Research at the University of Virginia School of Engineering & Applied Science

IMPACT

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Commercializing Engineering Research: Translating Discovery into Opportunity

University of Virginia Engineering

Developing Leaders of Innovation

175 years

ENGINEERING THAT SERVES SOCIETY

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Cover: Tatiana Globus has developed a terahertz vibrational resonance spectrometer so sensitive that it can distinguish between strains of a single bacteria. Key components include a Schottky diode microdetector, a micro-fluidic chip, a high-precision, three-dimensional positioning unit and an optical visualization system. See page 4.

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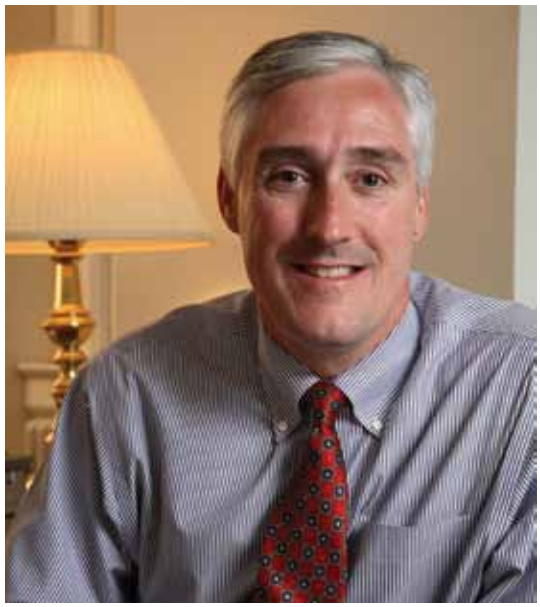
Engineering schools have become a pre-eminent source of the innovation society needs for economic growth and security. We take this responsibility very seriously at the U.Va. School of Engineering and Applied Science. Over the last five years, we have increased our research funding by more than 45 percent, to $63.13 million, even as University budgetary constraints have resulted in a 10 percent decrease in our faculty numbers.

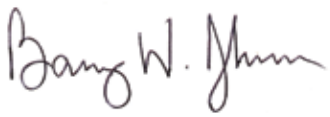
The Engineering School has also worked hard to break out of the ivory tower and target our research to areas of greatest need. The Wallace H. Coulter Foundation grant, creating a $20 million endowment for translational research in biomedical engineering, recognizes procedures we have put in place that encourage researchers to make potential application a critical criterion for research design.

Initiatives like the Applied Research Institute and the Commonwealth Center for Advanced Manufacturing (CCAM) help us better coordinate our research with the needs of industry and government partners. Thanks to these relationships, industry-funded research is one of the fastest growing components of our research budget. It has doubled over the last five years and now accounts for 20 percent of our total research.

In collaboration with the U.Va. Patent Foundation, we also strive to make our discoveries available to companies who can bring them to market. Technology developed by Engineering School researchers, for instance, is widely used by cardiologists to thread catheters to the heart.

Equally important, we drive innovation through education. Whether they have completed our undergraduate engineering business minor or a doctoral program in materials science, our graduates are ready to apply their knowledge of engineering to society's most difficult challenges.





Barry W. Johnson
Senior Associate Dean
Associate Dean for Research
U.Va. School of Engineering and Applied Science

ENGINEERING SCHOOL CELEBRATES ITS 175TH ANNIVERSARY

The U.Va. School of Engineering and Applied Science traces its origins to 1836, when the University's Board of Visitors authorized professors Charles Bonnycastle and William Barton Rogers to teach a sequence of courses in civil engineering. With this decision, the University became one of just a handful of institutions in the United States with a formal engineering program.

The spirit of innovation remains as strong today at the Engineering School as it was 175 years ago. Throughout 2011, the Engineering School will host a number of events celebrating its heritage and, more importantly, highlighting its determination to pioneer new technologies and solutions to address the challenges facing society.

Funding from the Coulter Foundation helped prepare William Walker and his colleagues to launch a startup.

PIONEERING
A NEW MODEL OF TRANSLATIONAL RESEARCH

In 2006, the Wallace H. Coulter Foundation chose the University of Virginia to receive a five-year, $5 million grant to develop methods to accelerate the movement of biomedical engineering research into commercial products and clinical practices. This year, in recognition of the University's success, the Coulter Foundation teamed with the University to create a $20 million endowment to expand these efforts.

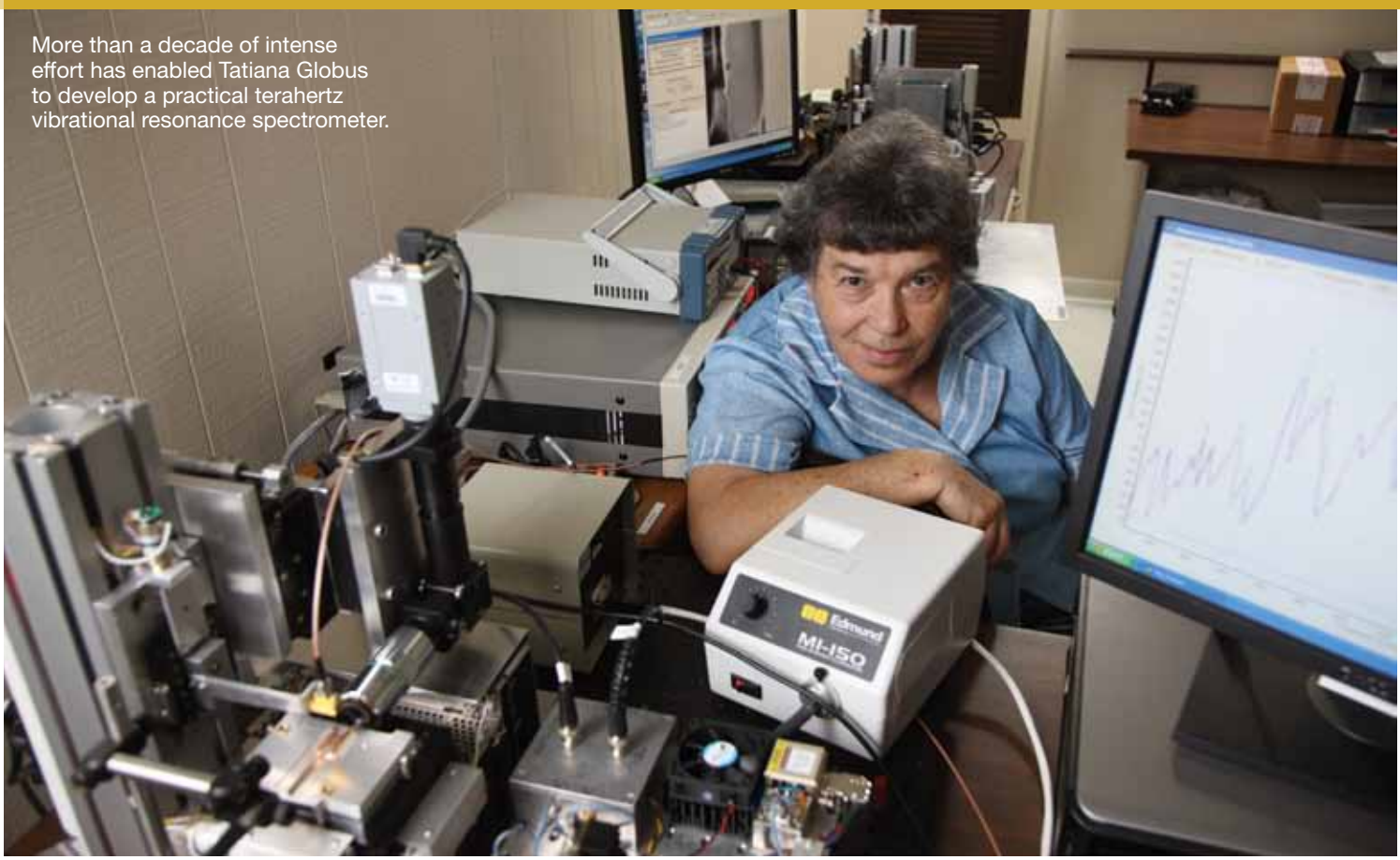
In effect, the original Coulter Foundation grant challenged the University to develop a rigorous screening mechanism for identifying and funding research projects with significant potential for product development and to track them through a strict milestone-based review. To ensure their relevance, the research teams include medical clinicians as well as engineering faculty. In addition, the U.Va. Coulter Translational Research Program recruits an advisory board of venture capitalists, entrepreneurs and industry leaders to counsel project teams about bringing ideas to fruition.

The results have been impressive. The more than 30 projects funded since 2006 have produced five startup companies, 11 licensing agreements, over $12 million in venture capital and private investments, and greater than $20 million in federal, state and foundation grants.

For instance, one Coulter Foundation project led biomedical engineering professor William Walker to form HemoSonics. The company is producing a device to help physicians quantify a patient's clotting capacity so that they can order the appropriate blood products or drugs.

"Our relationship with the Coulter Foundation has been an important lever for change," says David Chen, the program's director at the University. "It has increased the University's capacity to deliver valuable technologies to society."

READ MORE: *bme.virginia.edu/coulter*



More than a decade of intense effort has enabled Tatiana Globus to develop a practical terahertz vibrational resonance spectrometer.

"We can now discriminate between strains of the same species, for example, between harmless and deadly *E. coli* bacteria. And because there is no need to culture the bacteria, we can produce a result in a very small amount of time."

TERAHERTZ FINGERPRINTING

It is hard to believe in this age of cellular, Wi-Fi and Bluetooth connections that any part of the electromagnetic spectrum has not been tapped to fill our hunger for more powerful and pervasive technology. But there they stand, unused and, for the most part, ignored — the terahertz frequencies. Lying between 100 gigahertz and 10 terahertz, they rest on the cusp between electronics and photonics, with a reputation for being difficult to use.

One of the intriguing qualities of terahertz radiation is that it can excite the low-frequency molecular vibrations produced by groups of atoms in biomolecules. Because each type of biomolecule produces its own vibrational signature, there is the potential to use terahertz excitation to identify unknown molecules.

Associate Research Professor Tatiana Globus has devoted more than a decade to overcoming obstacles to developing a practical terahertz vibrational resonance spectrometer capable of detecting these signatures. With funding from several Small Business Innovation Research grants (SBIRs), she has made remarkable progress. When she began, she had to cool the detector gradually to 1.7 degrees Kelvin. Her current prototype produces high-resolution absorbance spectra from extremely small samples at room temperature. "We can now discriminate between strains of the same species," she says, "for example, between harmless and deadly *E. coli* bacteria. And because there is no need to culture the bacteria, we can produce a result in a very small amount of time."

With assistance from the U.Va. Patent Foundation, Globus has formed her own company, Vibratess, to commercialize this technology. A Vibratess spectrometer could be used to identify biological threats, monitor water quality and food safety, and track the effectiveness of new antibacterial or antiviral drugs, among many possible applications.

READ MORE: *vibratess.com*

A program developed by Jack Davidson and his colleague Jason Hiser is being used to protect cable boxes and military hardware from thieves known as software crackers.

SOFTWARE
SMOKE AND MIRRORS

There are just some days when, no matter how hard you try, nothing works out as expected. This is as true for software crackers, thieves who try to reverse engineer or alter software, as it is for the rest of us. But in their case, it just may be that they have run up against software protected by COAT, the continuous obfuscation and anti-tampering system developed by Jack Davidson and Jason Hiser in the Department of Computer Science. COAT is being used to protect cable boxes as well as military hardware from being hacked.

The first step in reverse engineering or modifying a piece of software is to understand it — and COAT makes this a frustrating experience. Because COAT uses dynamic obfuscation, every time crackers try to access the software's binary code, it looks different, making it impossible to develop a coherent picture. And if the crackers are successful in making a malicious change, COAT stealthily corrects it while making the software seem to run incorrectly. This is frustrating for crackers, because their goal is not to destroy a system but to steal or modify a working program.

"I appreciate how much time, effort and money goes into writing software," Davidson says. "COAT is an effective way of protecting that investment."

Working with the U.Va. Patent Foundation, Davidson and Hiser licensed COAT to Irdeto, a Dutch company that secures software used in digital media and pay TV. Davidson's own company, Zephyr Software, focuses on applications for the military. "When we sell a weapons system to another country," he says, "we don't want our customers reverse engineering or modifying the underlying software. COAT makes sure they get what they pay for and no more."

READ MORE: *www.zephyr-software.com*

Anthony Gadient, Kent Schlussel and Alfred Weaver are promoting University research with intelligence and defense applications.

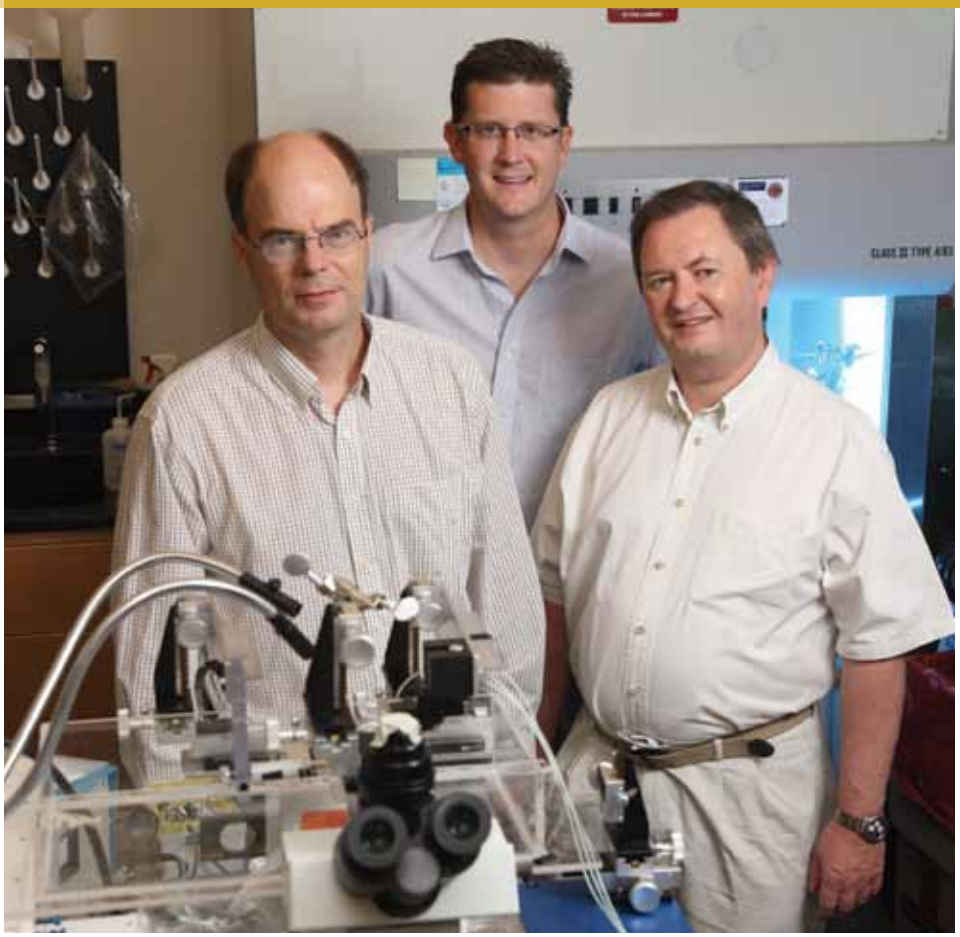
BROKERING UNIVERSITY RESEARCH

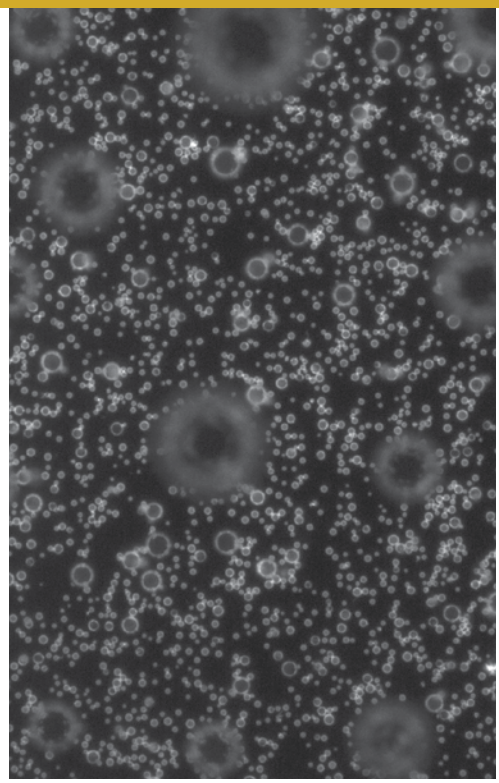
"One way to look at the role of the Applied Research Institute," says Alfred Weaver, the institute's director and a U.Va. computer science professor, "is as a specialized broker. We connect government agencies and corporations that focus on intelligence and national defense with University faculty members."

This view of the Applied Research Institute (ARI) as broker has shaped Weaver's activities. Along with Anthony Gadient, the institute's associate director, and Kent Schlussel, the chief technology officer, Weaver has spent the last two years collecting information and cultivating relationships, both on Grounds and throughout the defense establishment.

Their work has begun to bear fruit. They have three projects under way, including one with the Chantilly, Virginia–based defense contractor TASC. They also have 21 potential projects in the pipeline. "If even some of these come through," he says, "ARI could generate hundreds of millions of dollars in research funding for the University."

READ MORE: *weaver@virginia.edu*





An ultrasound technique created by John Hossack, Brian Wamhoff and Alexander Klibanov with the assistance of graduate student Linsey Phillips reduces the danger of clots forming after angioplasty.

THERAPEUTIC BUBBLES

Biomedical Engineering Professor John Hossack and Department of Medicine colleagues Associate Professors Brian Wamhoff and Alexander Klibanov were all familiar with the limitations of drug-eluting stents, which are used to prop open blood vessels in people with artery disease following balloon angioplasty. The drug coating on the stent prevents the cells in the wall of the vessel from proliferating and reclosing the artery, but in some cases it causes dangerous clots to form in the months after placement.

At a 2006 retreat sponsored by U.Va.'s Cardiovascular Research Center, the three researchers realized that together they had the expertise to develop an alternative that might deliver drugs more safely. They would base it on microbubble and ultrasound technologies, both U.Va. specialties.

Hossack is an expert in ultrasound transducers, giving him the ability to fine-tune the design of a dedicated ultrasound catheter. Wamhoff studies the smooth muscle cells that compose blood vessels and that consequently are the major therapeutic target to prevent post-stent vessel narrowing. And Klibanov specializes in the design of microbubbles — typically one to four microns in diameter — suitable for delivering drugs. Both Klibanov and Wamhoff have joint appointments in Biomedical Engineering. They enlisted the assistance of graduate student Linsey Phillips to work on the project.

After angioplasty, they plan to use a catheter to deliver microbubbles, carrying a smooth muscle cell antiproliferative drug, to the precise region where the vessel was reopened. Using ultrasound, they will image the diseased area of the blood vessel and then apply ultrasound pulses to move the microbubbles to the vessel wall and burst them, releasing the drug specifically to the diseased area. Because the pressure of the bubble bursting causes a brief disturbance in the cell membranes, the drug can more easily enter the cell and achieve efficacy.

"The system has a number of advantages," Hossack says. "Because you can deliver a drug exactly where it's needed, you can significantly decrease the amount required, minimizing side effects. You also have the flexibility to change drugs if your original choice doesn't produce the desired results."

The three researchers are in the process of forming a company and are actively working with the U.Va. Patent Foundation to secure a patent on the technology and license it.

READ MORE: *www.bme.virginia.edu/hossack*

APPLYING THE USEFUL SCIENCES

The holder of 17 U.S. patents, George Gillies has founded a series of companies to commercialize his inventions.

When Thomas Jefferson envisioned a university dedicated to promoting "all the useful sciences," he might have had a faculty member like George Gillies in mind.

Certainly Gillies has a broad range of interests, as did many of the University's original faculty members. He is a research professor of mechanical engineering and biomedical engineering and a visiting research professor of physics. (He is also a clinical professor of neurosurgery at Virginia Commonwealth University.) His research interests have included novel methods for delivering therapies to brain tumors, magnetic guidance systems for threading catheters and other devices through the cardiovascular system, and the development and testing of neurophysical instrumentation.

Like Jefferson, Gillies is an inventor. Altogether, he has 17 U.S. patents and 50 patents pending and has founded or co-founded Stereotaxis (now publically traded), NexGen Medical Systems and EpiEP. "Moving new technologies into society is a fulfilling way to devote my energies," he says. "You can really see how your work will benefit others."

A case in point is the EpiAccess technology he developed with Dr. Srijoy Mahapatra. It seeks to provide surgeons with safe, minimally invasive access to the outer wall of the heart, while minimizing the risks of penetrating it. Uses for the system could include treating cardiac arrhythmias, such as atrial fibrillation and ventricular tachycardia, and inserting pacemaker leads more safely.

In these and other projects, Gillies sees himself as a problem solver. "If you can reduce a complex problem to a set of simpler ones, you have a chance of coming up with useful new technology."

READ MORE: *www.stereotaxis.com*

THE SPIRIT OF INVENTION THRIVES AT THE ENGINEERING SCHOOL

The Edlich-Henderson Inventor of the Year Award is the highest honor bestowed by the U.Va. Patent Foundation. It honors an inventor or team of inventors whose technology has proven to be of notable value to society. Previous Engineering School faculty members (including those with joint appointments) named Inventors of the Year include John Mugler and James Brookeman (2009), George Gillies (2006), Haydn Wadley (2004), Doris Kuhlmann-Wilsdorf (2001) and John Herr (1999).

Patent Foundation
University of Virginia

ENGINEERING SCHOOL PATENT ACTIVITY

Fiscal Year	2010
Total Number of U.Va. Invention Disclosures Received	139
Number of Invention Disclosures Received From SEAS Faculty Members	41.2*
Percentage	29.7
Total U.Va.-Issued Patents	21
Number of Patents Issued with SEAS Faculty Inventors	6
Percentage	29%

*All disclosure counts are rounded to the nearest tenth. Fractional disclosures represent disclosures made by multiple inventors across different schools (e.g., a single disclosure shared equally by School of Engineering and Applied Science and School of Medicine faculty would contribute 0.5 toward each school's total).

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MENTORING ENTREPRENEURS

When Mark Hanson (EE, CpE '03, EE '09) completed his doctorate, he left the University confident he could start his own company, thanks to mentoring by John Lach, his electrical and computer engineering professor. Lach is co-director of the Center for Wireless Health, which explores the use of wireless technology to remotely monitor seniors and people with disabilities. "Professor Lach cultivated an ecosystem of people — physicians, caregivers, industry partners, insurance executives and policymakers — who together gave us the perspective needed to develop products that could succeed in the marketplace," Hanson says. "We follow his example as we grow our company."

Hanson is the co-founder of BeClose, which provides monitoring systems that enable people with health issues to live at home independently while keeping their caregivers abreast of their well-being. "The idea is to detect problems early, when they can be most easily treated," Hanson says.

When ultra-low-power microprocessors began to appear in the early 2000s, Lach began to see that they could be incorporated into sensors for medical monitoring. He challenged Hanson to help him develop body sensor networks, and Hanson rose to the occasion. "Mentoring is an important means of promoting translational research," Lach declares. "My responsibility is to prepare students to have a positive impact on society, and one way to do this is to encourage those who would like to be entrepreneurs."

READ MORE: U.Va. Center for Wireless Health: *wirelesshealth.virginia.edu*
BeClose: *www.beclose.com*

John Lach (center) mentored doctoral students Mark Hanson (left) and Adam Barth (right). Hanson and Barth are now building a startup company to popularize the use of wireless technology to help seniors live at home.