interface to the grid. A key issue being investigated involves energy storage configurations and whether, given advance warning of a power grid disturbance, the wind turbine/energy storage system can dampen some of the resulting oscillations.

He is also studying how to prevent wind turbine energy sources from negatively impacting the grid. For example, wind gusts can lead to active power fluctuations, causing voltage fluctuations in a weak grid. Another issue involves the low voltage ride-through capability of a wind turbine. A wind turbine will disconnect when the voltage dips below a given value. If the dip is caused by a nearby fault in the system, the disconnection of the turbine can create a second disturbance that leads to a cascade-effect of multiple wind turbines disconnecting.

Power System Security

Virginia Tech power engineers have been working with researchers from Arizona State University on a multi-year project to investigate methods of improving the security of electric power supply systems. The project has been funded under a $300,000 grant from the NSF.

"Innovations in computer-based monitoring, protection, and control of electric power supply systems, coupled with the availability of wide-band high-speed communications have made it possible to bring about the development of very highly secure electric supply networks," said Arun Phadke, the principal investigator on the project.

The project involves a multidisciplinary team of students and faculty members in the fields of power engineering, communications systems, and new sensor developments.

The team is also studying the social and economic impact of electric supply systems, with a goal of developing a metric to measure the societal and economic dependence on electricity supply and the cost of insecurity of the system.

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

FNET system sparks development of power-system analysis tools

Virginia Tech's frequency monitoring network (FNET), which is the first installed system to monitor the entire U.S. power grid, is providing data for a number of different investigations ranging from security, to system disturbance location.

FNET uses low-cost sensors, developed at Tech, that are plugged into standard 120V outlets at various university and office locations nationwide. Since the units do not need to be installed at substations, FNET provides an independent observation system of the U.S. power grids. Other monitoring systems are typically confined within the operational boundaries of their utilities.

To date, more than 30 units have been installed around the country and are relaying continuous data via the internet. Bradley Fellow Robert Gardner is on the team of researchers tapping the raw frequency data and developing useful applications.

Gardner's work focuses on frequency data analysis and conditioning, power-system event detection, and power system event location. Early results from data conditioning are helping the team understand the nature of power system frequency, he says. His future work in the area will focus on understanding more about the probability distribution of frequency data from different parts of the country.

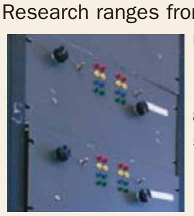
He has also been on a team to develop an oscillation analysis tool to serve as an inter-area power-flow-oscillation warning device. The tool complements others the FNET team has developed, such as generator trips and load rejections to detect and classify power system events.

Another key area is researching power system event location. Events with magnitudes greater than 300 MW disperse frequency perturbations throughout the grid. The waves are detected by FNET and the team is working on tools so that disturbances can be detected without respect to utility boundaries.

"Using the results of this research, operators in system A can understand and react to a disturbance caused by neighboring system B without having to instrument their neighbor's system," he said. "If such capabilities had existed in August of 2003, the Northeastern Blackout that left New York City in the dark could have been reduced or mitigated completely."

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



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

Helping AUVs find the obstacle-free path

The Autonomous Systems and Controls Laboratory (ASCL), directed by Dan Stilwell, is developing water-based autonomous vehicles that can operate in platoons for monitoring lakes, rivers, and coastal waters. ASCL projects include developing mobile, robotic biochemical sensors for lakes and rivers, as well as miniature underwater robots to map Chesapeake Bay coastal waters for environmental studies and help develop search, survey, and tracking methods for the U.S. Navy.

The research challenges involve developing the miniature vehicles and sensors with their control and guidance algorithms; and control and estimation strategies for cooperating autonomous platoons where there is limited communication bandwidth.

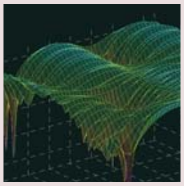
Bradley Fellow Jamie Riggins is working to develop and construct an obstacle map that identifies an obstacle-free path for the group's autonomous boat, or ASV (autonomous surface vehicle). When operating in unknown waters, or in changing environments, the ASV will need to detect obstacles quickly and accurately solely via imaging instruments.

The ASV will acquire a sequence of images, detect and track the obstacles in the images using image processing techniques, and use navigation sensors — including position and altitude — to calculate and map the location of the obstacles. "My work centers around the last part," she explained. "I assume that the obstacles have already been marked on the images, and then I use those processed images, along with navigation information, to estimate, via a Kalman filter, the location of the obstacles.

Xiaojin Gong and Chris Wyatt from the BioImaging Laboratory are helping with the vision algorithms.

RESEARCH

Digital Signal Processing Research Laboratory (DSPRL) *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

Motion Control Systems Research Group

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

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.

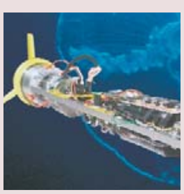
Active combustion control: Recent work has involved modeling and determining the performance limits of proportional modulation of the main fuel stream to control thermoacoustic instabilities in liquid-fueled combustors. The development of models to predict instabilities and lean blowout from first principles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

US Navy photo by Photogtaspher's Mate 2nd Class William H. Ramsey

Controls researchers are investigating the use of Tech's switched reluctance motor technology for applications including weapons elevators and ship elevators.

Autonomous Systems & Controls Lab

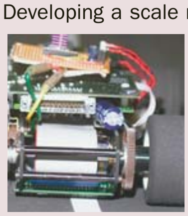
www.ascl.ece.vt.edu



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 automotive changes, such as autonomous vehicles. Director: Pushkin Kachroo



Computer Systems

FACULTY

Lynn Abbott
Peter Athanas
Virgilio Centeno
MohammedEltoweissy
Michael Hsiao
Mark Jones
Tom Martin
Leyla Nazhandali
Jung-Min Park
Cameron Patterson
JoAnn Paul
Paul Plassmann
Binoy Ravindran
Patrick Schaumont
Sandeep Shukla
Joseph Tront
Chris Wyatt

RESEARCH

Researchers in the e-Textiles laboratory are weaving textiles with embedded wiring, sensors, actuators, and processing elements. Their research includes textiles for health monitoring, monitoring physical therapy, monitoring gait, and sound detection and localization. Above, master's student Meghan Quirk adjusts the group's 40-inch industrial loom.

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

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.

RESEARCH

Building an environment for scenario design

Several pundits, including New York Times correspondent, Thomas Friedman, have posited that data communications on portable and handheld devices will mark the beginning of the IT revolution. Portable and handheld computing devices will replace desktops, laptops, and cell phones, ultimately morphing into something entirely new.

At the heart of these devices, single-chip computers will provide and integrate a diverse set of applications with growing complexity. These single-chip devices are becoming heterogeneous multiprocessors (HMs) with the potential integrating about 100 individual processing elements on single chips.

This trend creates a crisis in design, since conventional techniques fail to capture the level of abstraction required, according to JoAnn Paul, who heads an ECE effort to develop the science and design tools for HM systems. She was a member of the team that developed Carnegie Mellon's simulator, called MESH (Modeling Environment for Software and Hardware), which permits designers to study how the numbers and types of processors, communications, scheduling, and software tasks affect the overall performance of an HM.

With a $500,000 grant from the NSF, Paul is working to further develop a design environment that breaks away from "the specify-and-synthesize mindset of current CAD tools" to become a characterize-and-invent paradigm that still has ties to the lower level IC design methodology flows.

"These HM systems are not fully custom, nor general-purpose designs, nor pure embedded designs," she said. "These systems are more correctly referred to as 'scenario-oriented computers,' requiring that computer system designers start from trend analyses and look for future cross-over points between anticipated feature changes and the physical capabilities of the systems."

Current efforts include the development of new forms of system-level benchmarking. As applications compete for resources over time, system performance is evaluated and compared to conventional evaluations that average a collection of different programs over time or attempt to meet a real-time specification. "We believe our evaluations are more in accord with the way future systems are likely to be used," Paulaul said.

Sharing the load may speed up IC simulations

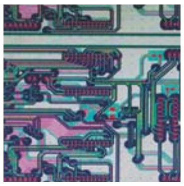
Verification, testing, and debugging claim the biggest role in product design, and most system houses and chip design firms report that 70 percent of total cost comes from checking to be sure their design is correct. Researchers around the world are seeking both hardware and software methods of cutting the time needed for testing and verification.

Bradley Fellow Aric Blumer, an experienced diagnostic engineer and ASIC design engineer, is working on a hardware acceleration approach to circuit simulations. "If we can simulate faster, we can test the design more," he says.

Blumer is investigating the use of virtual machines (VMs) in software and real machines (RMs) in a field-programmable gate array (FPGA), where each executes the same instruction set. The VMs execute serially, and the RMs in parallel. "Simulation characteristics often change as simulations progress," he says, "and we need the ability to migrate idle parts of the design out of the FPGA and busy ones into it." He plans to use the run-time reconfigurability of the FPGA to handle the process migration.

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

Real Time Systems Laboratory

www.real-time.ece.vt.edu/

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

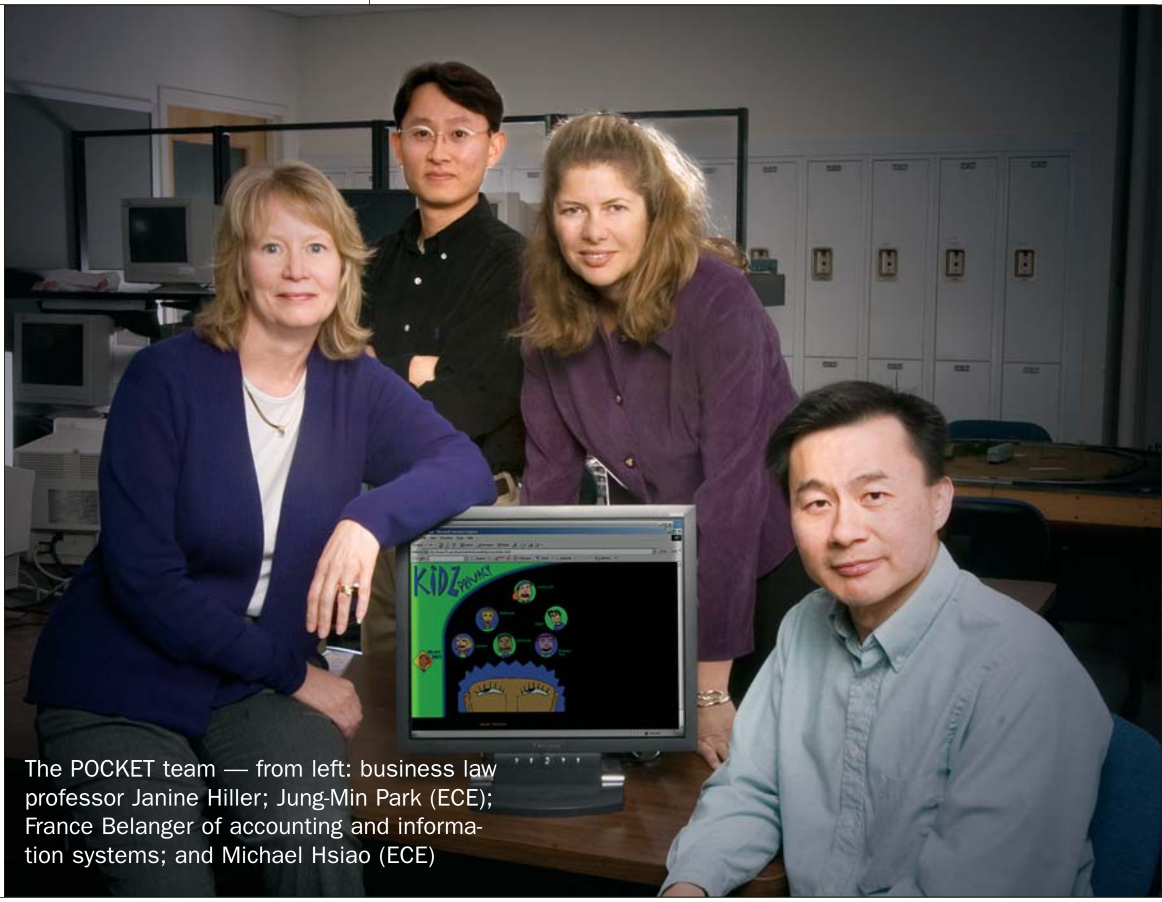
Networking

FACULTY

Luiz DaSilva
Mohamed Eltoweissy
Thomas Hou
Yao Liang
Allen MacKenzie
Scott Midkiff
Amitabh Mishra
Jung-Min Park
Binoy Ravindran

Creating new tools for kids' online privacy

Michael Hsiao and Jung-Min Park have teamed with business faculty members to develop a prototype system for parents to use to ensure their children's online privacy. The team received a $450,000 grant from NSF's Cyber Trust program for the project, called POCKET: (Parental Online Consent for Kids' Electronic Transactions. "POCKET aims to offer a technically feasible and legally sound solution for children's online privacy," said Hsiao who serves as principal investigator. "The challenges brought by the project also offer opportunities for collaborative research with law and e-business. We envision new tools and algorithms from the research and anticipate insights on model checking e-commerce protocols and related security mechanisms."



The POCKET team — from left: business law professor Janine Hiller; Jung-Min Park (ECE); France Belanger of accounting and information systems; and Michael Hsiao (ECE)

Researchers to develop 1st-of-its-kind wireless network testbed

Communications performance in complex defense and disaster-recovery operations depends on the ability of different technology-based networks to communicate with each other. In an effort to improve communication between different wireless technologies, an ECE team has been awarded a $246,000 grant to develop a first-of-its-kind testbed that integrates mobile ad hoc networks with wireless sensor networks. The grant was awarded through the U.S. Department of Defense's Defense University Research Instrumentation Program (DURIP).

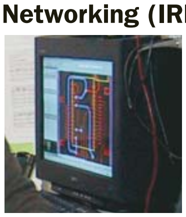
"Ad hoc networks are typically mobile and capable of handling a variety of traffic types for point-to-point or group communications," said Thomas Hou, principal investigator on the project. "On the other hand, wireless sensor networks are usually stationary, severely energy-constrained, and are used for many-to-one communications. Because of the different technology bases, research to date has addressed each network separately. "This has created a critical performance gap in communicating between them."

Hou is working with professor Jeffrey Reed, a wireless communications and software-defined-radio (SDR) expert, and with research scientist Shiwen Mao to create the testbed. The team plans a two-tiered logical network architecture, with a wireless sensor network on the lower tier and a mobile ad hoc network on the upper tier. "This architecture should seamlessly integrate the sensing capabilities of the sensor network with the processing and communications capabilities of the ad hoc network," he said.

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.

Integrated Research and Education in Advanced Networking (IREAN)

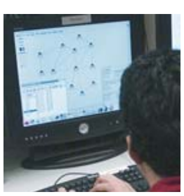


www.irean.vt.edu

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

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 network 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

MANIAC Challenge

to test student networking prowess, real-time ad hoc network cooperation

With the advent of wireless ad hoc networks, some of the toughest issues in communications networking are questions of cooperation: will users trade off bandwidth, signal strength, or speed to ensure system effectiveness? If so, how? What are the incentives that will get users to provide services (such as routing) to other nodes?

ECE professors Luiz DaSilva and Allen MacKenzie hope to get answers by developing a wireless networking contest that will not only further networking techniques and algorithms, but also provide one-of-a-kind opportunities to study actual, uncontrolled, ad hoc networks where users employ different hardware and software.

MANIAC Challenge

DaSilva and MacKenzie recently received a $450,000, three-year grant from the NSF Networking Technology and Systems program to develop a contest called the Mobile Ad Hoc Networking Interoperability And Cooperation (MANIAC) Challenge.

The two-in-one effort is aimed at meeting educational and research goals of improving network throughput, deepening understanding of overall network behavior, and motivating students in the field. "There is currently no such competition in the wireless networking field," said DaSilva. "These competitions are very motivating. They are fun. Failure often teaches us more than success; implementation is more convincing than simulation; and an information exchange of ideas moves research forward."

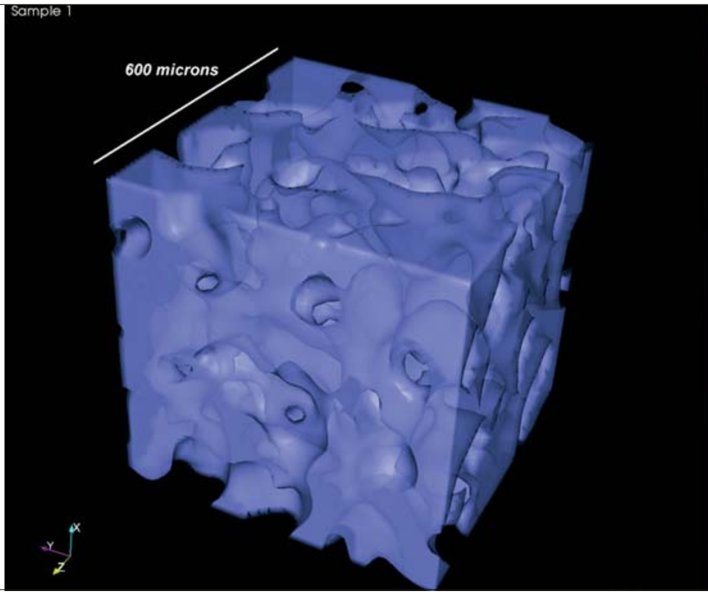
Teams competing in the MANIAC Challenge will match their algorithmic prowess in sending data across uncontrolled, ad hoc networks, where users employ different hardware and software. They will be judged on speed and efficiency. The first year's competition will entail a video relay race in which all the teams are on the mobile ad hoc network (MANET), but no teams will know the locations of the source and destination.

The software layer will also monitor node behavior and system effectiveness, giving researchers a goldmine of data on actual ad hoc network behavior in a field dominated by simulation and controlled testbed research. "Questions linger about how well MANETS will work in the wild — outside of tightly controlled lab environments or military deployments" MacKenzie said. This competition will provide researchers with a unique opportunity to study real-life network behavior in the wild."

Software & Machine Intelligence

FACULTY

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



RESEARCH

ECE researchers seek to improve diagnosis of muscular dystrophies

The Computational Bioinformatics and BioImaging Laboratory (CBIL) is working with biomedical researchers to improve the diagnosis of muscular dystrophies (MD). Muscular dystrophies are a group of rare genetic diseases that cause progressive weakness and degeneration of the muscles used for voluntary movement.

There are nine different identified types of MD, each with varying degrees of progression and disability. Some forms of MD are mild and progress slowly throughout a normal lifespan, while others progress quickly and can lead to death in the third decade of life. There is no treatment for the diseases, other than physical and respiratory therapy and sometimes surgery to improve quality of life.

MD is typically diagnosed and classified with blood tests, testing the electrical activity of the muscle (electromyography), ultrasound, muscle biopsy, and genetic testing.

The ECE researchers have teamed with researchers from the Children's National Medical Center, The Catholic University of America, and the University of Maryland to develop molecular diagnostic tools, build biochemical models of the different MD diseases, and identify new classifications of MD.

The team has worked on previous muscle biopsy projects, and is using its existing 107 biopsy data set for developing sensitive and specific methods for biomarker identification and subsequent molecular diagnostics. They will use 200 muscle biopsies of unknown diagnosis to determine the accuracy of the tests.

The second goal of developing biochemical pathway models is to eventually be able to identify interacting proteins and modification states in both normal and dystrophic muscles. The team is interested in identifying new classifications of MD. "Muscular Dystrophies are very hard to diagnose," said (Joseph) Yue Wang, director of CBIL. "Of 200 patient biopsies received at Children's National Medical Center, only 40 can be specifically diagnosed. We hope to identify previously unknown causes of MD, using comparisons of individual patients to the large data warehouse we build for the pathway modeling."

The team has a five-year, $3.5 million grant from the National Institutes of Health for the project, $469,000 of which is Virginia Tech's share.

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.

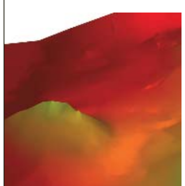
Computer vision refers to the analysis of images and video sequences, often with an emphasis on the interpretation of 3-D scenes. Current efforts include image compositing, human face recognition, industrial inspection, and content-driven image compression. Biomedical research includes the development 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.

Left: A visualization of the structure of a tissue engineering scaffold derived from a microCT image volume. Microcomputed tomography images of poly(L-lactic acid scaffolds for tissue engineering applications. The scaffolds were prepared by Michaela Schultz at the University of Graz, Austria and the image rendering done by the Bioimaging Systems Laboratory.

Right: A research project in the BioImaging Systems Laboratory is aimed at developing an open-source package that quickly, automatically, and consistently analyzes microCT images of fetal mice. The software will ultimately be able to count ribs, estimate rib fusion, or measure total bone volume or density, measure the skull, arms or limbs. (See page 16 for more information.)

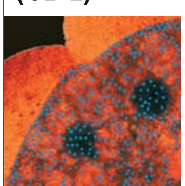
Computer Vision Laboratory

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

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, micro-array gene expression analysis, gene regulatory networks, and systems biology. (ARI)
Director: Yue Wang

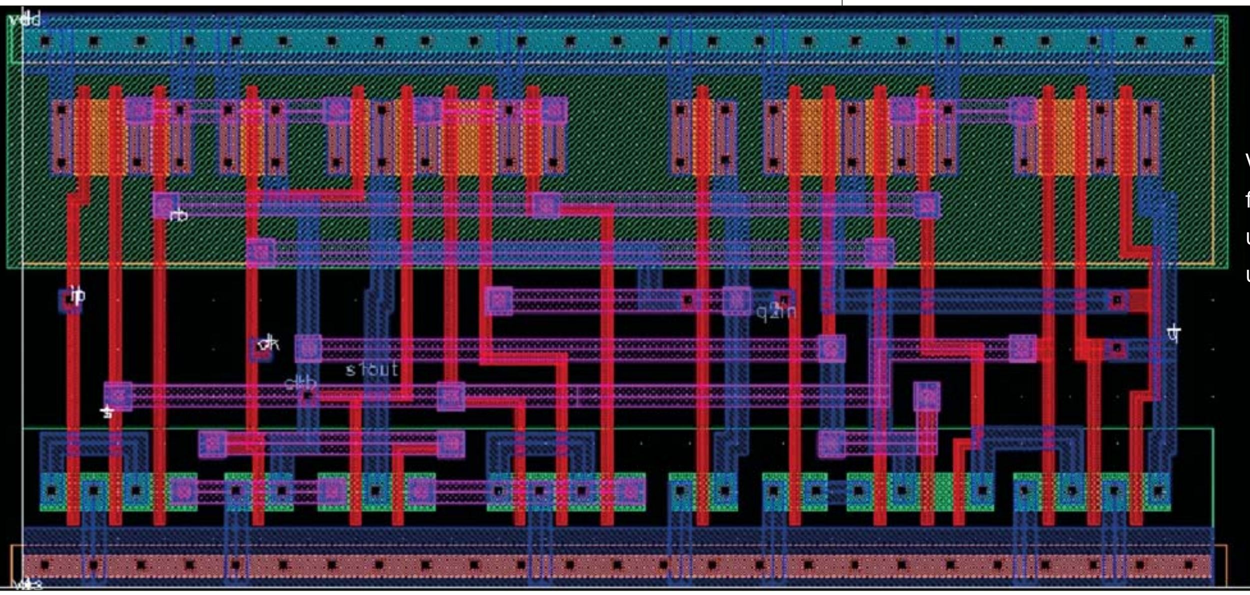
BioImaging Systems Laboratory

Seeks to develop technology to accelerate the use of imaging and image analysis in biomedicine, including computer-aided diagnosis, neuro-imaging, 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

Peter Athanas
Dong Ha
Michael Hsiao
Chao Huang
Tom Martin
Patrick Schaumont
Sandeep Shukla
Joseph Tront



Virginia Tech's cell libraries for VLSI design have been used by more than 280 universities worldwide.

Image courtesy of Dong Ha

Cell libraries boost academic VLSI research

Cell-based, VLSI design — the most widely used approach in system-on-a-chip design — relies on a building-block infrastructure with standard cell libraries. All aspects of VLSI benefit from standard cell libraries, including full custom design, automatic layout generation, physical design, logic synthesis, CAD tools, and testing.

An ECE research team, led by Dong Ha, has been developing and distributing a standard-cell library targeting the TSMC-0.25um, 2.5-volt CMOS process available via MOSIS, along with CAD tools for testing and the source code. The library has been used by more than 280 universities worldwide.

The team — VTVT (Virginia Tech for VLSI Telecommunications) group — recently has been awarded a $421,337 grant (subject to renewal for three years) from the NSF for further development of the library.

"Commercial library cells are the supplier's proprietary information, and understandably, suppliers usually impose certain restrictions on the access and use of their library cells," said Dong Ha, VTVT director. "Those restrictions on commercial library cells severely hamper academic VLSI research and teaching activities. This grant aims to address the problem so that academic researchers can freely exchange designs utilizing those library cells."

Planned improvements include development of library cells for other processing technologies; development of RAM and ROM compilers and data converters; and provision of additional features and simulation libraries.

Center for Embedded Systems in Critical Applications (CESCA)

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

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.

MIT startup taps FERMAT for technology transfer.

Researchers from the FERMAT (Formal Engineering Research with Models, Abstraction, and Transformation) laboratory are working with an MIT-startup firm, Bluespec, Inc., to extend the features of the firm's Electronic Design Automation tools.

Bluespec's toolset, which is based on functional programming technology, delivers a high-level design and verification environment to current Verilog and VHDL designers of ASICs and FPGAs.

Gaurav Singh, a FERMAT Ph.D. student is working to develop low-power features for Bluespec's hardware compiler, and Hiren Patel, also a Ph.D. student, is helping Bluespec develop extensions that would enable SystemC-based designers to apply Bluespec's computation model. FERMAT director, Sandeep Shukla, will also work closely with the firm this summer.

Reliability
of reconfigurable nanosystems

FERMAT researchers have been collaborating with the Los Alamos National Laboratory (LANL) to develop reliability analysis methodologies and tools for reconfigurable nanosystems.

As part of the DOE funded Reconfigurable and Adaptive Systems research project, Paul Graham from LANL's International, Space and Response (ISR) division has been working with ECE's Sandeep Shukla and Ph.D. student Debayan Bhaduri.

The effort has lead to the development of a number of tools, including NANOLAB — a tool for designing and analyzing commercial-off-the-shelf nanoscale CMOS systems. Tools for designing and analyzing molecular memories and molecular reconfigurable systems have also been developed.

Bhaduri has also been working with Heather Quinn from the ISR Space Data Systems, on transitioning these tools to the different projects within ISR. Quinn and Bhaduri are developing an improved reliability and performance analysis system called STARS for nanoscale computational structures. STARS integrates seamlessly with the current hardware design flow. These tools are being applied in image and signal processing systems critical for the threat reduction and nonproliferation missions of ISR.

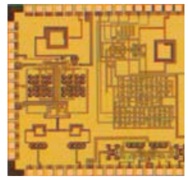
The effort's long-term goal is an unified framework for (1) designing reliable, high performance and power-efficient systems from unreliable nanodevices, and (2) developing computing architectures for novel non-silicon nanodevices such as carbon nanotubes and single electron transistors. Such a framework will help the development of complex nanoscale sensor systems — systems that will be very critical in national and homeland security. Further, with the development of the Center for Integrated Nanotechnologies (CINT) jointly between LANL and Sandia National laboratories, such a nanoscale design framework will impact a number of future applications. Further information on this research project is available at *www.rasr.lanl.gov* and *www.fermat.ece.vt.edu*. LAUR-06-1628

Proactive Research on Advanced Computer-Aided Testing, Verification, and Power Management Techniques

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.html



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

Ph.D. Degrees Awarded 2004/2005

Chen, Rengang
Integrated EMI Filters for Switch Mode Power Supplies
Committee Chair: van Wyk, J.D.

Chen, Zhou
Integrated Electrical and Thermal Modeling, Analysis and Design for IPEM
Committee Chair: Boroyevich, D.

Deng, Haifei
Modeling and Design of a Monolithic High Frequency Synchronous Buck with Fast Transient Response
Committee Chairs: Huang, A.Q., Thorp, J.S.

Deng, Jiangdong
Development of Novel Optical Fiber Interferometric Sensors with High Sensitivity for Acoustic Emission Detection
Committee Chair: Wang, A.

Gallagher, Timothy Michael
Characterization and Evaluation of Non-Line-of-Sight Paths for Fixed Broadband Wireless Communications
Committee Chair: Bostian, C.W.

Guo, Jinghong
Distributed, Modular, Open Control Architecture for Power Conversion Systems
Committee Chair: Boroyevich, D.

Hager, Creighton Tsuan-Re
Context Aware and Adaptive Security for Wireless Networks
Committee Chair: Midkiff, S.F.

Huang, Xudong
Frequency Domain Conductive Electromagnetic Interference Modeling and Prediction with Parasitics Extraction for Inverters
Committee Chair: Lai, J.S.

Huynh, Minh-Chau Thu
Wideband Compact Antennas for Wireless Communication Applications
Committee Chair: Stutzman, W.L.

Jackson, Brian Aliston
Translation of Heterogeneous High-level Models to Lower Level Design Languages
Committee Chair: Armstrong, J.R.

Jacoby, Grant Arthur
Battery-Based Intrusion Detection
Committee Chair: Davis, N.J.

Jiang, Jing
Capacity-Approaching Data Transmission in MIMO Broadcast Channels
Committee Chairs: Buehrer, R.M., Tranter, W.H.

Jones, Creed Farris
Color Face Recognition using Quaternionic Gabor Filters
Committee Chair: Abbott, A. L.

Li, Peng
Utility Accrual Real-Time Scheduling: Models and Algorithms
Committee Chair: Ravindran, B.

Licul, Stanislav
Ultra-Wideband Antenna Characterization and Modeling
Committee Chair: Davis, W. A.

Liu, Changrong
A Novel High-Power High-Efficiency Three-Phase Phase-Shift DC/DC Converter for Fuel Cell Applications
Committee Chair: Lai, J. S.

Liu, Xiao
ATPG and DFT Algorithms for Delay Fault Testing
Committee Chair: Hsiao, M. S.

Maricar, Noor M.
Efficient Resource Development in Electric Utilities Planning Under Uncertainty
Committee Chair: Rahman, S.

Park, JinSoo
Adaptive Asymmetric Slot Allocation for Heterogeneous Traffic in WCDMA/TDD Systems
Committee Chairs: Annamalai, A., DaSilva, L.A.

Pipattanasomporn, Manisa
A Study of Remote Area Internet Access with Embedded Power Generation
Committee Chair: Rahman, S.

Ren, Yuancheng
High Frequency, High Efficiency Two-Stage Approach for Future Microprocessors
Committee Chair: Lee, F.C.

Rieser, Christian James
Biologically Inspired Cognitive Radio Engine Model Utilizing Distributed Genetic Algorithms for Secure and Robust Wireless Communications
Committee Chair: Bostian, C.W.

Sarigul, Erol
Interactive Machine Learning for Refinement and Analysis of Segmented CT/MRI Images
Committee Chair: Abbott, A.L.

Sitapati, Kartik
Mixed-Field Finite-Element Computations
Committee Chair: Davis, W.A.

Svitek, Richard M.
SiGe BiCMOS RF ICs and Components for High Speed Wireless Data Networks
Committee Chair: Raman, S.

Wei, Jia
High Frequency High-Efficiency Voltage Regulators for Future Microprocessors
Committee Chair: Lee, F.C.

Xi, Hong
Theoretical and Numerical Studies of Frequency Up-Shifted Ionospheric Stimulated Radiation
Committee Chair: Scales, W.A.

Yu, Bing
Development of Tunable Optical Filters for Interrogation of White-Light Interferometric Sensors
Committee Chair: Wang, A.

Yu, Huijie
Driver-Based Soft Switch for Pulse-Width-Modulated Power Converters
Committee Chair: Lai, J. S.

Zhang, Bin
Development of the Advanced Emitter Turn-Off (ETO) Thyristor
Committee Chairs: Huang, A. Q., Thorp, J.S.

Zhang, Liang
Design Verification for Sequential Systems at Various Abstraction Levels
Committee Chair: Hsiao, M.S.

Zhao, Lingyin
Generalized Frequency Plane Model of Integrated Electromagnetic Power Passives
Committee Chair: van Wyk, J.D

Zhou, Jinghai
High Frequency, High Current Density Voltage Regulators
Committee Chair: Lee, F.C.

Bradley Fellows

Mark W. Baldwin
BSEE, '93, MSEE, '05, Virginia Tech
Advisor: Yilu Liu
Research: Power system dynamic response to line and generator outages. Primary focus is use of bulk power system eigenproperties to determine event type and location and to assess overall power system condition using frequency measurements.

Aric D. Blumer
B.S. Engineering Science, '92, Bob Jones; MSCPE, '94, Clemson
Advisor: Cameron Patterson
Research: Investigating hardware acceleration of IC simulations through the use of run-time reconfiguration of FPGAs that migrate processes between Virtual Machines and Real Machines.
Honors: Industrial Graduate Fellowship; U.S. patent #6,856,596

Jeffrey R. Clark
B.S. Physics, '01, University of Richmond; MSEE, '03, Virginia Tech
Advisor: Ahmad Safaai-Jazi
Research: Studying dielectric wave-guide configurations containing negative refractive index materials. Propagation modes unavailable in positive wave-guides is suggested by Maxwell's equations. Negative or zero phase velocity has also been predicted.
Honors: Pratt Fellowship; Rappaport Wireless Communication Scholarship

Stephen Craven
BSE, '99, University of Tennessee, Chattanooga; MSECE, '00. Georgia Tech
Advisor: Peter Athanas
Research: Dynamically modifying a computing application's underlying hardware during execution holds promise for improving performance and reducing cost. We seek to develop a practical design environment for dynamic hardware applications, so designers can capture and verify the unique specs found in such designs.

Alumni Bradley Fellows and Scholars

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

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

J. Shawn Addington (Ph.D. '96)
Department Head, ECE
Virginia Military Institute
Lexington, Va.

Sarah S. Airey (BSCPE '01)

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

Matthew Anderson (BSCPE '04)

Carrie Ellen Aust (BSCPE '98)

William Barnhart
(BSEE '00, MSEE '02)

Brian L. Berg (Ph.D. '01)

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

Kirsten Brown (BSEE '94)
Special Assistant to the CEO
MicroStrategy Inc.
Alexandria, Va.

Steve Bucca
(BSEE '87, MSEE '90)

Mark Bucciero
(BSCPE '01, MSCPE '04)
Argon ST, Inc.; Fairfax, Va.

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

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

Carey Buxton (Ph.D. '02)

Scott C. Cappiello (BSCPE '94)

J. Matthew Carson (BSEE '98)
Joe Gibbs Racing
Huntersville, N.C.

Ricky T. Castles (BSCPE '03)
Ph.D. Student; Virginia Tech

Eric Caswell (Ph.D. '02)

Kevin Cooley (BSEE '02)

Cas Dalton (BSCPE '03)

Phillip Danner (BSCPE '91)

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

Daniel Davis (BSEE '03)

Scott Davis (BSCPE '00)

Brian M. Donlan (MSEE '05)
Computer programmer, software developer; Arlington, Va.

Joel A. Donohue (MSEE '94)
Instructor
Virginia Tech

Thomas Drayer (Ph.D. '97)

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

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

W. Ashley Eanes (BSEE '95)

Richard B. Ertel (Ph.D. '00)

Brian F. Flanagan
(BSEE '97, MSEE '98)

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

Todd Fleming
(BSEE '94, MSEE '96)

Ryan J. Fong
(BSCPE '01, MSCPE '04)
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)
Luna Innovations
Blacksburg, Va.

Bradley Fellows (continued)

Daniel Friend
MSEE, BSEE, '98, Brigham Young University

Advisor: Allen MacKenzie
Research: Architecture of cognitive networks, which is the application of cognitive ability to communications networks.

Robert Gardner
BSEE, '03, MSEE, '05, Virginia Tech

Advisor: Yilu Liu
Research: Frequency data analysis and conditioning, power system event detection and location, using data from Virginia Tech's FNET (Wide-Area Frequency Monitoring Network) and Frequency Disturbance Recorders (FDRs).

Mark A Lehne
BSEE, '94, Seattle Pacific; MSME, '98, MSEE, '00, Oregon State
Advisor: Sanjay Raman
Research: Development of a new analog-to-digital converter circuit architecture for use with UWB wireless transceivers. The new circuit is able to significantly reduce power over conventional broad-band analog-to-digital converters.
Honors: TriQuint Semiconductor President's Award

More than 70 graduate students have been supported by the Bradley Fellowship program since it was instituted in 1988

Andrew Love
BSCPE, '05, University of Virginia
Advisor: Tom Martin

Research: e-Textiles

Keith McKenzie
BSEE, '01, MSEE '04, University of Tennessee
Advisor: Yilu Liu
Research: The utilization of wind energy with the power grid, particularly with energy storage, voltage control and point of connection, low-voltage ride-through, and interaction with FNET monitoring system.

Justin Rice
BSEE/BSCPE, '02, MSEE '04, University of Florida

Advisor: Cameron Patterson
Research: Rapid prototyping tools for reducing development time of SDR waveforms. The tools are aimed at developing model-based design, targeting a hardware platform, and deploying waveforms consistent with SCA specs.

Alumni Bradley Fellows and Scholars (continued)

Timothy Gredler (BSCPE '03)

Christopher Robert Griger (BSCPE '02)

Alex Hanisch (BSCPE/Math '03)
U.S. Navy employee
King George, Va.

Abigail Harrison (BSCPE '04)

Jennifer J. Hastings (BSEE '96)

Dwayne A. Hawbaker (MSEE '91)
Senior Staff Engineer
Johns Hopkins Applied Physics Lab
Frederick, Md.

Matt C. Helton (BSEE '01)

Benjamin E. Henty (MSEE '01)

Jason Hess (MSEE '99)

H. Erik Hia (MSCPE '01)

James Hicks (Ph.D. '03)

Hugh E. Hockett (BSCPE '03)

Janie Hodges (BSCPE '01)

Spencer Hoke (BSCPE '03)

Russell T. Holbrook (BSCPE '03)

Andrew Hollingsworth (BSCPE '02)

Ryan Hurrell (BSEE '03)

John Todd Hutson (BSEE '93)

Madiha Jafri (BSCPE '03)

Daniel A. Johnson (MSEE '01)

Adam Kania (BSEE '01)

David A. Kapp (Ph.D. '96)

Dimosthenis C. Katsis (Ph.D.'03)
Senior engineer/team leader, Army Research Lab Semiconductor Device Group, Bowie, Md.

David Kleppinger (BSCPE '04)

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

Gregory Kozick (BSCPE '03)

William B. Kuhn (Ph.D. '95)
Associate Professor, ECE
Kansas State University,
Manhattan, Kansas

Jeffery D. Laster (Ph.D. '97)
Product Specialist, Analog, Mixed-Signal, and RF IC, Mentor Graphics
Richardson, Texas

Charles Lepple (BSEE '99, MSEE '04)

Jason Lewis (BSEE '99)

Joseph C. Liberti (Ph.D. '95)

Zion Lo (BSEE '94)
Senior Software Engineer
NetRegulus Inc.
Highlands Ranch, Colo.

Daniel L. Lough (Ph.D. '01)

Cheryl Duty Martin (BSEE '95)

Stephanie Martin (BSEE '04)

Michael Mattern (BSEE '02)

Christopher Allen Maxey (BSCPE '02)

Eric J. Mayfield (BSEE '97)

Patrick McDougle (BSEE '03)

Brian J. McGiverin (BSCPE '96)

Jamie Riggins
BSEE/
BSCPE, '04,
Virginia Tech
Advisor: Daniel Stilwell
Research: Using camera images acquired on an autonomous surface vehicle to estimate the range and bearing to the shoreline and other surrounding obstacles.

David Gray Roberson, Jr.
BSEE '92,
MSEE, '00,
University of Virginia
Advisor: Daniel Stilwell
Research: Decentralized control and estimation algorithms for environmental mapping using platoons of AUVs. Emphasis on coordinating control and estimation activities where communication bandwidth is severely limited.

Neil Steiner
BA, '98, Wheaton; BSEE, '98, Illinois Institute of Technology;
MSEE, '02, Virginia Tech
Advisor: Peter Athanas
Research: Investigating autonomous computing systems responsible for their own resources and operations. Shifting more of the complexity into the systems permits more independent functioning and a simpler interface to their environments, leading to improved response to changes with minimal outside intervention.

Douglas Sterk
BSEE, '00,
MSEE, '03,
Virginia Tech
Advisor:
Fred C. Lee
Research: Voltage regulator modules for advanced microprocessors targeting Intel's 2010 microprocessor specifications. Modifying the system level interconnections from the VRM to the microprocessor to handle the ever-increasing load transient of the microprocessor.

Juan E. Suris
BSEE '96,
Puerto Rico;
MSCPE, '98
Northwestern;
MS Statistics, '99, Chicago
Advisor: Luiz DaSilva
Research: Applying a game theory approach to opportunistic spectrum access and analysis towards more efficient spectrum utilization. Exploring ways of applying cooperation among users to achieve fair and efficient spectrum access.

Daniel Tebben
B.S. Physics, Secondary Ed, '94, MSEE, '98, Kansas
Advisor:
Ira Jacobs
Research: Impairments and new detection techniques for optical subcarrier multiplexed systems to enable more efficient, lower cost, or larger LANs. He developed a detection technique that largely reduces the distance limitation of subcarrier signals.
Honors: Cunningham Fellowship


Durham Hall

John T. McHenry (Ph.D. '93)

David McKinstry (MSEE '03)

Garrett Mears (BSCPE '00)

Vinodh Menon (BSCPE '02)

Michael Mera (BSEE '03)

Carl Minton (MSCPE '99)

John Morton (MSEE '98)

Stephen Nash (BSCPE '03)

Troy Nergaard (MSEE '00)

Michael H. Newkirk (Ph.D. '94)
Applied Physics Laboratory
Johns Hopkins University
Laurel, Maryland

Paul Erik Nguyen
(BSCPE '98, MSCPE '99)

J. Eric Nuckols
(BSEE '97, MSEE '99)

Neal Patwari
(BSEE '97, MSEE '99)

Joseph Allen Payne (BSEE '00)

W. Bruce Puckett (MSEE '00)

Yaron Rachlin (BSEE '00)

Christian J. Reiser (Ph.D. '05)

Steve Richmond (MSEE '01)

Pablo Max Robert (Ph.D. '03)

Thomas W. Rondeau (BSEE '03)
Ph.D. student; Virginia Tech

Thomas M. Rose (MSEE '96)
Advanced radar upgrades
Boeing, University City, Mo.

Jon Scalera (MSCPE '01)

Amy Schneider (BSCPE '03)

Steven Schulz (MSEE '91)

David C. Schroder (BSEE '05)

Jeff Scruggs (MSEE '99)

Kashan Shaikh (BSCPE '02)
Ph.D. student
University of Illinois
Urbana, Ill.

Raymond A. Sharp (BSEE '02)

Roger Skidmore (Ph.D. '03)

Jeff Smidler (BSEE '98)

Amanda (Martin) Staley
(BSEE '99, MSEE '01)
Ph.D. student, Virginia Tech

Graham Stead (BSCPE '93)

Douglas R. Sterk (MSEE '03)
Ph.D. student, Virginia Tech

Scott Stern (BSEE '93)

Samuel S. Stone (BSCPE '03)

Anne (Palmore) Stublen
(BSEE '91)
Newark, Del.

Seema Sud (Ph.D. '02)

David Tarnoff (MSEE '91)
Assistant Professor
East Tennessee State University
Johnson City, Tenn.

Rose Trepkowski (MSEE '04)
Radar Engineer
Johns Hopkins University Applied Physics Lab
Baltimore, Md.

Christian Twaddle (BSCPE '01)

Matthew C. Valenti (Ph.D. '99)
Associate Professor
West Virginia University
Morgantown, W.V.

Wesley Wade (BSEE '93)

Kristin Weary (BSEE '03)
Knolls Atomic Power
Watervliet, N.Y.

Michael L. Webber (MSEE '03)

Jason Wienke (BSEE '02)

Thomas Williams (BSEE '00)

William J. Worek (BSCPE '99)

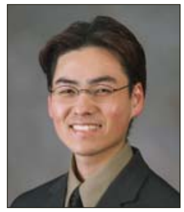
Kai Xu (BSEE '95)

Jason Jon Yoho (Ph.D. '01)

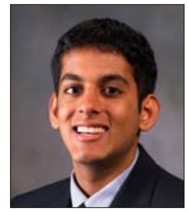
Gregory A. Zvonar (MSEE '91)

Bradley Scholars

Benjamin A. Beasley
EE/Music '09
Kernersville, N.C.
Symphonic Wind Ensemble; Chamber Winds; Horn Ensemble; J.B. West Scholarship; National Merit Scholarship; Robert C. Byrd Scholarship; Sam Walton Community Scholarship
Why ECE: EE is the ideal combination of math, science, and tinkering. It manages to be both abstract and practical in a very appealing way.



Dae Hee (Daniel) Cho
EE '07
Bartlett, Ill.
Research: Building and testing microplasma devices, Nano-CEMMS, University of Illinois, Urbana-Champaign; 2005 Undergraduate Research Symposium
Why ECE: Interested in nanotechnology, and found that many people in nanotechnology research were electrical engineers.



Brian Kalb
CPE/Econ'07
Aldie, Va.
Committee chair, SGA Senate; Society of Indian Americans
Work experience: Java-based sonar detection system for AHA, Inc.; InterCom Networks: worked on AutoCad software in LISP and ObjectARX
Why ECE: Because it will put me on the track to learn and also be a part of the technological advancement of the 21st century.

Ross Benjamin Clay
CPE '09
Raleigh, N.C.
Minor: Economics
Dean's Scholarship; Aikido; Work experience: IT consultant
Why ECE: It's been a lifelong interest.

Daniel Hager
CPE '08
High Point, N.C.
Hillcrest Honors Community; Robert Byrd Scholar
Career aspiration: NASA mission specialist astronaut
Why ECE: This field of engineering has undergone the most radical and exciting developments in the last several years.

Edward Jones,
EE '07
Richmond, Va.
President, Engineers without Borders; Tau Beta Pi; Honors thesis, new energy technologies and power electronics; research assistant, wireless communications
Career aspirations: Develop better power electronics for alternative energy technologies

Adam Shank
CPE '08
Stuarts Draft, Va.
Honors Program; fencing club; Co-op: Experience: Software engineer with IBM
Why ECE: I have always liked working with and building computers, and trying to figure out how they work.

Courtesy of Daniel Cho

Daniel Cho

The True Meaning of Research

When Daniel Cho first signed up for an NSF Research Experience for Undergraduates (REU) at the University of Illinois last summer, he had no idea that drilling holes measured in microns could be either fun or challenging. The Tech senior worked with faculty mentor James Eden on a project related to microdischarge plasma, which is plasma reactions confined to spaces only micrometers in size

The devices Cho and his graduate student mentor, Sung Jin Park, were using consisted of two aluminum plates, one with a 200-400 micrometer hole drilled through it. Both plates were electroplated with an alumina coating then sandwiched together using alumina paste. This hole is the reaction chamber for the plasma reaction; when a strong electromagnetic field is applied to the device, plasma is generated there.

The simplicity of the device, however, belies the intense care that must be put into its creation. Daniel tells of one incident when he had spent more than a week getting holes perfectly drilled through the top aluminum plate. When he then pasted the two plates together, he was horrified to see paste squeezing through hole - effectively ruining his sample. "After all that effort, I said no passionate words. I just looked at it for 30 seconds, put it aside, and went back to work. I learned that research takes much patience."

Daniel did not accomplish his initial research goal. However, the team did make several unexpected discoveries. The experience taught him what research is, he says. "You may not always accomplish what you set out to achieve, but you'll uncover something else instead."

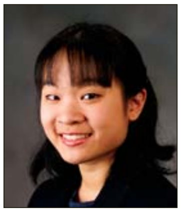
Edward Jones

An Engineering Ambassador

In addition to his rigorous EE studies, junior Edward Jones has been helping to introduce engineering to middle and high school students, as well as leading a student group dedicated to providing international engineering aid.

Last summer, Jones worked with Allen MacKenzie to design a crystal radio kit and to help teach basic communications concepts. Jones then used the kit to teach middle- and high-school students at a couple of Virginia Tech summer camps — Imagination, which introduces engineering to 7th and 8th graders, and

Zachary La Celle
CPE '09
Lansing, N.Y.
Honors college; soccer
Career aspirations: Develop AI for robotics
Most memorable experience: Coming to a complete understanding of Vector Geometry after starting from scratch.



Linh Pham
CPE/Physics '07
Annandale, Va.
Minors: Math, Microelectronics
Micron Scholar; Tau Beta Pi; Sigma Pi Sigma; Women's Chorale; Concert Choir; Solely Swing
Research: Designing and fabricating an autonomous boat; collaborated on NSF REU grant proposal
Career aspirations: Ph.D. and nanotechnology research
Why Virginia Tech: Individual attention from professors, advisors, deans

Jerry Alwynne Towler
EE '08
Greer, S.C.
Minor: Professional writing
Hillcrest Honors Community; Student Technology Council; writer, editor, web-master for YMCA
Project: Autonomous Aerial Vehicle, website creator

Matt Welch
EE '09
Collierville, Tenn.

Developing a Writer's Perspective on ECE

Taking a professional writing course to fulfill an ECE requirement has changed how Jerry Towler views not just writing, but also engineering.
"In professional writing, we learned to consider who is reading our work and why, and how they use it. It seems like common sense now, but I had never really thought of it before," he says. He was so intrigued by the experience, that he has completed additional courses on writing for the web and technical editing and style, and will earn a Professional Writing minor along with his BSEE degree.

Towler has been able to test his growing communications skills as a writer, editor, and designer for the local YMCA web site, and by editing, designing and coding the website for the Autonomous Aerial Vehicle Team.

He expects that the perspective that he is gaining from his writing program will improve his engineering designs. "Engineers should pay attention to the audience," he said. "We should consider the user when designing hardware and software. If we can't produce simple, elegant designs that work for the audience, customers will go elsewhere."

Jerry Towler

Courtesy of Linh Pham

Linh Pham

CTech2, which is geared specifically for girls.

Jones is also involved in engineering in the global community, serving as president of the Virginia Tech chapter of Engineers without Borders USA (EWB). As such, he visits local high schools to encourage students to become internationally responsible engineers. He presents a project similar to one of Tech's freshman engineering lessons — a hands-on MacGyver-type project in which the students try to build a functioning water tower using commonplace materials. Currently, the EWB chapter is developing its first project: providing clean water solutions to an impoverished working community in the Dominican Republic. During the 2006 spring break, three students went to the Dominican Republic to determine design parameters as a first step in the project.

Stranded on an autonomous boat

Linh Pham has spent a couple of years working on the design and fabrication of an autonomous boat in ECE's Autonomous Systems and Controls Laboratory. In addition to gaining experience and knowledge in engineering, she has improved her skills with a lasso and with murky-water navigation. Here is how she describes a particularly memorable afternoon at the Duck Pond.
"Last summer, while I was working on the autonomous boat, a couple of graduate students on the team and I were out at the Duck Pond testing the boat. They were required to attend a meeting for an hour or two in the afternoon, so they left me alone with the boat. During the time they were gone, the boat's motor controller overheated and automatically shut off, leaving the boat drifting just offshore.

"After spending a half an hour attempting to lasso the boat back to shore, I finally managed to pull the boat close enough to climb on so I could reset the motor controller. Unfortunately, I had forgotten to tie the boat to the shore and during the time it took me to reset the motor controller, the boat had drifted quite a distance away from shore again - leaving me stranded on the Duck Pond."

Donors to ECE During Fiscal Year 2005

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.

ECE Alumni who contributed to ECE during Fiscal Year 2005

Fred R. Adkins '83
Stanley C. Ahalt '79
John W. Ayres '75
Mark W. Baldwin '93
William D. Barnhart '00
Cecil E. Barton '94
Michael J. Batchelder '74
Andrew Beach '80
Thomas G. Beazell '79
James C. Becker '74
Rahul Bhatnagar '82
James H. Bowen '70
Howard A. Brown, Jr. '63
Robert F. Bruce '65
Vincent D. Bryan, Jr. '71
Ryan L. Bunch '99
Steven J. Burke '78
Kathleen M. Conway '83
Ernest D. Crack '66
Jeremy A. Crossen '99
Kenneth E. Cutler '85
George S. Davis '69
George Dimitriou '59
Steve O. Dixon '64
Grant A. Dove '51
Ana V. Dubon-Padilla '99
Stephen P. Earwood '93
Katherine A. Epley '69
Andrew B. Fitzgerald '82
Robert W. Freund '71
Michael S. Fulk '77
Michael W. Gandy '04
Ralph V. Geabhart, Jr. '70
James K. George, Jr. '64
Mark J. Greenwood '86
James T. Griffin '70
Paul S. Hamer '72
Edgar D. Harras '67
Bradley M. Harris '82
Christopher B. Haskins '97
Jason R. Hess '97
Kurt M. Hinds '89
Joseph B. Hoofnagle, Jr. '58
William E. Hotaling '46
Hsien L. Huang '68
Daniel S. Jarrett '74
Kenneth L. Johnson '79
Marvin L. Johnson '64
Ashok N. Katti '80
Edward F. Keller '64
Joseph P. Kurian '94
Joseph E. Kusterer '82
Robert E. Lambert '80
William K. Lamp '78
David S. Lehnus '84
Maja M. Lehnus '84
Thomas W. Little, Jr '03
John K. Loftis, Jr. '77
Ronald L. Marsh '77
Stephanie A. Martin '04
Mason L. Mattox '90
Jeffrey L. Meekins '88
Charles A. Moses, Jr. '71
Constance W. Moses '71
Christopher Munk '90
Forrest E. Norrod '86
Michael L. Oatts '79
Stewart L. Ocheltree '57
Stewart L. Ocheltree, Jr. '81
Jeffrey T. Olson '81
Robert C. Patterson, III '91
Trevor A. Paul '98
Billy K. Peele '65
Milton A. Pilcher '38
Craig L. Purdy '70
David K. Purks '87
Daniel M. Sable '85
James F. Schooler '85
Noel N. Schulz '88
Steven R. Seidman '82
Manoj R. Shah '77
James L. Sherwood, IV '65
Bernard Silverman '42
Stephen V. Smith '90
David W. Snodgrass '62
Bambang O. Soedarjatno '78
Drew D. Summers '79
Robert W. Sundeen, Jr. '78
Andrew A. Thompson, II '85
Paul T. Thurneysen '88
Edward G. Tiedemann, Jr. '75
C. Hyde Tucker '56
Donald J. Waltman, Jr. '65
Donna E. Wiltsey '91

Corporate Donors

ABB, Inc.
AK Steel Foundation
AMD Matching Gift Program
American Electric Power
Associated Power
AT&T Foundation
Bank of America Foundation Inc.
Boeing Matching Gift Company
ChevronTexaco Matching Gift Program
Cisco Systems, Inc.
Comcast Cable
Community Foundation Silicon Valley
Dominion Foundation
Electrical Distribution Design Inc.
Fuel Cell Technologies Inc.
Fujitsu Laboratories of America Inc.
GE Foundation
General Electric Multilin, Inc.
Intel Corporation
ITT Industries, Inc.
Kaydon Electro-Tec Corporation
Lockheed Martin Corporation
Marathon Oil Company Foundation, Inc.
The MathWorks Inc.
Micron Technology Foundation, Inc.
Microsoft Corporation
MISO
Northrop Grumman Foundation
NVIDIA Corporation
QUALCOMM, Inc.
Raytheon Company
RF Micro Devices Inc.
Robertson Chwalek Trust
Ronald A. Williams, Ltd.
Tektronix, Inc.
Texas Instruments Inc.
The Scholarship Foundation-Lockheed Martin Matching Gifts
Tyco Electronics Foundation
United Space Alliance Foundation
Via-Bradley College of Engineering Foundation
Wachovia Foundation, Inc.
World Reach Inc.
Xilinx Inc.

When you hear from The College Annual Fund this fall, make your gift to ECE.

ECE Friends who contributed to ECE

Steven J. Adamchak
Glenn M. Allen
Katherine L. Batchelder
Carol M. Becker
Jacqueline C. Chen
Rosemary P. Cole
Michael Diesman
James A. Eder
Wu-Che Feng
Barry & Laana Fishman
Gary J. Gawlas
Jon M. & Martha A. Goodney
Rita Hay
Leonard A. Hoey
Stanley Honda
Andre C. & Angela L. Houle
Ira & Irene Jacobs
Joanne Joe
Susan A. Johnson
Sudha N. Katti
William T. & Lynda M. Kissman
Gregory Kulon
Maryann W. Kusterer
Chester R. & Betty R. Lane
John W. & Patricia Lane
Evelyn W. Lane
Karen G. Liao
David M. Lofe
Jeanne C. Melone
Larry L. Miller, Jr.
David T. Nakatani
Kelvin D. Okimoto
Michelle L. Parker
George S. Powley
Deborah J. Purks
Kirk H. Schulz
Dennis R. & Angela A. Snyder
Harold H. Speed, III
David R. Spracher
Warren L. Stutzman
Susan C. Thomas
Robert D. Ward
P. A. West
James A. &. Carla V. Wilding

Corporate and Industrial Affiliates

CPES Partners

Principal Members Plus
The Boeing Company
Delta Electronics
GE Global Research
Hipro Electronics Co., Ltd.
Infineon Technologies
International Rectifier
Intersil Corporation
Linear Technology
National Semiconductor Corp.
Renesas Technology Corp.
Rolls-Royce

Principal Members
CEAG AG / FRIWO Group
Crane Aerospace, Inc. / ELDEC Corporation
DRS Power and Control Technologies, Inc.
Eaton Corporation
Eltek Energy AS
Emerson Network Power Energy Systems AB
Groupe SAFRAN
Philips Semiconductors
Rockwell Automation - Allen - Bradley
Schneider Toshiba Inverter Europe

Associate Members
Convertronic GmbH
Crown International
Densei-Lambda KK
Honda R&D Co., Ltd.
Intel Corporation
KEMA T&D Power
L-3 Communications, Power Paragon, Inc.
Matsushita Electric Works
MKS Instruments, Inc.
Nippon Chemi-Con Corp.
Northrop Grumman Corp.
SEMIKRON Elektronik GmbH & Co. KG
Shindengen Electric Mfg. Co., Ltd.
Silicon Laboratories, Inc.
TDK Corporation
Texas Instruments
Toyota Motor Corporation
York International

Affiliate Members
ABB Inc., Drives and Power Products Division
Agilent Technologies
Ansoft Corporation
AO Smith Corporation
Astronics Corporation
BAE Systems Controls, Inc
Ballard Power Systems, Inc.
Caterpillar, Inc.
Curtis Instruments
Danfoss Electronic Drives
Electronic Concepts
Emerson Motor Company
Engineous Software
Flomerics
Ford Motor Company
Fuji Electric Advanced Technology Co., Ltd.
GM Advanced Technology Center
Grundfos A/S
Hamilton Sundstrand
Hoganas AB
Honeywell International Corporation
Ingersoll-Rand Company
John Deere Worldwide Commercial & Consumer Equipment Division
Kimberly-Clark
Kohler Company
Magnetek, Inc.
Miller Electric Company
MPC Products Corporation
MTS Systems Corporation
Nissan Motor Co. Ltd.
Oak Ridge National Laboratory
Oshkosh Truck Corporation
Otis Elevator Company
Pacific Scientific EKD
Phoenix Integration
Rietschle Thomas
Rockwell Automation / Dodge / Reliance Electric
S&C Electric Company
Samsung Electronics Co., Ltd.
Schneider Electric - Square D
Synopsys
Thermadyne
Toshiba International Corp.
Trane Company
Transim Technology
Unico, Inc.
VPT, Inc.
Whirlpool Corporation
Yaskawa Electric America, Inc.

Wireless@Virginia Tech

CWT Affiliates
DRS Technologies
Freescale Semiconductor
NSA (National Security Agency)
Sony Ericsson Mobile Communications

MPRG Affiliates
Analog Devices
Army Research Office
DRS Technologies
DRT, Inc.
General Dynamics
Huawei Technologies Company
Motorola, Inc.
Qualcomm, Inc.
Raytheon IIS
Samsung Telecommunications America
Texas Instruments

Honors & Achievements

Honors & Awards

Jeffrey Reed was named the Willis G. Worcester Professor of Electrical and Computer Engineering.

Saifur Rahman was named the Joseph R. Loring Professor of Electrical and Computer Engineering.

Dushan Boroyevich was named an IEEE Fellow

Bill Stephenson was awarded a DSc by the University of Newcastle in England.

William T. Baumann was named one of three Virginia Tech W.E. Wine Award winners for excellence in teaching.

Joe Tront received the XCaliber Award for excellence in teaching with technology.

Thomas Hou was co-recipient of 2004 IEEE Communications Society Multimedia Communications Technical Committee Best Paper Award.

Amy Bell is serving as an advisory board member of "An Intergenerational Conference on Women and Work in the STEM Workplace" at UMass.

Carl Dietrich was licensed as a professional engineer in Virginia.

Sandeep Shukla was invited to the National Academy of Engineering's Frontiers of Engineering conference, September 2005 and is serving as secretary of the IEEE Computer Society task force on Nanotechnology, Nanocomputing and Nanoarchitectures.

National & International Service

William H. Tranter serves on the Board of Governors of the IEEE Communications Society.

Ira Jacobs serves on the Federal Communications Technological Advisory Council as a Special Government Employee.

Steven Ellingson is chair of Long Wavelength Array Working Group 12 and serves on the National Academies Panel on Frequency Allocations and Spectrum Protection for Scientific Uses and the National Academies Board on Physics & Astronomy Committee on Radio Frequencies.

Mohamed Eltoweissy was a visiting expert at King Fahd University in Saudi Arabia.

Amir Zaghloul is a member of the IEEE Publication Services and Products Board and the IEEE Antennas and Propagation Society AdCom.

Saifur Rahman has been elected vice president of the IEEE Products, Services and Publications Board.

Amy Bell is chair of the Public Awareness Committee, IEEE Educational Activities Board and the EAB representative, IEEE Women in Engineering Committee.

Patents Awarded

"Event triangulation based on wide area measurements," Robert Gardner, Kevin Zhong, Yilu Liu

"Multifunction hybrid intelligent universal transformer," Jason Lai

"Server-based network performance metrics generation system and method," Y. Thomas Hou, Y. Dong, T. Taniguchi

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

"Symmetric sweep phase sweep transmit diversity," R.D. Benning, R.M. Buehrer, and R.A. Saul

"Method and apparatus for packaging optical fiber sensors for harsh environments," G.R. Pickrell, Y. Duan, and A. Wang

"Smaller aperture for multiple spot beam satellites," Amir I. Zaghloul, Ozlem Kilic, Albert E. Williams

Editorships

Amir Zaghloul is a member of the editorial advisory board for IEEE's *The Institute*.

Wayne Scales is a guest editor of *Advances in Space Research*.

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

Lamine Mili is the co-editor and co-founder of the *International Journal of Critical Infrastructures*.

Daniel J. Stilwell is the associate editor for underwater vehicle control, dynamics and navigation for the *IEEE Journal of Oceanic Engineering*.

Thomas Hou is associate editor of *IEEE Transactions of Vehicular Technology*, editor of *ACM/Springer Wireless Networks, Elsevier Ad Hoc Networks Journal* and guest editor of *ACM/Kluwer Mobile Networks and Applications* special issues "Recent Advances in Wireless Networking" and "Energy Constraints and Lifetime Performance in Wireless Sensor Networks."

Sanjay Raman is serving as an associate editor of *IEEE Transactions on Microwave Theory and Techniques*.

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

Michael Buehrer is associate editor of *IEEE Transactions on Wireless Communications, IEEE Transactions on Vehicular Technologies* and *IEEE Transactions on Signal Processing*.

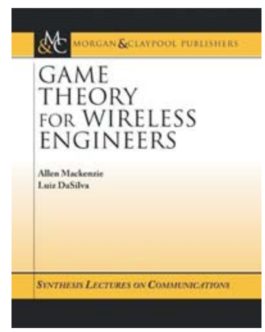
Mohamed Eltoweissy was a guest editor for the *Elsevier Journal of Computer Communications* special issues on "Dependable Wireless Sensor Networks" and "Sensor Actuator Networks."

William H. Tranter serves as senior editor of the *IEEE Journal on Selected Areas in Communications*.

Yue (Joseph) Wang is an associate editor for the *EURASIP Journal on Signal Processing and Bioinformatics.*

Books Published

Allen MacKenzii, Luiz DaSilva, and William Trenter published *Game Theory for Wireless Engineers*; Morgan and Claypool, 2006.



Conference Chairs

Amir Zaghloul was General Chair of the Joint IEEE Antennas and Propagation Society International Symposium/USNC-URSI National Radio Science Meeting, July 2005.

JoAnn Paul is serving as workshops chair for the 2006 International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS '06).

Wayne Scales is co-organizer of the 11th Workshop on the Physics of Dusty Plasmas, June 2006.

Sandeep Shukla served as General Chair of the International Workshop on Formal Methods for Globally Asynchronous and Locally Synchronous (FMGALS) Design.

Michael Hsiao is program chair for IEEE International High Level Design Validation and Test 2006.

Jason Lai served as General Chair of the 20th IEEE Applied Power Electronics Conference and Exposition (APEC 2005), March 2005.

Luiz DaSilva served as General Chair for the 14th International Conference on Computer Communications and Networks (ICCCN), October 2005.

Bill Davis was vice chair of the Joint IEEE Antennas and Propagation Society International Symposium/USNC-URSI National Radio Science Meeting, July 2005.

Thomas Hou was general vice-chair of the IEEE/CreateNet International Conference on Broadband Networks (BroadNets 2005), October 2005.

Peter Athanas served as co-chair of the IEEE International Conference on Rapid System Prototyping, June 2005, and the Dynamically Reconfigurable Architectures, April 2006.

Anbo Wang was chair of Sensors for Harsh Environments II, SPIE OpticsEast, October 2005.

Mohamed Eltoweissy served as chair of the Second IEEE/NASA Workshop on Dependability and Security in Sensor Networks and Systems, April 2006.

Saifur Rahman was keynote speaker for The Euro-Atlantic Partnership Consortium Workshop on Critical Infrastructure Protection & Civil Emergency Planning, the C12RCO Workshop on Critical Information Protection Research and Development, and the Conference on International Experience and Potential Applications of Renewable Energy.

ECE Faculty

A. Lynn Abbott
Associate Professor
Illinois ’89

Masoud Agah
Assistant Professor
Michigan ’05

Annamalai Annamalai
Assistant Professor
Victoria ’99

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

Claudio da Silva
Assistant Professor
University of California San
Diego ’05

Luiz DaSilva
Assistant Professor
Kansas ’98

William A. Davis
Professor
Illinois ’74

Jaime de la Ree
Associate Professor &
Assistant Department Head
Pittsburgh ’84

Steven Ellingson
Assistant Professor
Ohio State ’00

Mohamad Eltoweissy
Associate Professor
Old Dominion ’93

Louis Guido
Associate Professor
Illinois ’89

Dong S. Ha
Professor; Iowa ’86

Robert Hendricks
Professor; Cornell ’64

Thomas Hou
Assistant Professor
Polytechnic Univ. ’98

Michael Hsiao
Associate Professor
Illinois ’97

Chao Huang
Assistant Professor
Princeton ’05

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

Leyla Naghandali
Assistant Professor
Michigan ’05

Hardus Odendaal
Assistant Professor
Rand Afrikaans ’97

Jung-Min Park
Assistant Professor
Purdue ’03

Cameron Patterson
Associate Professor
Calgary ’92

JoAnn Paul
Associate Professor
Pittsburgh ’94

Paul Plassmann
Professor
Cornell ’90

T.C. Poon
Professor
Iowa ’82

Timothy Pratt
Professor
Birmingham ’68

Saifur Rahman
Joseph Loring 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
Willis G. Worcester Professor
UC Davis ’87

Sedki Riad
Professor
Toledo ’76

Ahmad Safaai-Jazi
Professor
McGill ’78

Wayne Scales
Associate Professor
Cornell '88

Patrick Schaumont
Assistant Professor
UCLA '04

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 Electrical
Engineering
Alabama '70

Joseph G. Tront
Professor
SUNY Buffalo '78

J. Daan Van Wyk
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

Joel A. Donahue
Instructor

Abdul Habayeb
Information Technology
Research Professor

Leslie K. Pendleton
Instructor

Arun G. Phadke
University Distinguished
Professor Emeritus

Gerald Reid
Instructor

Roger Stolen
Research Professor

Warren L. Stutzman
Thomas Phillips Professor
(Emeritus)

Jason Thweatt
Instructor

ECE Advisory Board

Andrew Beach ('80, '85)
Principal ASIC
Design Engineer
Raytheon Corporation

Shivon Dosky ('89)
Managing Partner
Evolvian

Steve Fredrick ('90, '92)
Grotech Capital Group

Truls Henriksen ('90)
Consultant

Sharon Holt ('86)
Senior Vice President
Worldwide Sales,
Licensing, and Marketing

Douglas B. Juanarena ('75)
Vice Chairman & Managing
Director, Business &
Organization Development
Luna Innovations, Inc.

Michael Keeton
Senior Program Director
Orbital Science Corporation

Robert E. Lambert ('80)
Senior Vice President,
Worldwide Technology
Strategy and President,
Technology Operations
and Licensing
The Walt Disney Company

Christopher G. Magnella ('84)
Manufacturing Manager
Motorola

Gino Manzo
Director, Semiconductor
Technology Center (STC)
Site Executive, Manassas
BAE Systems

Dave Marsell ('88)
Vice President
of Engineering
Pressure Systems, Inc.

Michael Newkirk
('88, '90, '94)
Principal Professional Staff
The Johns Hopkins
University Applied Physics
Laboratory

Stewart L. Ocheltree ('81)
Litho & Etch Section Manager
BAE Systems

Dan Sable ('85, '91)
President/CEO, VPT Inc.

Karl Salnoske ('76)
Chief Information Officer
Schering-Plough

Peter Santago ('73, '80)
Retired, Associate
Professor and Chair
Department of
Biomedical Engineering
Wake Forest University
School of Medicine

Wayne Snodgrass ('61)
Retired, Northrup Grumman
Engineering and Manufacturing
Electronic Systems Sector

James Stewart ('83)
Vice President
& General Manager
Imaging Systems Division
Avago Technologies

C. Hyde Tucker ('56)
Retired; President and CEO
Bell Atlantic International

Timothy J. Winter ('81)
Director, Air and Missile
Defense Department
Systems Development &
Technology Division
Electronic Systems Sector
Northrop Grumman
Corporation

Paul K. Wong ('80)
President/CEO, Prosoft

The Bradley Department
of Electrical & Computer Engineering
Virginia Polytechnic Institute and State University
302 Whittemore Hall
Virginia Tech
Blacksburg, VA 24061

Non-Profit Org.
U.S. Postage PAID
Blacksburg, VA 24060
Permit No. 28

www.ece.vt.edu