

VCU School of Engineering

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C O N N E C T C O L L A B O R A T E T R A N S L A T E



FROM THE DEAN **VCU** School of Engineering

Welcome to this overview of ongoing research at the Virginia Commonwealth University School of Engineering. As one of the newest schools of engineering in the United States located on the campus of the largest university in the Commonwealth of Virginia, we have embraced translational and transformational research. The engagement of economies and cultures in a world of remarkable interconnectivity draws the research community closer in the search for global solutions to shared problems. Among our faculty are internationally recognized experts in genomics, energy, nanomaterials, tissue engineering, quantum computing, and semiconductors. These researchers and their students are intimately connected to colleagues here and elsewhere who share our vision.

We believe that the future of research is in interdisciplinary collaboration. As you read these research summaries, I invite you to contact the individual faculty members involved to get more information or to explore opportunities to work together. We welcome experts, and those who want to be, to join us in engaging the grand challenges of the 21st century.

Russell D. Jamison, PhD

CONTENTS

2

Harvesting Energy

Dr. Karla Mossi

4

Developing Systems for Faster
Response to Traumatic Injury

Dr. Kayvan Najarian

5

Turn Up the Heat

Dr. Muammer Koç

6

Micro Solutions for Drug
Synthesis: Chemical Process
Development Laboratory

Dr. B. Frank Gupton

8

Information Processing
That is Multidimensional

Dr. Dianne T.V. Pawluk

10

Think Fast: Computer Models
and Multisensory Processing

Dr. Krzysztof Cios

12

Single Molecule Insights
Into the World of Protein
Interactions

Dr. Vamsi K. Yadavalli

14

Giving Kids a Chance:
Bench-to-Bedside
Development of Artificial
Heart Pumps

Dr. Amy L. Throckmorton

16

Microfabrication Technology:
The Picks and Shovels of the
Nanotechnology Gold Rush

Dr. Gary M. Atkinson

18

Unmanned Aerial Vehicles:
The Newest Tools in the Skies

Dr. Robert H. Klenke

20

Faculty

25

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Harvesting

Dr. Karla Mossi

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Dr. Mossi holds a pre-stressed piezoelectric laminate that reacts to mechanical pressure by converting stress to electrical energy.

Energy is all around us while we walk, eat, sleep—even while you read this magazine. Imagine that energy could be harvested from our day-to-day actions. Harvesting energy, which would otherwise be wasted, can be used in such a manner that the operational life of commonly used devices becomes longer; batteries do not need to be recharged, and, in fact, are not needed at all. This is particularly advantageous in systems with limited accessibility such as biomedical implants and structures with embedded micro and wireless sensors. With advances in design and manufacturing of electronics as well as reduced power requirements, the use of energy harvesting methods have become practical and have gained significant popularity. It is also feasible for such devices to generate their own power from the ambient environment reducing maintenance costs and decreasing the complexity in systems.

There are several types of ambient energy which exist in nature that can be harvested. Heat, electricity, solar, and biomass are forms of energy that are stored differently, but can be converted from one form to the other. Photocells convert light to electricity, thermocouples convert heat to electricity, and magneto-electric generators convert mechanical energy to electricity. These are all power generators and are frequently used in electricity generation.

Among the different materials that can be used for energy harvesting, piezoelectric materials are the material of choice because they contain a spontaneous dipole moment that can be reversed in an electric field. When piezoelectric materials are stimulated, a charge is developed on the surface of the material which can then be harvested into usable energy. In addition, the popularity of these materials has increased tremendously as they are reliable, relatively inexpensive and easily available. Due to their excellent properties as well as their simplicity, piezoelectric materials can be tailored to specific applications. For instance, they can be made small enough to fit inside micro electromechanical systems (MEMS). Until recently, piezoelectric materials as power conversion mechanisms were neglected because of their small electrical output. However, with advances in integrated circuit technology this is no longer an issue.

There are many piezoelectric materials from which to choose for designing a power conversion mechanism. Since vibrations occur in most dynamic systems and it is a source of energy not usually harvested, vibrations are one



Energy



of the energy sources that have been investigated as a stimulus for piezoelectric materials. In this particular area, piezoelectric materials are usually chosen because of their wide dynamic range and low output noise. Researchers around the world have demonstrated power densities of $250\text{mW}/\text{cm}^3$;¹ 1.8mW of power from a piezoelectric membrane vibrating between $0\text{-}5\text{g}$;² and a piezoelectric insert in a shoe that can be used for harvesting energy while walking.³

From the many piezoelectric materials available, ten are ferroelectric crystals that can also be termed pyroelectric. Some examples of these types of materials include BaTiO_3 , PbTiO_3 , PbZrO_3 , and NaNbO_3 . The charge developed by a pyroelectric material over the electrode surface area of a ceramic is proportional to the temperature gradient and the pyroelectric coefficient. Hence these materials can convert a temperature gradient to electricity. One widespread application of pyroelectric materials is in the use of infrared detectors that convert the changes in incoming infrared light to electric signals. The spontaneous dipole moment is then altered by temperature changes as infrared light illuminates the elements. In 2005, the pyroelectric properties of LiTaO_3 were used

to generate and accelerate a deuteron beam at a deuterated target. The result was “desktop” nuclear fusion.⁴

All applications of piezoelectric generators, however, are application specific such that a common solution does not exist. Hence, suitable circuitry is required to adapt to various applications and power requirements. The purpose of the energy harvesting circuitry is to efficiently convert and filter the signal from the energy harvesting device into a form that can be used by an application. The electrical charge generated from the device is usually insufficient to power a commercial sensor, but by rectifying and regulating the signal a usable voltage can be applied to the sensor directly or used to charge a battery (Elvin, Elvin, and Choi, 2005).

The focus of the work at VCU’s Smart Materials Laboratory is to optimize the energy harvesting material, design the appropriate signal conditioning circuitry and determine the best way to transfer the harvested energy to specific applications. The team in particular is studying pre-stressed piezoelectric composites with increasing success in harvesting larger energy densities than conventional materials.

1 Roundy, Wright, P.K., Rabaey, J., *Energy scavenging for wireless sensor networks : with special focus on vibrations*, Boston, MA: Kluwer Academic Publishers, 2004.

2 M. Ericka, Vasic, D., Costa, F., Poulin, G., Tliba, S., “Energy harvesting from vibration using a piezoelectric membrane,” *Journal de Physique IV France*, vol. 128, pp. 187-193, 2005.

3 Kymissis, J., Kendall, C., Paradiso, J., and Gershenfeld, N. (1998). “Parasitic Power Harvesting in Shoes,” *Second IEEE International Conference on Wearable Computing (ISWC)*, IEEE Computer Society Press: 132-139.

4 Naranjo, B. Gimzewski, J.K.; Putterman, S. (2005), “Observation of nuclear fusion driven by a pyroelectric crystal,” *Nature*, v 434, n 7037, p 1115-17.



Dr. Kayvan Najarian

Associate Professor,
Department of Computer Science

of care. In other words, the computer-aided system integrates the new data made available at any new stage into the system and provides not only updated predictions/recommendations but also recommendations/predictions for new decision-making scenarios. In this project, the focus is to extract quantitative features from CT/MRI images, some not visible to human eyes, and to combine these features with those captured from other physiological signals to present physicians with diagnosis and/or recommendations. This project will also provide reliable and quantitative measurements from CT/MRI images that can be used for a number of surgical decision-making processes. For instance, a method is being designed for processing CT images to predict the intracranial pressure (ICP), for which the preliminary results are very promising. Advanced visualization methods are designed to allow effective interaction between physicians and the algorithms. These visualization methods allow physicians to render 3D images and navigate through different parts of the processed images using a highly interactive system.

Another element of this project is forming a computer-aided decision making system for traumatic pelvic injuries. The second most common injury diagnosis in frontal impacts is internal abdomen or pelvic injuries—constituting at least 58% of cases. In this project, advanced signal/image processing and machine learning methods are applied to analyze patient images, such as CT and X-ray; physiological signals which include ECG, blood pressure and respiration; demographics and injury information to create a set of rules as recommendations for both diagnosis and treatment.

Image processing methods developed for this project allow not only detection of fracture(s) but also quantitative analysis of the fracture such as the number of bone pieces and the size of the gap among the pieces. These methods also detect hemorrhage and measure its severity by processing the CT images. All the measures captured from the images and signals are used to form quantitatively evaluated recommendations/predictions to physicians.

The computer-assisted trauma decision-making project conducted at Dr. Najarian's lab is a multi-institutional collaboration that involves Virginia Commonwealth University and the Carolinas Healthcare System.

DEVELOPING **Systems** for FASTER RESPONSE to **Traumatic Injury**

The designing of advanced image processing and machine learning methods to analyze a patient's biomedical images and signals in a typical trauma case can provide physicians with real-time quantitative predictions and recommendations. The current project defines new strategies for diagnostics and treatment in both civilian and military settings. Dr. Kayvan Najarian's active involvement in Virginia Commonwealth University Reanimation Engineering Shock Center (VCURES) has enabled him to design, develop and implement revolutionary approaches in trauma care using engineering methods.

Trauma is the leading cause of death for Americans under the age of 45. As such, injury research has become a federal priority, particularly since the survival rate has not improved in the last decade. Many fatal complications and long-term disabilities can be reduced with more objective and accurate clinical decisions. In order for care givers to make better decisions, they need access to all relevant clinical data using advanced computational methods as opposed to simple visual inspection. This research focuses on

designing computational methods for building computer-aided systems that will analyze all patient information. These computational methods extract diagnostically important knowledge that is hidden to the human eyes in order to assist trauma experts in making better and faster decisions.

Currently being developed are computer-aided decision making systems for all types of traumatic injuries in particular traumatic brain and pelvic injuries. Among all causes of death and permanent disabilities, traumatic brain injury (TBI) is the most prominent. Despite the abundance of information existing in CT images and biomedical signals such as blood pressure and heart rate, no digital signal/image processing tool is currently used in TBI care to extract this information for real-time clinical use and decision making. The inclusion of the processed signal/image level information has the potential to significantly improve the overall clinical approach towards TBI care. To fulfill this need, this ongoing project designs a "floating/evolving" computer-aided system that acquires, processes and integrates all clinical data to support decision making at every stage



Turn Up the HEAT

One of the basic elements of fuel cell stacks is the heat and mass transfer plates known as either bipolar plates in PEMFCs or interconnect plates in SOFCs. Their main functions are to (1) equally distribute the gases (hydrogen and oxygen) to anode and cathode surfaces for electrochemical reactions, (2) structurally support the MEA, and (3) transmit the electrons. Thus far, various methods are developed to fabricate such plates addressing their needs for efficient flow field designs, weight and volume, contact resistance and cost. For the interconnect plates, based on the type of SOFC whether it is an anode supported, electrolyte supported or interconnect-supported plate, there are various methods of fabrication and types of materials used. For the interconnect-supported type, micro-channeled stainless steel alloys are being developed as they promise a remarkable cost reduction.

Regardless of whether it is a PEMFC or SOFC, alternative surface structures on these plates have been developed in order to increase the efficiency of fuel cells

and reduce weight and cost. Micro-scale porous surface texture on the metallic bipolar/interconnect plate can enhance the thermal and chemical reaction properties, and hence, increase the efficiency and performance of a fuel cell (i.e., kW per weight or kW/volume). The benefit of such innovative plate concept utilizing porous surface structure has been demonstrated previously using metallic foams. However, the cost of such thin foams is high, and only passive control of the porosity is possible. Modulated porous surfaces at micro-scales (i.e., micro-channels or micro-bump arrays on a large surface) were found to enhance the heat transfer efficiency up to 300% when compared to plain surfaces.

It has been reported that functionally engineered surfaces with micro-scale features and porosity can enhance the heat/mass transfer mainly by offering (a) increased surface area in a given volume and mass; (b) capillary-assistance to liquid flow effect; (c) increased nucleation site density; (d) enhanced vapor escape paths; and (e) increased catalyst loading

Dr. Muammer Koç

Associate Professor, Department of Mechanical Engineering

capacity. This type of surface can also find applications in fuel processor or reformers to obtain high purity hydrogen and in biomedical devices.

However, their fabrication under mass-production conditions for marketable and cost-effective products requires well established process parameters. In our study, warm compaction of copper powders onto thin copper solid substrates has been experimented with under different compaction pressure (15-50MPa), temperature (350-500°C) and surface geometry (flat, large and small channeled) parameters using a design of experiment (DOE) approach to determine the proper fabrication conditions. Porosity and bonding strength of compacted samples were measured to characterize their feasibility for heat transfer applications.

Micro Solutions for Chemical Process Development Laboratory

Traditionally, the chemical processes used to produce Active Pharmaceutical Ingredients (API's) have been batch-oriented unit operations. Technical, financial and regulatory issues have had a significant influence on this mind set. From a technical perspective, bench-scale process development is carried out on a batch basis. As a laboratory process evolves through the various stages of drug development into commercial operations, the batch mode perspective is usually retained. Financially, the raw material costs associated with these processes are significant due to the level of chemical complexity of the building blocks required for the synthesis. Batch mode operations can mitigate the risk associated with production excursions resulting in off-spec material. By operating in a batch mode, the financial exposure from a production excursion can be easily isolated to the affected number of batches. Likewise, regulatory control of product quality can be readily managed on a lot-to-lot basis in a batch production mode.

In contrast, chemical processes for industrial (non-pharmaceutical) applications are typically continuous due to their lower capital and operational requirements. These processes are more automated and are therefore less labor intensive. Equally important, non-pharmaceutical processes are not subject to the same regulatory constraints as those used for the production of API's. However, both batch and continuous processes can be subject to significant challenges during the various stages of scale up to commercialization.

Recent advances in the development of microreactor technology offer the opportunity to combine the advantages of both continuous and batch operations in pharmaceutical applications, while minimizing the issues associated with process scale up. These highly machined

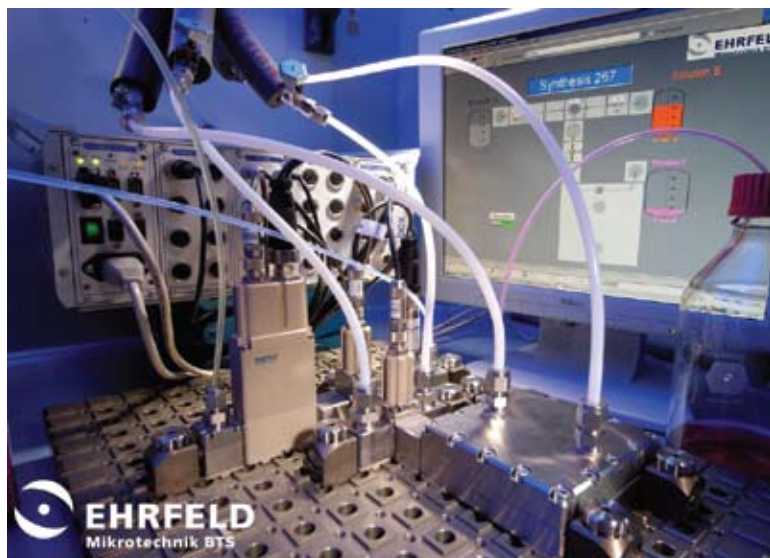
desktop production units are especially suited for extremely exothermic reactions. Reactions typically requiring hours for completion can be carried out within seconds. These devices are also capable of carrying out chemical reactions in reaction volumes ranging from microliter to multi-liter scale. In addition, they can tolerate extreme reaction conditions including temperatures up to 650°C and pressures up to 100 bar. Although microreactor technology also offers the advantage to significantly lower capital investment requirements, it can be limited in applicability by reaction kinetics. Due to the inherently shorter residence time associated with these systems, chemical processes with slower reaction rates may not be suitable for this technology.

One of the most effective methods for increasing the rate of chemical transformations is by microwave (MW) irradiation. Microwave heating of chemical reaction media has been utilized routinely in bench-scale synthetic applications as well as in high throughput drug development. The ability to uniformly heat reaction media with microwaves not only results in the acceleration of reaction rates but also increases yields and minimizes byproduct formation. To date, this technology has been confined to laboratory-scale applications due to current limitations in microwave technology as applied to larger commercial-scale chemical operations.

Because of the scale of operation associated with microreactors, our group has focused on the application of accelerating reaction rates by coupling microwave irradiation with these devices. We anticipate that this will broaden the window of commercial applicability for both of these technologies. Our group is currently evaluating the application of these systems with the synthesis of multi-functional benzimidazoles, which are strategic precursors in pharmaceuticals directed at anti-arrhythmic and anti-viral applications. In addition, our group is assessing the use of VCU-developed nano catalysts in these systems. We expect that a range of chemistry from hydrogenations to cross coupling reactions may be carried out utilizing this high throughput methodology at every stage of drug development. During the development of these processes, in-line infrared spectroscopy will be used as a tool to evaluate process variability, emulating currently employed commercial-scale quality control operations.

It is the overall objective of our group to develop common efficient methods applicable to the synthesis and production of drug substances at the laboratory, pilot and commercial scale operations. It is our expectation that in doing so, this will promote streamlining the chemical process development component of drug development.

Pictured at left, commercial scale chemical and pharmaceutical production can be performed using this desktop microreaction system for organic synthesis.



Drug Synthesis



Dr. B. Frank Gupton

Professor and Interim Chair,
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A woman with short blonde hair and glasses, wearing a teal turtleneck and a dark beaded necklace, is looking down at a large sheet of paper with embossed Braille. The background is a dark blue wall with a grid of small, circular, metallic-looking protrusions.

Dr. Dianne T.V. Pawluk

Assistant Professor, Department of
Biomedical Engineering

Information Processing that is **Multidimensional**

Haptic Graphical Displays and Display Methods for Individuals who are Blind or Visually Impaired

Graphical visual representations have always been important for conveying unfamiliar information, such as learning about new objects and places, the spatial layouts of buildings and other areas, and how to use machinery and devices. They are also very valuable in creative environments, such as when artisans must interpret intricate design patterns or engineers develop new devices. Unfortunately, for individuals who are blind or visually impaired, there are a dearth of tools and appropriate representations to provide them with access to the graphical information commonly available in their environments (e.g., at school and in the workplace). This lack of access affects these individuals beginning at a very young age and progresses cumulatively over their lifetime. It likely explains, at least in part, the very high unemployment rate of 74% for individuals who are blind or visually impaired, which is significantly above the rate for those with other disabilities. (*Braille Monitor*, 2000)

Although word or auditory descriptions may sometimes substitute for graphics, there are many situations for which these substitutes are simply inadequate. One example is in teaching young children about objects that are not readily available or that cannot be physically handled without danger—it is difficult to replace pictures with words if a child's vocabulary has not yet fully developed. Often looking at pictures and picture books is the way young children acquire a basic vocabulary, as well as basic relational concepts such as “up” and “down.” In contrast to the very limited resources for children who are blind or visually impaired, there is a staggering amount of resources for sighted children to discover objects and their relationships through colorful, engaging books with numerous pictures. This can be critical, inasmuch as limitations in the variety of information to which a child is exposed can negatively impact a child's cognitive, emotional, neurological, and physical development. (Dept. of Health & Human Services, 2005).

Another example of the inadequacy of words is that the ability to discover patterns and spatial relationships in graphically presented information is lost when replacing the graphic with words. For instance, displaying time series data and its analyses in a graph or, more typically, multiple graphs in succession, is a fundamental way of enhancing insight into an experiment. The process of turning the data into a “word description” is the most valued part of the research. Another example is in describing concepts involving mathematical waveforms (e.g., a sine wave and

the concept of phase), which are poorly conveyed when relying on text or sound alone. However, the concepts described are often critical to understanding all fields in science and engineering. This is also true for geography, where diagrams are important for examining the inter-relationships between such features as topography, natural resources, population and cities.

In the workplace, in addition to analyzing data in a variety of fields, graphically displayed information is often needed from the onset to learn the layout of the work environment and to learn about machines and devices that must be operated. Access to graphical information can enable an employee to assume more tasks independently, such as for a retail manager to be capable of rearranging the layout of a store. This can, in turn, improve the individual's job function and value to his or her employer. Graphical information is also important for an individual's control over his or her own safety and work environment. For example, a machine operator learning the job may be unsure how a machine operates. Rather than trusting the word instructions someone has provided, he can rely on his own ability to obtain information about his safety.

The most frequent method of representing 2D graphical information for individuals who are blind or visually impaired is the use of static raised-line drawings. However, this method is very poor in relaying information in unconstrained tasks, such as those mentioned above. The general project objective is to develop (1) highly interactive and (2) enriched representations of haptic graphics which will improve the user's ability to make discoveries or propose explanations about patterns, groups of items or individual items. The highly interactive graphics proposed will allow the user to actively control both the magnification and simplification of a graphic during its examination. This will allow the user to make trade-offs between the two main limitations of haptic processing: the need to serially integrate information and poor tactile spatial resolution. The enriched representations proposed will use texture or vibration as a way to encode the separation of a graphic into objects and object parts, and describe the 3D orientation of parts—two of the most difficult aspects of interpretation.

As the project emphasizes the discovery of information and relationships that cannot be obtained by other means, its intent is to open up access to areas that have been traditionally very difficult for people who are blind or visually impaired to access.

Think Fast

Computer



Dr. Krzysztof J. Cios has been working closely with neuroscientists for more than a decade. His interest in learning more about how the brain learns arose from his research in computer learning algorithms. His initial research, using a simple model of the neuron, led to the development of several artificial neural network algorithms. Such networks build “black box” models of data, not easily interpretable by humans, based on available training data consisting of known inputs with corresponding outputs. The developed computer learning algorithms, although performing on par with the best such algorithms in the field, were realized to be inferior to the nervous system in solving difficult tasks such as image processing and recognition. The realization of this gap between computer and brain learning led to the collaboration with neuroscientists to study neural processing in order to develop algorithms that would perform in a way comparable to the nervous system. Such an approach, known as biomimetics, involves learning how living organisms solve problems and then constructing algorithms to perform the same.

Initially Cios studied plasticity of the somatosensory cortex and modeled organization of the somatosensory cortex and its reorganization after injury, based on data collected on primates. Somatosensory structures contain map-like representations of the body, which first need to be learned. This process, also called organization, can later be modified if need be, a process called reorganization or brain plasticity. To model the two processes, a network of spiking neurons consisting of complex integrate-and-fire artificial neuron models was designed. Although the modeling was successful, it was not adequate to solve complex practical problems. However, success was realized in using the network of spiking neurons for solving problems like finding the shortest path in a graph or finding natural groups (clusters) in data without any supervision. Note that clustering is the most important and difficult

problem in analysis of data about which no knowledge exists.

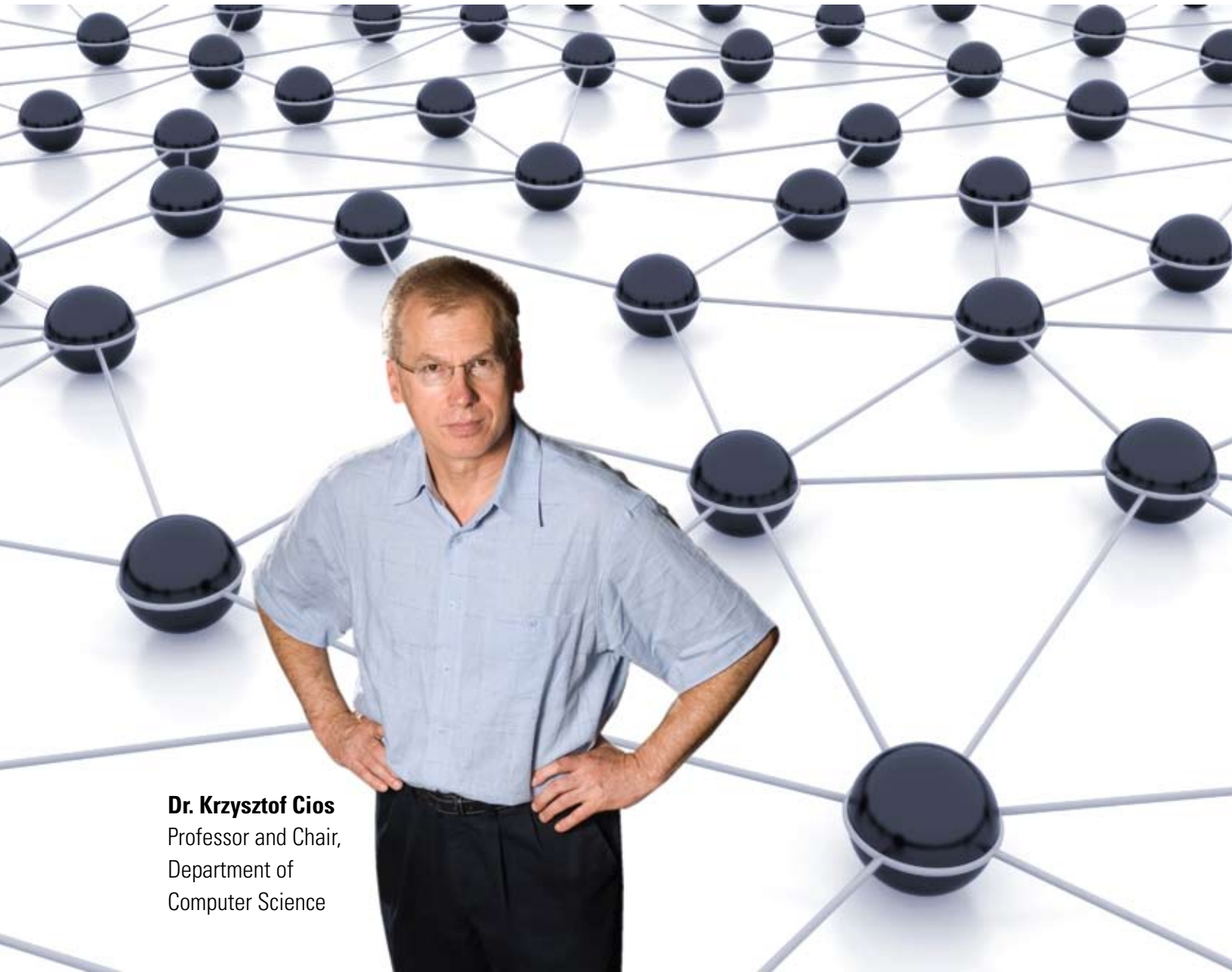
Further studies involved modeling of the hippocampus, and in particular, the onset and ending of epileptic seizures, an uncontrolled chaotic simultaneous firing of all neurons. Investigation led to the development of a new learning/synaptic plasticity rule. Such rules are used to update strengths of connections between neurons. The developed rule was dynamic, meaning that instead of using some pre-defined function for updating the connections it used the actual post-synaptic potentials between neuron. It was the first-ever such rule. Using the network and the learning rule for image analysis, the network was able, on its own, to detect edges in the images.

The focus of current work is on multisensory processing, i.e., neurons that respond to stimuli, from more than one sensory modality, such as both vision and hearing. Multisensory processing is believed to underlie numerous perceptual phenomena, such as early childhood learning, language perception, stimulus detection and localization as well as perhaps being involved in crossmodal plasticity that results from the loss of one sensory modality (e.g., blindness, deafness). Because the requisite first step in all of these functions is the convergence of information from different sensory systems onto individual neurons, the modeling of multisensory convergence and the resulting processing effects using networks of spiking neurons is now being investigated.

In the future, based on better understanding of the brain, it will theoretically be possible to design algorithms that perform on par with humans. For example, a network of spiking neurons should be able to analyze an image with little supervision (learning) and be able to recognize objects on its own, be it an enemy plane or a cancer cell. Presently, even the fastest supercomputers cannot perform this task with the accuracy and speed of humans, but this method of approach is leading to its eventuality one day.



Models and Multisensory Processing



Dr. Krzysztof Cios
Professor and Chair,
Department of
Computer Science

Single Molecule Insights Into the World of Protein Interactions

Molecular recognition between specific receptors and ligands is a key step in many biological processes. It also forms the basis for biosensors that are used to detect analytes in vivo or in the environment. Biorecognition may include enzyme-substrate, antigen-antibody and lectin-carbohydrate binding. While most biological and biochemical assays study the interactions of proteins at a bulk or ensemble scale, it is now recognized that biological systems are much more complex and involve a host of non-equilibrium states in space and time. One approach to uncover these unique pathways is to study biomolecules at the single molecule level.

Our main research tool is single molecule imaging and force spectroscopy using atomic force microscopy (AFM). The AFM is a powerful technique that allows us to directly observe and manipulate single molecules of proteins, other biomolecules (e.g. DNA) and polymers. We use the AFM not only as a high resolution imaging tool but also to measure the mechanical properties of proteins, observe interaction profiles and study the spatio-temporal folding/unfolding landscapes of proteins. The ability to observe these events under physiological conditions and at levels on the order of a few nanometers offers unprecedented insight into the world of proteins.

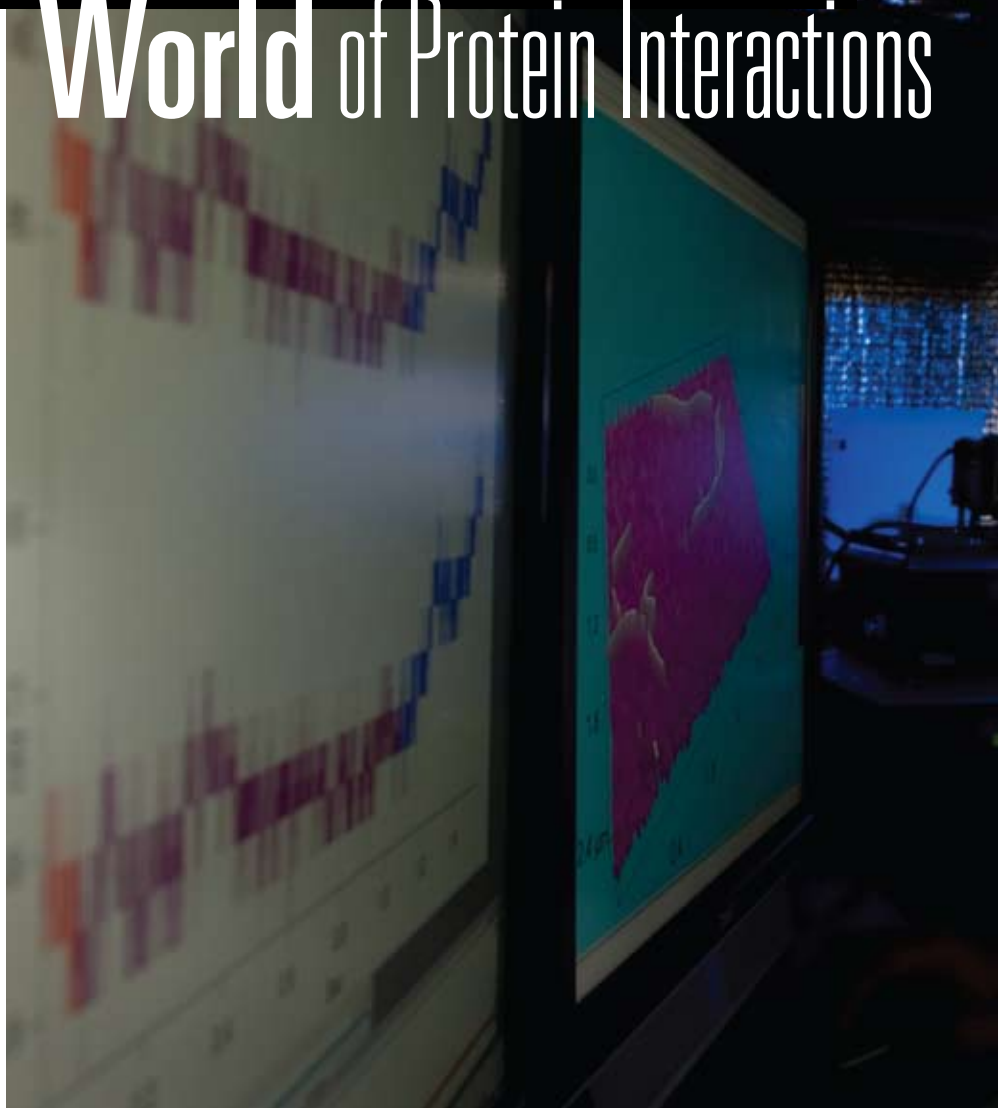
The objective of our research is to develop experimental strategies that can elicit structural and biophysical information about processes such as biomolecular recognition and molecular self-assembly at the single molecule level. We attempt to understand the mechanical properties of proteins (e.g. structural proteins, molecular motors) at the single molecule level. We can then use techniques such as self-

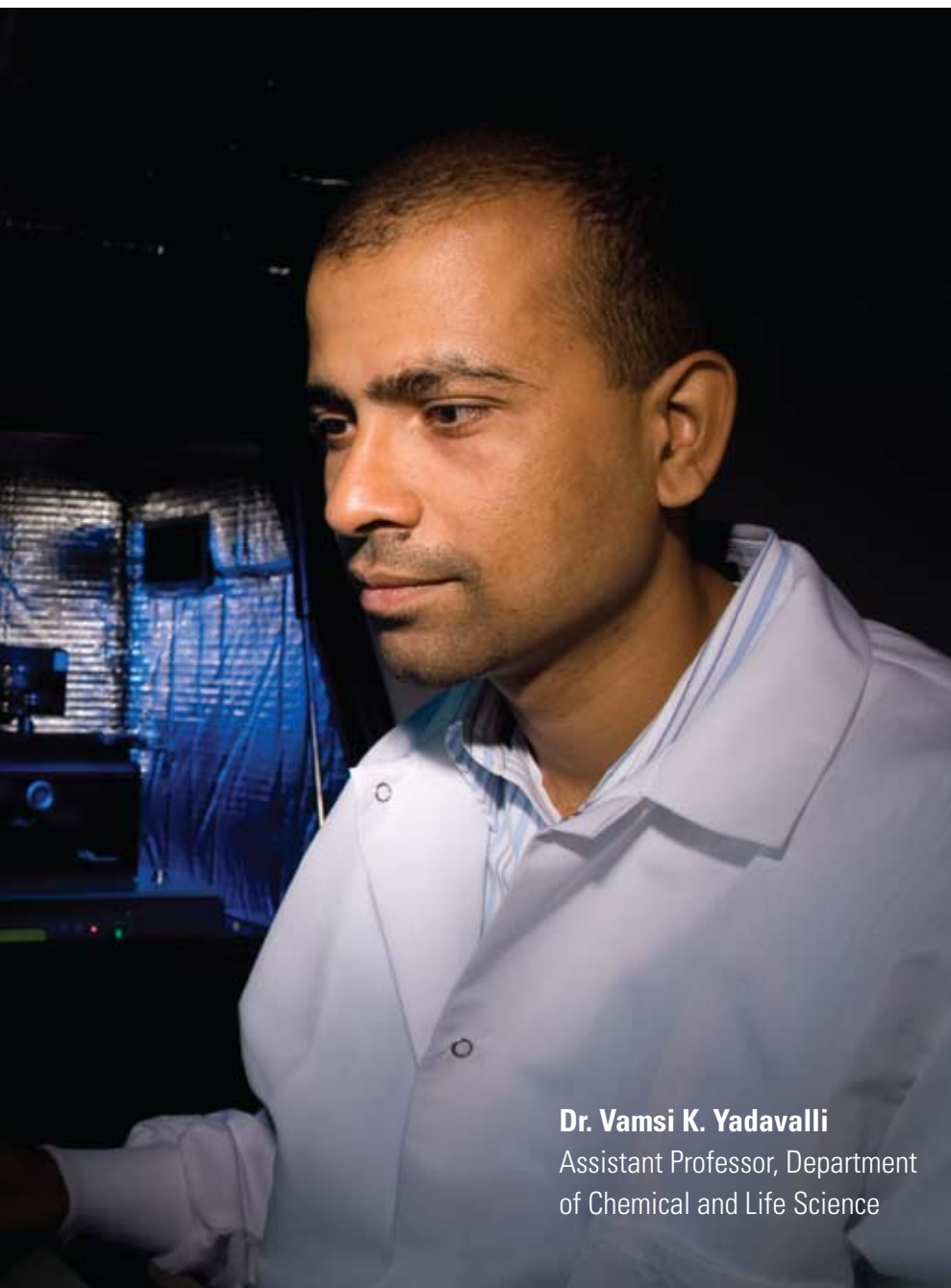
assembly to fabricate protein/synthetic polymer complexes with tailored mechanical properties to be used as functional and structural components for smart materials and nanomechanical devices.

The key questions we are attempting to answer are: Can we use engineering principles to combine biophysical measurements with transduction strategies and fabrication tools to create portable bench-to-bedside diagnostic devices and ultrasensitive biosensors, and can we use these

single molecule studies to develop novel materials for bio and nano technology?

One of our current projects involves the force mapping of protein-carbohydrate interactions on single molecule arrays. Carbohydrates are important biomarkers in the process of biomolecular recognition and the regulation of a multitude of complex biological functions. Interactions with specific carbohydrate binding proteins (lectins) form an important part of cell-surface recognition and cellular





Dr. Vamsi K. Yadavalli
Assistant Professor, Department
of Chemical and Life Science

signaling pathways. Advances in microarray technologies have led to carbohydrate microarrays emerging as tools for high-throughput glycomic research. The usefulness of carbohydrate arrays depends on how diverse libraries of ligands are immobilized on a surface and how other biomolecules interact with them, primarily elucidated in bulk measurements. The fundamental interaction forces that govern the recognition and binding/unbinding process have

yet to be clearly understood. In addition, the isolation of natural glycans in large amounts needed for fluorescence or bulk analysis has tended to be a limiting factor in the application of arrays. Our approach is to uncover the force signatures of a single molecule lectin-carbohydrate binding pair and understand and ultimately identify the specific interaction event. Force signatures are captured by bringing a pair of molecules in contact with one another and then

observing their interaction and rupture profiles as they are separated. We can vary the environment and surface conditions to observe their influence on recognition events. Understanding these protein-surface and protein-environment interactions will help in engineering cell-surface interactions and improve the performance and efficacy of glycomic devices and arrays. A cross-disciplinary expertise in materials chemistry, surface science and microfabrication is coupled with protein biophysics to establish devices for such study.

We are also working on the development of hybrid nanomaterials. Hybrid nanomaterials comprising synthetic and biological components have emerged as an exciting option to combine the structural and functional control of biopolymers with the adaptability of synthetic polymers. Such bioinspired and biomimetic materials have widespread applications including the development of smart materials such as self-organizing nano-membranes and self-repairing artificial materials. However, the development of most of these materials has been hampered by a lack of insight into the fundamental self-organizing and self-assembly processes that accompany the formation of hybrids. The key to fabricating molecular devices is understanding how these materials assemble and interact at a molecular level. We are investigating the self-organizing process of collagen fibers with synthetic polymers at a single molecule level using a “bottom up construction” of hybrid nanomaterials. We are developing theoretical and experimental strategies to optimize the fabrication of hybrid synthetic polymer-collagen biomaterials into novel nanostructures via chemical and environmental methods.

This research integrates surface chemistry, materials engineering and experimental tools with knowledge of proteins, their behavior and nanomechanics. Specifically, interfacial characterization tools, fluorescence and atomic force microscopy are used for a better understanding of how to build better, smaller and more efficient devices.



Giving Kids a Chance

An estimated eight million children are born each year with a serious heart defect which requires surgery, according to the 2006 March of Dimes study carried out in 193 countries [1]. In the United States alone, approximately one million babies are born with a congenital heart defect in need of corrective treatment. Of this cohort, the treatment of single ventricle anomalies represents a formidable challenge for clinicians caring for patients with congenital heart disease. In the first year of life, single ventricle heart defects are the leading cause of death from all structural birth defects in the United States [2]. These surgeries are also among the highest risk operations performed in a pediatric cardiac unit.

For single ventricle patients, surgical palliation is achieved in three staged operations. In the neonate, the first operation is performed and is known for mortality since blood flow to the lungs must be supplied by a systemic-to-pulmonary arterial shunt. When the risk of elevated pulmonary vascular resistance is low, a second operation is then completed to disconnect the systemic-to-pulmonary arterial shunt. Blood flow to the lungs is then supplied by connecting the vena cavae to the pulmonary artery during the final palliative procedure (cavopulmonary connection). The end result is a 'man-made' physiology that has a single functional ventricle to drive blood flow through the systemic circulation and no right ventricle to pump venous return through the lungs. The compliant venous circulation must adapt to a higher pressure for blood to flow passively through the lungs. This significant alteration of venous return contributes to early and late pathophysiology and comorbidities [3].

The overall survival through these operations is 50% to 70% [3, 4], and those who survive have lifelong physical limitations and costly hospitalizations. As a result, individuals with a univentricular Fontan circulation or cavopulmonary connection are at high risk of developing complications of systemic venous hypertension, thromboembolism and congestive heart failure [5]. Stenotic lesions may also develop within the pulmonary arteries and lead to hypoplasia, thromboembolism, limited exercise capacity, arrhythmias and protein losing enteropathy [6,7]. Approximately 25%

Bench-to-Bedside Development of Artificial Heart Pumps

Dr. Amy L. Throckmorton

Assistant Professor, Department of Mechanical Engineering

of the first generation of Fontan recipients will develop heart failure within 15 years postoperatively [7]. The second generation of Fontan recipients, having had a modified procedure, appear to be living longer with 87% surviving to 10 years [8]. Heart transplantation for these patients is a treatment option, if they can be medically stabilized and survive the organ waiting period [9]. In pediatric patients, transplantation has a mortality of 14% and an operative mortality of 27%, including a lifetime of immunosuppressive therapy and a high probability of noncompliance [10].

Clinicians have theorized that a mechanical pump specifically designed to augment flow from the great veins through the lungs would ameliorate the poor physiology of the univentricular circulation. At present, no pediatric blood pump has received premarket approval from the Food and Drug Administration (FDA) for cavopulmonary assist in patients with failing single ventricle physiology. Clinically available mechanical blood pumps were designed and developed for the systemic circulation, not the unique cardiophysiology of the cavopulmonary connection. These devices produce pressures far in excess of the desired range to be used for cavopulmonary support. Pressure rises of as little as 5 to 10 mmHg may be sufficient to stabilize and reverse hemodynamic deterioration. In an effort to provide more options for the treatment of pediatric patients that experience cardiopulmonary failure, the National Heart Lung and Blood Institute (NHLBI) launched a program in 2002 to support the development of pediatric blood pumps. The NHLBI awarded funding to five contracts, but all of these pumps are being developed for the pediatric systemic circulation, not the Fontan circulation.

The BioCirc Research Laboratory at the Virginia Commonwealth University under the direction of Dr. Amy Throckmorton, Assistant Professor of Mechanical Engineering, is designing and developing a unique cavopulmonary assist device for these sick infants and children. More specifically, as a bridge-to-transplant, bridge-to-hemodynamic stability, or bridge-to-Fontan conversion, they are developing a collapsible, percutaneously placed, axial flow blood pump. Mechanical pressure augmentation of blood flow in the cavopulmonary circulation would reduce elevated systemic venous pressure, increase ventricular preload and improve survival.

The blood contacting regions of the axial pump will consist of a rotating impeller with helically wrapped blades around the hub and a protective cage to prevent contact between the rotating blades and the vessel wall. The impeller blades and cage filaments will retract and fold to allow percutaneous placement. After insertion into the larger central veins, the cage and blades will expand to provide mechanical cavopulmonary support. A combined-motor bearing suspension will be employed to levitate the rotor within the protective cage and generate sufficient energy to induce rotation. The operating range is 50 mL/min to 4 L/min with a pressure generation of 5 to 20 mmHg at rotational speeds from 3000 to 9000 RPM. We have generated pilot data through numerical modeling and hydraulic performance testing pump prototypes to demonstrate the feasibility of this approach.

This research team combines a broad expertise in engineering, pediatric cardiology and cardiothoracic surgery, radiology, blood pump development, and manufacturing experts through a

multidisciplinary collaboration among the School of Engineering at the Virginia Commonwealth University, School of Medicine at the Virginia Commonwealth University, School of Engineering at the Georgia Institute of Technology, School of Engineering and Medicine at the University of Virginia, ThreeD Design and Manufacturing LLC (Powhatan, Va.) and Windings Incorporated (New Ulm, Minn.). This collaborative spectrum of engineers, manufacturers, and clinicians presents an exciting opportunity to achieve a bench-to-bedside development of this cavopulmonary assist device.

In addition to the development of an effective cavopulmonary assist device, a main objective is to numerically and experimentally examine mechanical circulatory assist of the univentricular Fontan physiology. This objective will be accomplished through the following aims: 1) characterization of the interaction of mechanical assist in a simulated total cavopulmonary connection; 2) performance of flow visualization on a plastic prototype of the cavopulmonary circulation and a blood pump configuration; and 3) blood bag experimentation using fresh bovine blood to measure the hemolytic levels as generated by the interaction of the cavopulmonary flow and mechanical circulatory assist.

This research will answer critical hypothesis-driven and technology-driven questions regarding a new therapeutic option that will provide mechanical assist to patients with failing single ventricle physiology. The work proposes new approaches to circulatory support and will produce new bioengineering findings which may apply to other circulatory support modalities. It will advance the newly emerging field of cavopulmonary assist and substantially contribute to the development strategy of an exciting new therapeutic tool that may revolutionize the treatment approach for patients with single ventricle physiology—addressing a significant human health problem.



The tiny cavopulmonary device developed by Dr. Throckmorton and a collaborative team of researchers could potentially provide life-saving support for babies with single ventricle heart physiology.

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The Picks and Shovels of the Nanotechnology Gold Rush

In the Wright-Virginia Microelectronics Center, research is being conducted on advanced micro and nanoscale devices and systems. Most people are aware of the considerable efforts, a veritable research frenzy, being made in laboratories all across the world to create new types of nanotechnology based materials. People now routinely refer to these as “smart,” “electroactive” or “nanostructured” materials. One often hears the structure of these films being described as nanocomposites, nanotubes, nanowires or nanoflakes. Fabricating these structures currently relies on a variety of techniques, such as nanolithography, plasma, arc or self-assembly. Whatever the approach, this research is often heralded as the new wave of technology that will revolutionize the world as we understand it today, a technological “gold rush” as it were, with researchers and industries worldwide positioning themselves to cash in. What’s important to realize, however, is that it isn’t enough to simply create a new material. Granted, new materials create new capabilities that provide exciting new potential, but in order for us to reap the benefits of a new high performance material, we must somehow incorporate this new material into some useful device or system.

New materials offer the ability to create new high-performance devices and systems, but they must generally be incorporated into some type of existing micro-fabricated or nanofabricated structure in order to take advantage of their useful properties. The method for synthesizing the nanostructures must be incorporated into a fabrication process in which the final result consists of a completed device where the nanostructures, and all their magnificent properties, reside within the device and are

still intact. This is what the Wright-Virginia Microelectronics Center is all about. What was established as a center for microfabricated electronic circuits has evolved into a “micro/nano shop” that is capable of fabricating numerous types of micro and nanofabricated systems. The center currently hosts research in high-K dielectric materials for microelectronics, micro-electro-mechanical systems (MEMS), biomimetic microfluidics pumps and mixers, nanostructured surface acoustic wave sensors, self-assembled block copolymer lithography, and self-assembled quantum dots and wires. In general terms, one can think of the Wright-Virginia Microelectronics Center as one of the advanced centers, mining the ore of our technological future. This is where our advanced microfabrication technologies serve as the picks and shovels of the “nanotechnology gold rush.” One particular example is an area of Dr. Gary Atkinson’s research, the development of nanostructured surface acoustic wave sensors.

In high performance nanostructured sensors, a device structure is typically fabricated around the nanostructured film and used to “interrogate” the nanostructures. The device senses changes in the structure or properties of the nanofilm and produces a proportionate electronic sensor signal. In research here, nanostructured surface acoustic wave (SAW) sensors are formed by incorporating nanostructured films into a surface acoustic wave delay line structure. The nanostructured films incorporated into these high performance sensors can be made highly selective and sensitive to a variety of different stimuli. For example, these films can be sensitive to chemicals, proteins, adsorbing mass, heat, radiation or magnetic fields. For any particular stimuli,

the nanostructured film, lying in the path of the SAW delay line, gives rise to changes in the surface wave phase velocity when exposed to its stimulant. This changes the timing delay of the SAW element, which can be detected by incorporating the SAW device into a simple oscillator circuit. Generally, the nanostructure of the film gives it an incredible amount of surface area to be exposed, relative to its volume. A nanostructured film typically has two to three orders of magnitude more surface area than a simple flat film. The high surface to volume ratio of the film translates





Dr. Gary M. Atkinson

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to sensors that are two to three orders of magnitude more sensitive than current SAW delay line sensor designs.

These surface acoustic wave nanosensors are fabricated on piezoelectric substrates such as lithium niobate or ST-Cut quartz. Interdigitated transducers (IDTs) form the transmitting and receiving structures as is common in this type of technology. The electrodes are fabricated out of aluminum, and this forms the basis for the self-assembled nanostructuring of the sensing film that lies in the center of the device. Simultaneously with the deposition

and lithography used to fabricate the IDT's, a thick pad of aluminum is also deposited in the path of the delay line. Isolated from the IDTs, this aluminum pad can be separately anodized with weak acidic solutions such as oxalic or sulfuric acid to form self-assembled nanopores in a hexagonally close-packed structure. This nanostructured alumina film has been demonstrated as a high performance sensor for ammonia. Additionally, using techniques developed at VCU's Quantum Device Laboratory, headed by Dr. Supriyo Bandyopadhyay, this nanoporous alumina template can be electrodeposited

with a variety of metals to form nanowires and quantum dots. By removing the alumina template, one can expose the surface area of the electrodeposited materials to form the high performance nanostructured sensing films. Additionally, we are currently investigating using atomic layer deposition (ALD) to fill the nanopores of our SAW nanosensors with other new interesting films. Due to the myriad of techniques with which we can fill these nanopores, the SAW nanosensor structure proves to be a powerful tool for high performance nanosensor research.

UNMANNED AERIAL VEHICLES



Unmanned Aerial Vehicles (UAVs), what people used to call “drones,” are the newest tools in the skies. These sophisticated autonomous vehicles are being used for a vast variety of applications, both in the civilian and military arena. Any job that is “dirty, dangerous, or monotonous” is a candidate for the use of a UAV. Examples include search and rescue; land, crop and forest surveying; pipeline and power line inspection; and the military applications that are in the news these days including surveillance, targeting and actual weapons delivery.

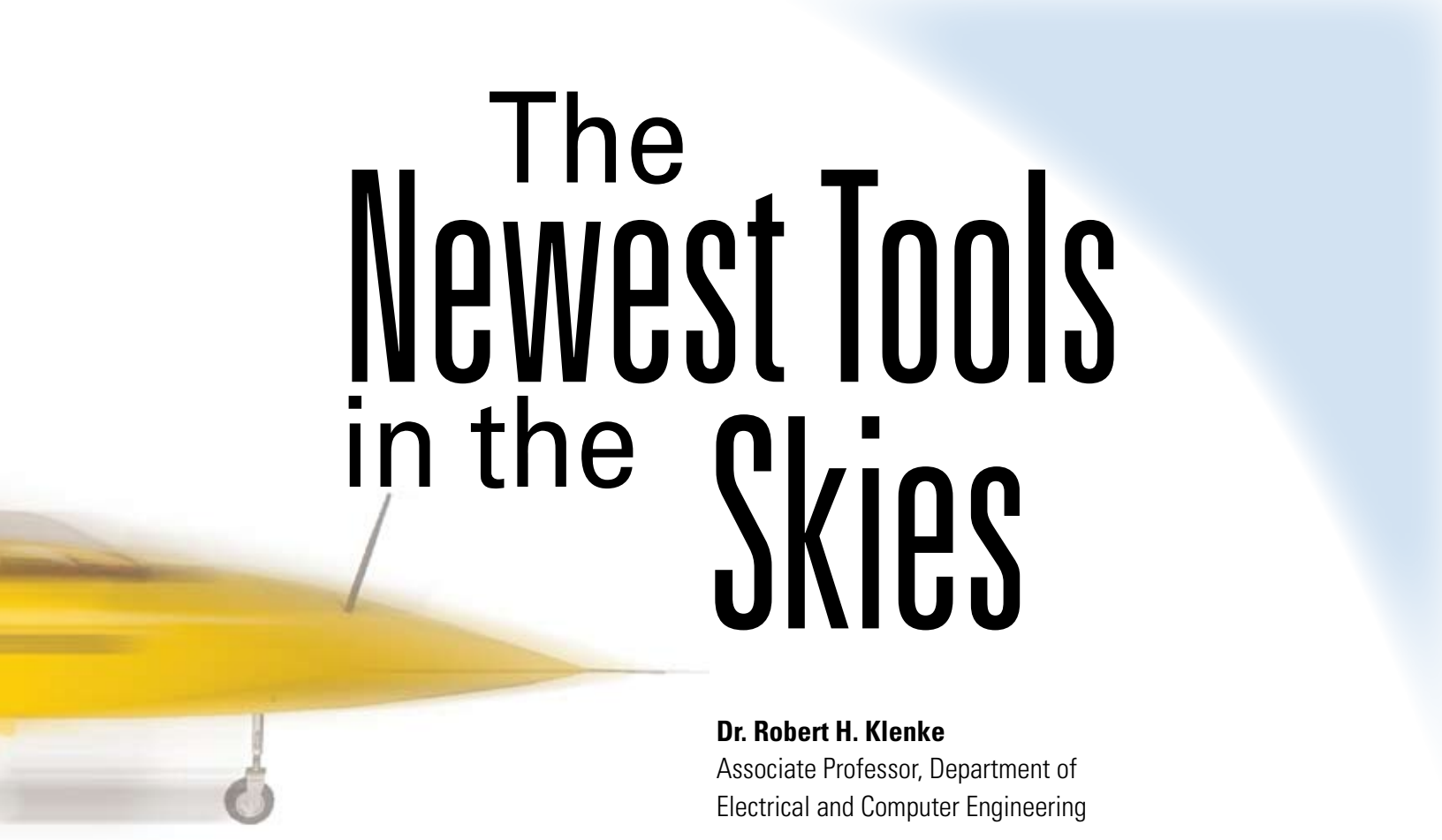
Researchers at the NASA Langley Research Center in Hampton Virginia, have their own novel use for UAVs. They are using them to help make airline travel safer in a program called AirSTAR. In the AirSTAR program, researchers are using scaled models of airliners to conduct aerodynamic research to determine how these aircraft perform in what are termed “upset conditions.” Upset conditions occur when the aircraft flies out of its normal operating envelope. Aerodynamic experiments involving upset conditions often cannot be performed in full-scale airliners because of the risk to the aircraft and its test pilots. The NASA Langley researchers have devised a way to perform these maneuvers using a dynamically scaled model of the airliner to collect the aerodynamic data and then scale the results up to the full-scale aircraft. The result is a better understanding of how airline pilots can recover from these situations and even make the aircraft’s control system capable of assisting in the recovery process.

In the dynamically scaled model tests, there are requirements for high-speed data collection and telemetering that data to a

ground station. The high-value scaled research model also must have an autopilot system onboard that is capable of assisting the ground-based safety pilot in returning the aircraft to the launch point should the RF links fail during the experiment.

The VCU UAV Research Group, led by Dr. Robert Klenke, is making a vital contribution to the NASA AirSTAR program. Most commercial UAV autopilots are designed for tactical applications and thus do not meet the stringent size, weight, and performance requirements of the AirSTAR research aircraft. The VCU UAV research group has developed a high-performance UAV autopilot/data system that not only captures, records and telemeters the research data but also can take control of the research aircraft and provide the required autonomous return-to-base capability. In development for over four years, the VCU UAV group’s autopilot/data system is based on state-of-the-art embedded systems technology such as one million gate-equivalent Field Programmable Gate Arrays, PowerPC processors and real-time operating systems. The autopilot/data system has proven capable of controlling aircraft as complex as helicopters and turbine-powered jets capable of speeds in excess of 130 knots.

The VCU UAV Research Group, part of the Department of Electrical and Computer Engineering in VCU’s School of Engineering, brings together not only the capability to develop the complex embedded systems hardware and software used in UAV flight control systems, but also the capability to construct and outfit the aircraft, integrate the autopilot and data system into the aircraft, and perform the actual flight testing. Aircraft ranging from small



The Newest Tools in the Skies

Dr. Robert H. Klenke

Associate Professor, Department of
Electrical and Computer Engineering

propeller-driven aircraft, to helicopters, to turbine jet aircraft are available within the group for flight test duties. Flight tests are often performed in concert with NASA Langley's research operations at the Wallops Island Flight Facility and also may take place at several FAA approved VCU-specific test locations. Recently, the VCU UAV Research Group began the development of a third generation autopilot/data system suitable for commercialization in conjunction with Coherent Technical Services Incorporated (CTSi) of Lexington Park, Md. This system will be used as the primary research avionics suite for the AirSTAR research flights scheduled for the summer of 2009 and onward.

In addition to the AirSTAR project, the group is involved in a project with the US Navy to provide additional aerodynamic data on their new P-8A Poseidon Maritime Multimission Aircraft (MMA). The P-8A MMA is a derivative of the Boeing 737-900 commercial airliner and is intended to replace the Navy's aging fleet of P-3 Anti-Submarine Warfare aircraft. The Navy intends to fly the P-8A more aggressively than commercial operators of the 737-900 do; thus, they require more data on how the aircraft performs in regions of the flight envelope which are close to upset conditions. Like the AirSTAR project, this data cannot be gathered using flight tests of the full-scale aircraft for safety reasons. The group will be leading a team that will build, outfit and test fly a dynamically-scaled model of the P-8A aircraft to gather the needed aerodynamic data. The VCU-developed autopilot/data system will be used as the primary avionics system for the test aircraft. The data gathered during flight testing will be used by the Navy to improve the accuracy of the P-8A

MMA flight simulators so that future P-8A pilots can learn to fly the aircraft in the safest, most effective manner possible.

The VCU group also is working on several projects involving tactical military UAVs. One such project involves the testing of a new digital video and data down-link system called Tactical Common Data Link (TCDL). TCDDL is a program within the Department of Defense (DoD) to provide a common down-link format from tactical UAVs in the battlefield. The use of TCDDL will allow warfighters to receive the video and data from any friendly UAV in the area on a common, compact and inexpensive video terminal. For this project, a military tactical UAV, called an Outlaw, has been outfitted with the VCU-developed autopilot system. The Outlaw is a medium-sized, rail-launched UAV with a 13-foot wingspan and a takeoff weight in excess of 100 lbs. The VCU autopilot will not only fly the aircraft during its surveillance exercise missions, but will provide the aircraft metadata (position, altitude, attitude, etc.) to the TCDDL data link in the proper format. This metadata is necessary to display the associated digital video in the proper context within the operating environment. The VCU autopilot was chosen for this project because it provides the computation power and programming flexibility necessary to be easily modified to provide the properly formatted metadata. The goal of this project is to pave the way for the incorporation of the TCDDL data link standard in the DoD's next generation of tactical UAVs, thus providing better performance at lower cost than is currently possible with the industry proprietary data formats generally in use today.

BIOMEDICAL

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Research Topics

- Algorithms and systems development of brain-computer interface
- 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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- Development of novel tissue engineering scaffolds via electrospinning

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Research Topics

- 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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Research Topics

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Research Topics

- Non-invasive cerebral spinal fluid pressure device
- High noise speech communication system
- Baby echolocator is a device to allow deaf babies to "see" acoustically facilitating perceptual motor development
- Baby multimodal (bone conduction and vibrotactile) hearing aid using algorithms to track mothers voice
- Tinnitus (phantom 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

- Use of haptic devices for rehabilitation
- Application of tactile feedback for prosthesis design
- Tissue modeling for surgical simulators, development of simulators
- Human factors analysis during minimally invasive surgery and telesurgery
- Haptic displays for blind and visually impaired individuals.

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Research Topics

- Structural Stability of Fixation Constructs
- 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

- Primary research emphasis is the development of Human-Machine Interfaces based on eye movement and visual analysis

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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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Research Topics

- Systems biology
- Evolutionary biology
- Metabolic engineering
- Molecular engineering
- Molecular evolution
- Computational modeling

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Research Topics

- Advanced polymer coatings for highly selective membranes and sensors
- Preparation of nano-structured materials using supercritical fluid technology
- Controlled and targeted delivery of therapeutic agents
- Processing biomaterials for improved biocompatibility

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Research Topics

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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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Research Topics

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

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Research Topics

- Polymer surface science
- Fluoropolymer science
- Silicone science
- Functional polymer surfaces including biocidal polymers
- "Green" processing and synthesis in supercritical CO₂
- Nonlithographic patterning of functional inorganic and 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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Research Topics

- Computer security, medical applications, semi-real-time algorithms, performance evaluation, graphics, database and networks

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Research Topics

- Software engineering
- User interface design and specification

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Research Topics

- Cellular automata, compilers, functional programming, logic programming and expert systems

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Research Topics

- Optical networks, high-speed networks, and network congestion control
- Graph theory
- Combinatorics

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Research Topics

- Biomedical informatics, data mining and learning algorithms

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Research Topics

- Computational biology
- Genome sequencing
- Algorithm design and analysis
- Data mining
- Computer and biological networks

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Research Topics

- Software analysis, testing, verification, and reliability

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Research Topics

- Biomedical signal and image processing, biomedical informatics, signal processing for finance and banking and artificial intelligence

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Research Topics

- Database systems, operating systems and concurrency

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Research Topics

- Artificial neural networks
- Machine learning
- Knowledge-based systems
- Parallel algorithms
- Ethics

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Research Topics

- Programming languages, compiler design and automatic generation of software

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Research Topics

- Multimedia systems, computer networking, wireless networks, digital image/video processing, video-on-demand over wireless networks, video watermarking and hand off control in G3 systems

ELECTRICAL / COMPUTER

Dr. Gary M. Atkinson

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Research Topics

- Microelectromechanical Systems (MEMS)
- Biochips
- Sensors and Actuators
- Smart Materials
- Micro/Nano Fabrication

Dr. Supriyo Bandyopadhyay

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Research Topics

- Self-assembly of nanostructures
- Mesoscopic superconductors
- Quantum computing and cryptography
- Architectures for nanoelectronics and circuit design
- Quantum devices and single electronics
- Hot carrier transport in submicron devices and quantum wires
- Nanoelectronics

Dr. Alen Docef

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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

Dr. A. Vennie Fillipas

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Associate Chair
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Research Topics

- GPS Applications
- Neural Networks
- Linear and Nonlinear Control Theory
- Robotics for Nuclear Waste Handling

Dr. Robert H. Klenke

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Research Topics

- Parallel algorithms for design automation problems
- Digital system design
- Hardware/software codesign, hardware description languages
- System-level performance and hybrid modeling

Dr. Robert J. Mattauch

Dean Emeritus and Commonwealth Professor
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Dr. James M. McCollum

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Research Topics

- Computational Biology
- Reconfigurable Computer
- Stochastic Simulation
- High Performance Computing
- Digital Systems Design

Dr. Hadis Morkoc

Founders Professor
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Research Topics

- Group III-V Semiconductors
- Light Emitting Diodes
- Nitride Semiconductor Heterostructures

Dr. Yuichi Motai

Assistant Professor
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Research Topics

- Medical imaging
- Computer vision
- Robotics
- Human-computer interaction

Dr. Umit Ozgur

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Research Topics

- III-Nitride and Zinc Oxide Optoelectronics
- Nonlinear Optics
- Ultrafast Spectroscopy
- Coherent Phonons
- Magnetic Semiconductors
- Magneto-optical Spectroscopy
- Near-field Optical Microscopy
- Nanophotonics

Dr. Jerry H. Tucker

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Website:

Research Topics

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

MECHANICAL

Dr. Stephanie G. Adams

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Associate Professor
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Research Topics

- Teams and Team Effectiveness
- Engineering Management
- Collaborative and Active Learning
- Engineering Education and Pedagogy

Dr. Jayasimha Atulasimha

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Research Topics

- Nonlinear and hysteretic systems: dynamical response, development of inverse compensation and control design
- Experimental control in aerospace, automobile and biomedical applications (planned)
- Magnetostriuctive, piezoelectric and magnetoelectric materials
- Design and fabrication of MEMS devices
- Behavior of smart materials at micro/nano scale (planned)

Dr. Mohamed Gad-el-Hak

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Research Topics

- Fluids in motion
- Flow control
- Viscous pumps and microturbines
- Microtechnology

Dr. Muammer Koç

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

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

Assistant Professor

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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 and 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

Dr. Manu Mital

Lecturer

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Research Topics

- Micro/Nano-scale heat transfer
- Heat transfer in biological systems
- Thermal management of electronic equipment
- Artificial Intelligence & Neural Networks

Dr. Karla Mossi

Associate Professor

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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.)

Dr. Ramana Pidaparti

Professor

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Research Topics

- Design innovation through arts
- Computational mechanics
- Fatigue and fracture
- Biological composites
- Design engineering
- Neural networks and computational intelligence
- Nanotechnology and biomolecular motors
- Smart materials and structures

Dr. John E. Speich

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Research Topics

- Smooth muscle biomechanics
- Developing robotic devices for medical applications
- Robotic devices for delivering rehabilitation therapy
- Robot-assisted surgery
- Robotic devices to aid persons with disabilities
- Telemanipulation - especially scaled bilateral telemanipulation
- Human-robot interaction and haptic interfaces
- Compliant-mechanism-based robots and devices

Dr. Vishnu Sundaresan

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Research Topics

- Applied Membrane Biophysics
- Active Implantable Material Systems

Dr. Hooman Tafreshi

Assistant Professor

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Research Topics

- Modeling and Experiment on Waterjets and Nozzle Cavitation
- Aerosols 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

Professor

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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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* deceased



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