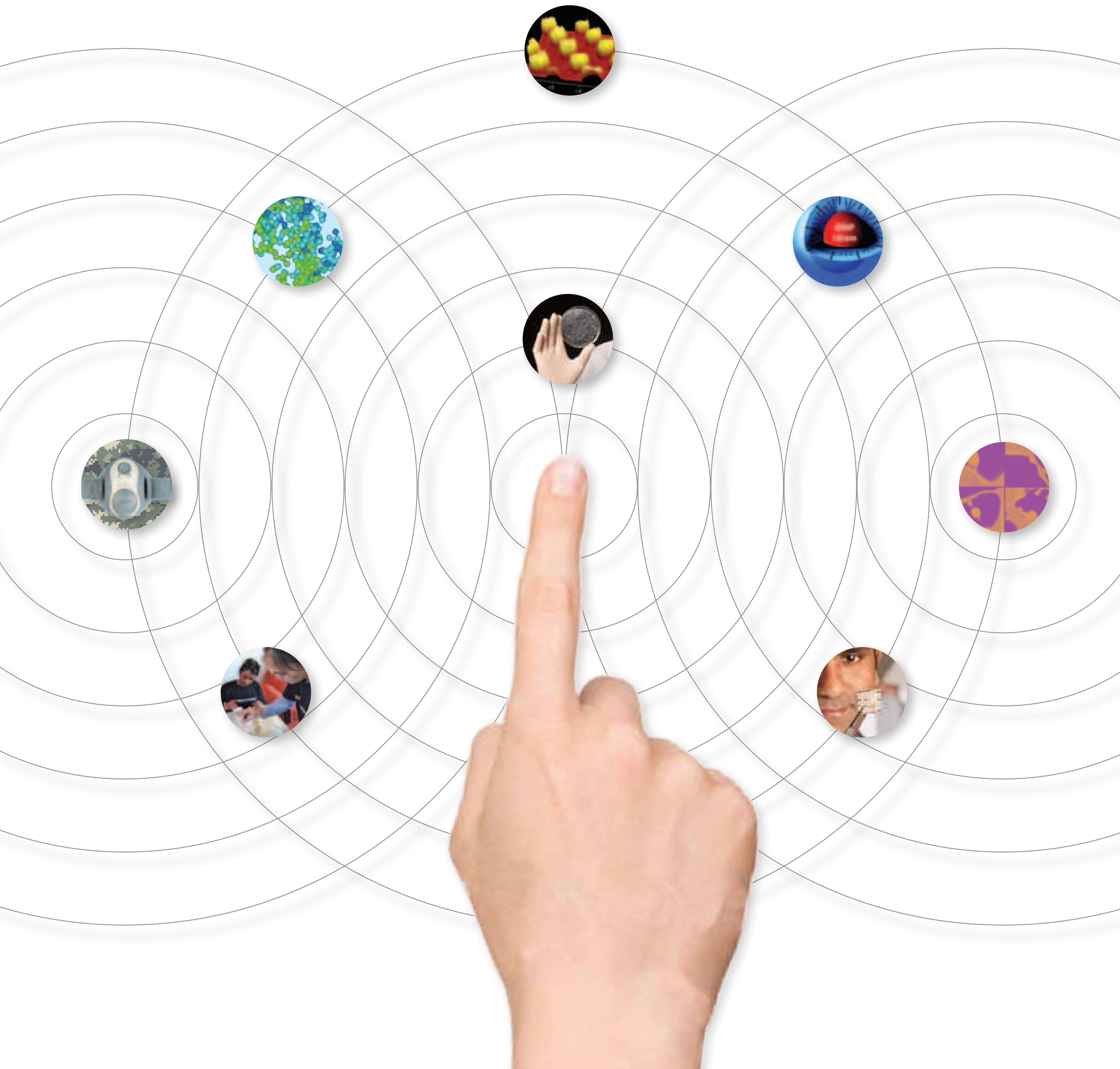
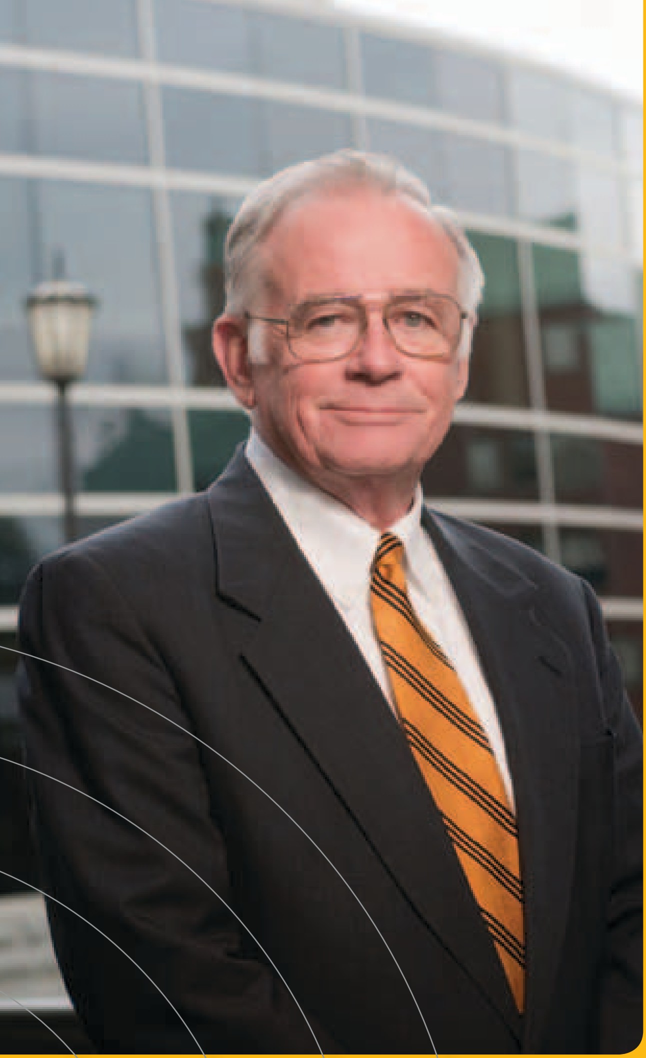
VCU Engineering

Virginia Commonwealth University

TOUCHING LIVES

Volume 5





Dear Colleagues and Friends,

Our School of Engineering is committed to creativity and discovery in all aspects of our experience here at Virginia Commonwealth University and in the community at large. We engage in respectful collaborations, we foster problem solving and we are driven by the need to improve human life at home and around the world.

I proudly share this issue of the VCU Research Report in which you will learn of remarkable work devoted to improving the human condition.

In the pages to follow, you will learn about nanoparticle-based drug-delivery technology to help treat brain cancer in a less invasive way, a new type of smart material to reduce invasive surgical procedures, and privacy protection in cloud computing environments. You will read about promising work to create resorbable vascular grafts, battery-free computer processors, and improved pulmonary drug delivery through aerosol dynamics—as well as machine-based early cancer detection advancements, biomedical signal and image processing to detect hemorrhagic shock, and a breakthrough in soft-surface antimicrobial coatings.

It is this work that exemplifies our devotion to all things possible. As you read these research summaries, I invite you to contact the individual faculty members and students—join in the meaningful discovery to solve problems and improve human life.

Please join me in celebrating all of our scholars and students. Your School of Engineering is truly amazing and has advanced more in its 16-year history than any other school I've seen.

Congratulations!

Dr. J. Charles Jennett — Interim Dean, VCU Engineering

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Dr. Gerald E. Miller–Professor and Chair, Biomedical Engineering

By its very nature, biomedical engineering can be defined as the intersection of engineering and medicine. Nowhere is that intersection more highly defined than in our research labs. In this issue, we highlight our work in tissue engineering and drug delivery where we imagine a day when our own body tissues are replaced, enhanced or restored, and personalized genetic-based drug delivery to the central nervous system and the brain combats cancer. Both are examples of promising research designed to improve or maintain the quality of our lives and the lives of those around us. We also provide an update about the Virginia Commonwealth University Chapter of Engineers Without Borders where students advanced water quality and provided health checks in Bolivia.

Dr. B. Frank Gupton–Research Professor and Chair, Chemical and Life Science Engineering

Chemical Engineering is one of the most diverse and versatile disciplines within the broader field of engineering. Our Chemical and Life Sciences Engineering program is organized to leverage advancements within chemical engineering by incorporating the areas of biotechnology, material science, and nanotechnology, as well as chemical and bioprocessing. This program exemplifies Virginia Commonwealth University's continuing commitment to excellence in teaching and research, and has been recognized nationally and internationally. Our students apply fundamental skills from the classroom to specific areas of research in emerging technologies. Highlighted in this issue is Dr. Ken Wynne and his research team who are developing soft surface antimicrobial materials to reduce hospital infections.

Dr. Krzyzstof Cios–Professor and Chair, Computer Science

As the Virginia Commonwealth University School of Engineering's youngest department, Computer Science is part of a dynamic and fast-growing field of opportunities for students and faculty alike. The work of computer scientists touches nearly every aspect of life today from business and manufacturing to bioinformatics and cybersecurity. Highlighted in this issue are two examples of computer science research projects devoted to improving life now and in the future: biomedical signal and image processing to monitor key vital signs at home and on the battlefield, and new mechanisms to ensure greater computing security for consumers using cloud technology.

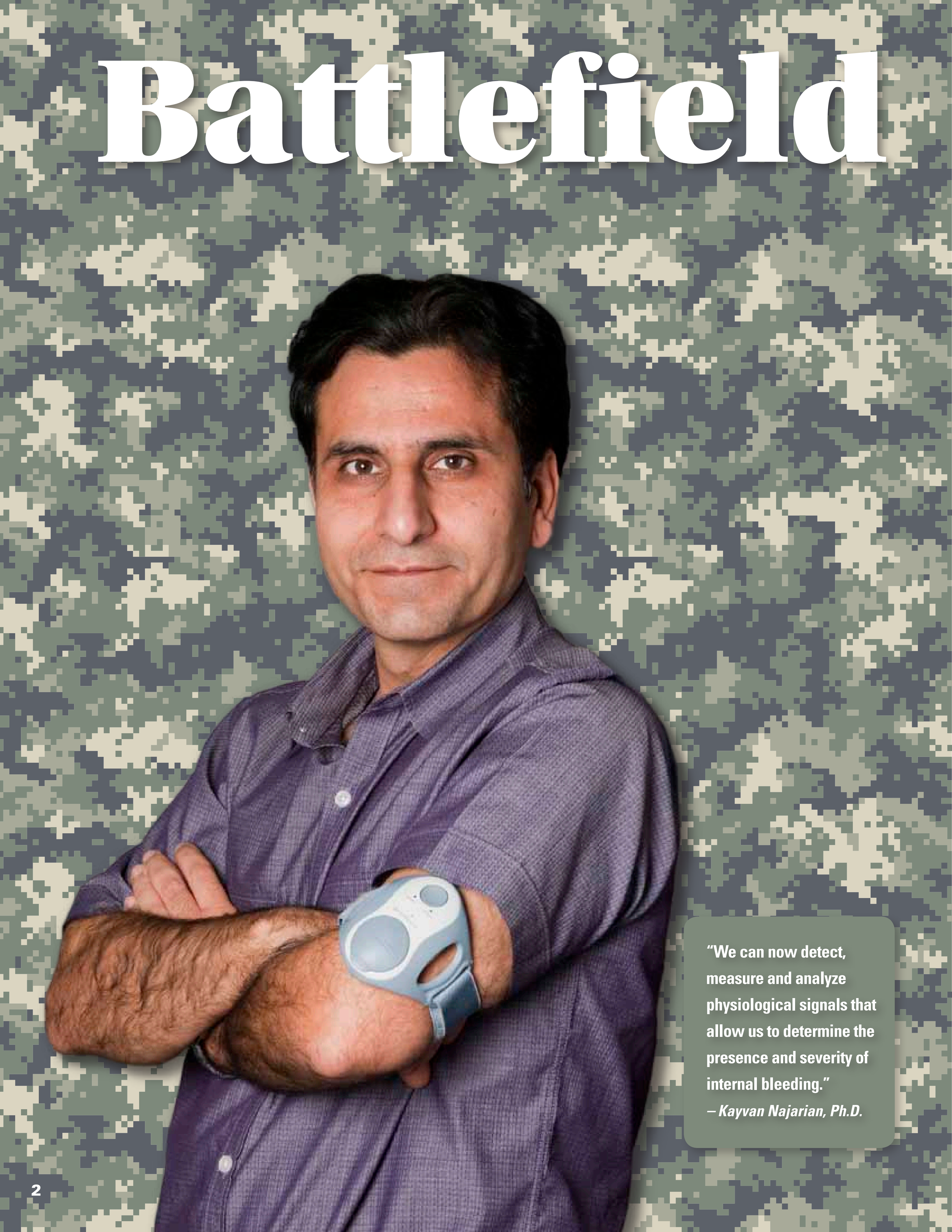
Dr. Ashok Iyer–Professor and Chair, Electrical and Computer Engineering

Three critical areas of focus steer the work of the Electrical and Computer Engineering Department: computer engineering, controls and communications, and nanoelectronics and solid-state materials. Our research labs are hives of advanced activity that include quantum devices, storage technology and computer architecture, sensory intelligence, and semiconductor optoelectronics. On the pages to follow, you will learn about two of our highly recognized projects each with a long-term impact. One has the potential to virtually eliminate the need for battery-operated computer circuits; the other is a noninvasive computer-based analysis of colonography data. Both are multi-disciplinary collaborations involving researchers from a number of esteemed universities.

Dr. Gary C. Tepper–Professor and Chair, Mechanical and Nuclear Engineering

Three "spires of excellence" drive our work: medical devices, energy and functional materials. Our researchers have developed new respiratory drug delivery strategies where lung cancer treatments, for example, can be targeted to specific areas of the lung for greater efficiency. Energy researchers have created a technique to produce energy-efficient computing devices, which eliminate the need for battery-powered computers, and our research with self-sensing magnetoelectric actuator replaceable tips (SMART) has a far-reaching impact on the future of diagnostic surgery. We are proud to present these examples of our most recent collaborative work designed to make a difference in human life today and tomorrow.

Battlefield



"We can now detect, measure and analyze physiological signals that allow us to determine the presence and severity of internal bleeding."
– Kayvan Najarian, Ph.D.

Vital Signs

On the battlefield, hemorrhagic shock from combat injuries is the leading cause of death. Here at home, it is one of the leading causes of death among trauma patients as reported by the National Center for Injury Control and Prevention. In the United States, automobile accidents and sports injuries are among its main origins and because its symptoms are internal, the condition is difficult to detect.

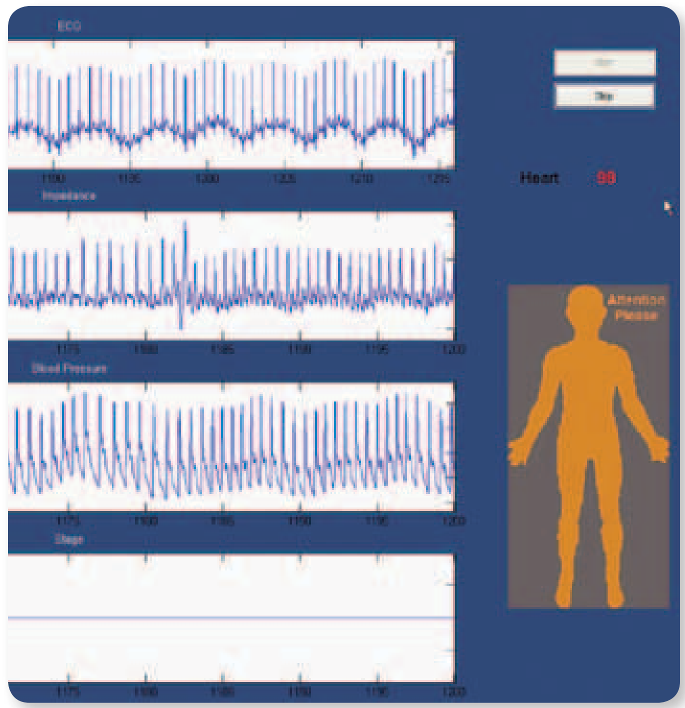
Using advanced biomedical signal and image processing combined with machine learning algorithms, associate professor in the department of computer science Kayvan Najarian, Ph.D., is only steps away from launching a consumer-based technological device for early detection of the trauma-induced killer.

Najarian, associate director of Virginia Commonwealth University's Reanimation Engineering Science Center (VCURES), is working in collaboration with Kevin Ward, M.D., VCURES director and professor of emergency medicine on the MCV Campus, and BodyMedia Advanced Development Inc. in the development of a portable wireless device to assist in the early diagnosis and monitoring of hemorrhagic shock.

"Both in civilian and military trauma cases, it is critical to know about internal bleeding," Najarian explained. "We can now detect, measure and analyze physiological signals that allow us to determine the presence and severity of internal bleeding." The technology also allows triage teams and paramedics to locate and track a patient, which is especially significant in battlefield applications.

The analysis of biomedical signals is nothing new – one trip to an emergency room or in an ambulance shows monitors of various designs used to collect data about heart rates and other vital signs. Najarian and his research colleagues, however, are processing and analyzing these signals using computation methods designed specifically for the purpose of identifying hemorrhagic shock and related indicators including its severity.

"We've created algorithms to detect and monitor this type of condition and in a much more comprehensive way," he said. "We're able to discern whether the signals stem from trauma or from exercise, which often appear to be the same." The long-term goal of the technology, he explained, is to be able to follow a patient through the healthcare system – from the site of an accident, for example, to the emergency room, to the operating room and beyond.



In an effort to stem the tide of combat fatalities due to hemorrhagic shock, the U.S. Department of Defense (DOD) awarded a Phase I Small Business Technology Transfer award to VCURES and BodyMedia Advanced Development Inc., developer of wearable physical activity and lifestyle monitoring systems, to demonstrate the technology's capability to detect various states of blood volume loss in a human model of hemorrhage developed by the U.S. Army Institute of Surgical Research.

Success in Phase I led to a DOD Phase II award to continue the work. Najarian and his colleagues have successfully designed and developed a highly technical device for every day use including the measurement of a variety of biomedical signals including oxygen consumption, blood pressure, pulse pressure and stroke volume. From trauma victims to women with high-risk pregnancies, the technology will play a role in the lives of many. "There is even a significant role for rehabilitation and home healthcare," Najarian said.

Airstream *Delivery*

Chronic lower respiratory diseases and pneumonia are among the top ten causes of death in the United States according to the Centers for Disease Control and Prevention. To help combat these statistics, Worth Longest, Ph.D., and his cross-campus colleagues are focusing their research efforts on the development of new and improved mechanisms for more efficient and effective therapeutic pulmonary drug delivery.

Longest, associate professor in the department of mechanical and nuclear engineering and specialist in aerosol dynamics, is collaborating with a number of his Virginia Commonwealth University Medical Center partners on three exciting projects. With Federal Drug Administration (FDA) and National Institutes of Health (NIH) funding in excess of $2.5 million, the teams are studying systems and devices to better deliver and distribute medical therapies for upper and lower respiratory diseases and illnesses.

One of the projects, an FDA funded study, compares two types of handheld inhalers to determine the effectiveness of drug delivery within the respiratory airways. Through his joint appointment with the VCU School of Pharmacy's Department of Pharmaceutics, Longest and research associate professor in the department of pharmaceutics, Michael Hindle, Ph.D., are using modeling and experiments to discover the differences between the inhalers including where the drugs go once delivered inside the airways by the devices.

Another project is designed to develop a new generation of handheld inhalers using nanoparticles to improve drug delivery efficiency and to reduce dosage variability between subjects. Only 10 percent of a drug delivered by way of inhalers actually reaches the lungs; the rest goes into the mouth and throat and is swallowed. Experiments have shown a dramatic improvement in drug delivery and efficiency through the use of nanoparticles.

Experiments have shown a dramatic improvement in drug delivery and efficiency through the use of nanoparticles.

"We can get the 10 percent up to 80 or 90 percent using nanoaerosols," Longest said. "If we can improve the device, we can better target drug delivery in the lungs in cases of cystic fibrosis, for example, or lung cancer and other respiratory diseases." Other applications for nanoaerosol drug delivery include inhaled insulin for diabetes and inhaled chemotherapy.

Longest and Hindle have a rich history of collaboration on similar work and were awarded a four-year investigator-driven Research Project Grant (RO1), the oldest funding mechanism used by the NIH, to study the use of nanoaerosols to improve pulmonary drug delivery during mechanical ventilation. It is the first R01 grant in the School of Engineering with faculty in a primary investigator role. Such work, Longest explains, involves three patient groups who often require pulmonary ventilation: critically ill infants, injured people and the elderly in critical care.

"Using nanoparticles to improve delivery of inhaled drugs during ventilation is known, but our nanoaerosol approach improves delivery rates by a large amount," Longest said. "This technology can help minimize or eliminate respiratory infection while patients are receiving ventilation."

The long-term impact of his work is significant. Improved medical therapies through aerosol dynamics stand to benefit those suffering from pulmonary diseases or illnesses, and others for which inhaled drug delivery increases efficacy.

Longest also collaborates with assistant professor Dr. Kelly Dodson in the VCU School of Medicine's Department of Department of Otolaryngology - Head and Neck Surgery; Peter Byron, Ph.D., E. Claiborne Robins Professor and Chair of the VCU School of Pharmacy's Department of Pharmaceutics; and Dr. Bruce Rubin, Jessie Ball duPont Professor and Chair of the VCU School of Medicine's Department of Pediatrics.

Multidisciplinary collaborations such as these lead to groundbreaking discoveries that transform lives.

"We can get the 10 percent up to 80 or 90 percent using nanoaerosols. If we can improve the device, we can better target drug delivery in the lungs in cases of cystic fibrosis, for example, or lung cancer and other respiratory diseases."

– Worth Longest, Ph.D.

Using an extended database network approach to identify precancerous polyps through a statistically validated group feature method helps increase accuracy in early detection up to 100 percent. This machine-based detection system can ultimately lead to a reduction in colon cancer mortality.

Yuichi Motai, Ph.D

Extended Databases for Early Detection

Colorectal cancer is the second leading cause of cancer-related deaths among men and women in the United States, according to the Centers for Disease Control and Prevention. Screening for precancerous polyps, or abnormal growths, is critical for early detection of the disease.

Screening for colorectal cancer varies and includes invasive procedures such as colonoscopy and sigmoidoscopy, lab and genetic tests, and imaging procedures such as computed tomographic (CT) colonography scans and magnetic resonance imaging (MRI) scans. Imaging procedures are becoming more prevalent as a diagnostic tool.

Accurate interpretation of CT images is the key to success in polyp and abnormality detection. To improve the accuracy of image interpretation, Yuichi Motai, Ph.D., assistant professor in the electrical and computer engineering department at Virginia Commonwealth University, along with department colleague associate professor Alen Docef, Ph.D., and Hiroyuki Yoshida, Ph.D., at Harvard Medical School developed a computer-aided detection method for use on soft tissue tumors, such as polyps in the colon, to classify whether the detected polyps are positive or not.

In their most recent work, the team shares multiple datasets with hospitals across the country through cloud computing for use with pattern-driven recognition and machine-learning diagnostic techniques versus the traditional techniques of classification of a limited number of small testbeds. The result is a faster, more flexible, and more accurate method to detect polyps in the colon.

"Because of the huge datasets, people can misdetect cancer," according to Motai. "Each hospital has its own colon data, but 99 percent of it isn't cancer data." Motai's approach is to use huge datasets from multiple hospitals in order to identify precancerous polyps through a statistically validated group feature method. "We can achieve at least 95, up to 100, percent success by using an extended database network approach," he said.

The promise of this work has not gone unnoticed by research funders. The team has received an Institutional Research Grant from the American Cancer Society through the Massey Cancer Center, and a VCU Presidential Research Incentive Program award. Motai is a National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award recipient for this research. The CAREER Award is the NSF's most prestigious award and recognizes and supports outstanding junior faculty members who successfully and consistently integrate research and education.

This machine-based detection system can ultimately lead to an improved screening rate and a reduction in mortality due to colon cancer. The technology's additional medical applications are many.

Gary L. Bowlin, Ph.D.

Resorbable Vascular Grafts

From the Dacron® vascular grafts of the 50s to the resorbable sutures of the 80s, biomedical developments through engineering have come a long way to help save lives and improve the overall quality of life. Sometimes looking to the past to improve the future is the key to their success.

The process of electrospinning, using an electrical charge to extract fine fibers from a liquid, has century-old roots and is active today in the Tissue Engineering Lab led by Virginia Commonwealth University biomedical engineering professor Gary L. Bowlin, Ph.D.

"Electrospinning has been revived from more than 100 years ago," Bowlin said. "It's nothing new, but only a few people, mostly the polymer guys, knew of it and nobody was using it for biomedical purposes." Today, Bowlin is leading research efforts to grow a living, resorbable vascular graft to replace the plastic tubes used in a multitude of surgical procedures requiring vascular grafting. "From the 50s to today they just use plastic grafts and the plastic just doesn't go anywhere," he said. "That's how challenging this area is knowing that the same materials are still being used today with minimal improvement, but there still remains a tremendous need for an improved vascular replacement."

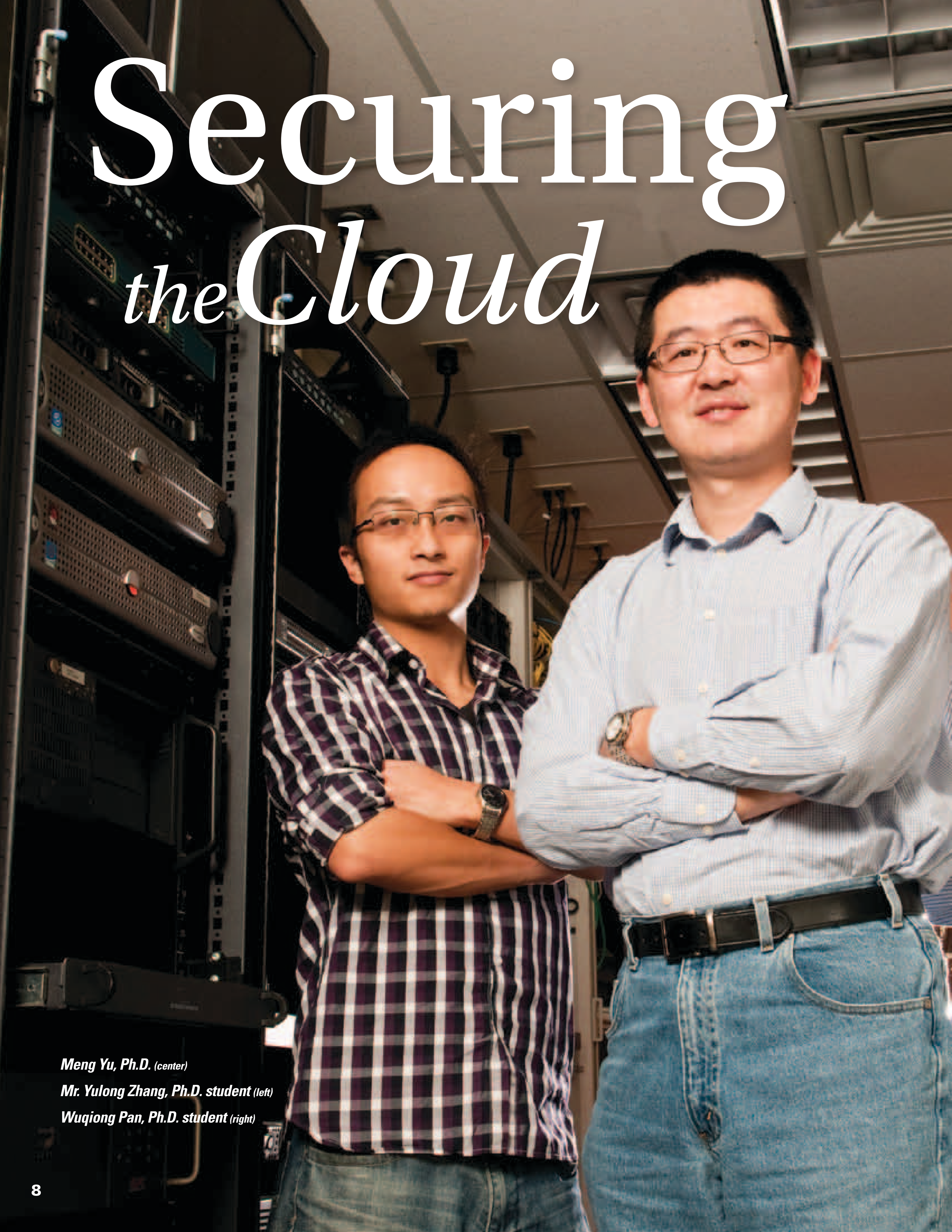
A basic electrospinning system is much like a cotton candy machine, says Bowlin. "You look in the machine and you don't see anything because the fibers are so small and translucent. Then you can start collecting it and it builds up to form a defined structure. The same thing happens in electrospinning. It takes a while to build up a structure since the fibers are so small, on the nanoscale."

Unlike a plastic tube, a bioengineered vascular graft will dissolve and go away while promoting vascular regeneration in it's place. The key, Bowlin explains, is to design it so that the body promotes regeneration, not rejection. The development process is time consuming and expensive but Bowlin is hopeful.

"The hope for the future is to use tissue engineering technology to create biomedical products, such as vascular prosthetic grafts, that are within reach of all populations who need them. Including those in developing countries." – ***Gary L. Bowlin, Ph.D.***

"We're trying to keep it simple, keep it affordable and keep it effective." The hope for the future is to use tissue engineering technology to create biomedical products, such as vascular prosthetic grafts, that are within reach of all populations who need them. Including those in developing countries.

Securing the Cloud



***Meng Yu, Ph.D.** (center)*
***Mr. Yulong Zhang, Ph.D. student** (left)*
***Wuqiong Pan, Ph.D. student** (right)*

Millions of people around the world create and share documents through Google Docs, upload and store music or photo files through Amazon.com, or write and publish posts through blogging platforms such as WordPress.

In these simple scenarios, and in much more complex examples such as homeland security planning or a healthcare record exchange, "cloud computing" allows users to create, store, access and share data through a network of Internet-based software and middleware applications, services and providers.

These same millions of people, in both the simple and complex examples, have security concerns. Who's viewing the information? Will the data be available 24/7/365? Can anyone else access the data? What happens if the networks crash? What about third party services?

These are precisely the questions being tackled by Meng Yu, Ph.D., and his associates in the Computer and Network Security Lab at Virginia Commonwealth University. Yu, associate professor in the School of Engineering's Department of Computer Science and National Science Foundation (NSF) cyber trust panelist, directs research projects designed to identify vulnerabilities, threats and cyber attacks targeted to computer systems and networks.

"One of our key approaches for system security is to track and utilize various cause and effect relations in the system to support self-healing and automated response," Yu said. "Our ongoing projects include data center security and multi-interface, multi-channel wireless networks security. We are also working on security monitoring through visualization tools."

A grant from the NSF funds Yu's most recent project to create new privacy architecture for security monitoring in cloud computing. The research studies new ways to reduce the visibility of consumer data and computations among cloud service providers while maintaining its accessibility for security monitoring. The work also includes a mechanism to evaluate a cloud user's privacy disclosure and tools to monitor cause and effect relationships, which could potentially lead to increased data vulnerability.

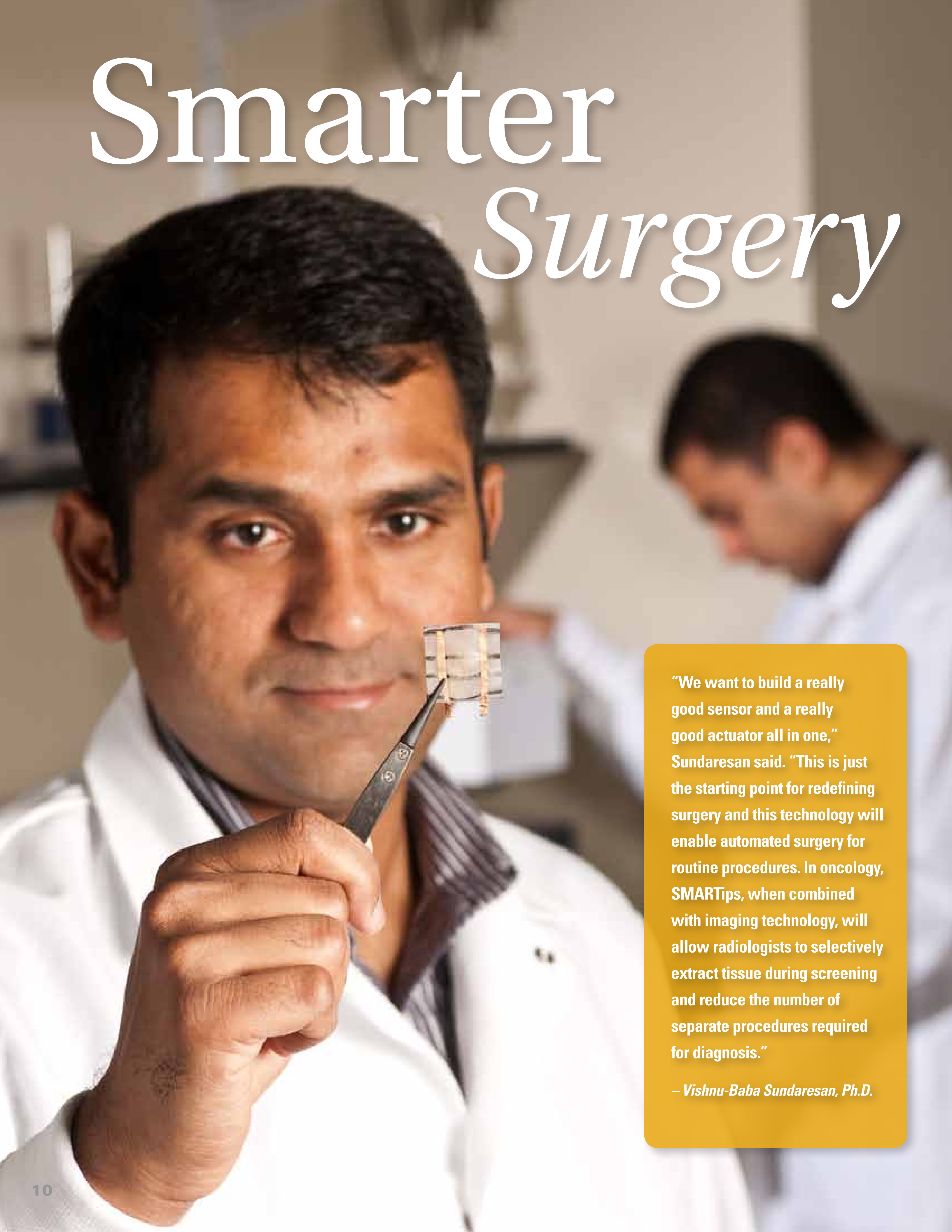
"The most important aspect of our work is privacy protection," Yu explained. "We care very much about users' privacy protection in a public computing environment. We would like to protect users' privacy while not harming service provider's capability of defense."

Working with 11 students in his lab, Yu and his team concentrate on privacy protection within the public, or cloud, computing infrastructure. A strong isolation of users' computing environments in this infrastructure is critical for trust on both ends of the user experience. Work also involves the development or improvement of attack-resilient wireless networks, especially the cognitive radio networks (or multi-radio multi-channel wireless networks).

A private cloud of Yu's lab is dedicated for security research. Naturally!

"One of our key approaches for system security is to track and utilize various cause and effect relations in the system to support self-healing and automated response. Our ongoing projects include data center security and multi-interface, multi-channel wireless networks security. We are also working on security monitoring through visualization tools." ***– Meng Yu, Ph.D.***

Smarter *Surgery*



"We want to build a really good sensor and a really good actuator all in one," Sundaresan said. "This is just the starting point for redefining surgery and this technology will enable automated surgery for routine procedures. In oncology, SMARTips, when combined with imaging technology, will allow radiologists to selectively extract tissue during screening and reduce the number of separate procedures required for diagnosis."

– Vishnu-Baba Sundaresan, Ph.D.

In the world of smart materials – functionally polymorphic materials that can selectively react and adapt to their environment – the future is full of possibilities.

Smart materials play a special role as sensors, actuators and energy harvesting devices and are well suited for use in electronic devices, healthcare, aerospace and homeland security applications. Smart materials exhibit coupling between two physical domains such as a piezoelectric actuator converting an applied electrical signal into mechanical motion. Precise operation of this actuator, however, requires additional hardware for sensing and adds bulk to the engineered system while an energy-harvesting platform, as another example, lacks the ability to store power for later use.

These limitations in the efficient utilization of the unique properties of smart materials are motivating factors in the work of Virginia Commonwealth University (VCU) assistant professor in mechanical and nuclear engineering Vishnu-Baba Sundaresan, Ph.D. A leader in the field of smart materials system design and bioderived materials, Sundaresan has designed a system to ultimately reduce the use of invasive surgical procedures.

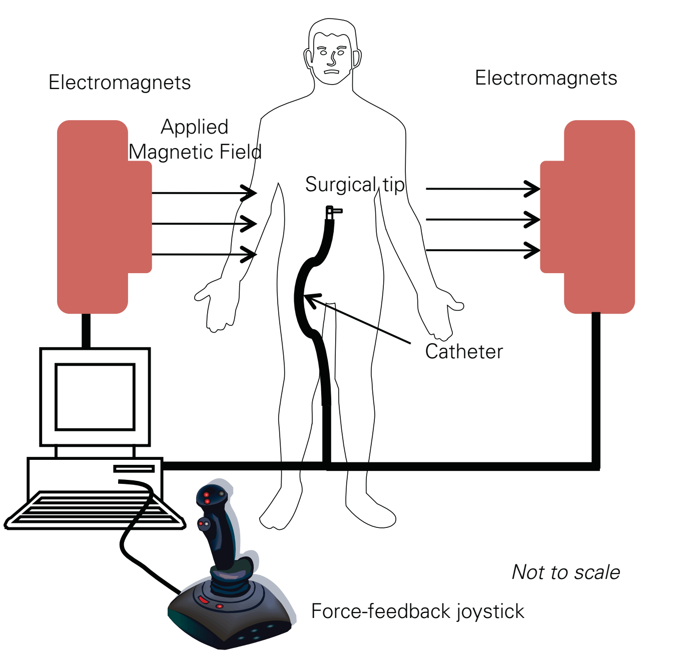
The system, he explains, includes the development of self-sensing magnetoelectric actuator replaceable tips (SMARTips) used as a surgical ablation tool. SMARTips, installed on a catheter and controlled with a joystick, use remotely applied magnetic fields to perform cutting tasks through a computerized interface. These tasks include, for example, the extraction of tissue for examination and diagnosis, the removal of arterial plaque or malignant cells, the correction of congenital heart disease and more.

"We want to build a really good sensor and a really good actuator all in one," Sundaresan said. "This is just the starting point for redefining surgery and this technology will enable automated surgery for routine procedures. In oncology, SMARTips, when combined with imaging technology, will allow radiologists to selectively extract tissue during screening and reduce the number of separate procedures required for diagnosis. We hope to build the ultimate cutting tool."

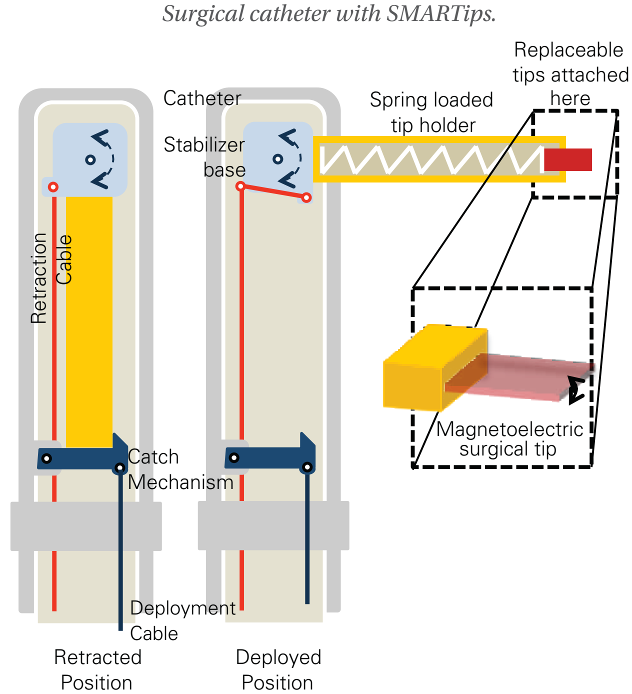
His research group has created mathematical models for the cutting action of the tool using variational principles and he hopes to build a telepresence surgical platform through a network of computers controlled by a joystick. "While a cantilever is used as a cutting tool in minimally-invasive surgery, uncontrolled movement of the cantilever riding on a catheter could cause damage to the patient because of its tendency to shift from the cutting action itself," he said. "We have added a second segment to the cantilevered end of the tool to stabilize the shift to reduce the chance for internal damage from the tool itself." This magnetoelectric cantilever device can also be used, he says, as a damper in vibration isolation and as an adaptive mirror in optics.

Sundaresan is an NSF Faculty Early Career Development (CAREER) Award recipient. The CAREER Award is the NSF's most prestigious award and recognizes and supports outstanding junior faculty members who successfully and consistently integrate research and education.

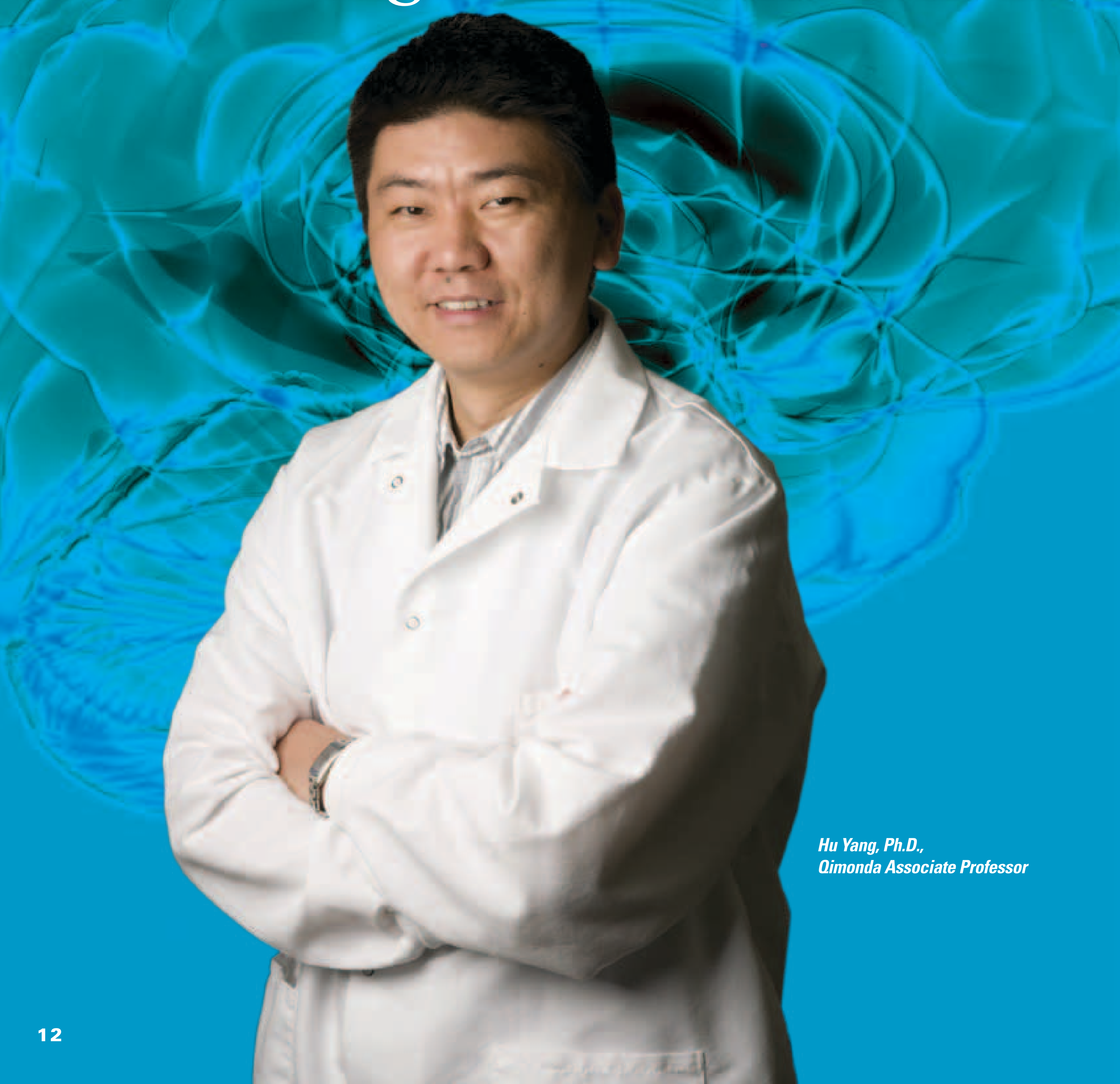
Overview of the proposed surgical system



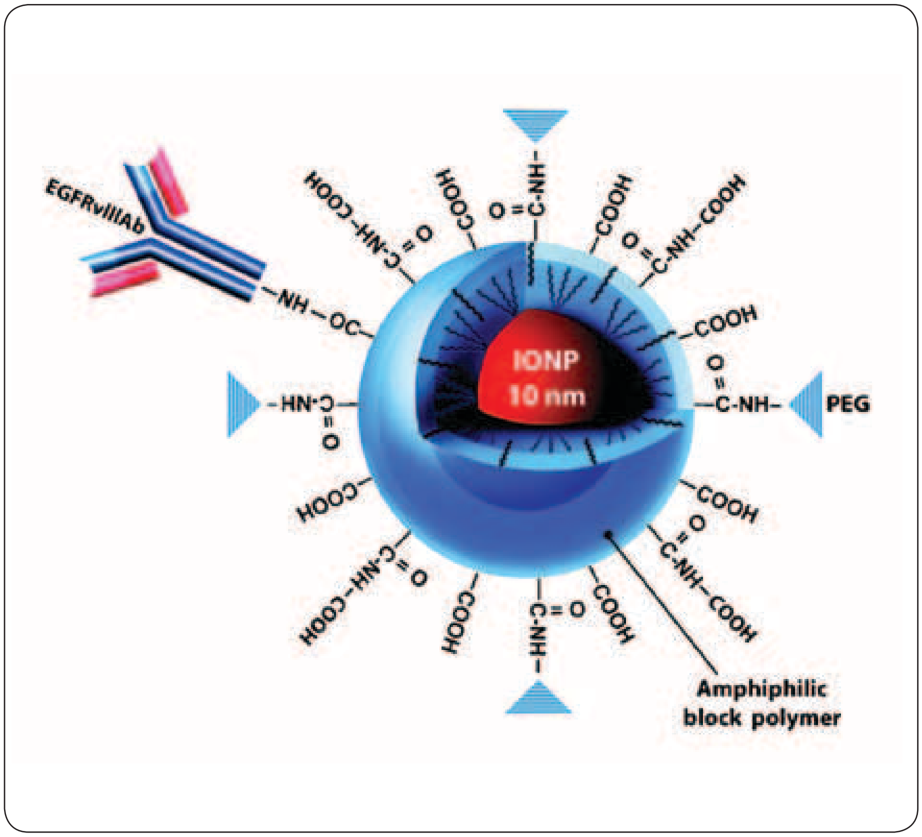
Surgical catheter with SMARTips.



Breaking *through* Barriers



Hu Yang, Ph.D., Qimonda Associate Professor



Magnetic iron oxide nanoparticles coupled to tumor-specific antibody for imaging and targeted therapy of brain tumors. Reproduced with permission.

Central nervous system (CNS) diseases, such as brain cancer, epilepsy, Alzheimer's and multiple sclerosis, represent one of the largest areas of medical need in the world today as reported in the Journal of the American Medical Association. Treating and managing CNS diseases through therapeutic drug delivery is sometimes invasive and painful. It's made even more difficult by the blood-brain barrier (BBB), the capillary endothelial cells that line the cerebral microvessels and surrounding perivascular elements that protect the brain from blood-borne chemicals and toxins.

Because nanotechnology plays a significant role in the development of brain-specific drug delivery, including permeating the BBB, its continued development is an important weapon in the arsenal against CNS diseases.

With a major interdisciplinary research interest in the development of nanoparticle-based biomedical applications such as drug delivery, Hu Yang, Ph.D., Qimonda Associate Professor of Biomedical Engineering at Virginia Commonwealth University, is working with his collaborators, graduate students, and postdoctoral scholars to develop an alternative to painful and invasive treatments for CNS diseases.

"The goal is very clear," Yang said. "To make something useful to treat diseases and to improve the quality of human life." Pharmaceuticals are coupled to nanoparticles and then delivered into the brain, for example. "Encapsulating as much as possible so that the drug can be slowly released is a means to reduce the number of invasive administrations," he explains. "Drug delivery takes place over time for the best possible outcome. The initial goal is to deliver higher doses, then minimize dosing frequencies through slow release for chronic disease treatment."

A National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award recently recognized Yang's research for developing a transformative hypoxia-targeted delivery system to enhance penetration of anticancer drugs to solid tumors including brain cancer. The CAREER Award is the NSF's most prestigious award and recognizes and supports outstanding junior faculty members who successfully and consistently integrate research and education.

This new delivery system will be explored by hybridizing monocytes with dendrimer nanoparticles through cell surface engineering where nanoparticles immobilized on the cell surface are intended for anticancer drug loading. Drug delivery, then, through the cell surface-immobilized nanoparticles will potentially minimize the toxic effects of anticancer drugs to the monocyte vehicle and represents a transformative way to utilize the best aspects of both cellular and nanostructured carriers.

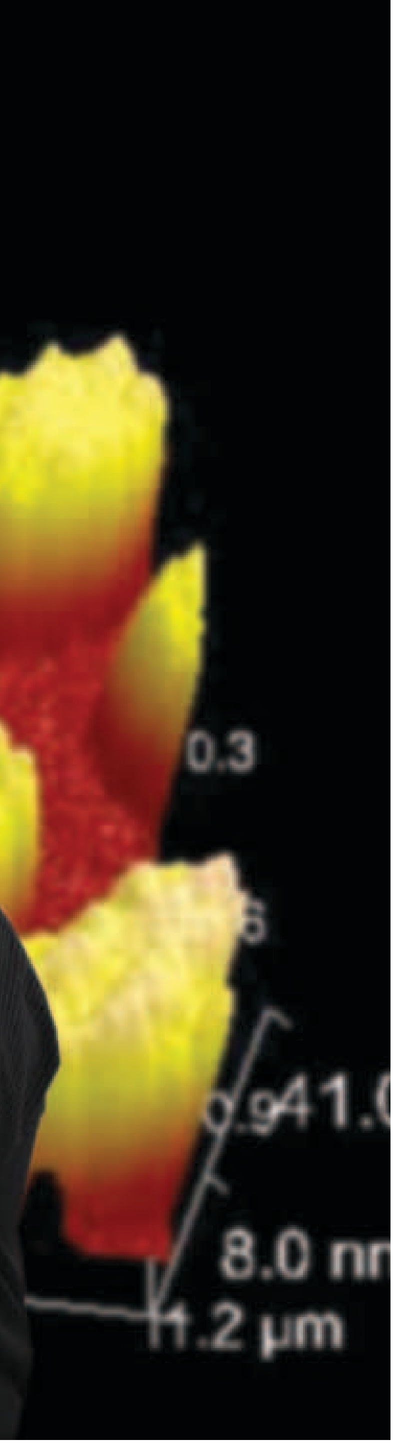
This new drug-delivery system may eventually complement surgery, chemotherapy or radiotherapy and help to eradicate metastasis, improve survival rate and increase the quality of life for cancer patients.

"The goal is very clear: make something useful to treat diseases and improve the quality of human life."

– Hu Yang, Ph.D., Qimonda Associate Professor

Nanomagnetic Computing

to Reduce Heat Generation

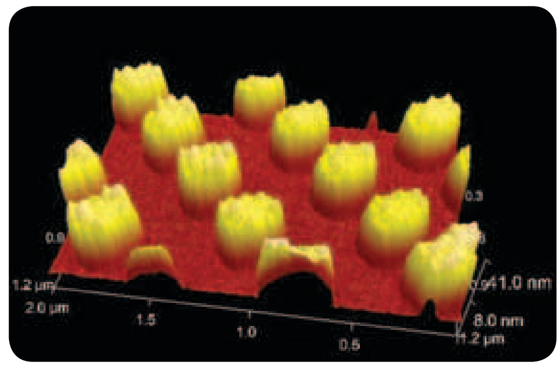


Imagine a day when battery-powered computer processors are a thing of the past. When a smart phone can be charged with a few quick shakes, or when an epileptic person is warned of an impending seizure by brain-implanted devices powered by his head movements.

That day may not be too far off thanks to a team of researchers led by Virginia Commonwealth University's (VCU) Jayasimha Atulasimha, Ph.D., assistant professor in the mechanical and nuclear engineering department, and Supriyo Bandyopadhyay, Ph.D., Commonwealth Professor in the electrical and computer engineering department.

Atulasimha and Bandyopadhyay are leading a coast-to-coast collaboration involving VCU, the University of Virginia, the University of Michigan at Ann Arbor and the University of California at Riverside. The team's work to create energy-efficient computing devices is funded by grants totaling $1.75 million from the National Science Foundation and the Nanoelectronics Research Initiative of the Semiconductor Research Corporation.

The stimulus for the work stems from Moore's Law as well as from the vast amount of energy generated by computers. "Intel co-founder, Gordon Moore, noticed a trend in the mid-60s, which continues today whereby the density of transistors on a computer chip doubles every 18 months. It's a major deal," Bandyopadhyay explains. In order for that to continue to happen, he says, energy consumption must be dramatically reduced. "Further, it is projected that by 2020, more than 5 percent of the energy consumed in the U.S. will be attributed to computers and other computing devices such as smart phones. Given the problems with inefficient energy generation and global warming, this work is significant."



AFM – Ni nanomagnets capped with Au.

Transistors in a computer processor generate heat when the computer works, which must be removed for the processor to remain efficient and viable. Packing more transistors on a single chip generates too much heat that cannot be easily removed and ultimately will burn up the chip.

"This work will result in more efficient digital computing which allows us to pack more computing devices on a chip without having to worry about excessive heat generation," Bandyopadhyay said.

Reducing the amount of heat generated when a transistor switches on or off is challenging. By replacing transistors with nanomagnets to process information, the heat dissipated in the switching action can be reduced by 1,000 to 10,000 times as noted in the VCU team's paper published in the August 2011 issue of the *Applied Physics Letters* journal. They have demonstrated the theoretical feasibility of significantly reducing heat dissipation using nanomagnets.

Other applications for more efficient digital computing systems include medically implanted processors that harvest energy from body movements or ambient electromagnetic energy generated by cable TV and 3G networks. The use of such processors reduces the number of invasive procedures for battery replacement.

Similarly, the structural health of a bridge or building could be monitored with a distributed array of processors that are powered solely by the structure's vibrations from wind or passing traffic. Another application is the "smart dust" processor on the battlefield, which processes information and makes decisions based on certain combat parameters fed by sensors.

These applications, made possible by energy reduction, which enables processors to be run with energy from the ambient environment using existing energy harvesting devices, are promising, Atulasimha says. "The prospect of building processors that can run without a battery is fascinating."

"The prospect of building processors that can run without a battery is fascinating."

–Jayasimha Atulasimha, Ph.D *(pictured right)*

Supriyo Bandyopadhyay, Ph.D., Commonwealth Professor *(pictured left)*

SURFACE SCIENCE:

A recent breakthrough in Wynne's surface science laboratory shows promise for delivering long-term contact antimicrobial kill. The breakthrough could lead to a reduction in infections acquired during hospital stays.

– Kenneth Wynne, Ph.D., Commonwealth Professor

Bottle Brush-Nanoglass

Though considerable research on antimicrobial coatings has taken place in the last decade, creating a durable antimicrobial coating that retains its function over an extended time remains a challenge according to Kenneth Wynne, Ph.D., Commonwealth Professor in the Virginia Commonwealth University School of Engineering's Department of Chemical and Life Science Engineering.

A recent breakthrough in Wynne's surface science laboratory shows promise for delivering long-term contact antimicrobial kill. The breakthrough could lead to a reduction in infections acquired during hospital stays. One target of soft surface technology being developed in Wynne's laboratory is catheter applications.

Catheter associated urinary tract infections (CAUTIs) are responsible for more than 60 percent of hospital-acquired infections, Wynne explains. "Women are particularly susceptible," he said. "Paraplegics, quadriplegics and other catheterized patients who are immobilized or confined are also susceptible."

Wynne has developed a new approach to surface modifier research in hopes of reaching a durable 100 percent kill of bacteria in a short amount of time to reduce the incidence of CAUTIs. "We call this new surface modification mode 'bottle brush-nanoglass' and it appears to be an interesting success," he says. "We have a macromolecular architecture that looks something like a bottle brush. That is, the main chain of the polymer is like the spine of a bottle brush while the side chains that have the antimicrobial function stick out like bristles."

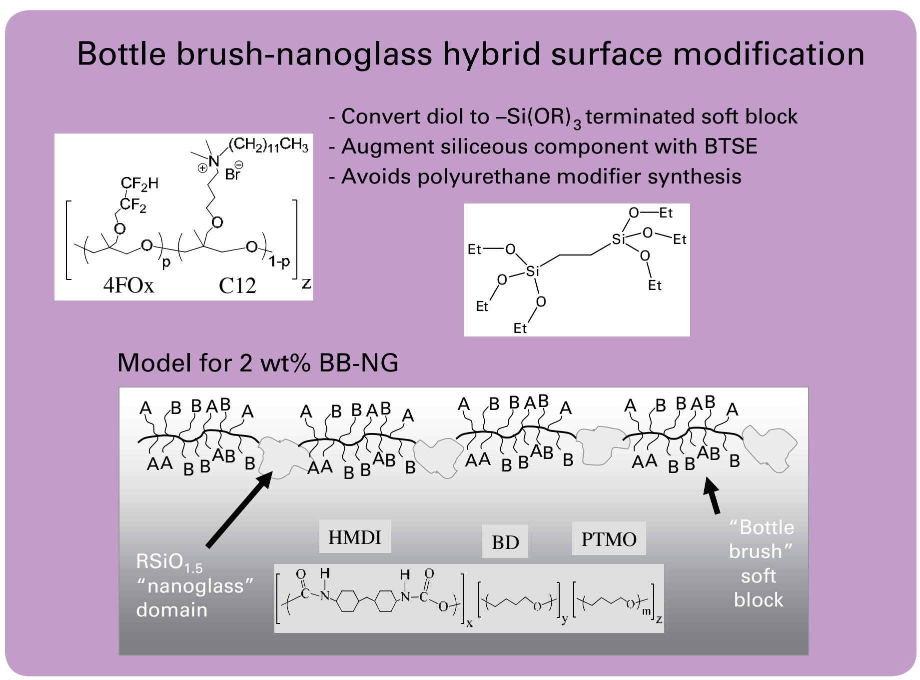
Unlike a conventional bottle brush that has one handle, the macromolecular brush has handles at both ends. Each of these handles (chain ends) facilitates connection to a nanoglass component that is formed near the surface of the coating. "The macromolecular bottle brush ends become fixed near the surface of the nanoglass and the nanoglass bits prevent the brush from escaping. Trapped, the bottle brush does its antimicrobial "cleaning job" over an extended period of time," says Wynne. A high bar was set for antimicrobial kill. "Our test mimics deposition of bacteria by a cough or sneeze," he said. "We wanted 100 percent kill of bacteria in one hour or less."

Testing in the laboratory of professor Dennis Ohman, Ph.D., Chair of Microbiology and Immunology in the VCU School of Medicine, indicates a durability of the antimicrobial surface of at least two months and a stability in saline solution at least 1000 times better than previous systems. This stability is essential to catheter applications.

The collaboration with the Ohman laboratory, including Dr. Lynn Wood, made possible by support from the National Science Foundation's Division of Materials Research and the National Institutes of Health, is an interdisciplinary effort between the School of Engineering and the School of Medicine. The new bottle brush-nanoglass surface modification may be used in wound care, catheters, or other medical devices.

"We have lots of bacteria on our skin," said Ohman. "For example, *Staphylococcus epidermitis* can be transmitted by touch in sequential use of computer keypads. These opportunistic bacteria see catheters as 'superhighways to a nice food source'."

The new bottle brush-nanoglass modified surfaces kill bacteria on contact.



Unlike a conventional bottle brush that has one handle, the macromolecular brush has handles at both ends. Each facilitates connection to a nanoglass component near the surface of the coating.

National Science Foundation
Honors Engineering Faculty

Virginia Commonwealth University's goal of engaging students at every level in research, creativity and critical thinking helps prepare them to be leaders in 21st century. This interactive engagement is also a goal of the National Science Foundation (NSF), an independent federal agency created by Congress in 1950 to promote the progress of science.

The prestigious NSF Faculty Early Career Development Award (CAREER) provides financial support and public recognition for junior faculty members who exemplify the role of teacher-scholars through outstanding research, education and the integration of education and research. Approximately 3,000 of the world's brightest research faculty scholars annually vie for grant funding through the CAREER Award program.

Four teacher-scholars from the VCU School of Engineering have been recognized as CAREER Scholars for their outstanding contributions to VCU, to its students and to the community at large. The university is proud to announce and celebrate their accomplishments.

Four teacher-scholars from the VCU School of Engineering have been recognized as CAREER Scholars for their outstanding contributions to VCU, to its students and to the community at large. The university is proud to announce and celebrate their accomplishments.

Yuichi Motai, Ph.D., for his electrical engineering research in data-intensive prediction and classification for medical testbeds with nonlinear, distributed and interdisciplinary approaches, which may substantially advance the clinical implementation of cancer screening, promote the early diagnosis of colon cancer, lead to an improved screening rate and reduce the mortality rate of colon cancer.

Raj R. Rao, Ph.D., for his chemical engineering work in the development of propagation systems for engineering of chromosomally stable human embryonic stem cells, which may contribute towards the use of high quality cells in regenerative clinical applications.

Vishnu-Baba Sundaresan, Ph.D., for his mechanical and nuclear engineering work in ionic transistor devices that will lead to sensing platforms using proteins for the detection of chemical analytes and as chemomechanical actuators.

Hu Yang, Ph.D., for his biomedical engineering work in surface engineering of monocytes for anticancer drug delivery, which may eventually serve as a complement to surgical procedures, chemotherapy and radiology.

Engineers Without Borders

working to improve water supply in Bolivia.

When Chris Holden, a Ph.D. candidate for biomedical engineering, helped form the Virginia Commonwealth Chapter of Engineers Without Borders (EWB) in early 2011, he had a vision. Along with his fellow founding and current chapter members, Holden wanted to combine his engineering training with opportunities to provide assistance to those in need around the world. A lot has happened since Spring 2011.

With more than 350 projects in over 45 developing countries, EWB chapters work to bring basic necessities of life such as clean water, sanitation, energy and education to those who need it most. In accordance with EWB guidelines, each chapter makes a five-year commitment to a project by designing and implementing solutions suited to a specific community. Local community members and non-governmental organizations (NGOs) are then trained to sustain the work after the chapter leaves.

"We wanted to go somewhere where transportation costs wouldn't be too high," said Holden. "So we applied to work on a water distribution project in Boliva. Our group of five went on an assessment trip in October to the San Antonia de Lomerio community in the Amazon basin, close to Brazil. We were there for four days working on a tight timeline."

The group performed water testing, geographical studies and community health assessments designed to assist in the development of a long-term strategy to bring safe water access to families, farms and businesses.

"It's usually the women and children who have to handle the water," Holden said. "They spend hours standing in line to get clean water from one of the community's wells. We want to minimize the burden and the time it takes to get water."

Location photos courtesy: Aruna Anbazhagan, Allison Yaguchi

Christopher Holden(left), Aruna Anbazhagan, Luca Terziotti(top), Allison Yaguchi(center), Thea Pepperl, and Sergio Salinas(right).

BIOMEDICAL

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- Human motor control physiology
- Development of brain-computer interface-based device for patients with movement disorders
- System development of imagery-based motor learning for stroke rehabilitation
- Development of algorithms and graphic-user interface for investigation brain neuronal connectivity
- Development of algorithms and systems for computer-aided diagnosis
- Algorithm development of neurophysiological signal processing and classification
- Multimodal functional neural imaging

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- Bone tissue engineering
- Hemostatic devices
- Electrostatic endothelial cell seeding techniques and transplantation/transfection
- Development of novel tissue engineering scaffolds via electrospinning
- Vascular tissue engineering

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- Ultrasonic imaging techniques for studies of cardiovascular dynamics
- Technologies for radiation oncology

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- Tissue engineering
- Smooth muscle cell signaling

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- Non-invasive cerebral spinal fluid pressure device
- High noise speech communication system (Northrop Grumman Inc.)
- Baby echolocator a device to allow deaf babies to "see" acoustically facilitating perceptual motor development. (NIH)
- Military echolator (DHS)
- Baby multimodal (bone conduction and vibrotactile) hearing aid using algorithms to track mother's voice
- Tinnitus (phantom sound perception) management system using high frequency stimulation and custom actuator (US ARMY)

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- Cellular traction forces
- Cell mechanosensing

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- Man-machine interfacing-analysis and design of voice-recognition systems
- Artificial hearts-analysis and design of a multiple disk centrifugal blood pump

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- Human factors analysis during minimally invasive surgery
- Haptic technology for engineering education
- Haptic devices for rehabilitation
- Tissue modeling for surgical stimulators

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- Structural Performance of Fixation Constructs
- Articular Cartilage: normal function, reparative techniques, tissue engineering

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- Effects of neurological diseases on eye movement control
- Visual task analysis
- Physiological instrumentation and signal processing systems
- Human-machine interfaces based on eye and head movement

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- Cancer research
- Dendrimer
- Drug Delivery
- Gene therapy
- Nanoparticles
- Nanoscience and nanotechnology
- Smart polymeric materials and structures
- Tissue engineering

CHEMICAL AND LIFE SCIENCE

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- Synthetic biology
- Evolutionary biology
- Metabolic engineering
- Computational modeling

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- Phase behavior and modeling of polymer solutions at high pressures
- Phase behavior studies and fluid properties of mixtures at geologically relevant pressures and temperatures
- Novel materials for biomedical and pharmaceutical applications
- Supercritical fluid solvent technology utilized for processing natural and synthetic materials
- Scattering phenomena in polymer solutions at high pressures

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- Cellular therapeutics
- Real-time biomolecular simulation
- Vascular tissue engineering
- Stem cell engineering

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- Stem cell bioprocessing
- Biomaterials
- Biomarkers and cell-based assays
- Pluripotency
- Cancer stem cells
- Cellular reprogramming
- Neural differentiation
- Cellular engineering
- Regenerative medicine

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- Polymer surface science
- Fluoropolymer science
- Silicone science
- Functional polymer surfaces including biocidal polymers and self-stratified coatings for easy release of ice and fouling
- Nonlithographic patterning of functional polymeric materials

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Research Topics:
- Single molecule biophysics
- Protein-protein and protein-surface interactions
- Optical biosensors
- Functional biomaterials
- Micro-and nano-fabricated devices
- Biophotonics

COMPUTER SCIENCE

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- Medical applications
- Semi-real-time algorithms
- Performance evaluation
- Graphics
- Database and networks

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- Computational analysis of complex metabolic networks to study robustness for evolutionary related/distant species
- Predictive modeling of complex biological processes from expression data and prior knowledge using machine learning
- Computational and statistical exploration of rules that govern evolution of proteins
- Development of pattern recognition and machine learning methods for applications in biomedical informatics

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- Computational neuroscience
- Bioinformatics

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- Graph theoretic analysis of protein interaction networks to identify functionally significant modules
- Mobile, ubiquitous and grid Computing
- Optimization problems in wireless networks

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- Machine learning, data mining
- Bioinformatics, biomedical informatics
- Fuzzy logic modeling
- System dynamics modeling and analysis
- Algorithms for parallel, GPU based and cloud computing

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- Biomedical informatics
- Signal processing for finance, banking and artificial intelligence

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- Machine learning
- Ethics

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- Compiler design
- Automatic generation of software

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- Mechanisms to enable new detection, defense, and response techniques
- Mobile device and wireless network security
- Defense mechanisms in multi-interface multi-channel wireless networks

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- Intrusions and defense mechanisms in multi-interface multi-channel wireless networks
- System recovery including self-healing systems and survivability analysis

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- Biochips
- Sensors and actuators
- Smart materials
- Micro/nano fabrication

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- Spintronics
- Quantum computing
- Architectures for nanoelectronics and circuit design
- Quantum devices and single electronics
- Hot carrier transport in submicron devices and quantum wires
- Nanoelectronics

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- Molecular electronics

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- Signal processor architectures
- Document compression for archiving
- Efficient, error-resilient, network-optimized image and video coding
- Medical image processing

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- High availability computing
- High performance and reliable I/O systems
- I/O architecture and data storage
- Cluster virtualization

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- Signal processing and nonlinear statistical analysis techniques

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- Neural networks
- Linear and nonlinear control theory
- Robotics for nuclear waste handling

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- Artificial neural network applications
- Science and technology in international development

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- Embedded system performance modeling and design
- Unmanned aerial vehicle (UAV) flight control system design and testing
- UAV payload design, integration, and testing

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- Light emitting diodes
- Nitride semiconductor heterostructures
- Oxide electronics
- Microcavity lasers

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- Sensory intelligence
- Medical imaging
- Computer vision
- Robotics
- Online machine learning
- Adaptive target tracking

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- Data fusion and distributed signal processing in sensor networks
- Detection, estimation, and tracking
- Dynamic resource management in networked systems
- MIMO radar networks

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- Near-field optical microscopy
- Nanophotonics

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- Low-power computing

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- Simulation of stress induced magnetization dynamics in multiferroic nanomagnets
- Magnetostrictive spintronic nanowire for strain sensor
- Nonlinear magnetostrictive, piezoelectric, magnetoelectric response
- Fabrication of MEMS devices

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- Modeling of advanced nuclear systems and applications with subchannel, system and computational fluid dynamics (CFD) codes
- Design of advanced nuclear power plant concepts that rely on sophisticated thermal-hydraulic phenomena (e.g., natural circulation, supercritical water systems, molten salt systems, liquid metal systems)
- Nuclear safety and severe accidents
- Energy and environmental policy, energy planning and nuclear infrastructure development, in support of emerging and expanding nuclear programs

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- Micro- and nanotechnology
- Large-Scale Disasters

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Research Topics:
- Teaching engineering education
- Total quality management

Dr. Brian Hinderliter
Associate Professor
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Fax: (804) 827-7030
Website: www.egr.vcu.edu/me/faculty/me-faculty_hinderliter.html
Research Topics:
- Monte Carlo and finite element simulation of composite material's response to electromagnetic fields, stress and strains, and mass transport to emulate environmental degradation
- Mechanisms of polymer coating degradation and corrosion protection
- Nuclear power plant design, thermal hydraulics, and radiation transport for shielding design
- Radiation safety and aspects related to health physics

Dr. P. Worth Longest
Associate Professor
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Website: www.egr.vcu.edu/me/faculty/me-faculty_longest.html
Research Topics:
- Multiphase biofluid transport with applications to respiratory and cardiovascular therapies
- Transport of toxic and therapeutic aerosols and vapors in the respiratory tract
- Multiscale modeling of respiratory dosimetry down to the cellular level
- Development of next-generation inhalation devices for therapeutic aerosol delivery
- Simulating the role of particle hemodynamics in vascular diseases
- Microcirculation transport and thrombosis occlusion models
- Optimal design of vascular prostheses (grafts & stents)

Dr. James T. McLeskey Jr.
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Fax: (804) 827-7030
Website: www.engineering.vcu.edu/ecsl/index.html
Research Topics:
- Photovoltaic materials and devices
- Power generation
- Energy conversion systems
- Engineering education
- Optical characterization of semiconductor materials

Dr. Manu Mital

Assistant Professor
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Fax: (804) 827-7030
Website: www.egr.vcu.edu/me/faculty/me-faculty_mital.html

Research Topics:

- Micro/nano-scale heat transfer
- Heat transfer in biological systems
- Thermal management of electronic equipment
- Artificial intelligence and neural networks

Dr. Karla Mossi

Associate Professor and Graduate Program Director
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Fax: (804) 827-7030
Website: www.people.vcu.edu/~kmmossi/

Research Topics:

- Electrical and mechanical characterization of smart materials and their applications in aerospace, automotive, medical, and electrical fields
- Materials and their response to different environments and the variation of their properties under different temperatures and boundary conditions (fluid mechanics, controls, equivalent circuits, mechanic of materials)
- Energy scavenging using pyroelectric and piezoelectric materials for low-power electronics

Dr. Ramana Pidaparti

Professor
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Website: www.egr.vcu.edu/me/faculty/me-faculty_pidaparti.html

Research Topics:

- Design innovation through arts
- Computational mechanics
- Corrosion engineering
- Biological composites
- Micro devices for health care application
- Neural networks and computational intelligence
- Nanotechnology and biomolecular motors
- Smart materials and structures

Dr. Robert M. Sexton

Associate Professor
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Website: www.egr.vcu.edu/me/faculty/me-faculty_sexton.html

Research Topics:

- Response dynamics and vibrations of offshore drilling and production systems and equipment arising from various sources of excitation (wind, waves, currents, seafloor soil conditions, fluids, pressure, thermal, floating platform motions)
- Deepwater marine riser systems and the various nonlinear effects arising from the six degree-of-freedom motions of ships and floating platforms, vortex-induced vibrations, axial dynamics, and three-dimensional nonlinear interactions of the riser systems
- Simulation and control of sophisticated, high-capacity tensioning systems with mechanical, fluid, and thermal transients and floating platform motions are examined by computational methods for operational situations

Dr. John E. Speich

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Fax: (804) 827-7030
Website: www.engineering.vcu.edu/fac/speich/website/

Research Topics:

- Smooth muscle biomechanics
- Developing robotic devices for medical applications

Dr. Arunkumar Subramanian

Assistant Professor
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Fax: 804-827-7030
Website: www.egr.vcu.edu/me/faculty/me-faculty_subramanian.html

Research Topics:

- Nanoelectromechanical systems (NEMS)
- Electrokinetic nanoengineering
- Nanomaterials
- Nanofabrication
- Advanced microscopy
- Nanomechanics
- Small-scale energy storage/harvesting/generation

Dr. Vishnu-Baba Sundaresan

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Website: www.egr.vcu.edu/me/faculty/me-faculty_sundaresan.htlm
Research website: www.people.vcu.edu/~vbsundaresan/

Research Topics:

- Nanoscale transport phenomena
- Smart materials
- Ionic active materials
- Magnetostrictive polymers
- Piezoelectric polymers
- Self-healing materials
- Bioderived materials

Dr. Hooman Tafreshi

Qimonda Assistant Professor
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Fax: (804) 827-7030
Website: www.people.vcu.edu/~htafreshi

Research Topics:

- Modeling superhydrophobic surfaces
- Multi-phase fluid transport in fibrous porous media
- Aerosol flows and nanoparticle filtration
- Modeling and experiment on water jets and nozzle cavitation
- Heat and mass transfer
- Molecular dynamics simulation of granular materials

Dr. Gary C. Tepper

Professor and Chair
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Fax: (804) 827-7030
Website: www.egr.vcu.edu/me/faculty/me-faculty_tepper.html

Research Topics:

- Chemical sensors
- Nanomaterials
- Radiation detectors
- Functional coatings
- Electroprocessing of polymers

Dr. Amy L. Throckmorton

Qimonda Assistant Professor
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Fax: (804) 827-7030
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Research Topics:

- Experimental and computational fluid dynamics
- Turbomachinery design and applications
- Bench-to-bedside development of medical devices
- Artificial organs research, especially for the pediatric population
- Prediction and quantification of blood trauma and thrombosis in medical devices
- Cardiovascular modeling and univentricular fontan physiology

Dr. Gokul Vasudevamurthy .

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Research Topics:

- Actinide bearing ceramic nuclear fuel
- Nuclear structural materials
- High temperature materials processing and mechanical testing
- High temperature irradiation behavior of ceramics including mechanical properties and microstructural changes
- Materials-coolant interaction
- High temperature deformation mechanism maps
- Neural networks for probabilistic risk assessment
- Design of nuclear materials irradiation experiments
- Nanofluids for reactor applications
- Computational methods in nuclear reactor physics and advanced nuclear reactor design

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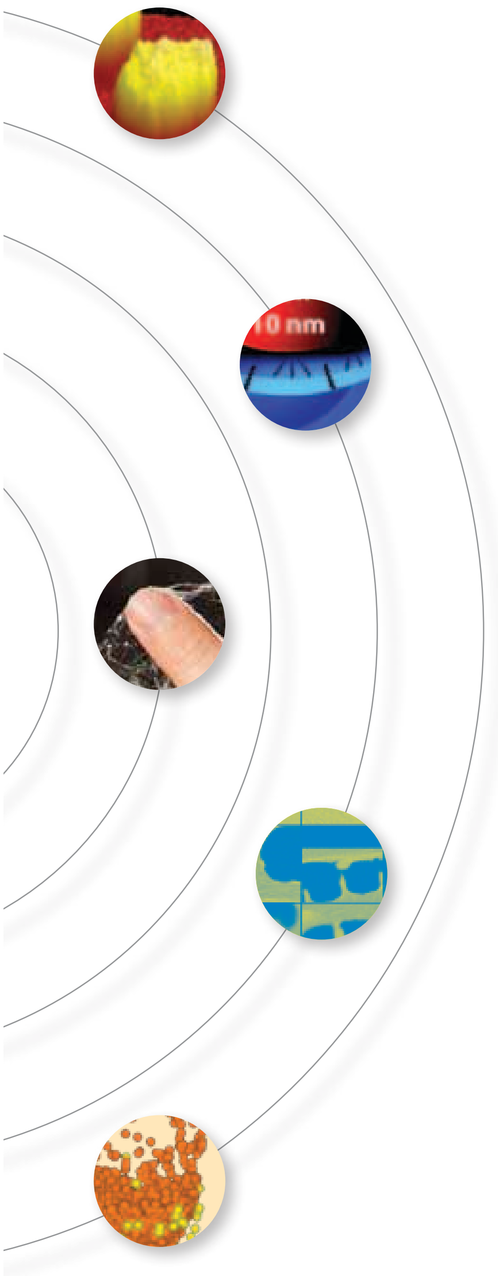

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