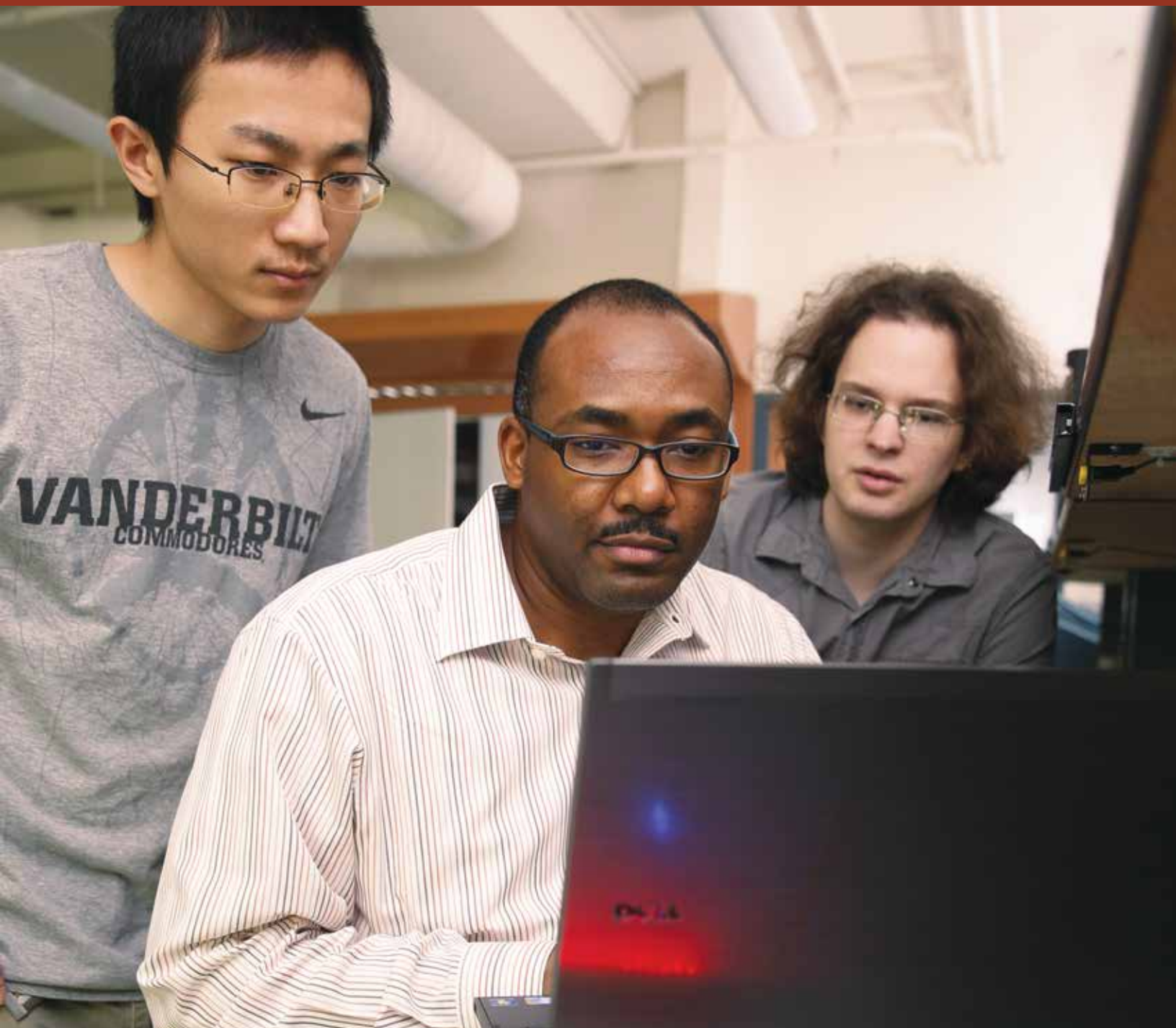
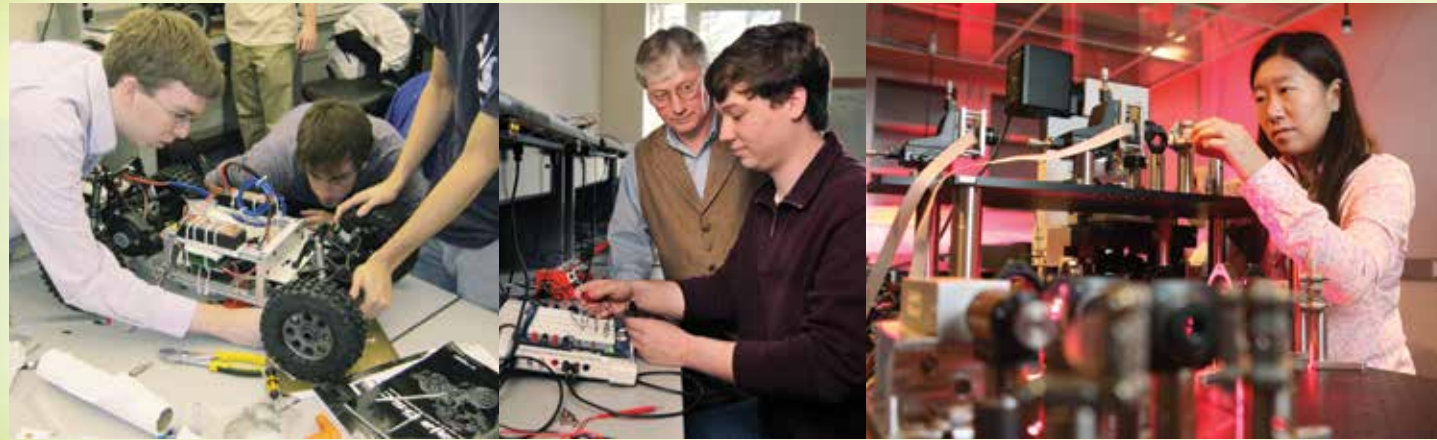


Vanderbilt

Department of
Electrical Engineering and
Computer Science



SCHOOL OF ENGINEERING



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- 8 **Security and Faulty Tolerance**
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Our programs leading to bachelor of engineering degrees in electrical engineering and computer engineering are accredited by the Engineering Accreditation Commission of ABET, abet.org.

Degrees Offered in EECS

Undergraduate

- Bachelor of Engineering (B.E.) in Computer Engineering
- Bachelor of Science (B.S.) in Computer Science
- Bachelor of Engineering (B.E.) in Electrical Engineering
- Double Major in Electrical Engineering and Biomedical Engineering
- Minors in Computer Science, Engineering Management and Scientific Computing

Graduate

- Doctor of Philosophy (Ph.D.) in Computer Science
- Doctor of Philosophy (Ph.D.) in Electrical Engineering
- Master of Science (M.S.) in Computer Science
- Master of Science (M.S.) in Electrical Engineering
- Master of Engineering (M.E.) in Electrical Engineering

A shared passion for research and education is a hallmark of the Vanderbilt environment, and the undergraduate and graduate programs in the electrical engineering and computer science department exemplify that drive for excellence. Faculty, research engineers and students engage in leading-edge scholarship along with research of significant importance in both industry and government.

The undergraduate and graduate computer science programs provide opportunities for students to join vibrant, collaborative and interdisciplinary efforts in artificial intelligence, computer animation and virtual environments, cyber-physical systems, distributed real-time and embedded middleware, human-systems integration, image processing, intelligent learning environments, model-integrated computing, robotics, software engineering and trustworthy computing. Students can explore a broad range of research areas in computer science, as well as interdisciplinary research opportunities in areas related to the School of Engineering's strategic directions in health care and medicine, security, energy and natural resources and entertainment.

Electrical engineering students have the opportunity to participate in research that is propelling changes in science and engineering through rapid innovation in information technology. Such research has the potential to impact virtually every human system, from health care to education, transportation, defense and the environment. Significant research programs in electrical engineering focus on carbon, diamond and silicon nanotechnology, hybrid and embedded systems, medical image processing, photonics, radiation effects and reliability and robotics. Many faculty members are involved with the Institute for Software Integrated Systems and the Institute for Space and Defense Electronics, which support leading-edge basic and applied research important to critical commercial and government systems. In addition, several faculty members are affiliated with the Vanderbilt Institute of Nanoscale Science and Engineering and the Vanderbilt Initiative in Surgery and Engineering.

Finally, the undergraduate program in computer engineering combines the basic principles of electrical engineering and computer science and focuses on the organization, design and application of digital processing systems. Centered on digital technology and the principles and techniques of computer science, the design-based program enables engineers to evaluate the impact of their decisions by applying these principles to the task at hand, whether they're working with hardware, software or the interface between the two.



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isde.vanderbilt.edu

The mission of the Institute for Space and Defense Electronics is to contribute to the design and analysis of radiation-hardened electronics, the development of test methods and plans for assuring radiation hardness and the development of solutions to system-specific problems related to radiation effects. ISDE was launched with initial support from the United States Navy Strategic Systems Program and

C.S. Draper Labs. In addition, ISDE currently supports the Defense Threat Reduction Agency, Arnold Engineering Development Center, NASA Goddard Space Flight Center, NASA Marshall Space Flight Center, Boeing, Defense Advanced Research Projects Agency, Naval Research Laboratory, Air Force Office of Scientific Research, Department of Energy and many others, including over 20 commercial enterprises around the world.

Ronald Schrimpf

Orrin H. Ingram Chair in Engineering
Professor of Electrical Engineering
Director of the Institute for Space and Defense Electronics



Space and defense systems require the highest levels of performance, but at the same time, levels of reliability exceeding those of commercial systems are required. These two requirements are often in conflict, as the most modern and highest performance devices don't have extensive operational histories upon which reliability models can be built. The reliability challenges include long-term degradation, as well as loss of data (soft errors).

To address these concerns, Ronald Schrimpf is leading a

team of ISDE researchers to develop more predictive reliability models based on physical understanding of the failure mechanisms, funded by the United States Air Force, United States Navy and the Defense Threat Reduction Agency. This challenge requires a fundamentally new and revolutionary approach to designing-in and assuring reliability.

The research team aims to use a practical and unified approach, developing understanding of basic mechanisms at a fundamental level and efficiently propagating that information into practical capabilities. Understanding the physical phenomena responsible for degradation and soft errors is a key reliability challenge associated with deploying future generations of electronics in space and defense systems.

Dan Fleetwood

Olin H. Landreth Chair in Engineering
Professor of Electrical Engineering
Chair of the Department of Electrical Engineering and Computer Science



Dan Fleetwood is a leader in understanding the effects of defects on the radiation response and long-term reliability of semiconductor materials and devices. He specializes in the effects of radiation and/or bias/temperature stress on Si and compound semiconductor-based devices and integrated circuits. He is an internationally recognized authority in the area of low-frequency noise and has led research efforts that have resulted in the identification of key manufacturing defects responsible for limiting the performance, reliability and radiation response of electronic

devices in terrestrial and space environments.

Along with collaborators in the radiation effects community, Fleetwood performed basic research that unified models of the complex time and dose rate dependencies of metal-oxide-semiconductor (MOS) defect growth and annealing, which provided the technical basis for the present standards for total dose radiation testing. He developed irradiation and high-temperature anneal sequences that ensure MOS devices that pass short-term radiation tests on the ground will not fail at long times in space. These methods were the first standards to specifically address the difficult issue of predicting MOS total dose response in space and now govern acceptance of electronics for all military and space radiation environments.

Lloyd Massengill

Professor of Electrical Engineering and Computer Engineering
Director of Engineering for the Institute for Space and Defense Electronics



Lloyd Massengill's area of expertise is the study of single-event (SE) radiation that produces soft errors (data glitches or bit-flips) in microelectronics. Soft errors are due to isolated strikes by ionizing particles such as high-energy particles discharged by the sun, objects in deep space or natural radioactive decay of common materials. Although the impact of single events on a computer chip is localized and transient, as circuits become smaller, the deleterious effect on computer operation can increase dramatically. Of additional concern is total-dose radiation, which is caused by bombardment over time of subatomic particles released from a variety of sources, including ambient or background radiation on Earth. The accumulated effect of this type of radiation



impairs performance over time and can ultimately destroy integrated circuit functionality.

To address these challenges, Massengill is currently leading a team of researchers to investigate radiation mechanisms, high-speed

circuit response, compact model development and design hardening for deep sub-100 nm (32 nm/22 nm/14 nm) complementary metal-oxide semiconductor technologies exposed to SE radiation. Using three-dimensional technology computer-aided design, mixed-mode simulation and IC fabrication/testing to elucidate mechanisms and circuit responses, Massengill is developing SE hardening guidelines and radiation-hardened-by-design techniques under the DoD's Defense Threat Reduction Agency funding.

Ken Galloway

Distinguished Professor of Engineering
Professor of Electrical Engineering



Ken Galloway has been actively engaged in research related to radiation effects in microelectronics for 40 years. He has worked on the development of new technologies, characterization tools, test methods and basic mechanisms. He has, at various times, contributed to work on both single-event effects and total ionizing dose effects. He has published numerous technical papers in these areas and has conducted research sponsored by several United States Department of Defense organizations including the United States Navy, United States Air Force, Defense Threat Reduction Agency and DARPA.

Galloway played a key role in establishing ISDE and the Radiation Effects and Reliability Group, which studies the underlying phenomena behind the effects of radiation on electronic devices and integrated circuits and proposes new solutions to increase the reliability of systems in space and other systems exposed to ionizing radiation. During his tenure as executive vice-chair and chairman of the NPSS Radiation Effects Committee, a comprehensive set of guideline documents describing every aspect of organizing the Nuclear and Space Radiation Effects Conference was created and the Radiation Effects Data Workshop began. Galloway's role resulted in the strong and cordial relationship that exists today between NPSS and the premier European radiation effects conference, RADECS.

Robert Reed

Professor of Electrical Engineering



Robert Reed and ISDE researchers are launching a miniature satellite into space in a quest to help future space missions better combat the harsh conditions of space, particularly radiation that can cause glitches or breakdowns in electronic components. Funded by NASA and the DoD, this multi-mission, radiation effects test bed payload will be

among the first of its kind in the United States. Using a CubeSat (a small square satellite only 10 cm or four inches), the launches provide an unprecedented

opportunity to test the billions of calculations ISDE researchers have conducted on the ground using computers. More than that, these projects expose a new generation to the potentially exciting discoveries where electrical engineering and computer science intersect with space exploration.

Under funding by the DoD's Defense Threat Reduction Agency, Reed is also addressing the mechanisms of charge carrier generation and motion that affect non-silicon channel transistors during an ionizing radiation-induced event. Reed is applying multiscale simulations and targeted experiments on test structures to understand the production and motion of ionizing radiation-induced charge carriers that are critical for future generations of nanoscale electronics.

Robert Weller

Professor of Electrical Engineering



Nothing in the modern world is more critical for countering threats to the United States than maintaining robust and secure electronic and information systems that can continue to perform even when subjected to harsh environments. Whether these systems are aboard spacecraft or in fixed terrestrial infrastructure, they must be

engineered to withstand their respective environments and to continue to function as expected.

Robert Weller and ISDE colleagues are developing first-principles methods for computing radiation effects in sub-100 nm semiconductor devices with arbitrary composition and design. In the last few years, the scaling of devices to quantum sizes, the introduction of radically new materials and an increasing dependence on commercial technologies for defense applications have made it necessary to develop new methods for predicting the reliability of devices in radiation environments. By advancing the science and computational techniques for first-principles analysis of radiation effects in microelectronics, the team aims to reduce the development cost and increase the reliability of microelectronics used in radiation environments, as well as to support the development of advanced radiation detectors.

Bharat Bhuva

Professor of Electrical Engineering



Soft errors pose a major reliability threat to advanced semiconductor technologies. The decrease in minimum feature sizes, accompanied by the decrease in transistor currents and nodal capacitances, has resulted in this increased vulnerability. As a result, it is imperative to develop a full characterization

of soft errors at advanced technology nodes to guide designers and fabrication engineers in meeting reliability requirements of electronic systems.

With a coalition of semiconductor companies, Bharat Bhuva is leading a team of ISDE researchers in evaluating advanced technology platforms for soft errors to develop design strategies that mitigate soft error threats. Results from this project will allow better understanding of single-event effects and will facilitate development of mitigation strategies.

ISDE Research and Affiliated Faculty

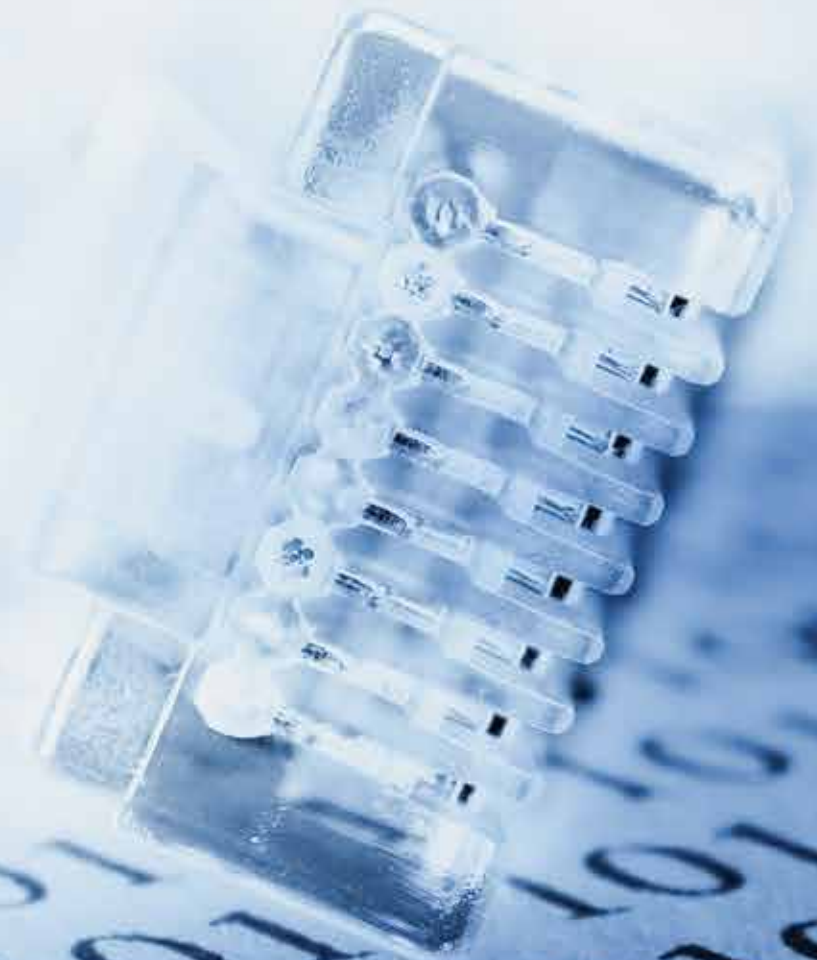
- Michael Alles
Research Associate Professor of Electrical Engineering
- Tim Holman
Research Associate Professor of Electrical Engineering
- Daniel Loveless
Adjunct Assistant Professor of Electrical Engineering
- Marcus Mendenhall
Research Associate Professor of Electrical Engineering
- Sokrates Pantelides
University Distinguished Professor of Physics and Electrical Engineering
- William Robinson
Associate Professor of Electrical Engineering and Computer Engineering
- Arthur Witulski
Research Associate Professor of Electrical Engineering
- Enxia Zhang
Research Assistant Professor of Electrical Engineering



SECURITY AND FAULT TOLERANCE

William Robinson leads Vanderbilt University's Security and Fault Tolerance (SAF-T) Research Group, whose mission is to conduct transformational research that addresses the reliability and

security of computing systems. His group aims to design, model, verify and implement robust computing systems that positively benefit stakeholders with consumer, defense, industrial and medical applications.



William Robinson

Associate Professor of Electrical Engineering and Computer Engineering



Under recent NSF funding, William Robinson and collaborators are using the concept of information leakage to bridge the computer architecture and computer networking fields. An integrated, holistic approach can yield tremendous benefits in many areas such as network security and management and job scheduling in cluster grids.

This integration is a result of delay signatures in the network traffic that are composed of information leaked from internal components of a compute node (processor utilization). This information will be used to create completely new approaches to solve existing networking or architecture problems or to significantly improve the performance of existing approaches that address networking or architecture problems.

Using a hardware test bed, Robinson and researchers are investigating how various architectural components

contribute to the delay signature. They hope to develop empirical and analytic models that will provide the framework to implement a general purpose engine that automates the process of using delay signatures. This engine would allow others to develop applications based upon the delay signature. The delay signature could also be used to increase the system's resiliency against degraded performance or failure.

The end goal is to provide extensive characterization and modeling of the behavior of the internal components of a node and the corresponding effect on network traffic generation. These results will enable researchers to address different aspects of node security/manageability and cluster grid scheduling.

In addition to this work, Robinson and his group address the threat of security vulnerabilities during the design and manufacture of integrated circuits (ICs) under both DARPA and the NSF Team for Research in Ubiquitous Secure Technology funding. The research would develop analysis techniques that can be used within traditional flows for electronic design automation to predict the risk associated with a particular IC.



isis.vanderbilt.edu

The Institute for Software Integrated Systems conducts basic and applied research in the area of systems and information science and engineering. Applications of ISIS technology span a wide range of software-intensive systems, from small, embedded devices through real-time distributed systems to globally deployed complex systems. The work

focuses on systems with deeply integrated software that are networked, embedded and cyber-physical. Annual funding is \$20+ million, and there are active projects with dozens of academic and industry collaborators at Vanderbilt and other leading universities and companies in the United States and around the world.



Janos Sztipanovits

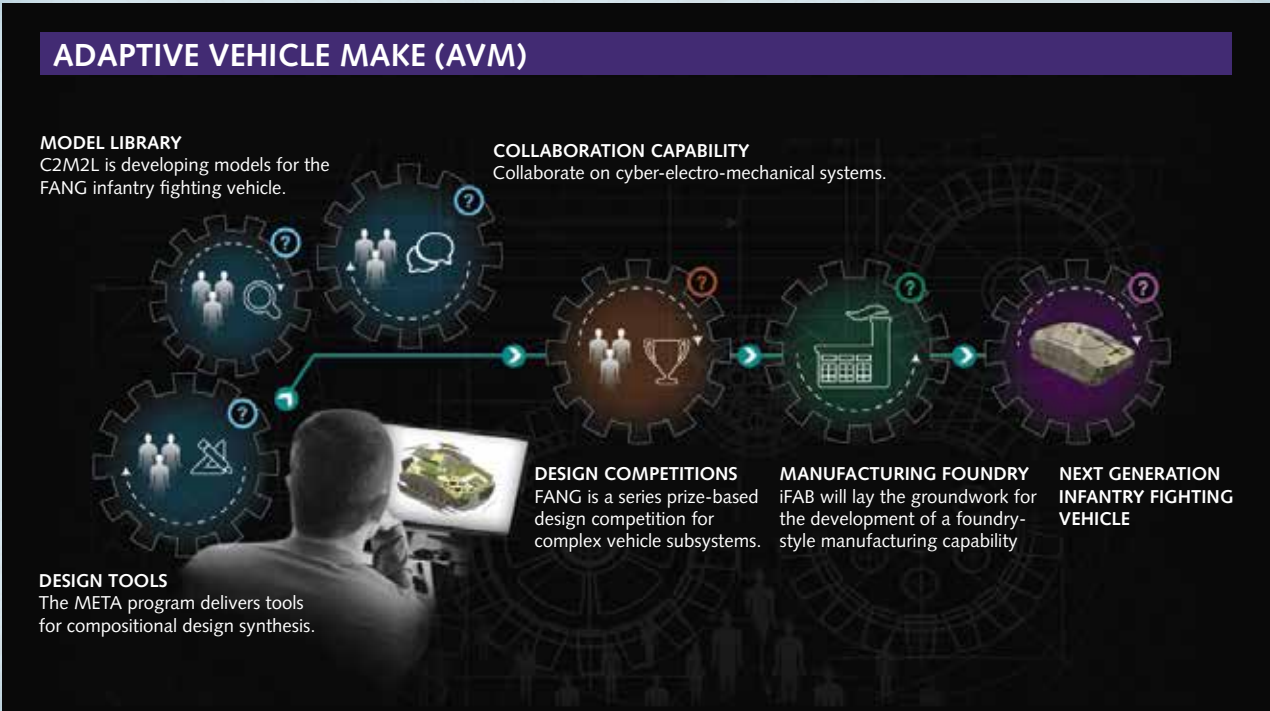
E. Bronson Ingram Distinguished Professor of Engineering
Professor of Electrical Engineering and Computer Science
Director of Institute for Software Integrated Systems



Systems today—everything from pacemakers to remotely piloted aircraft to the power grid—are complex and the processes used to build the software platforms that make them work are surprisingly creative. More importantly, these processes leverage decades of R&D on innovative tools and methods—the kind of innovative software design work

going on at ISIS every day to ensure software and hardware integrate together successfully. A good example of ISIS's impact on safety-critical system development is the recently completed Model-Based Design of High Confidence Systems project led by Janos Sztipanovits. This Air Force Office of Scientific Research funded project generated powerful model-integrated computing techniques and tools for software platforms that underlie many complex cyber-physical systems used by humans. Cyber-physical

systems have become so complicated that it's neither practical nor affordable to build them without first testing the joint behavior of the physical and computational system by using precise-scale computer models. Methods and tools created for the Model-Based Design of High Confidence Systems project became the building blocks for the next generation of ISIS model-integrated computing efforts, such as the META portion of the DARPA Adaptive Vehicle Make program that aims to radically alter the way military vehicles are built or the Science of Integration of Cyber-Physical Systems project funded by the National Science Foundation. With Sztipanovits at the helm, the institute is at the forefront of the cyber-physical system revolution due to the strong focus on the foundations of model-based design and model-integrated computing. These foundations include meta-programmable design automation tools that enable the use of domain-specific abstractions in design flows and rigorous semantic foundations for modeling and model analysis.



Gabor Karsai

Professor of Electrical Engineering and Computer Science
Associate Director of Institute for Software Integrated Systems



Gabor Karsai is leading a team of researchers to create a sophisticated software platform: a novel operating system that is distributed (it runs software apps dispersed on networked computers), real-time (it satisfies stringent timing requirements) and embedded (it interacts with a physical system such as a vehicle). One potential applica-

tion for such a platform can be found with networked vehicles such as driverless cars traveling as a platoon, unmanned aerial vehicles that fly in formation or a fractionated spacecraft, which is a cluster of independent, but wirelessly connected, small satellites that work together to perform



There are several challenges that such a software system has to solve. The system has to be safe and reliable, operate securely under fault conditions, be able to share resources (sensors, processors and networks), satisfy stringent timing requirements and operate under the constraints on size, power, weight, computational and communication resources. Most importantly, software applications for it should be easy to construct, deploy and manage.

coordinated missions. This research has been supported by DARPA's System F6 program, a cooperative effort of government, academic and industry entities aimed at building novel satellite architecture.

Douglas Schmidt

Professor of Computer Science and Computer Engineering
Associate Chair of Computer Science and Engineering



A consortium of industry, academic and government entities known as the Future Airborne Capabilities Environment (FACE) is helping to define a common operating platform environment for mission- and safety-critical avionics systems. This operating platform is comprised of a set of new standards, recommendations, reference implementations and conformance tools to help reduce the cost of software acquisition for DoD avionics systems.

Schmidt works with a team of researchers at ISIS who are developing a reference implementation and associated model-integrated computing software toolkit as part of FACE. This software will be available in open-source form to anyone building avionics systems for the DoD. Adoption of FACE will lower total ownership costs, improve



performance, speed innovations and leverage government and defense contractor workforces more effectively than traditional proprietary approaches to avionics software. Schmidt has more than 20 years of experience leading the development of ACE, TAO, CIAO and CoSMIC, which are widely used, open-source middleware frameworks and model-integrated computing tools that implement patterns and product-line architectures for common operating platform environments, such as FACE. The middleware platforms and modeling tools developed by Schmidt and his colleagues at ISIS constitute some of the most successful examples of software R&D ever transitioned from research to industry.

performance, speed innovations and leverage government and defense contractor workforces more effectively than traditional proprietary approaches to avionics software.

Schmidt has more than 20 years of experience

Akos Ledecz

Associate Professor of Computer Engineering



Detecting and accurately locating snipers has been an elusive goal of the armed forces and law enforcement agencies for many years. Prior counter-sniper efforts at ISIS and elsewhere focused on special-purpose hardware and software that displayed the location of enemy shooters.

Akos Ledecz and ISIS engineers recently invented a next-generation counter-sniper mobile app for commodity Android smartphones that has reached the final testing phase.

Called the Shooter Localization with Mobile Phones, this mobile app under the Defense Advanced Research Projects Agency collects sound waves through microphones mounted on soldiers' headsets. These measurements are then used to determine precise enemy shooter location data



that are displayed on the soldiers' phones via Google Maps. The smartphones are networked together so data can be fused from multiple units, filtering out echoes and other unrelated sounds.

Location data is then processed and displayed directly on the phones.

The wireless sensor network group at ISIS is also developing a novel, software-defined radio under National Science Foundation (NSF) funding that allows researchers to experiment with novel wireless communication protocols that consume considerably less power than conventional radios. In addition, the group is working on novel GPS-based localization technology funded by NSF and a Google Research Award.

Yuan Xue

Associate Professor of Computer Science



As cyber-security has become a national priority, ISIS has focused a great deal of work on the science of security, including ensuring privacy for the next generation of information systems, such as electronic medical records (EMRs). Yuan Xue and ISIS researchers aim to understand the fundamental issues that cause cyber vulnerabilities

and to develop model-based methods and tools to help prevent problems before they occur.

Among the projects on that front are Team Research in Trusted Ubiquitous Security Technologies, which is a large NSF Science and Technology Center and Strategic Healthcare IT Advanced Research Projects on Security funded by the Department of Health and Human Services. Xue and ISIS researchers



have developed techniques to build an architecture that protects the EMR system and the Web portal. The system works like a firewall that's intelligent enough to recognize intended information and updates so the entire system need not be shut down for every change.

Xue is also working on smart resource management for smartphones under an NSF CAREER award. She is developing a theoretical foundation for a dynamic-based approach to managing wireless network resources and a mobile application execution based on the usage profile and the network condition. Xue is testing her theories with a remote medical care system that is undergoing a clinical trial at the Vanderbilt University Medical Center.

Aniruddha (Andy) Gokhale

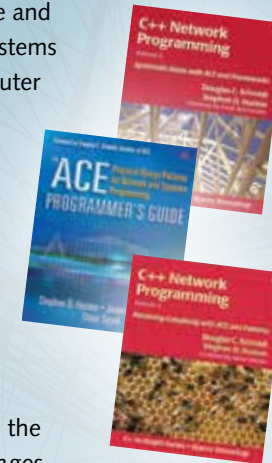
Associate Professor of Computer Science



Distributed real-time and embedded (DRE) systems middleware is computer software that integrates diverse programming languages, operating systems, networks and hardware, and it serves as an important build-

ing block for many projects at ISIS.

Andy Gokhale and Douglas Schmidt have led the development of the influential middleware packages ACE (ADAPTIVE Communications Environment) and TAO (The ACE ORB), which are popular open-source, pattern-oriented frameworks. Their recent research led to the development of component abstractions and their deployment and configuration for DRE systems. These efforts leverage their prior work on ACE/TAO and have resulted in the open source



Component-Integrated ACE ORB (CIAO), and Deployment and Configuration Engine (DAnCE) middleware. Complementing their middleware efforts, they have developed model-driven engineering (MDE) techniques to deal with a number of inherent and accidental complexities stemming from the use of the middleware technologies, which has resulted in an open source tool called Component Synthesis using Model Integrated Computing.

Gokhale's ongoing projects focus on developing solutions to support cyber-physical systems in cloud computing environments. Topics of interest to him in this area include algorithms

for real-time versus reliability tradeoffs in virtualized environments, power versus performance tradeoffs for multicore servers, optimal deployment of CPS application functionality and security solutions, all of which are encoded as MDE tools and middleware that support CPS applications in mobile, resource-constrained cloud environments.

Xenofon Koutsoukos

Associate Professor of Computer Science



Among the hardest problems facing researchers and engineers are those associated with producing robust and secure integration of physical and computational processes for cyber-physical systems, which deliver advanced capabilities in airplanes, cars, spacecraft, smartphones and even smart power grids. To address the

challenges of cyber-physical system validation and verification, Xenofon Koutsoukos and Janos Sztipanovits are leading the Science of Integration for Cyber-Physical Systems, funded by the National Science Foundation.

This project is creating model-integrated computing techniques, which enable the design, analysis and integration of complex cyber-physical systems using automated



tools. These tools will enable incremental validation and verification of key system properties, such as functional correctness, safety and stability, so these systems need not

be built and retested from scratch to accommodate every change. Koutsoukos is also focusing on how to combine disparate model-integrated computing tools into an open tool integration framework that cyber-physical system practitioners and engineers can apply to develop and sustain complex systems more rapidly and reliably throughout their lifecycles. These integrated tools are essential to aid in building and assuring future safety and mission-critical cyber-physical applications, such as autonomous air and ground vehicles.

Gautam Biswas

Professor of Computer Science



Working closely with Honeywell engineers, ISIS researchers are mining regional airline flight and maintenance data to build the Vehicle Integrated Prognostic Reasoner (VIPR), which uses knowledge derived from advanced data mining and machine learning techniques to diagnose and detect potential problems in an airplane before

an accident or emergency landing. Gautam Biswas leads the NASA-funded VIPR project, which aims to find evolving faults in aircraft systems, such as the engine and the avionics system, as well as anomalies that occur due to pilot actions and unusual environmental conditions, such as inclement weather or the orientation of a runway in a particular airport.

Although plane crashes are rare, the growing complexity of aircraft systems has increased the chances for unexpected



occurrences; hence the need to combine machine-driven exploration with human expertise to understand these situations. VIPR explores and analyzes large amounts (terabytes) of flight data to derive new

and useful knowledge. Human experts then use that knowledge to improve diagnostic monitors and reasoning systems available on today's aircrafts.

Beyond conventional machine learning, Biswas, together with Honeywell experts, has discovered new monitors and more accurate diagnostic knowledge to detect faults in fuel supply lines, the fuel injection systems and the engines. Their results show that faults can be detected more quickly and accurately, allowing the initiation of maintenance actions in a timely manner to avoid compromising aircraft safety.



ISIS Research and Affiliated Faculty

Ted Bapty

Research Associate Professor of Electrical Engineering

Tihamer Levendovsky

Research Assistant Professor of Computer Science

Sandeep Neema

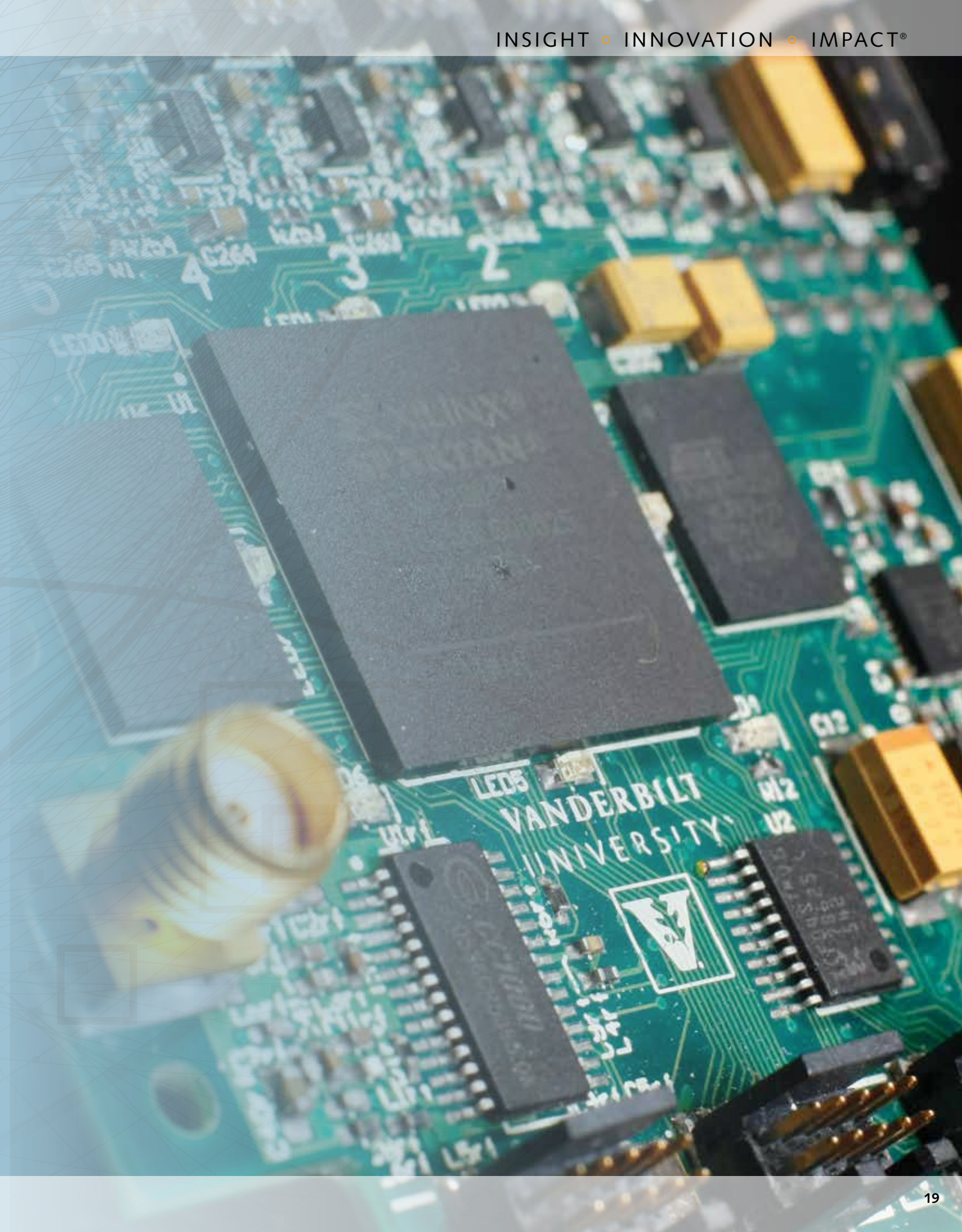
Research Associate Professor of Electrical Engineering

William Robinson

Associate Professor of Electrical Engineering and Computer Engineering

Jules White

Assistant Professor of Computer Science



MEDICAL IMAGING PROCESSING

Medical images are a fundamental element in medical diagnosis and treatment, as they reveal the internal anatomy of patients. These images include both projection X-ray images and cross-sectional images, like those acquired through computed

tomography or medical resonance imaging. Medical image processing explores the medical applications of these unusual images. At Vanderbilt, research in this field primarily focuses on image segmentation, image registration and image-guided surgery.



Benoit Dawant

Cornelius Vanderbilt Professor of Engineering
Professor of Electrical Engineering
Director of the Vanderbilt Initiative in Surgery and Engineering



Benoit Dawant works at the interface between engineering and medicine with particular expertise in image processing and surgical guidance. Current projects focus on the development and clinical evaluation of algorithms and systems to assist in the placement of deep brain stimulators used for the treatment of Parkinson's disease and other movement disorders,

the placement and programming of cochlear implants used to treat hearing disorders, the removal of brain tumors and the creation of radiation therapy plans.

For more than 10 years and with National Institute of Health funding, Dawant and Vanderbilt researchers have developed a system that facilitates the pre-operative, intra-operative and post-operative phases of deep brain stimulation (DBS) procedures. The system, which consists of a data repository called CranialVault and a suite of software tools called Cranial Vault Explorer, is the first computer-assistance system that spans the entire spectrum of the procedure.

In addition to his research, Dawant is at the helm of the Vanderbilt Initiative in Surgery and Engineering, an interdisciplinary, trans-institutional center whose mission is the



creation, development, implementation, clinical evaluation and commercialization of methods, devices, algorithms and systems designed to facilitate interventional processes and their outcome. The center facilitates the exchange of ideas between physicians, engineers and computer scientists. Primarily funded by federal research support, the center is also engaged with industrial partners for the commercialization of its intellectual property, the early evaluation of industrial devices and techniques and the joint development of innovative solutions.



Medical Image Processing Research and Affiliated Faculty

- Pierre D'Haese**
Research Assistant Professor of Electrical Engineering
- Michael Fitzpatrick**
Research Professor of Computer Science
- Bennett Landman**
Assistant Professor of Electrical Engineering
- Jack Noble**
Research Assistant Professor of Electrical Engineering

Bennett Landman

Assistant Professor of Electrical Engineering



Bennett Landman's projects range from understanding the neurological basis of psychological disorders and mapping brain tumors to statistical method development and visualizing abdominal defects. The common theme that unifies his work is capturing quantitative information from three (or higher)-dimensional medical images.

Under the Vanderbilt University Institute of Imaging Science, he leads the Center for Computational Imaging, which develops support and informatics tools and infrastructure to help advance imaging research for the center's users,

collaborators and the medical imaging community. The group aims to provide infrastructure, image analysis and informatics expertise to facilitate basic science research using imaging data, while developing novel approaches to computational imaging techniques. Landman is currently working on projects that investigate statistical label fusion techniques and multi-modal MRI approaches.

In addition to this work, Landman is developing computational tools for imaging genetics analysis under National Institute of Health funding. The emerging field of imaging genetics combines modern statistical genetics methods, which embrace quantitative phenotyping, with neuroimaging, which is capable of providing detailed structural and functional phenotypical measurements.

Jack Noble

Research Assistant Professor of Electrical Engineering



Longtime cochlear implant (CI) users are reporting dramatic improvements in their hearing, thanks to new image-guided programming methods developed by Vanderbilt University researchers. Jack Noble is collaborating with an interdisciplinary team that includes Benoit Dawant, René Gifford and Robert Labadie to

develop software that can boost the performance of existing cochlear implant technology and improve the quality of hearing for CI recipients.

Current devices use a combination of surgically implanted electrodes that stimulate auditory nerve pathways and an external sound processor worn behind the ear to provide hearing sensations. The new automatic technique uses patients' pre- and post-implantation CT scans



to determine the location of the implanted electrodes and where stimulation overlap is occurring, possibly causing interference in the transmission of signals. The image-guided strategy and software,

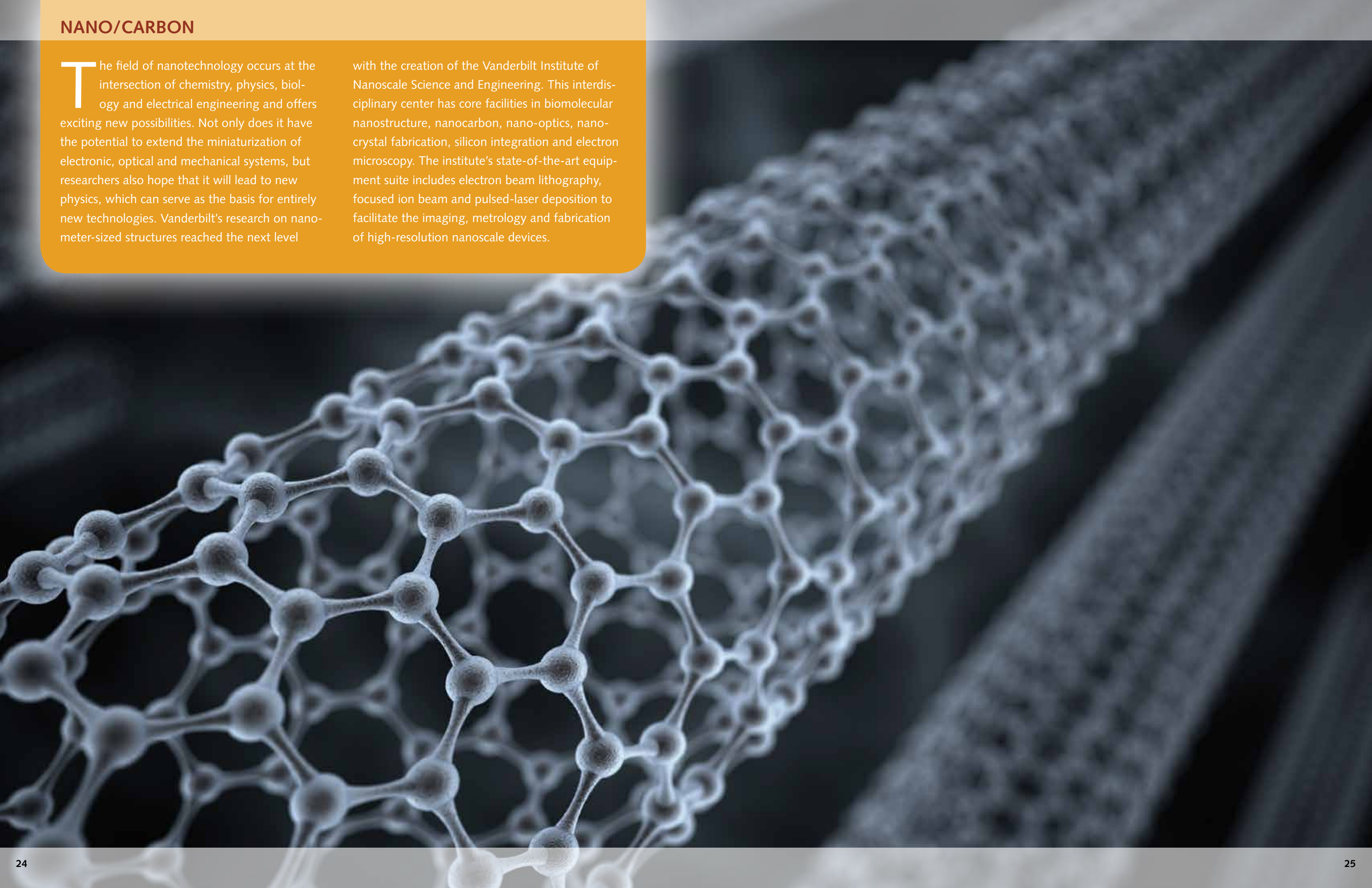
which Noble developed as a Ph.D. student, then pinpoint which electrodes can be turned off without loss of hearing fidelity—in fact, improving it. An audiologist uses this programming plan to create a revised custom program for that person's needs. The process is completely noninvasive—no surgery is required—and can be accomplished in one office appointment.

Under NIH funding, Noble plans to expand the technology in the future to test a wide range of position-dependent CI tuning techniques and to make these techniques available to the population of existing and new CI recipients.

NANO/CARBON

The field of nanotechnology occurs at the intersection of chemistry, physics, biology and electrical engineering and offers exciting new possibilities. Not only does it have the potential to extend the miniaturization of electronic, optical and mechanical systems, but researchers also hope that it will lead to new physics, which can serve as the basis for entirely new technologies. Vanderbilt's research on nanometer-sized structures reached the next level

with the creation of the Vanderbilt Institute of Nanoscale Science and Engineering. This interdisciplinary center has core facilities in biomolecular nanostructure, nanocarbon, nano-optics, nanocrystal fabrication, silicon integration and electron microscopy. The institute's state-of-the-art equipment suite includes electron beam lithography, focused ion beam and pulsed-laser deposition to facilitate the imaging, metrology and fabrication of high-resolution nanoscale devices.



Philippe Fauchet

Dean of the School of Engineering
Professor of Electrical Engineering



In today's world, success in the field of engineering is marked by collaboration, creativity and the ability to solve problems. Philippe Fauchet's diversity of interests and innovative projects are perfect examples. Fauchet's multidisciplinary research combines elements from semiconductor and device physics, materials science, physical chemistry and optics to form three major centers of interest that involve silicon.

His research group is focused on nanoscience and nanotechnology with silicon—from manufacturing and processing to modeling and testing devices. Silicon has been developed



into a very inexpensive, highly manufacturable material for one application—microelectronics. Fauchet is investigating the use of silicon for other applications. One focus of Fauchet's research is nanometer-thin porous silicon membranes for purification of biological samples. The second focus is ultra-thin silicon solar cells that maintain high conversion efficiency while decreasing the material costs thanks to the use of nanoplasmonics. The third focus is developing optical components made of silicon, such as lasers, modulators or chemical/biological sensors.

Weng Poo Kang

Professor of Electrical Engineering



Design, fabrication, characterization and modeling: these are the pillars of Weng Poo Kang's research on micro- and nano-electronic devices and sensors. Kang has worked alongside fellow Vanderbilt researchers to develop innovative electronic devices that are tolerant of harsh environments. He has also developed physical, chemical

and biological sensors, nanostructured high-power, high-energy supercapacitors and lithium-ion batteries.

For one such project, Kang collaborated with Jim Davidson, research professor of electrical engineering, to develop the technology to produce vacuum microelectronic devices out of thin films of nanodiamond. This technology could be used in designing computer chips and electronic circuitry for extreme environments, since diamond-based devices can operate at much higher temperatures than silicon-based ones and are largely immune to radiation damage. Kang also collaborates with Supil Raina to develop



nanodiamond-based biosensors for detecting, measuring and monitoring the concentration of neurotransmitters, such as dopamine. Though many of Kang's research initiatives involve utilizing emerging diamond, carbon nanotubes and graphene technologies, he also conducts research on silicon-based devices and sensors. In addition to this work, Kang partners with defense sciences companies to develop novel nano-architected electrodes such as CNT-MnO₂, graphene-MnO₂ and CNT-orthosilicates for ultracapacitor and lithium-ion batteries applications. The electrode unit has the potential to produce hybrid supercapacitors and batteries that last longer, provide more power, charge faster, meet high-energy and high-power requirements for energy storage and delivery and, most importantly, are environmentally friendly.

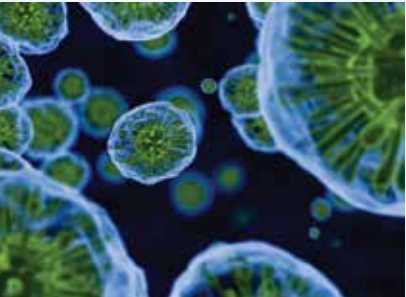
Sharon Weiss

Associate Professor of Electrical Engineering



Accurate and reliable detection of biological and chemical materials is essential to improving medical diagnostics, environmental monitoring and homeland security. Sharon Weiss aims to achieve more sensitive and efficient detection of biomolecules by developing sensors made from porous silicon, a material with billions of nanometer-sized holes. These cost-effective biosensors have the potential to revolutionize medical diagnostics, as they are used to identify specific DNA sequences, various toxins and viruses. In micro- and nanoparticle form, porous silicon may also be used for superior disease treatment through improved targeted drug delivery and controlled drug release.

The Weiss Group is currently working on several other projects in the areas of photonics, optoelectronics and



materials research. The focus of one such project is to develop an optical silicon-based modulator, which could be a building block for next generation computers and communication networks. Other current projects theoretically and experimentally investigate novel photonic crystal microcavity and nanobeam structures for advanced optoelectronics and optomechanics.

Weiss's innovative research has positioned her as one of the nation's top young scientists. She received the Presidential Early Career Award for Scientists and Engineers, the highest honor bestowed by the United States government on young professionals beginning their research careers.

James Wittig

Associate Professor of Materials Science and Engineering



Materials science is the foundation for developing new technologies, and it demands collaboration among a variety of disciplines in order to advance in today's complex climate. James Wittig is one of 40 faculty members involved in Vanderbilt's Interdisciplinary Program in Materials Science, a collaborative research and teaching program. Wittig's work on the magnetic properties of monodispersed FePt nanoparticles exemplifies the interdisciplinary nature of the field, as it combines chemistry with materials science and engineering. The project aims to improve nanoparticle synthesis in order to increase magnetic properties, possibly providing a basis for future magnetic recording media.



Wittig is also collaborating with Joachim Mayer, of the RWTH University in Aachen, Germany, on a project that focuses on understanding the deformation mechanisms in iron-manganese steels as a result of changes in stacking fault energy (SFE). Iron-manganese steels are candidates for commercial applications that require high formability and energy absorption due to their ductility and toughness. The SFE of the alloys affects these mechanical properties by influencing the deformation mechanisms of the steel. Therefore, increased understanding of the SFE for iron-manganese steels through experimental determination will play an important role in their optimization for commercial use.

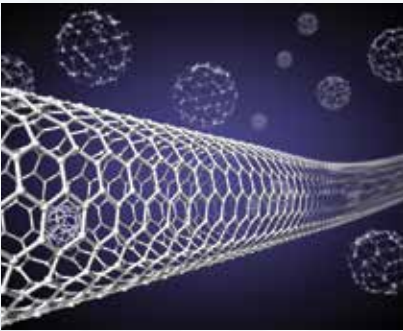
Yaqiong Xu

Assistant Professor of Electrical Engineering and Physics



Combining biomolecules with carbon nanotubes (CNTs) has resulted in a new class of materials known as CNT-based nanobiohybrids. These unique materials have potential to be used in many fields, including tissue engineering, drug delivery, biosensors and diagnostic imaging. However, their applications are impeded by lack of information about their fundamental properties and behaviors.

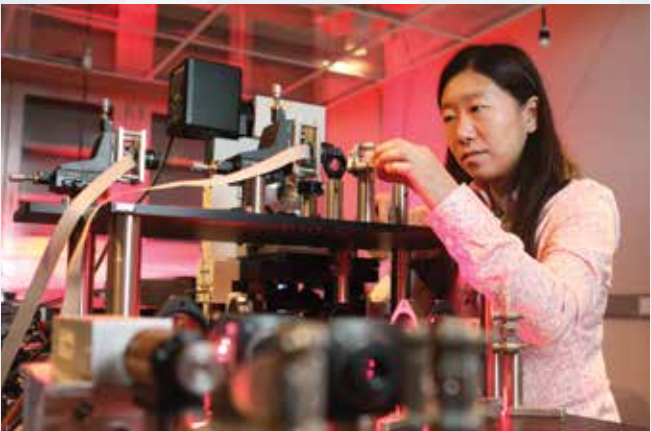
Yaqiong Xu has developed an optoelectronic probing system to investigate the complicated interface between CNTs and biomolecules through electrical, optical and mechanical measurements at the single-molecule level. She is also collaborating with groups in the Department of Biomedical Engineering and Department of Cancer Biology to study the optical and magnetic properties of CNT-based nanobiohybrids and explore their applications in image-guided drug



delivery. Recently, she and collaborators at Vanderbilt University Medical Center combined the newly developed probing system with graphene transistors to build a 2-D optoelectronic platform with ultra-

high spatial and electrical sensitivity to explore the electrical and optical processes in the brain and other complicated biological systems.

Xu is also the principal investigator for Vanderbilt's Nano-carbon Group, which synthesizes carbon-based nanomaterials, investigates their electrical and optical properties and explores their applications in energy conversion systems. In one such project, she manipulates the morphology of graphene to enhance their photocurrent response.



Nano/Carbon Research Faculty

Bo Choi

Research Assistant Professor of Electrical Engineering

Jim Davidson

Research Professor of Electrical Engineering

Jeremy Mares

Research Assistant Professor of Electrical Engineering

ROBOTICS, ARTIFICIAL INTELLIGENCE AND COMPUTER GRAPHICS

These three disciplines aim to develop machines and interfaces capable of assisting humans with a variety of activities, from emergency response to virtual learning. Research in these disciplines focuses on optimizing

man-machine relationships in order to improve efficiency and effectiveness. At Vanderbilt, this research encompasses multiple topics, including improving human-robot interactions and developing computer-based learning environments.



Julie Adams

Associate Professor of Computer Science



Development of unmanned vehicle systems is essential in removing humans from dangerous situations, such as exposure to harmful chemicals. To increase their effectiveness and efficiency, it is necessary to increase the number of deployed unmanned vehicles, while limiting the number of humans that operate them. However, current

state-of-the-art, unmanned vehicle technology doesn't support human interaction with a large number of unmanned vehicles. Julie Adams is working towards designing artificial intelligence and interaction capabilities that allow a few humans to supervise and coordinate swarms of ground and aerial unmanned vehicles. These systems could provide support for emergency response to biological, nuclear, chemical, radioactive or explosive incidents.

Adams also focuses on intelligence and interaction capabilities for unmanned aerial vehicles via a collaborative research project with Vanderbilt archaeologist Steven



Wernke. The project aims to reduce the time it takes to map archaeological sites from years to minutes by using a semi-autonomous unmanned aerial vehicle. The system will provide high-resolution imagery and a three-dimensional model of the site. In addition to these projects, Adams is developing methodologies that allow robots to gain situation awareness and use that awareness to determine future actions and behaviors.

Robert Bodenheimer

Associate Professor of Computer Science



Robert Bodenheimer's primary research in the area of virtual environments aims to promote positive experiences by developing and improving such environments. Specifically, he investigates higher level design issues in order to build systems that allow learning in meaningful contexts and situations. His current work examines how people

learn and perceive affordances (possibilities for action) in virtual environments, and how virtual environments can be made to better match real-world affordances. He is particularly interested in this question as it pertains to the advent of commodity level virtual environment technology such as the Microsoft Kinect, Oculus Rift and Playstation Move.



Bodenheimer's research on computer animation has also contributed to improving learning systems. This work investigates methods to create visually appealing human motion. In one such project, he developed a way

to generate new animation from existing cartoons. This model-free method has applications in learning environments for children, in which non-human characters may serve as more effective teaching agents.

Bodenheimer has also worked on several collaborative research projects on topics that include computational photography, learning and generation of robotic behaviors and visualization of computational models of cognition. He is a founder and director of the scientific computing minor at Vanderbilt.

Douglas Fisher

Associate Professor of Computer Science

Director of the Vanderbilt Institute for Digital Learning



As technology advances, digital learning is becoming one of the cornerstones of higher education, offering new and exciting areas of research. In order to anticipate and design for these changes, Vanderbilt has launched the new Institute for Digital Learning, led by Douglas Fisher. The institute will focus on developing a strategy for digital learning

for courses offered on campus, in addition to massive open online courses (MOOCs). Fisher is a vocal advocate for MOOCs, as open access to high-quality course materials has the potential to facilitate community between faculty and



students, as well as relationships between students on campus and global learning communities.

Fisher is also a member of Vanderbilt's Climate Change Research Network and the Vanderbilt Institute for

Energy and the Environment, which are interdisciplinary groups conducting research on many environmental topics involving the environmental consequences of human decision-making. His additional research interests include artificial intelligence, particularly machine learning, computational models of creativity, artificially intelligent storytellers and applications in environmental sustainability.



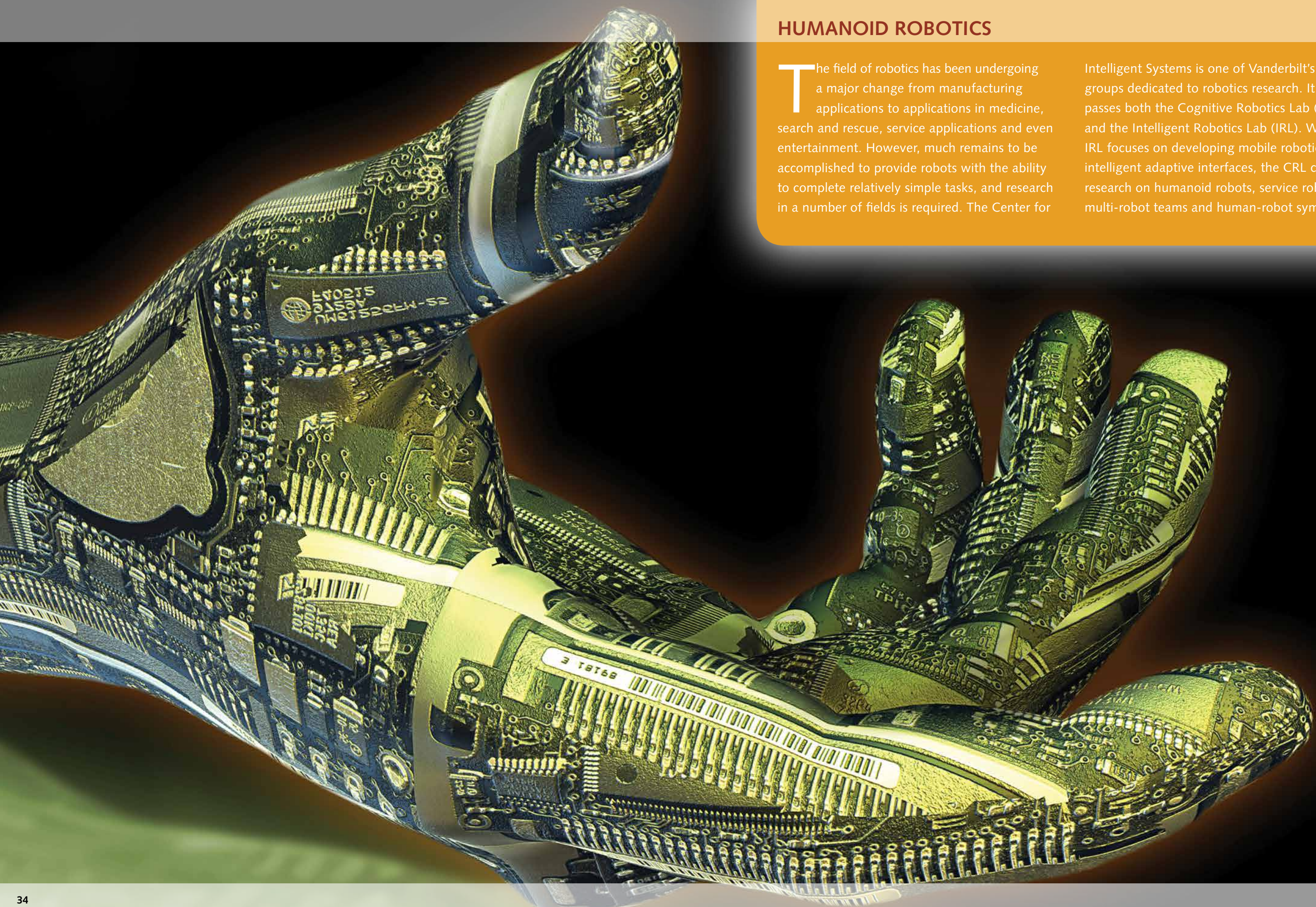
Affiliated Faculty

Guatam Biswas

Professor of Computer Science and Computer Engineering

Eugene Vorobeychik

Assistant Professor of Computer Science



HUMANOID ROBOTICS

The field of robotics has been undergoing a major change from manufacturing applications to applications in medicine, search and rescue, service applications and even entertainment. However, much remains to be accomplished to provide robots with the ability to complete relatively simple tasks, and research in a number of fields is required. The Center for

Intelligent Systems is one of Vanderbilt's research groups dedicated to robotics research. It encompasses both the Cognitive Robotics Lab (CRL) and the Intelligent Robotics Lab (IRL). While the IRL focuses on developing mobile robotics with intelligent adaptive interfaces, the CRL conducts research on humanoid robots, service robots, multi-robot teams and human-robot symbiosis.

Kazuhiko Kawamura

Professor of Electrical Engineering



Humanoid robots are leaving research laboratories and finding their way into medical, space and domestic applications. For example, they have the potential to be used in often chaotic emergency rooms in order to address critical concerns facing these departments in major hospitals. Kazuhiko Kawamura is leading a collaborative effort

with Vanderbilt University Medical Center that investigates the potential for robotic co-workers to assist doctors with less pressing emergency room tasks, so that staff can focus

on those with potentially life-threatening conditions. These robotic assistants could register patients, collect basic diagnostic data and even periodically check up on patients. This novel system has the potential to shorten patient waiting time, relieve strain on emergency room staff and reduce the number of mistakes in emergency rooms. In addition to this work, Kawamura’s research interests include intelligent systems design, cognitive robotics development, human-robot interaction and cognitive control. He is a leader in intelligent and cognitive systems and has spearheaded research projects to develop cognitive robots, robot skill learning, working memory-based task learning and intelligent control algorithms.

Richard Alan Peters

Associate Professor of Electrical Engineering



Sensorimotor coordination is the basis for intelligent behavior by animals, including people. Alan Peters’ research involves developing a control system for industrial robots that will enable them to react in real time to a dynamic environment and to learn from that interaction. Essentially the robot learns patterns that describe “what it

feels like” to perform a specific task. In theory, such patterns should enable the robot to generalize its knowledge—to apply it to new tasks and to solve new problems. Peters’ current research is to represent the robot’s sensorimotor patterns mathematically so that they can be modeled, compared and combined.

In addition to this work, Peters’ research interests include digital image processing, computer vision, digital signal processing, microcontrollers, embedded systems, applications



of electromagnetic theory and applied mathematics. He is a member of the Intelligent Robotics Lab, which investigates the fundamental problems of human-robot interaction with the goal of incorporating the results of this research into real, working systems.

Mitchell Wilkes

Associate Professor of Electrical Engineering



An area of importance for current robotics research is developing intelligent and assistive robots for health care, capable of conducting trend analysis and explaining the results to human co-workers. Specifically, this research is motivated by the pressing need to improve diagnosis and management of cardiovascular disease, the number one killer of American males and females. Mitchell Wilkes hopes to address this problem by designing cognitive control robot architecture that would allow a robot co-worker to develop the skills needed to monitor and interact with chest pain patients. Since heart attack is a possible cause of chest pain, the successful development of a cognitive robot co-worker has the potential to save lives through early diagnosis and rapid treatment of chest pain.

Wilkes is also a member of a Vanderbilt team who is investigating the possibility of utilizing cognitive robots in



emergency rooms in order to decrease patient waiting time and reduce the number of mistakes made. In addition, Wilkes conducts research on digital signal processing, image processing and computer vision, digital signal processing hardware, structurally adaptive systems, sonar and signal modeling.



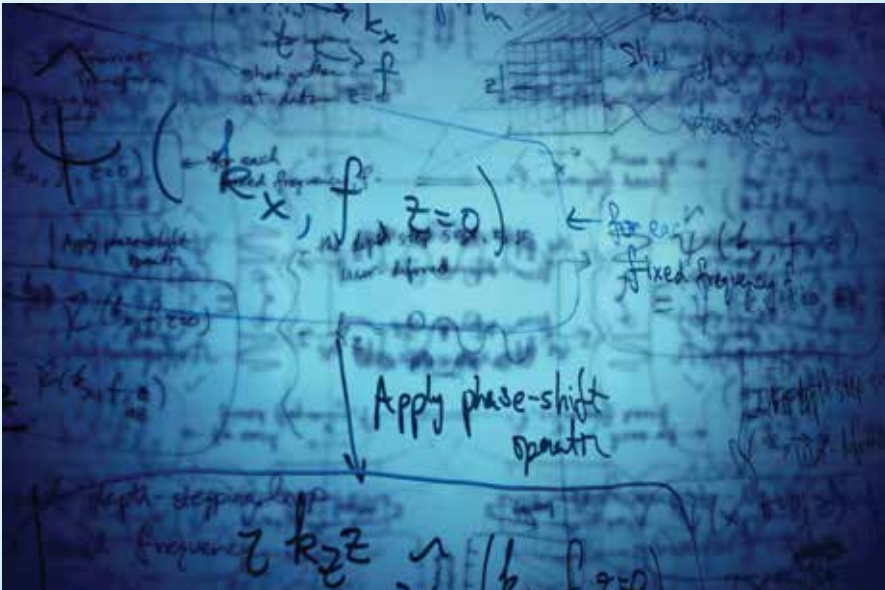
Algorithm research at Vanderbilt focuses on graph algorithms, specifically recognition algorithms for classes of graphs with interesting representations. Some of these graph classes are used to model specific problems, while others are constructed because of theoretical properties of the class itself.

Jeremy Spinrad
Associate Professor of Computer Science



Jeremy Spinrad's collaborative research has led to the development of the fastest known algorithms for recognizing many classes of graphs including permutation graphs, comparability graphs, circular arc graphs, circle graphs, trapezoid graphs, two-dimensional partial orders, permutation graphs, weakly chordal graphs and probe interval graphs. One such project deals with probe-interval graphs, which have applications for gene sequencing. Spinrad and

collaborators from Vanderbilt and the University of Colorado at Denver have designed the first polynomial time algorithm to recognize and provide a possible genetic model for these graphs. The group's current work involves investigating the possibility of reducing the time complexity and solving a particular generalization of the problem. In addition to his current work, Spinrad was the primary person responsible for developing a theory he calls robust algorithms. He was also involved in the development of certifying algorithms, which are algorithms that produce a certificate of their correctness on the given input as part of the output.



Julie Johnson
Assistant Professor of the Practice
of Computer Science



As an assistant professor of the practice of computer science, Julie Johnson's primary focus is teaching undergraduates. Johnson considers it a privilege to work with students who are motivated to learn and ready for a challenge. It is her belief that great students make great professors. She has worked with students in a variety of activities from the classroom to VUcept groups, a peer mentor organization that facilitates personal and academic growth within the living and learning community of The Ingram Commons, to the University Programming Team and is always impressed with students' commitment to their endeavors. Johnson believes these students challenge her to deliver the best instruction possible and to create a learning space where discoveries can happen.

Gerald Roth
Associate Professor of the Practice
of Computer Science



In the field of computer science, it is important for students to develop two critical skills: programming in a computer language and solving problems by designing algorithmic solutions. Gerald Roth uses several different methods to build both of these skills in his students. In lectures, he involves students in the problem-solving process by developing a solution algorithm interactively with them. Afterward, he and the students critique the algorithm and discuss alternatives. Similarly, class time is spent developing actual program code interactively, which is subsequently critiqued. More importantly, the assignments Roth creates for his classes challenge the students to develop these skills to a much greater extent than could be attained by lectures alone. He firmly believes in learning by doing. Only by challenging students to solve difficult problems by themselves, outside of class, do ideas taught in class solidify in the minds of the students. It is in these assignments that students experience rapid personal growth. Roth has gone to great lengths to design his assignments to clearly and completely specify what must be accomplished, but never how to accomplish it. This requires the student to develop skills in both aspects of computer science: designing a solution and then implementing it in a computer program.

Ralph Bruce
Professor of the Practice
of Electrical Engineering



Ralph Bruce's basic approach to facilitating the learning process is to call upon his more than forty years of engineering experience. He has come to appreciate the underlying creative processes that are involved in the practice of engineering. This can best be summarized in the precept: Providing creative solutions to human needs and limitations—that's engineering! To be an engineer is to be creative. We take materials and ideas and work them into useful devices and processes that allow us to communicate over great distances and travel faster than we can walk/run, assist in physical healing, model and compute in evermore detailed and robust ways. While at Vanderbilt, undergraduates can expect to work and become more able at doing these things. For example, in senior design courses and implementation sequences, students put into practice in a more formal way what they have learned here and apply it to future roles after leaving campus.





There is no better time than now to start your career as a computer scientist, computer engineer or electrical engineer! There is increasing demand for our graduates, and our alumni base can be found in prominent companies such as National Instruments, Google, Microsoft, Apple, Boeing, Northrop Grumman, Schlumberger and many other technology, energy-related, finance and consulting businesses in the United States and abroad.

The department strives for continuous improvement, and we adapt our undergraduate and graduate curricula to better meet the needs of today's students and tomorrow's practicing engineers, as well as for students who desire a strong technical background as preparation for a career in business, law, medicine, finance or a variety of other professions for which electrical engineering, computer engineering and computer science provides a firm foundation.

Electrical engineering and computer science is the largest department in the School of Engineering, as measured by the number of faculty and amount of externally sponsored research awards. Our department is a dynamic and growing community of scholars whose shared passion for research and education is a hallmark of the Vanderbilt environment.

Our internationally recognized core faculty members are diverse and participate in many interdisciplinary initiatives. These are the same faculty who teach our undergraduate and graduate classes.

The two largest research areas within the department are the Institute for Software Integrated Systems and the Institute for Space and Defense Electronics. These institutes include nearly one-half of the department faculty, as well as a large number of professional researchers who are engaged in leading-edge scholarship of significant importance to critical commercial and government systems. Other significant research programs include medical imaging processing, security and fault tolerance, carbon and nanotechnology, robotics, artificial intelligence, image processing and graphics, humanoid robotics and algorithms. As you navigate through these pages, you will see why I am excited about the future of our department.

On behalf of the faculty of the Department of Electrical Engineering and Computer Science, I welcome you to browse our brochure and learn more about us. If you are a prospective undergraduate or graduate student, please come visit us as we always have time to welcome new and talented students to our programs!

Sincerely,

Dan Fleetwood



Undergraduate

The Office of Undergraduate Admissions manages admission to the undergraduate school. Prospective students are encouraged to investigate the university by visiting the campus. Admissions staff are available to answer questions, arrange campus tours, provide additional information about degree programs and link visitors with appropriate campus offices and members of the university community.

Contact:

Office of Undergraduate Admissions
Vanderbilt University
2305 West End Avenue
Nashville, TN 37203-1727
U.S.A.
Phone: (615) 322-2561 or (800) 288-0432
Web: admissions.vanderbilt.edu

Dates to Remember

- November 1:** Application deadline for Early Decision I
- December 15:** Early Decision I notification
 - January 1:** Earliest deadline to submit the Free Application for Federal Student Aid (FAFSA) to processors
- January 1:** Application deadline for Early Decision II and Regular Decision
- February 5:** CSS PROFILE and FAFSA due to addresses as indicated
- February 15:** Early Decision II notification
 - April 1:** Regular Decision notification
 - May 1:** Deadline for matriculation deposit



Graduate

To apply for admission to the graduate program in electrical engineering and computer science, you must first meet the general requirements of admission by the Vanderbilt University Graduate School. Application for admission for may be made electronically through the Graduate School website at vanderbilt.edu/gradschool. The Graduate School Catalog may be viewed at vanderbilt.edu/catalogs.

Contact Information:

Engineering Graduate Programs
ATTN: Electrical Engineering and Computer Science
Vanderbilt University
411 Kirkland Hall
Nashville, TN 37240
U.S.A.
Phone: (615) 343-2727
Web: vanderbilt.edu/gradschool

Dates to Remember

- October 22:** Last date to take paper-based general GRE
- November 19:** Last date to take TOEFL (Internationals)
- December 1:** Last date to take computer-based general GRE
- December 15:** Application deadline, all supporting credentials for fall semester
- February 15:** Admissions offers made
- April 15:** Deadline to accept admission



Undergraduate

Vanderbilt is committed to enrolling talented, motivated students from diverse backgrounds. More than 60 percent of Vanderbilt students receive some type of aid. The university offers a full range of merit-based scholarships, need-based financial assistance and financing/payments options to families of all income levels. More information can be found at vanderbilt.edu/financialaid.

Opportunity Vanderbilt

Beginning in the fall of 2009, need-based financial aid packages for all undergraduate students no longer include need-based loans. This latest initiative does not involve the use of income bands or “cut-offs” to pre-determine levels of eligibility and applies to all undergraduate students with demonstrated financial need who are U.S. citizens or eligible non-citizens. The end result is that, in addition to a realistic academic year earnings expectation, all need-based aid packages now include scholarships and/or grants (gift assistance) in place of need-based loans that would have previously been offered to meet demonstrated need.

Graduate

Graduate students in the electrical engineering and computer science department seeking the Ph.D. degree receive a competitive stipend, full tuition waiver and health insurance. Typically, students are first supported on a Teaching Assistantship and then a Research Assistantship once a thesis advisor has been identified. Students on a Teaching Assistantship assist the faculty with undergraduate courses, typically by grading assignments and holding office hours. Opportunities to teach are available for those that wish to gain such experience. Both Teaching and Research Assistantships can be supplemented by any one of the following university fellowships, which are awarded through a competitive process to highly qualified applicants.

- University Graduate Fellowships:**
\$10,000/year for up to 5 years.
- Provost's Graduate Fellowships:**
\$10,000/year for up to 5 years.
- Harold Stirling Vanderbilt Graduate Scholarships:**
\$6,000/year for up to 5 years.
- School of Engineering IBM Fellowships:**
\$4,000/year for up to 4 years plus an award of \$1,000 for professional development.

In order to be considered for these fellowships, an applicant's file must be complete by January 15. Prospective applicants are also urged to apply for external fellowships or grants from national, international, industrial or foundation sources.

Vanderbilt

Cornelius Vanderbilt had a vision of a place that would “contribute to strengthening the ties that should exist between all sections of our common country” when he gave a million dollars to create a university in 1873. Today, that vision has been realized in Vanderbilt, an internationally recognized research university in Nashville, Tenn., with strong partnerships among its 10 schools, neighboring institutions and the community.

Vanderbilt offers undergraduate programs in the liberal arts and sciences, engineering, music, education and human development, as well as a full range of graduate and professional degrees. The combination of cutting-edge research, liberal arts education, nationally recognized schools of law, business and divinity, the nation’s top ranked graduate school of education and a distinguished medical center creates an invigorating atmosphere where students tailor their education to meet their goals and researchers collaborate to address the complex questions affecting our health, culture and society.

An independent, privately supported university, Vanderbilt is the largest private employer in Middle Tennessee and the second largest private employer based in the state.

Nashville

Vanderbilt’s hometown of Nashville is a vibrant, engaging city known proudly as “Music City, U.S.A.” The university’s students, faculty, staff and visitors frequently cite Nashville as one of the perks of Vanderbilt, with its 330-acre campus located a little more than a mile from downtown.

From serving as home to the nation’s largest Kurdish population to being named America’s friendliest city for three years in a row, Nashville is a metropolitan place that exudes all of the charm and hospitality one expects from a Southern capital.

The city was settled in 1779 and permanently became state capital in 1843. The city proper is 533 square miles with a population of nearly 570,000. Major industries include tourism, printing and publishing, technology manufacturing, music production, higher education, finance, insurance, automobile production and health care management. Nashville has been named one of the 15 best U.S. cities for work and family by *Fortune* magazine, was ranked as the No. 1 most popular U.S. city for corporate relocations by *Expansion Management* magazine and was named by *Forbes* magazine as one of the 25 cities most likely to have the country’s highest job growth over the coming five years.



INSIGHT ◦ INNOVATION ◦ IMPACT®

The Vanderbilt University School of Engineering is internationally recognized for the quality of its research and scholarship. Engineering faculty and students share their expertise across multiple disciplines to address four specific research initiatives that characterize the school’s commitment to help solve real-world challenges with worldwide impact. They are health and medicine, energy and natural resources, security and entertainment. All programs leading to the bachelor of engineering degrees are accredited by the Engineering Accreditation Commission of ABET (abet.org).

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