VCU School of Engineering

Virginia Commonwealth University

Volume four

Solving Global Problems
Embracing International Partners

This issue of the VCU Engineering Research Magazine describes collaborations among our students and faculty and their counterparts in research universities throughout the world. In his widely cited book, *The World is Flat*, Thomas Friedman identifies the role of technology and political change in the lowering of obstacles to global commerce and industry. These changes affect the United States in ways that are yet to be fully comprehended. Only if we as a nation engage actively and effectively in this historical realignment in global relationships, can we expect to realize its potential benefits and ensure our future welfare.

One could reasonably argue that academic scholarship has been functioning in a flat scientific world for centuries. Communities of scientific practice have often transcended geographical and political boundaries. As those communities have continued to evolve and specialize, the imperatives for international collaboration among academic scholars have in fact increased.

In this issue, we highlight just a sampling of global collaborations at VCU. We know that such collaborations are not unique to VCU. We are always interested to hear your stories. At the end of the magazine we provide contact information for all of our faculty. If your interests align with those of the VCU Engineering faculty, I encourage you to make contact — whether you are in Alexandria, Virginia or Alexandria, Egypt. We welcome any opportunity to grow our network of collaborators.

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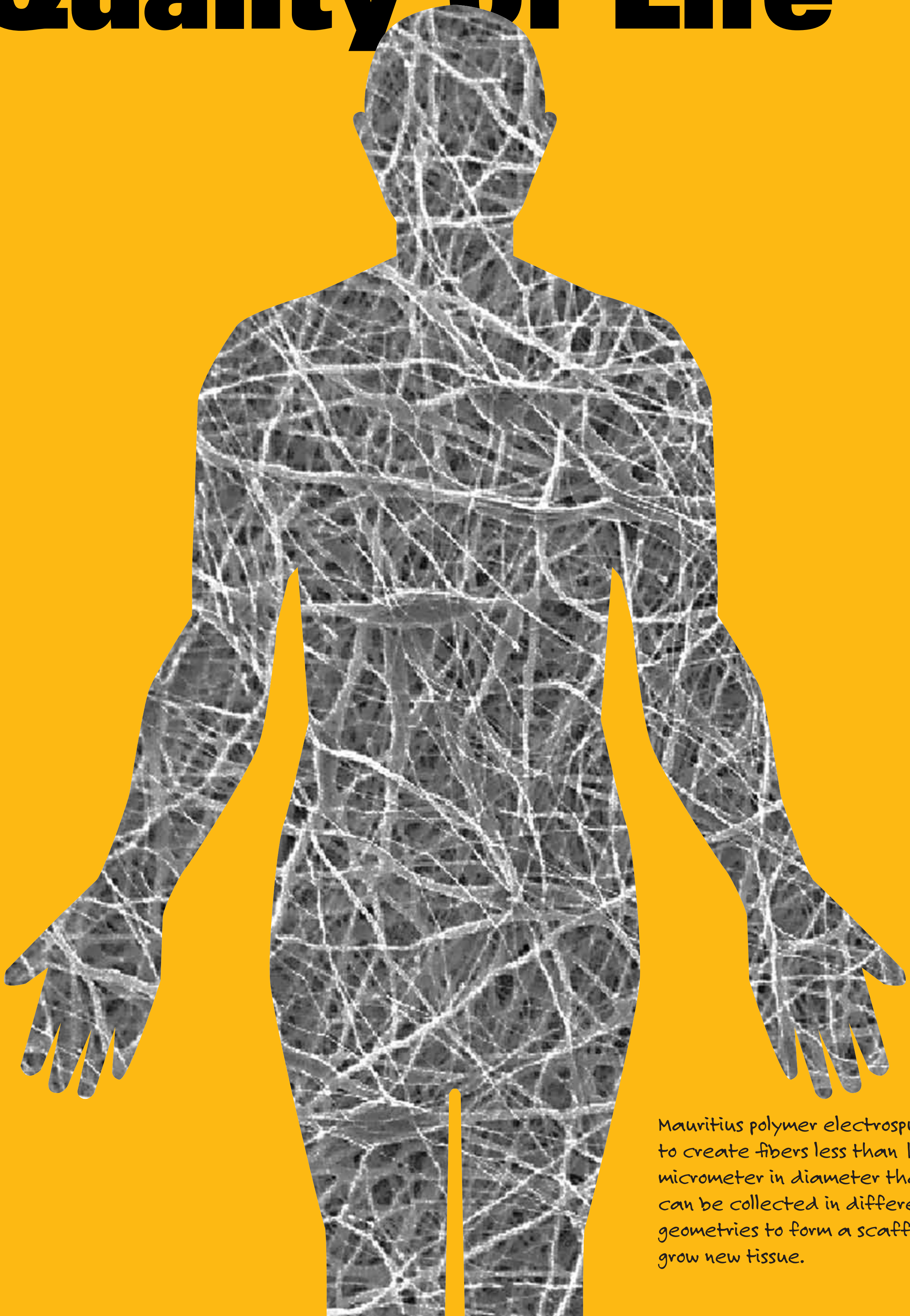
The Future of Tissue Engineering:

Improving the Quality of Life



Mauritius polymer electrospun to create fibers less than 1 micrometer in diameter that can be collected in different geometries to form a scaffold to grow new tissue.

"Tissue engineering applies engineering and biological innovations to design and fabricate new tissues and organs for those who need replacements due to disease or injury."

In April 2009, an exchange of e-mails between VCU Professor Gary L. Bowlin and University of Mauritius Professor Dhanjay Jhurry inspired a collaboration of ideas. After receiving his first e-mail from Jhurry, Bowlin's first move was to find Mauritius—a tropical island nation off the southeast coast of Africa, directly east of Madagascar, in the Indian Ocean—on the world map.

After their first exchange, Bowlin, VCU's Harris Professor of Biomedical Engineering, and Jhurry, a Professor of Chemistry with expertise in Polymer Science, formed a partnership aimed at creating innovations in the tissue engineering field. Tissue engineering applies engineering and biological innovations to design and fabricate new tissues and organs for those who need replacements due to disease or injury. The goal of Bowlin and Jhurry's work is helping patients in need of tissue and organ replacements.

Jhurry sought Bowlin's advice for the electrospinning of novel polydioxanone analogues. Polydioxanone is a base material used in a resorbable suture. Bowlin is a pioneer in using the process of electrospinning to fabricate biomaterial-based nanofibrous fabrics for use as tissue engineering scaffolds, and Jhurry was interested in exploring the potential for applying these materials in designing novel tissue engineering scaffolds. Bowlin explains, "These scaffolds are essential because they are the temporary (resorbable) structural element/form used to initiate the growth of new tissues, such as blood vessels."

Soon after their first email exchange, Bowlin and Jhurry had the chance to work together at the first USA-Mauritius Workshop, entitled "Biomaterials: Possibilities and Perspectives." This workshop was held at the University of Mauritius in December of 2009, and its purpose was to help establish an integrated interdisciplinary research, education and training program with a focus on the engineering of biomaterials for application in the biomedical field in the Indian Ocean region.

Bowlin led the syllabus design for the first course in Biomaterials offered by the University of Mauritius, which was taught by various workshop participants mainly from the US. This course was first offered online in October 2010 with Dr. Bowlin teaching several modules in biomedical textiles, biomaterial infection and complement system, as well as biomaterials testing and vascular and bone tissue engineering applications.

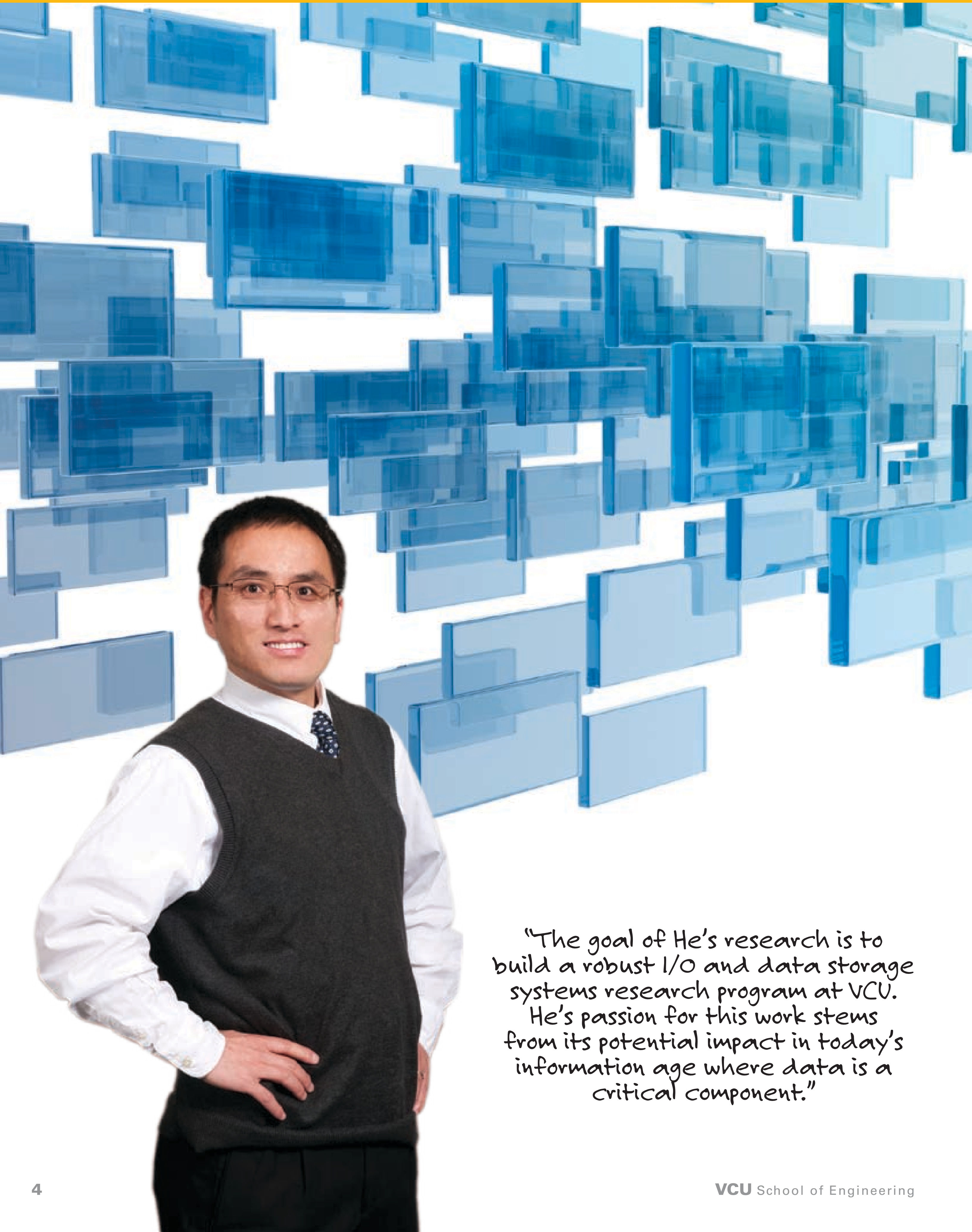
Early on in their research, Jhurry had sent Bowlin some of the novel polymer samples synthesized in his laboratory to begin characterization and optimizing processing conditions. This work was conducted by Patricia Wolfe, a Ph.D. student in Bowlin's laboratory. These efforts resulted in an article, prepared by Wolfe, entitled "Scaffold Characterization of Electrospun Novel Poly(ester-ether) Copolymers: 1,4-Dioxan-2-one and D,L-3-Methyl-1,4-dioxan-2-one," which was recently accepted for publication in the *Journal of Engineered Fibers and Fabrics*.

In November 2010, Bowlin visited Jhurry in Mauritius. The primary emphasis of his visit was to review recent research findings and plan the next phase. Bowlin also agreed to co-supervise a PhD student at the University of Mauritius who was continuing the synthesis of novel polymers for vascular tissue engineering. As part of that co-supervision, Bowlin will host the student for six to eight months, allowing her to conduct extensive characterization of the synthesized polymers in his laboratory.

In an effort to generate support for this work, Bowlin and Jhurry organized several high-profile meetings. One meeting was with Craig White, a Public Affairs Officer, and Peter Chisholm, a Consul at the US Embassy in Mauritius. They reviewed potential funding options to allow Jhurry and researchers/students of his group to visit and conduct research in Bowlin's laboratory, where they could utilize equipment not yet available in Mauritius.

The professors also met with Dr. Rajesh Jeetah, Minister of Tertiary Education, Science, Research and Technology. They briefed Jeetah on their research efforts and its importance, and they requested support from his office as biomaterials research and education continued to expand at the University of Mauritius. Bowlin and Jhurry also explained novel polymer variations that they envision for potential use in bone tissue engineering. This meeting resulted in broadening awareness about the on-going attempts to synthesize novel, functional polymers in order to meet a critical need in developing the next generation of bone tissue engineering scaffolds.

Bowlin and Jhurry have found this collaboration, despite being separated by thousands of miles and nine time zones, to be stimulating and productive. They look forward to the discovery of novel polymers and scaffolds made of polymers that will allow development of products to improve the quality of life for those in need.



"The goal of He's research is to build a robust I/O and data storage systems research program at VCU. He's passion for this work stems from its potential impact in today's information age where data is a critical component."

Data Storage:

Demand Performance

Data storage is the blood of modern computer systems. However, the gap between I/O and computation power is increasing and many large-application computer systems crash because their storage systems are vulnerable. To address this issue, Dr. Xubin He, Associate Professor in the Department of Electrical and Computer Engineering, and his team are working toward solutions for high performance and reliable data storage systems.

Performance and reliability are critical issues for storage systems. During the last decade, high-end computing (HEC) and cloud computing systems have become a necessary tool for scientists worldwide to understand and address complex problems, such as nuclear fusion, biological processes and nano-technology. However, modern storage systems face several challenges to satisfy this demand, particularly reliability and performance, which is an increasing concern as we evolve toward petascale computing systems with tens to hundreds of thousands of processors. The robustness of the I/O system is crucial to large-scale applications that generate and analyze terabytes of data. Storage systems are vulnerable to numerous hardware and software failures (eg. I/O and metadata server crashes) and contribute to as much as twenty-five percent of all system failures. Building a robust high performing, reliable storage system is becoming increasingly more critical as high-end computing systems scale up in size.

Currently, He is working with visiting professor Huailiang Tan, Ph.D. students Chentao Wu and Guanying Wu, and undergraduates Vladislav Sorkin and David Lyons to conduct three NSF funded projects on high performance and reliable I/O and data storage systems.

The team is investigating different solutions to improve storage system performance and reliability. They are cultivating specific techniques such as developing an I/O and storage benchmarking and analysis framework to efficiently profile the storage systems in both native and virtualized environments so as to identify the performance bottlenecks and optimize the systems.

Another technique the team is working on is developing different data cache schemes adaptive to the I/O hierarchy, including cache for networked storage systems (iCache and STICS), cache for distributed systems (Hint-K) and cache for solid state devices (BPAC). These cache schemes dramatically improve the data I/O performance.

The team also proposes and generates different schemes to increase the storage system reliability. As a proactive approach, active-active metadata service provides a robust solution to ensure the data is available even when partial meta data servers crash. They are also developing different coding schemes (Code-M, H-Code, and HDP Code) to tolerate multiple disk failures.

His successful research has earned him international reputation in the area of data storage systems. Through his research, He has collaborated with national institutions such as Oak Ridge National Lab, University of Florida, and RPI as well as schools in China including Huazhong University of Science and Technology, Dalian University of Technology, and the Institute of Computing, Chinese Academy of Sciences. Since 2007, He has been an invited speaker to schools throughout China and Thailand. He was the keynote speaker at the Third International Symposium on Parallel Architectures, Algorithms, and Programming in December of 2010. He has also co-chaired several international conferences including the research track of the 26th IEEE Symposium on Massive Storage Systems and Technologies (MSST) which is a premier international conference in data storage systems.

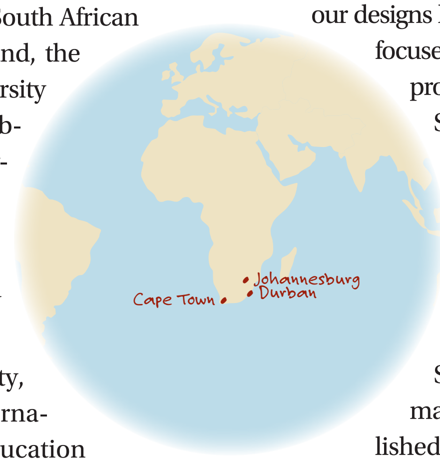
The goal of He's research is to build a robust I/O and data storage systems research program at VCU. He's passion for this work stems from its potential impact in today's information age where data is a critical component. He also relishes the opportunity to work with the talented students in the data storage field, a crucial growth area in the twenty-first century.

"She traveled extensively, analyzing ways in which engineering could be used to improve health, energy, agriculture, rural development, education and economic growth in some of the world's poorest countries."

Empowering Students: **Encouraging Change at Home and Abroad**

Dr. Rosalyn S. Hobson's belief that engineering can transform lives in developing countries has taken her all over the world. She has worked to create opportunities for VCU students to learn what it means to practice engineering as global citizens.

In November 2007, Hobson was named the Director of a partnership between VCU and the University of KwaZulu-Natal in Durban, South Africa. In addition to her collaborations with faculty and students at the University of KwaZulu-Natal, Hobson has created connections with three other South African universities: the University of Witwatersrand, the University of Cape Town, and the University of Johannesburg. During one of the collaborative research study programs she spearheaded, Hobson worked with students and faculty to create an automated speech-recognition program for different languages. Another project predicted a person's HIV status based on demographic information.



While on leave from the university, Hobson worked at the U.S. Agency for International Development (USAID) as a High Education Science and Technology Specialist. She traveled extensively, analyzing ways in which engineering could be used to improve health, energy, agriculture, rural development, education and economic growth in some of the world's poorest countries. She also helped facilitate collaborations between the National Science Foundation, the Department of State, the Department of Education, and the American Association for the Advancement of Science to promote STEM educational activities in developing countries.

Hobson says, "Collectively, there are so many problems—health care, global climate change, energy needs—that we, as global citizens, face."

Short-term research projects, such as the ones Hobson organizes, provide engineering students with an important chance to study abroad. One of her former students, NeKole Varnado, concurs, stating "The experience opened my ideas to the importance of the sustainability of projects and the impact that our designs have on cultures." Her company, IT Enginuity, focuses on projects in sustainability and solving problems related to homelessness in Richmond. She attributes her time abroad as having a major influence on her current career path.

As the Associate Dean for Graduate Studies and Associate Professor of Electrical and Computer Engineering, Hobson has overseen an increase in the number of doctoral and funded students in engineering. She has also helped to establish three new master's degree programs. Hobson has published over thirty peer reviewed conference and journal articles and has presented many lectures and keynote addresses around the world. She has received over 3.2 million dollars in federal and private research funding for projects on which she has served as the principle or co-principle investigator. Hobson's current research involves artificial neural networks and their application to biomedical signal and image processing and biological modeling and improving engineering education.

Engineers Without Borders: **Students Inspired** to Change the World

The national organization of Engineers Without Borders (EWB) started as a small club with a handful of members in 2002. Today, it has over 12,000 members. That number now includes VCU students who want to help change the world.

EWB-USA, which has more than 350 projects ongoing in over 45 developing countries, works to bring basic needs for clean water, sanitation, energy and education to those who need it. The membership is made up of professionals and students of over 250 chapters across the country. Each chapter makes a five-year commitment to a community. The chapter will design and help implement solutions to the needs of that community. Local community members and non-governmental organizations are then trained to work and sustain the projects.

The work of EWB-USA inspired two VCU students to inquire about opening a VCU chapter. Jeffrey Stumb, an undergraduate senior in mechanical engineering (pictured first row, right), and Chris Holden, a PhD candidate for biomedical engineering (pictured first row, left), have worked together to bring EWB-USA to VCU's campus.

"There was nothing like this in the School of Engineering at VCU," says Stumb, "and I wanted future students to be able to take advantage of the program." They currently have 18 members and hope this number rises once they start their first project and spread the word to the rest of the student body. Students from disciplines other than engineering are also encouraged to get involved.

For their first project, the students will collaborate with the James River chapter. There are several opportunities in Central America and the Carribean for a gravity-fed water transportation project. After completing their first project, the chapter will be able to split into different teams, running multiple projects simultaneously in different parts of the world.

Stumb and Holden have high aspirations for the group's future. They hope to become a multi-disciplinary effort, including medical students, who would first visit a community and identify conditions to understand why people are getting sick; engineering students, who would be able to design projects to improve sanitation; and art students, who would be able to create visual aids to help educate community members on living a healthy lifestyle. The VCU chapter of EWB-USA gives engineering students another opportunity to inspire and change the world.

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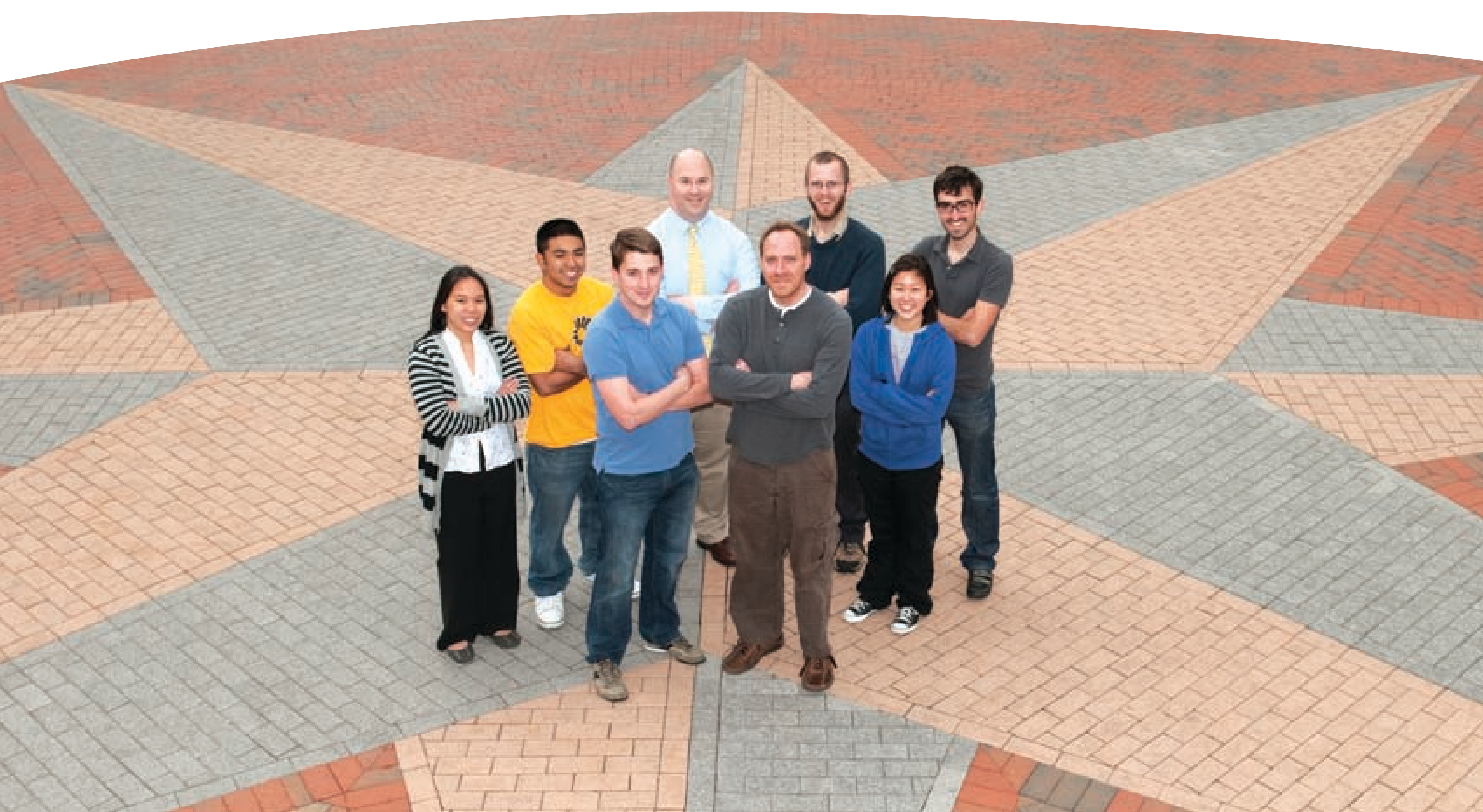


The Case for Micro-fluidic Devices: Safer Drug-Delivery for Patients

Every medical condition presents its own set of challenges. What is the best medication (or combination of medications) for restoring a patient's health? Once that question is answered, researchers grapple with the question of how best to administer those medications. The research of Dr. Ramana Pidaparti and his group, including VCU faculty and graduate students as well as faculty and students at the Indian Institute of Technology (IIT) in Kharagpur, addresses this need.

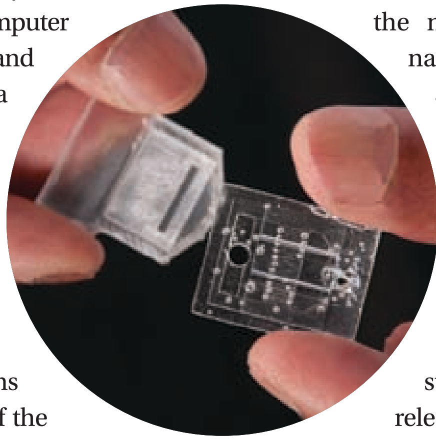
Pidaparti's team works with micro-fluidic devices to create safe, effective systems for drug delivery. These devices, due to their size and efficiency, are increasingly being used for various health care applications including treatment of ocular and respiratory diseases.

For patients with neovascular (or "wet") age-related macular degenerative disease, there is an urgent need for an implantable drug delivery device. An estimated 1.6 million adults in the US over the age of 50 suffer from age-related macular degeneration. This form of macular degeneration results from the growth of abnormal leaky blood vessels from the choroid and choriocapillaris beneath the macula. About 200,000 cases are diagnosed annually.

Only a few drugs are currently used to treat neovascular AMD since there is no device available to deliver the drug into the vitreous body of the eye. Drugs such as pegatanib sodium and ranibizumab (still in clinical trials) and bevacuzumab (off-label use in neovascular AMD) are delivered via repeated intravitreal injections of the drug into the eye. Yet the risks associated with repeated intravitreal injections are high: intraocular infections (endophthalmitis), intraocular hemorrhage, and retinal detachment.

Pidaparti and his team are working on an implantable, microfluidic device that will help to reduce the frequency of dosing and improve the pharmacokinetics of the drug in the eye.

In a project funded by the National Science Foundation (ECCS-1058067) and supported by the School of Engineering, Pidaparti along with Dr. Moorthy, President and CEO of Associated Vitreoretinal and Uveitis Consultants and Chairman of the Department of Ophthalmology at St. Vincent Hospital and Health Services in Indianapolis, Dr. Gary Atkinson, Associate Professor in Electrical and Computer Engineering, post-doc Dr. Guoguang Su and graduate students Jae-Hwan Lee and Kareka Aradi are developing an implantable drug delivery micro-device based on the fabrication of nano-channels and aided by computational studies for applications in treating ocular diseases such as AMD, diabetic retinopathy, uveitis, and glaucoma.



The drug delivery rate will depend on the nano-channel design specifications to meet the required flow rate at the exit of the device. Initially, the drug delivery device is being envisioned for application to treat macular degenerative disease with zero-order kinetics and continuous release rate over an extended period of time.

Schematics of the nano-drug delivery prototype structure are shown below. The drug to be delivered is contained inside a hydrogel, where it diffuses through a series of nanochannels and finally reaches the outlet, where it diffuses into the vitreous cavity at controlled rates. The use of hydrogels (MAI or MIRAgel consisting of Poly (methyl acrylate-Co-2-Hydroxyethyl acrylyte) will be explored as a means to actively induce the drug delivery into the nanochannels. The drug-laden hydrogel, nanochannels and outlet are contained within a top and bottom cover, which integrates all of the components together.

Currently, the device design concept is being investigated through computational simulations and prototyping. If the fabricated micro-device can satisfy the required drug release kinetics of the proposed nano-channel array and is suitable for the targeted application (ocular release device), a prototype drug delivery system will be developed and demonstrated during the next phase of the research program in collaboration with clinicians in implementing the developed device.

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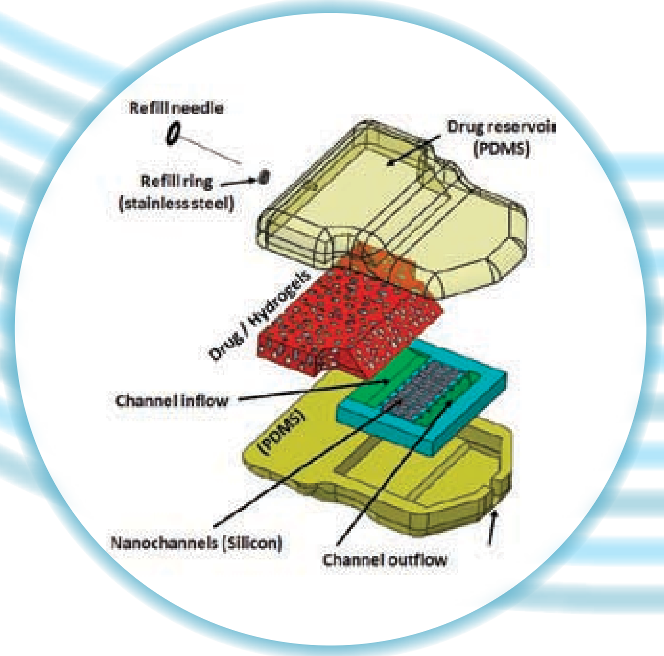
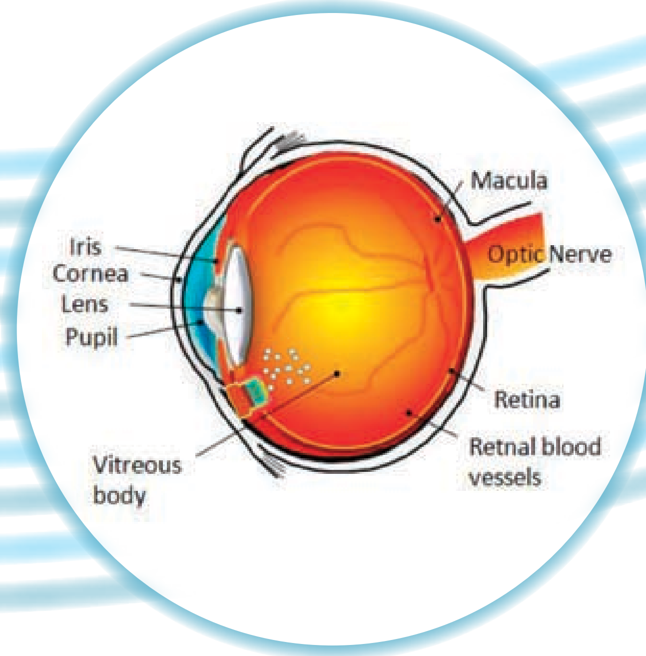




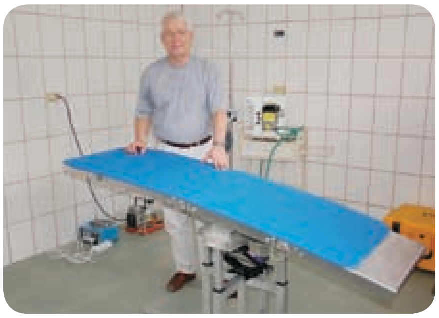
At the Center of Design and Innovation:

A Unique Human Need

After visiting struggling hospitals in Bangladesh, biomedical engineering student Seule Kabir returned to VCU with the goal of developing low-cost surgical equipment for use in developing countries. From her vision, Operation Simple was born. The Operation Simple team, a group of interdisciplinary students taking part in a da Vinci Center project, set out to design, create, prototype and distribute a low-cost surgical table.

School of Engineering Dean Russell Jamison served as the engineering advisor on the project, directing students as they faced the challenge of creating a durable, portable surgical table for less than one percent of the cost of surgical tables on the market.

To test the table, Jamison packed up the table and flew to Honduras in March of 2010 to take part in a medical mission. Here is his story of engineering in action.



In route to Honduras:

I set out early in the morning to join a team of surgeons, anesthesiologists and nurses from the University of Illinois Urbana Champaign, Carle Hospital in Urbana, and hospitals in Chicago. We were traveling with a sense of purpose: to use our skills to help children without adequate access to health care. I brought with me the Operation Simple surgical table to supplement the lack of equipment and provide the first field test of the device. We prepared the shipment to fit within a compact, 2'x 2'x 2' corrugated box, weighing only eighty-nine pounds. For a fee, I was actually able to check the table as baggage on our flights from Richmond to Atlanta to San Pedro Sula.

Day 1, Quimistan: The first hospital we visited was Gracias A Dios Clinic in Quimistan, a very small town three hours from the capital city of Tegucigalpa. Quimistan is a rural town with overwhelming levels of poverty and ill health. It was clear the team would be a great help here.

The clinic was modest in size and clean, but it had few medical supplies. The first day, Sunday, was busy and devoted to patient screening. Since our arrival had been announced in the local newspapers and on the radio, a large group of families had petitioned for their children to be scheduled for surgeries. The team saw boys and girls with cleft palates and cleft lips and children with burn scar contractures on their arms and legs, webbing of their fingers and incidents of ear or nose deformities.

In some cases, the surgeries were too complicated to perform with our limited resources, and that was truly difficult. Not being able to help every child was frustrating for the team, but most cases were suitable for the surgeons to correct.

Day 2, Quimistan: Surgery was conducted in two rooms on Monday. The first room had a modestly equipped surgical table already in place. In the second room, we assembled and set up the surgical table. As surgery got underway, the table performed well. Because most of the patients were children, however, the full load-bearing capability of the table was not adequately tested. And, while the surgeons observed that the vertical elevation capability was adequate, they felt the number of detents for positioning the tilt of the table were coarser than they would prefer.

During cleft palate surgery, the surgeon sits with his head tilted down over the head of the child. The surgeon

"We were traveling with a sense of purpose: to use our skills to help children without adequate access to health care."

noted that this placed the lip of the Operation Simple table just above his lap, in an unobstructed and convenient configuration. The clear space allowed him to move his chair well underneath the table, which was an advantage.

There was one worrisome moment on the morning of the first day when I was called into the surgery because one of the welded fittings of the table had failed, causing the table to suddenly tilt. The nursing staff quickly secured the child, and thankfully, surgery was able to continue with no injury. In response to this flaw, we developed an intermediary mechanism to fix the adjustment of the table and used that for the rest of the trip.

Day 3, Quimistan: At the end of the day we packed up our equipment for transportation to San Pedro Sula. Before leaving Quimistan, we held a ceremony during which I gave the surgical table to the Gracias A Dios Clinic. The director of the clinic, Dr. Turcios, responded with great emotion and gratitude at having a second surgical table for permanent use at the clinic. We, too, were pleased and hoped the table would aid in the incredible work they do there. Before our departure, we advised Dr. Turcios that we would return the table after using it in the Social Security Hospital in San Pedro Sula for two days.

Day 4, San Pedro Sula: Like large urban hospitals in the United States, the hospital in San Pedro Sula was a beehive of activity with dark and unclean corridors, hundreds of people waiting to be seen, and a general sense of overwhelming demand and insufficient resources.

The team setup in adjacent surgery rooms. Again, the room in which the Operation Simple table was used was essentially empty. The Operation Simple table was clearly in desperate need during the second phase of the medical trip.

Day 5, San Pedro Sula: At the end of the second and final day in San Pedro Sula, the surgical team did one final assessment of the table. They suggested that it would be useful to have an attachment for an IV pole on the table to eliminate the need for a stand-alone IV pole.

Updates: As a field test this experience was invaluable. It allowed us to see, first-hand, the need for low-cost surgical tables like the Operation Simple table. It also allowed us to learn the limits of the table and make needed design changes before manufacturing the next prototype.

Organic spintronics:

Where chemistry, physics, computer science and electrical engineering meet

Computers have been around since Charles Babbage designed the first computing machinery in the early 1800's. Today, they permeate everyday life—from shuffling music in handheld devices to carrying out a thousand trillion operations every second in massive multiprocessors. For the data-hungry world, even this mammoth computing power is not enough. The ever-increasing need for computing prowess has spawned some truly radical ideas for number crunching.

One such idea is the notion of 'quantum computing' where principles of quantum mechanics are harnessed to carry out computations with unprecedented speed. Here, the rules of the classical world are discarded and the rules of the quantum world are embraced. Classical computers store and manipulate information in digital format where the most primitive unit of the computer holds one bit of information with one of two values – 0 or 1. Even if this unit could be fashioned from a single atom, we would still be unable to build an extremely powerful computer since the number of atoms available in the universe is limited. This number may not even be as large as 2^{300}, which will limit us to a computer with a bit capacity of no more than 2^{300}. However, in the quantum world only 300 atoms need to be 'entangled' to handle 2^{300} bits of information. Thus, just 300 quantum-mechanically entangled atoms could hold more information than all the storage disks that can be manufactured with all the material in the universe over the entire life of the universe!

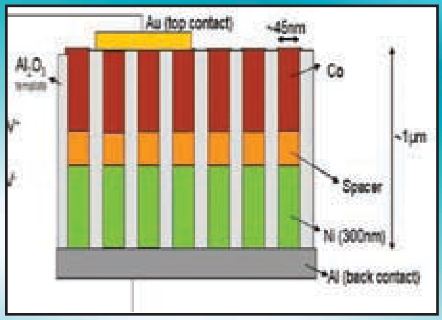
A team in the Department of Electrical and Computer Engineering leads an effort to fashion quantum computers out of electrons trapped in tiny molecules of organic substances. In the early 1990s, the team's leader Dr. Supriyo Bandyopadhyay conceived the idea of encoding bits 0 and 1 in an electron's "spin," which is a quantum mechanical property enabling the electron to act like a miniature magnet. This magnetic behavior allows the electron to encode coherent admixtures of two bits 0 and 1, as long as 'coherence,' a quantum mechanical property of the magnet, can be preserved. Yet, coherence is a delicate property and the slightest disturbance can destroy it. The team has shown that spins in organic molecules are relatively robust with long-lived coherence. The icing on the cake is that it is also easy to "read" the data encoded in the spin by using simple methods that involve sending another electron of known spin into the molecule to see if it emits a photon, i.e. whether light is present.

The team uses a device called a spin valve to measure the longevity of spin in organic molecules. This device consists of three layers: a ferromagnet, an organic semiconductor and another ferromagnet. The tri-layered structure is produced within a nanopore with a diameter of 50 nanometers, which is roughly 1/10,000th the width of a normal human hair. With spin valve measurements, it is possible to determine how long an electron's spin will survive in a pristine state within the organic semiconductor.

Able to make nanopores with extreme precision, the team assembled spin valve devices of exceptional quality. Measurements revealed that the spin's orientation remains intact for nearly one second at relatively high temperatures in some types of organic molecules. This is the longest spin lifetime demonstrated in any material. Furthermore, the coherence of the spin survives for several tens of nanoseconds, which makes them suitable for quantum computers.

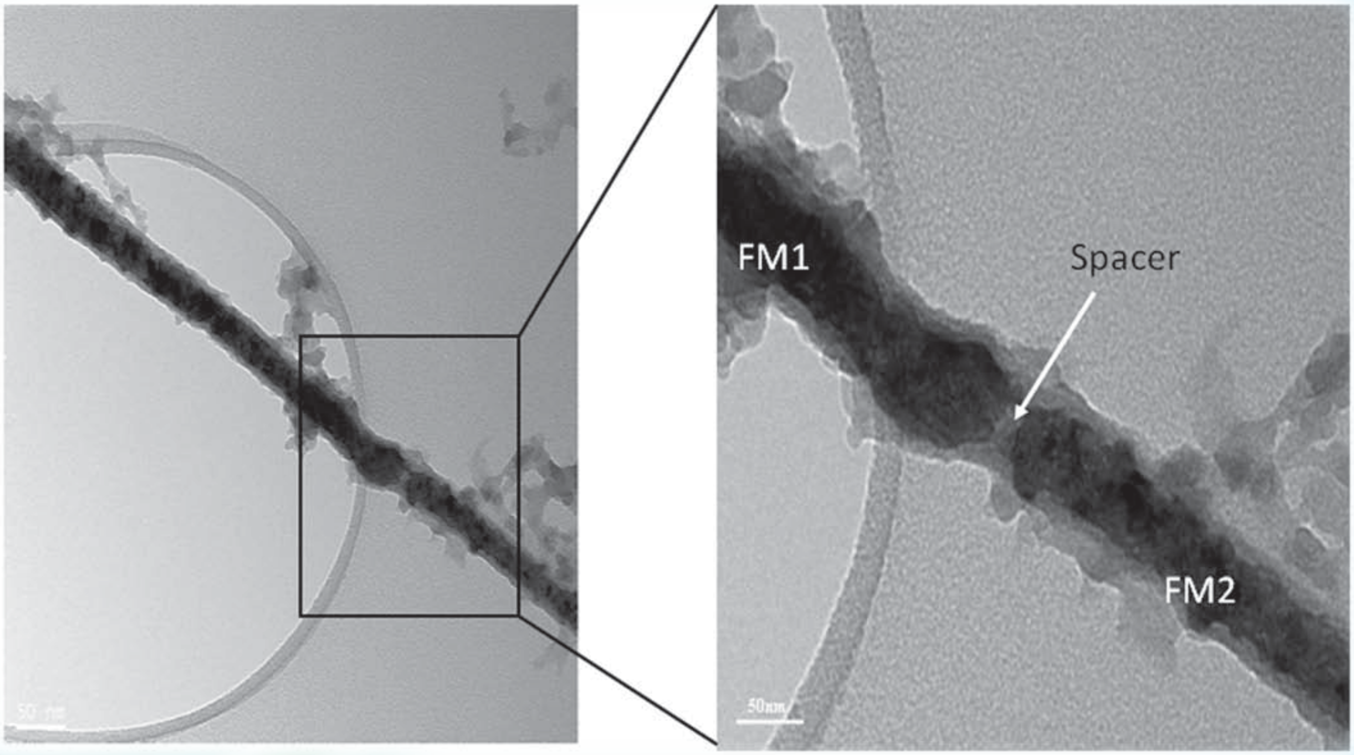
In an effort to find the optimum organic materials to act as hosts for long lived electron spins, Bandyopadhyay's team works with several organic chemists from East Anglia University in the UK. Synthetic chemists Drs. Michael Cook and Andrew Cammidge are designing molecules with properties that will allow the VCU team to demonstrate longer spin lifetimes. Dr. Marc Cahay from the University of Cincinnati, who also collaborates with the VCU team, is developing theoretical simulators to study the dynamics of an electron's spin in organic molecules with an eye to applications in quantum computing.

Bandyopadhyay's team has funding from the US National Science Foundation (NSF) to study spin based quantum computers employing organic molecules. The international team is seeking further funding from NSF and EPSRC, the NSF's sister organization in the UK. This group's work has received significant international acclaim and has been featured in the worldwide scientific press through news outlets such as Business Week, The Register, HPC-Wire, and the Bangkok Post.

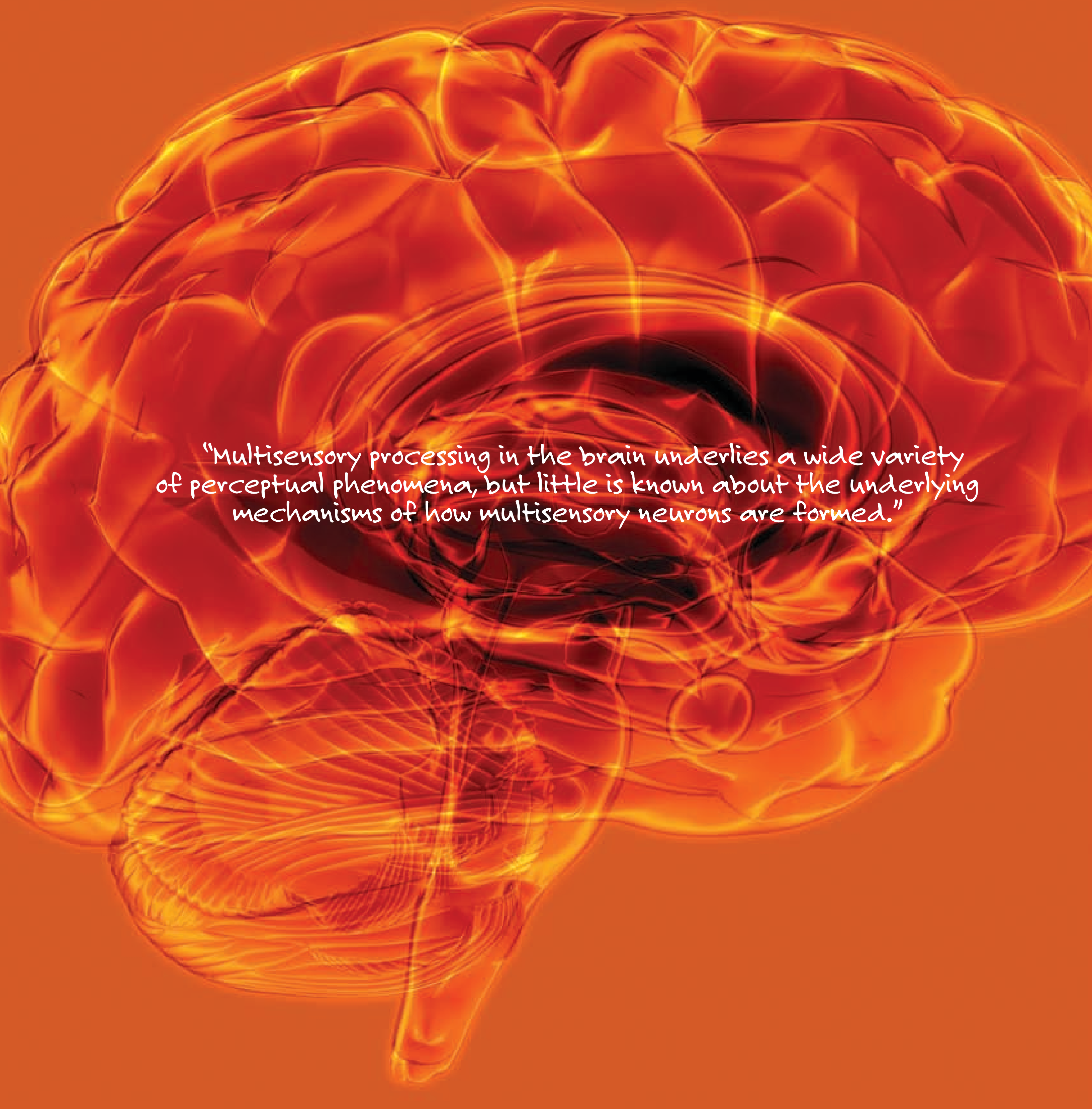


Schematic of a "spin valve" structure (above) produced within a nanopore. The porous structure is produced by chemically treating an aluminum foil. The three layers comprising the spin valve are nickel, organic and cobalt.

"Just 300 quantum-mechanically entangled atoms could hold more information than all the storage disks that can be manufactured with all the material in the universe over the entire life of the universe!"



Cross-section transmission electron microscope picture of a single spin valve and a magnified image of the spin valve.



"Multisensory processing in the brain underlies a wide variety of perceptual phenomena, but little is known about the underlying mechanisms of how multisensory neurons are formed."

Multisensory Convergence:
Collaborating to Design Better Engineering Systems

Computer Science Department faculty and Chair, Krzysztof Cios, have been actively fostering research connections between the Universities of Messina and Cordoba for the last four years. Several faculty members from these institutions serve as Affiliated Professors of Computer Science at VCU and are members of the Ph.D. committees of VCU's computer science students.

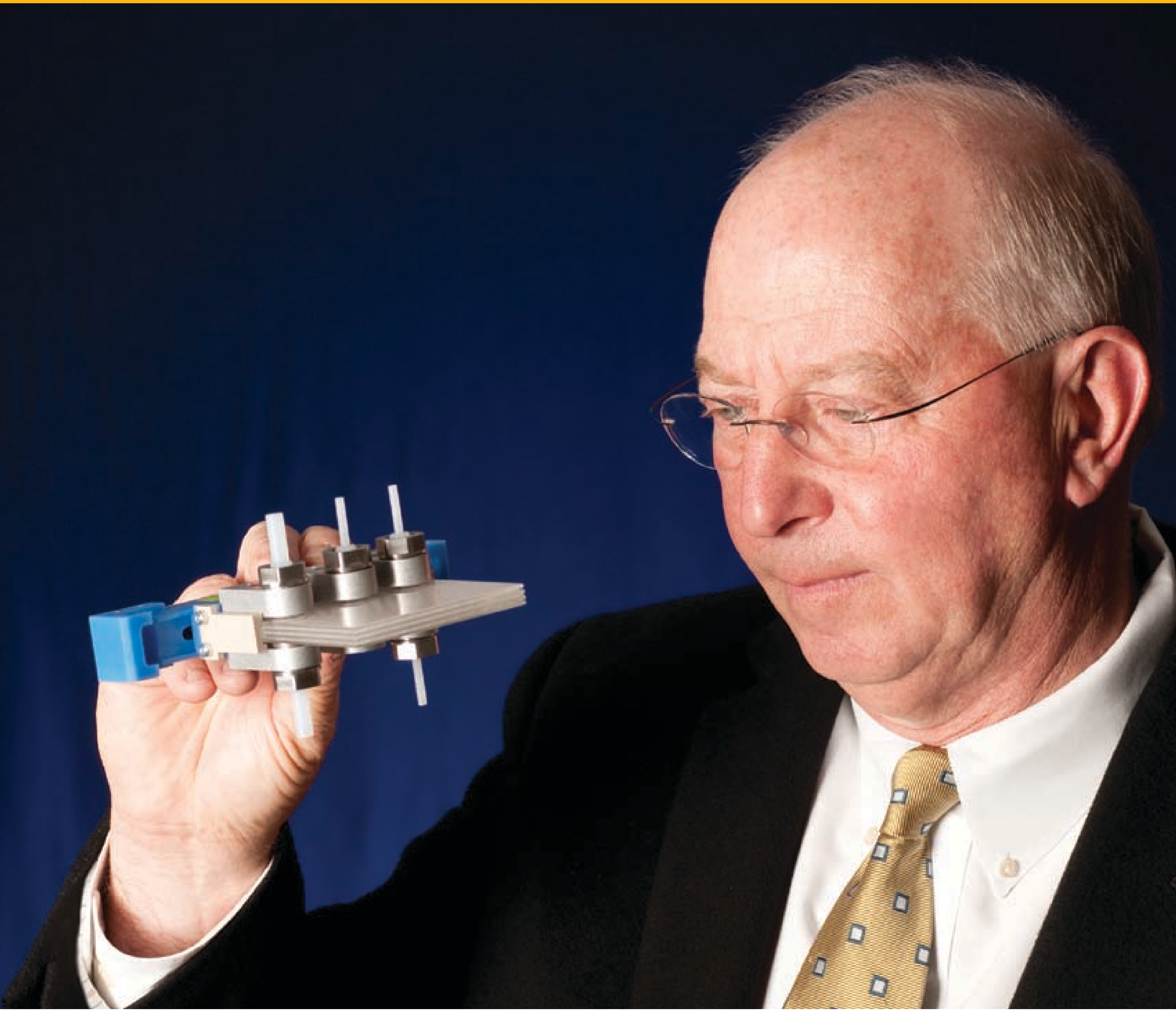
Cios and Sebastián Ventura from the University of Cordoba are General Co-Chairs of the 11th International Conference on Intelligent Systems Design and Applications that will take place in Cordoba in November 2011. They also helped organize the 10th ISDA conference in Cairo.

Through his work with Ventura and Alessio Plebe from University of Messina, Cios has created new opportunities for his students, as Ventura and Plebe often co-advise his doctoral students. These relationships offer the benefits of an open dialogue with and direct mentorship by other leaders in the field of computational modeling and computational neuroscience.

One of these co-advised students, Joo Heon Shin, a graduate of Cios's lab, was recently awarded a post-doctoral position at Johns Hopkins University and at the National Institutes of Health. Shin's work with Cios culminated in a significant contribution published in *IEEE Transactions on Neural Networks*. In the article, "Recognition of Partially Occluded and Rotated Images With a Network of Spiking Neurons" they used knowledge of how parts of brains operate in order to design better, smarter engineering systems for image recognition. Cios explains, "It is easy for a human to recognize even partially complete face images, but it is very difficult for a computer."

Another of these co-advised students who will graduate in May, Hun Ki Lim, is modeling multisensory processing in the brain. Cios's group investigates aspects of biological systems, specifically, the ability to fuse and interpret diverse sensory signals, such as visual and auditory. It's this ability that allows us to listen to the radio at the same time that we work a crossword puzzle, for instance. They study multisensory convergence in the brain to understand how the same convergence can be accomplished computationally. Multisensory processing in the brain underlies a wide variety of perceptual phenomena, but little is known about the underlying mechanisms of how multisensory neurons are formed. This lack of knowledge is due to the difficulty involved in using biological experiments to manipulate and test the parameters of multisensory convergence, the first step in the multisensory process. By using a computational model of multisensory convergence, Cios's group seeks to provide insight into the mechanisms of multisensory convergence. In a recent study, they reverse-engineered multisensory convergence by using a biologically realistic neuron model and a biology-inspired plasticity rule. The results showed that the generation of multisensory neurons related to the topological properties of the network, in particular, the strengths of connections after training were found to play an important role in forming and thus distinguishing multisensory neuron types. The work resulted in the articles "Modeling of Multisensory Convergence with a Network of Spiking Neurons: A Reverse Engineering Approach" in *IEEE Transactions on Biomedical Engineering* and "Connectional Parameters Determine Multisensory Processing in a Spiking Network Model of Multisensory Convergence" in *Experimental Brain Research.*

Cios and his collaborators in Messina and Cordoba anticipate that their relationship will strengthen as a new project gets underway. Now in the preparation stage, the ATLANTIS project – to be supported by a grant from the U.S. Department of Education's International and Foreign Language Education Programs and the European Union's Directorate General for Education and Culture — will allow VCU students the opportunity to spend a semester at the University of Messina or the University of Cordoba, and to work closely with Italian and Spanish faculty and students, some of whom may come to VCU's Computer Science Department for two semesters.



More Access, Less Expense:

The Way Microreactors Could Change the Pharmaceutical Industry.

Gaining access to basic medical care is a daily struggle for people in developing and underdeveloped countries. Among other factors, the limits of current pharmaceutical, economic and manufacturing models keep important anti-viral, anti-bacterial, anti-malarial, anti-tubercular and pain management medications from being administered to people in need.

In the case of anti-HIV drugs, these limits include a reduced capacity to produce the active ingredients (API's) and a lack of economic incentive to produce more drugs at a lower price. As a result, the amount of HIV anti-retroviral drugs being manufactured does not meet the demands of the existing HIV-infected patient population. The World Health Organization (WHO) reports that only 5.2 million of the 33 million HIV-infected individuals currently receive anti-retroviral therapy.

A change in drug manufacturing could help to alleviate this problem, and Dr. Frank Gupton, Research Professor and Interim Chair in the Department of Chemical and Life Sciences, and his group are actively researching methods that could change current drug-manufacturing models through the use of continuous flow manufacturing technology. Recent advances in small dimension continuous flow technology (i.e microreactors) provided the opportunity to apply continuous processing capabilities to pharmaceutical applications.

Aided by a gift of advanced-flow glass microreactors from Corning, Gupton is working on ways to make continuous flow technology more efficient, so as to provide a mechanism through which production could be increased at costs lower than current batch methods. The operational and environmental advantages of small-dimension synthesis are clear, and yet the commercial implementation of this technology has been limited for reasons as varied as insufficient time to evaluate alternative technologies during drug development and limited technical experience in continuous chemical processing.

Changing drug synthesis and manufacturing paradigms by implementing continuous flow technology provides the potential to simplify the translation of laboratory routes into multi-kilogram operations by "scaling out" into parallel units rather than "scaling up" into larger batch vessels. This parallel approach mitigates issues associated with heat transfer, reactor configuration and agitation when moving to larger-scale operations. By "scaling out" into parallel reactor units, heat transfer and agitation can be more effectively maintained. The effective control of these critical reaction parameters also results in more consistent product quality.

By experimenting with the Corning microreactors, Gupton's group, in collaboration with partners at Corning in France, Florida State University and the University of Washington has also become interested in their use beyond anti-HIV drugs. Specifically, the group has been investigating the potential use of microreactors to advance the concepts of personalized medicine in which drugs can be synthesized and formulated to meet the specific physiological needs of individual patients.

Such a system would be very compact and would be inclusive of hardware, software, sensors, and onboard storage, all tailored to synthesize and formulate drugs. The size and portability of the system also lends itself to applications in underdeveloped countries where decentralized remote drug manufacturing capabilities would be most advantageous. NASA has also recognized the impact of Gupton's research and is planning to evaluate this new technology with regard to meeting the pharmaceutical requirements associated with extended space travel.

From a broader perspective, a shift from batch manufacturing to continuous flow manufacturing has the potential to transform the process development, manufacturing, and administration of brand name and generic drugs. Gupton has recently presented his research on microreactors at the International Symposium on Green Processing in the Pharmaceutical and Fine Chemical Industries in Boston and at the International Symposium on Continuous Flow Reactor Technology in Paris, France.

"NASA has also recognized the impact of Dr. Gupton's research and is planning to evaluate this new technology with regard to meeting the phamaceutical requirements associated with extended space travel."

"To encourage collaborations between students of different disciplines, Rao and McLeskey traveled to IIT-KGP in August of last year and met with nearly 60 faculty."

Two Schools, One Goal: **Working Together for Those in Need**

For several years, VCU has sustained an educational collaboration with the Indian Institute of Technology, Kharagpur (IIT-KGP) including summer internship programs for IIT-KGP students at the VCU campus, seminars, short courses, and research with faculty members. Developing plans aim to enhance this relationship to include collaborative research projects between students and faculty members of both institutions to begin for the Fall 2011 semester.

The VCU-IIT collaboration has resulted in sixteen joint publications and/or conference presentations. Both universities look to increase direct activity between students and faculty.

Dr. Raj Rao, Assistant Professor of Chemical and Life Science Engineering, and Dr. James McLeskey, Associate Professor of Mechanical Engineering, lead an effort to create senior projects, actualized by students and faculty at both institutions, which address needs in the developing world.

Both have extensive experience working with undergraduate education and international programs. Rao, the Director of the IIT-KGP partnership, was recognized with the Faculty Career Development Award by the US-National Science Foundation and the Qimonda Professorship by the School of Engineering. McLeskey was awarded the 2006 Outstanding Faculty Award from the State Council of Higher Education for Virginia and has received US-NSF funding for his national and international projects.

To encourage collaborations between students of different disciplines, Rao and McLeskey traveled to IIT-KGP in August 2010 and met with nearly 60 faculty across campus.

To begin this new partnership, McLeskey and Assistant Professor Dr. Vamsi K. Yadavalli of Chemical and Life Science Engineering will gather ideas from VCU faculty and, then, compare and share ideas with students and faculty from IIT-KGP. An official project list will result and professors from VCU and IIT-KGP will contact one another to discuss project potential. They will submit proposals to explain projects and how they will be conducted. From these proposals, four projects will be selected for the year. Students will apply to participate and, in August 2011, VCU faculty will travel to IIT-KGP to discuss and plan each project.

Projects are expected to be finished during the Spring 2012 semester. A Senior Design Showcase on the VCU campus will allow students to display prototypes of their devices and explain how they work. This program is expected to run for two years.

Dr. Amit Patra, Dean of International Relations at IIT-KGP, comments on the partnership's benefits: "Through this process IIT-Kharagpur expects better exposure of its undergraduate students to current research problems and international state of the art. Even those projects, which are not selected for joint supervision, are going to be benefited through internal competition."

According to Rao, "One of the rewarding aspects of working with students and faculty as part of an international partnership is the opportunity to bridge different cultures and to work towards the common good . . . This experience is vital to developing the interdisciplinary twenty-first-century engineer."

The goals for these projects and educational collaboration will be to increase both international exposure of VCU students and international scholarship between faculty at VCU and IIT-KGP, and to work on projects that will have a direct societal impact. Participating students will gain concrete experience in their respective disciplines, develop leadership skills and generate projects with the potential to aid local or international communities. They will also benefit by forming partnerships with students and faculty from a different school and country.

Reflecting on the broad significance of the program, McLesky says, "Students benefit by learning what it is like to collaborate with people from another culture. Very practically, they also learn how to collaborate over long distances —this is much more common in the business world today."

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
- Multi-modal functional neural imaging

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Research Topics
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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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Research Topics
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- Telemedicine
- Magnetic resonance imaging (MRI) techniques for studies of vessel properties and vascular hemodynamics
- Ultrasonic imaging techniques for studies of cardiovascular dynamics

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- Tissue engineering
- Smooth muscle cell signaling
- Cellular biomechanics

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Research Topics
- Non-invasive cerebral spinal fluid pressure device
- High noise speech communication system
- Baby echolocator (device to allow deaf babies to "see" acoustically facilitating perceptual motor development)
- Baby multimodal (bone conduction and vibrotactile) hearing aid using algorithms to track mother's voice
- Tinnitus (phanton sound sensation) management system using very high frequency stimulation with custom actuator

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Research Topics
- Rehabilitation engineering - analysis and design of devices to aid the disabled
- 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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Research Topics
- Haptic displays for blind and visually impaired individuals
- Haptic devices for rehabilitation
- Haptic technology for engineering education
- Human factors analysis during minimally invasive surgery
- Tissue modeling for surgical simulators

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Research Topics
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- Ligament and tendon mechanics
- Experimental and computational modeling of diarthrodial joint function
- Articular cartilage: normal function, reparative techniques, tissue engineering

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Research Topics
- Eye tracking systems and eye movement analysis
- 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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Research Topics
- Bioactive and environment-responsive surfaces for pharmaceutical and biomedical applications
- Brain-targeted drug delivery and gene therapy
- Dendrimer-based drug delivery, controlled release, and gene transfer
- Nanomedicine
- Tissue regeneration
- Polymer synthesis, characterization, and biofunctionalization

CHEMICAL AND LIFE SCIENCE

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

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Research Topics
- Polymer solution behavior at high pressures
- Scattering phenomena in polymer solutions at high pressures
- Supercritical fluid solvent technology

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Research Topics
- Small molecule drug synthesis
- Cellular therapeutics
- Real-time biomolecular simulation
- Vascular tissue engineering
- Stem cell engineering

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- Stem cells
- Regenerative medicine
- Cellular/tissue engineering
- Genomics
- Biomaterials
- Cell-based assays

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Research Topics
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- Fluoropolymer science
- Silicone science
- Functional polymer surfaces including biocidal polymers
- Nonlithographic patterning of functional inorganic, and polymeric materials

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- Protein-protein and protein-surface interactions
- Optical biosensors
- Functional biomaterials
- Micro- and nano-fabricated devices
- Biophotonics

COMPUTER SCIENCE

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Research Topics
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Research Topics
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- 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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Research Topics
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Research Topics
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- 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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Research Topics
- Artificial neural networks
- Machine learning
- Knowledge-based systems
- Parallel algorithms
- 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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- Wireless network security and DDOS attacks
- Intrusions and defense mechanisms in multi-interface multi-channel wireless networks
- System recovery including self-healing systems and survivability analysis

ELECTRICAL AND COMPUTER

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

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Research Topics
- GaN- InGan light-emitting diodes for general lighting.
- GaN-based field-effect transistors for high-power, high-speed electronics.
- ZnO-based transparent and conducting oxides for semiconductor photovoltaics (solar cells) and light emitting devices.
- Complex oxides for passive microwave components (to be used in radars and high-gain antennas.

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Research Topics
- Self-assembly of nanostructures
- 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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Research Topics
- Signal processor architectures
- Document compression for archiving
- Efficient, error-resilient, network-optimized image and video coding
- Medical image processing

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- Signal processing and nonlinear statistical analysis techniques

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

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

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

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Research Topics
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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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Research Topics
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- Reconfigurable computer
- Stochastic simulation
- High-performance computing
- Digital systems design

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Research Topics
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- Light emitting diodes
- Nitride semiconductor heterostructures

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- Computer vision
- Robotics
- Human-computer interaction
- Online machine learning
- Adaptive target tracking

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- Nonlinear optics
- Ultrafast spectroscopy
- Near-field optical microscopy
- Nanophotonics

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- Reconfigurable logic
- VHDL-based FPGA design
- Hardware and software for embedded microprocessor systems
- Parallel processing
- Computer architecture

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- Worst-case execution time (WCET) analysis
- Computer architecture and compiler
- Low-power computing

MECHANICAL AND NUCLEAR

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Research Topics
- Teams and team effectiveness
- Engineering management
- Collaborative and active learning
- Engineering education and pedagogy

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Research Topics
- Probabilistic risk analysis
- Nuclear safety

Dr. Jayasimha Atulasimha
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Research Topics
- Magnetostrictive, piezoelectric and magnetoelectric actuators and sensors
- Multiferroic nanomagnet based computing
- Dynamics of nonlinear and hysteretic systems
- Design and fabrication of MEMS devices

Dr. Sama Bilbao y León
Associate Professor and Director of Nuclear Engineering Programs
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- Experimental and computational thermal-hydrolics, two-phase flow and heat transfer for nuclear applications, including the develpement and verification of suitable thermal-hydrolic and heat transfer correlations.
- 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-hydrolic 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.

Dr. Charles Cartin
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Research Topics
- Design Optimization of Microfluidic Devices
- Microdevices for Health Care Applications

Dr. Mohamed Gad-el-Hak
Caudill Eminent Professor
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Research Topics
- Fluids in motion
- Flow control
- Viscous pumps and microturbines
- Microtechnology

Dr. Brian Hinderliter
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Research Topics
- 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 initiation
- Nuclear power plant design, thermal hydraulics, and radiation transport for shielding design
- Health and safety aspects related to health physics

Dr. Muammer Koç

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Research Topics

- Manufacturing processes and systems
- Product and process design
- Micro/nano-manufacturing
- Design and manufacturing of alternative energy devices (such as fuel cells) and medical devices
- Design and manufacturing of nano/micro-scale functional surface structures
- Deformation mechanics, tribology, and process in material forming plasticity
- CAE applications in design and manufacturing

Dr. P. Worth Longest

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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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Research Topics

- Photovoltaic materials and devices
- Power generation
- Energy conversion systems
- Engineering education
- Optical characterization of semiconductor materials

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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

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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, etc.)
- Energy scavenging using pyroelectric and piezoelectric materials for low-power electronics

Dr. Ramana Pidaparti

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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

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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

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Research Topics

- Smooth muscle biomechanics
- Developing robotic devices for medical applications

Dr. Vishnu Sundaresan

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Research Topics

- Applied membrane biophysics
- Active implantable material systems

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Research Topics

- Modeling and experiment on water jets and nozzle cavitation
- Aerosol flows and nanoparticle filtration
- Nanoparticle focusing and deposition
- Fluid transport in fibrous porous media
- Heat and mass transfer
- Molecular dynamics simulation of granular materials

Dr. Gary C. Tepper

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Research Topics

- Chemical and biological sensors
- Nanomaterials
- Molecularly imprinted polymers
- Radiation detectors
- Supercritical fluids
- Electroprocessing of polymers

Dr. Amy L. Throckmorton

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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

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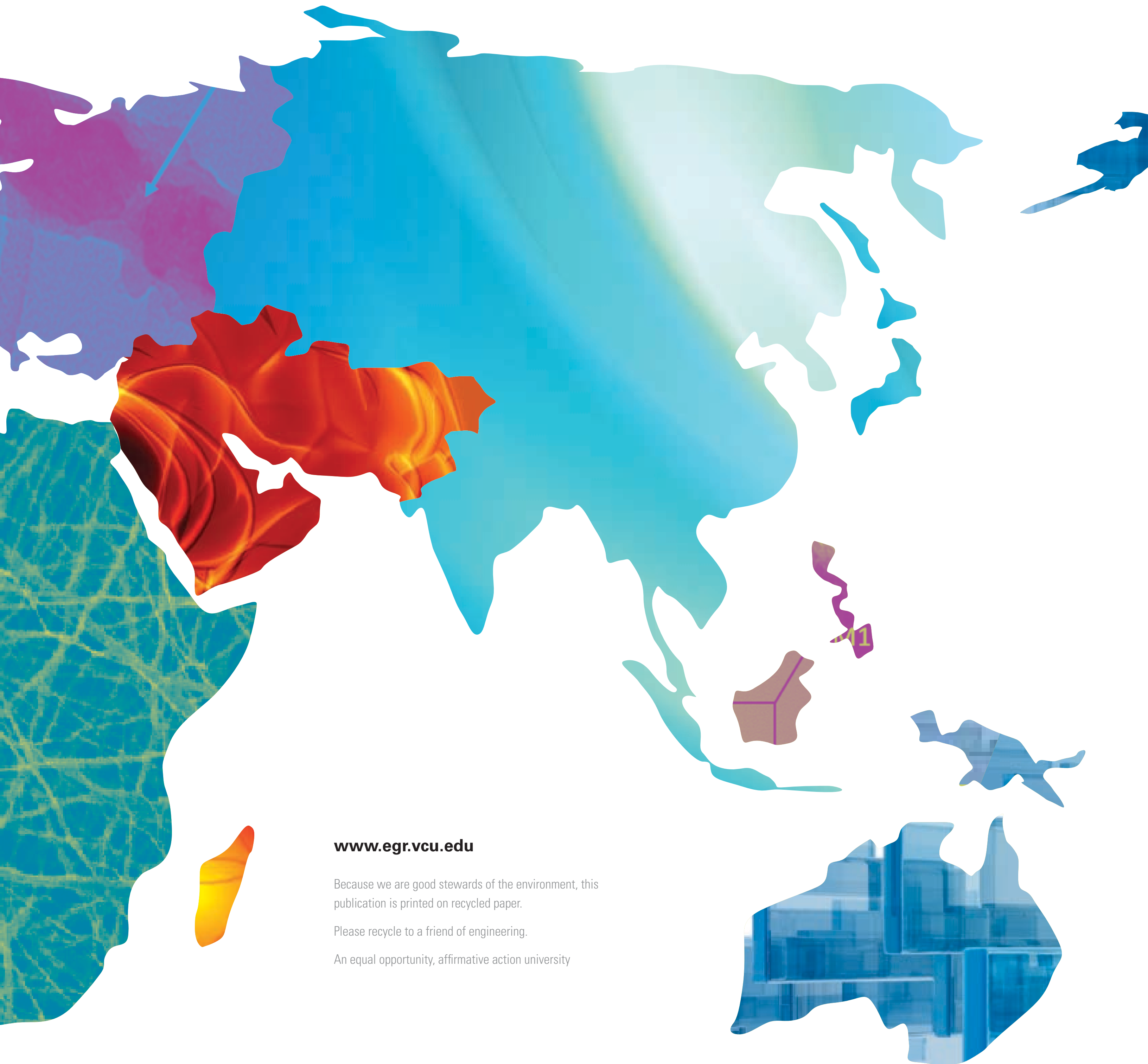

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