U.Va. Engineering Secures Five MURI Awards
Hundreds of faculty teams compete for the few dozen Multidisciplinary University Research Initiative (MURI) awards that the Department of Defense offers each year — and for good reason. Multimillion-dollar, five-year grants — long enough and large enough to pursue truly innovative basic research — are extremely rare.

For an engineering school to be singled out for just one MURI is cause for celebration. To have faculty members leading four MURI efforts and another faculty member serving as an investigator on a fifth, as we do at the U.Va. Engineering School, is an exceptional accomplishment.

MURIs are vitally important because they can both energize and stabilize a research program. Our five MURI awards collectively represent more than $30 million in funding for the participating schools, enabling faculty members to recruit outstanding graduate students knowing they can offer them a significant, long-term research project.

In addition, MURIs foster the kind of sustained cross-fertilization of ideas that is essential for groundbreaking research. In the process of coming together to collaborate on a MURI, faculty from different disciplines and from different universities build relationships that can continue to seed new ideas for decades to come.

One way of looking at these MURI awards is that they are a confirmation of the quality of research done here. If you are known by the company you keep — and our MURI partner institutions, for instance, include MIT, Cambridge, Princeton and the University of California campuses at Berkeley, Davis and Santa Barbara — then the Engineering School is now traveling in elite company.
Chemical Engineer Lands NSF CAREER Award

People have been mixing polymers and particles for centuries to create such mundane materials as house paint, ink and toothpaste — but the process of creating polymer-particle composites with precise qualities has been a hit-or-miss affair. With a National Science Foundation Faculty Early Career Development (CAREER) Grant, David Green, an assistant professor of chemical engineering, is determining how particles can be distributed evenly throughout a polymer. This sets the stage for manufacturers to produce existing materials with more uniform properties — more effective toothpaste, for example — but more excitingly, to create new kinds of materials with novel mechanical, thermal, optical, electrical and biological properties.

Green’s research spans an impressive array of fields, including interfacial phenomena, surface engineering, thermodynamics, mass transport, fluid dynamics, reaction/synthesis engineering and statistical mechanics. The materials that he creates have applications for automotive, aerospace, product packaging and medical industries, among others.

“When you add particles to a polymer, they tend to clump up,” Green observes. “Our goal is to determine how changes in their interfacial properties affect how they disperse.” Green is experimenting with grafting polymer chains to nanoparticles, which affect their dispersion in concentrated polymer solutions and melts. His approach is to use “grafting from” technologies, which entails building the graft layers a monomer at a time from surfaces of nanoparticles. His early research shows that adding polymer-grafted nanoparticles to shorter-chain polymer melts actually enhances the mechanical properties of the composite through increased swelling of the graft layer. Green believes these results could lead to a paradigm shift in the design of polymer composites, which are routinely formulated with longer-chain polymer melts.

The CAREER award is one of the most prestigious research grants available to junior faculty members in science and engineering, but it also requires awardees to integrate their research and teaching. Green is using his grant to increase the diversity of the engineering workforce. “One of my goals is to augment the pipeline of minority and female students who will go on to graduate studies in chemical engineering,” he says.

Engineering School Joins National Technology Alliance

The Engineering School has qualified as a member of the National Technology Alliance (NTA), a government program designed to meet national security and defense technology needs with products that also have commercial applications. For prototype projects that are directly tied to Department of Defense needs, the alliance can provide fast-track funding. To date, faculty from electrical and computer engineering, computer science and systems and information engineering have tapped NTA funding.
Modern warships are packed with powerful radar, sonar, communications, navigation and weapons systems that depend on sophisticated integrated circuits and advanced processors. The U.S. Navy now plans to take its reliance on electronics a step farther in its next generation of destroyers, substituting electricity to power the tasks currently assigned to gas turbines, pressurized air, steam and other means of propulsion.

There is, however, one issue that could keep these all-electric vessels in dry dock — heat. Electronic devices produce heat — and the inexorable progress of Moore’s law means that as components are more densely packed with ever-smaller transistors, the amount of heat they produce grows exponentially as does the difficulty of dissipating it. The resulting high temperatures degrade device performance and shorten product life.

Mechanical and Aerospace Engineering Professor Pamela Norris and a team of investigators recruited from Arizona State, the University of California at Berkeley, the University of Illinois and Rensselaer Polytechnic Institute have been awarded a $7.5 million MURI Award to address this problem.

“We’re breaking new ground,” Norris says. “Our task is to explore new integrated ways to cool ship-wide systems that are unprecedented in their size and complexity, yet composed of millions of individual elements with features on the micron scale.”

Norris’ own contribution to the process illustrates the fundamental nature of the project. One source of heat is the resistance created at the interface between the layers in a semiconductor chip. She is leading an effort to substitute a vertical array of carbon nanotubes for current methods used to eliminate gaps and improve conductivity between layers. Even more exciting from a scientific point of view, she’s attempting to develop a better understanding of thermal boundary resistance, a phenomenon that occurs even between perfectly smooth layers. “There’s been very little research on this, but it’s clearly the ultimate frontier in cooling,” she says.

For Pamela Norris and her MURI team, the mechanics of thermal boundary resistance represent the ultimate frontier in managing heat transfer.
MoTHer naTure has created an ocean full of models for building undersea craft, but until recently we’ve been unable to duplicate them. Though powerful, submarines are essentially rigid surface vessels that have been modified for underwater conditions. Hilary Bart-Smith, an associate professor of mechanical and aerospace engineering, has been awarded a $6.5 million MURI Award to address the fundamental issues needed to develop undersea vessels that move with the effortless agility and precision of fish.

Bart-Smith and her group will explore ways to combine active tensegrity structures — artificial structures that can change their shapes in response to external conditions — and newly developed control strategies to mimic the fluid motions of one of nature’s most efficient and maneuverable swimmers, the manta ray. Her group includes departmental colleagues Hossein Haj-Hariri, Tetsuya Iwasaki and Joseph Humphrey, as well as Lex Smits from Princeton University and Frank Fish from West Chester University in Pennsylvania.

Their object is to create the numerical and experimental tools needed to develop an autonomous underwater drone that would be difficult to track with sonar. “We will begin by analyzing and modeling the biology and hydrodynamics of manta ray propulsion,” Bart-Smith says. “This information will provide a foundation for learning how to employ tensegrity structures and controls to create a shape-changing wing.”

But Bart-Smith and her team will not be satisfied with simply imitating Mother Nature. “Amazing as the manta ray is, we will look for opportunities to outperform it,” she says.

Heat Transfer Program Produces Truman Fellow

ONE OF the mainstays of Pam Norris’ lab is leaving . . . and Norris couldn’t be happier for him. Patrick Hopkins has worked closely with Norris since his third year as an undergraduate and completed his dissertation under her direction. He has now accepted the Harry S. Truman Fellowship in National Security Science and Engineering at Sandia National Laboratories in Albuquerque, N.M. He was one of two fellows selected from a field of 18 finalists.

The Truman Fellowship program offers a three-year postdoctoral position with an annual salary of more than $100,000. While at Sandia, Hopkins will have the opportunity to work with some of the nation’s foremost scientists and engineers.

“He will be like a kid in a candy shop at Sandia,” Norris comments. “He’s always interested in exposing himself to new ideas and new people.” The Truman Fellowship is the latest in a series of awards Hopkins has earned during his short career. In addition to receiving research support from the Engineering School and the University, he was a National Science Foundation Graduate Fellowship winner and a Virginia Space Grant Consortium Aerospace Graduate Fellow.
MURI Focus: The Information Advantage

For today’s military, computing power has come to rival firepower as a means of defeating adversaries. Engineering School faculty members are answering fundamental questions that may lead to substantial increases in the military’s computing power and in the security of its computer networks.

Self-Protecting Networks

As Department of Defense planners see it, real-time information delivered to decision makers as well as to soldiers in the field is an invaluable strategic advantage — but this dependence on information only makes sense as long as the network that conveys that information can itself repel and recover from attack. Walling off such a decentralized network is impossible, while simply focusing on building networks that function when breached can lead to an endless programming arms race between computer scientists and network adversaries.

A multiuniversity team brought together by John Knight, a professor of computer science, has received a $4.6 million MURI Award to determine if it is possible to create a network architecture that is, in the most exacting sense of the word, incorruptible. He and his fellow researchers from the University of New Mexico, the University of California at Santa Barbara and at Davis, and U.Va. are approaching the problem from three different perspectives. First, they challenged themselves with creating a network that continuously alters its “attack surface,” making it much more difficult for adversaries to break in. Second, in the event that an attacker does get through, they want to build a network that can identify and repel the intruder and recover from the attack without breaking stride. And finally, they would like to design a network that would learn from experience, metamorphosing to eliminate the vulnerability without compromising functionality. And if this research agenda weren’t ambitious enough, these processes would occur automatically without any human intervention.

Anh Nguyen-Tuong, Jack Davidson, David Evans and Westley Weimer from the Department of Computer Science are collaborating with Knight on the project as co-principal investigators. They have dubbed this new network architecture Helix.
After graduating from Harvard and working at the IBM Watson Research Center in Cambridge, Claire Le Goues came to U.Va. because of the number of faculty at the Engineering School specializing in compilers and programming languages, two fields of interest. “I knew that having a critical mass of faculty in these two areas would improve my chances of landing a project I really liked,” she says.

She found it in the MURI Helix project. As part of the MURI team, Le Goues is exploring ways to determine a program’s fundamental specifications, which are rarely comprehensively documented, by analyzing the way its programming language is used. “It’s a bit like discovering the rules of grammar by reading a bunch of high school essays,” she explains.

Unless these specifications are truly understood, any attempt to modify the program to close security gaps runs the risk of interfering with an essential function. Le Goues is bringing to this analysis, called specification mining, a much broader array of data than has been used in the past in order to provide more accurate and more precise specifications.

Electrons are known for their charge, but they have another property that has the potential to transform computing. It’s their spin. If researchers can harness their spin to manipulate and store data, the chances are good that they can create a new generation of computer chips that will be dramatically faster, smaller and less power-hungry than existing hardware. This emerging technology is called spintronics.

Stuart Wolf, who holds appointments in both the Department of Materials Science and Engineering and the Department of Physics, has been one of the leaders in the field. Through his own research and through the research he funded as a program manager at the Defense Advanced Research Projects Agency, Wolf has been instrumental in many of the basic discoveries necessary for a transition from electronics to spintronics.

Wolf is now a member of a new MURI team, led by Dan Ralph, a professor at Cornell University, that is trying to develop a fundamental understanding of how electricity can be used to manipulate spin devices. “This grant is meant to generate insight into the basic science of spintronics,” Wolf says.

The group is focusing on electrical control of electron spin because it creates a bridge to the current generation of charge-based electronics, much the way adapting the typewriter keyboard eased the transition to computers.

Wolf’s role in the project is to explore the use of multiferroic materials, which have both ferroelectric and magnetic properties, to create both random-access and media-based spintronic memory that is electronically controlled. Wolf is starting with the multiferroic bismuth ferrite but believes that his research will soon progress to metamaterials composed of ferromagnetic and ferroelectric substances, arranged either in layers or by embedding ferromagnetic islands in a ferroelectric matrix.
UNTIL RECENTLY, societies building with metals considered the corrosion tax — the costs of over-design, maintenance, loss of efficiency and, ultimately, replacement — an inevitable consequence of construction.

In the United States alone, the corrosion tax adds up to about 4 percent of gross national product each year — hitting the construction, manufacturing and transportation sectors particularly hard.

But with energy prices rising — metallurgy is extremely energy intensive — and governments and corporations alike tightening their belts, the cost of corrosion is starting to impact our standard of living and undermine our military preparedness. Simply put, we can no longer afford it.

Accordingly, the Department of Defense has made this issue a priority and turned to the Engineering School’s world-class program in corrosion to provide next-generation approaches to corrosion prevention. With $1 million in annual funding and the prospect of multiyear renewals, Materials Science and Engineering Professor John Scully is leading an effort to expand our fundamental understanding of corrosion, develop more robust and reliable predictive tools and accelerated tests, and pioneer new smart coatings that will deliver more effective corrosion control at a better price.

“Each of these activities is mutually reinforcing,” Scully says. “For instance, the more we know about the basic science the more accurate we can make our predictive tools.” Scully’s team reflects the multidisciplinary nature of this research. It includes departmental colleagues Robert Kelly and Richard Gangloff and atmospheric scientists from the U.Va. Department of Environmental Sciences, as well as collaborators from The Ohio State University, the University of Southern Mississippi and the University of Hawaii.