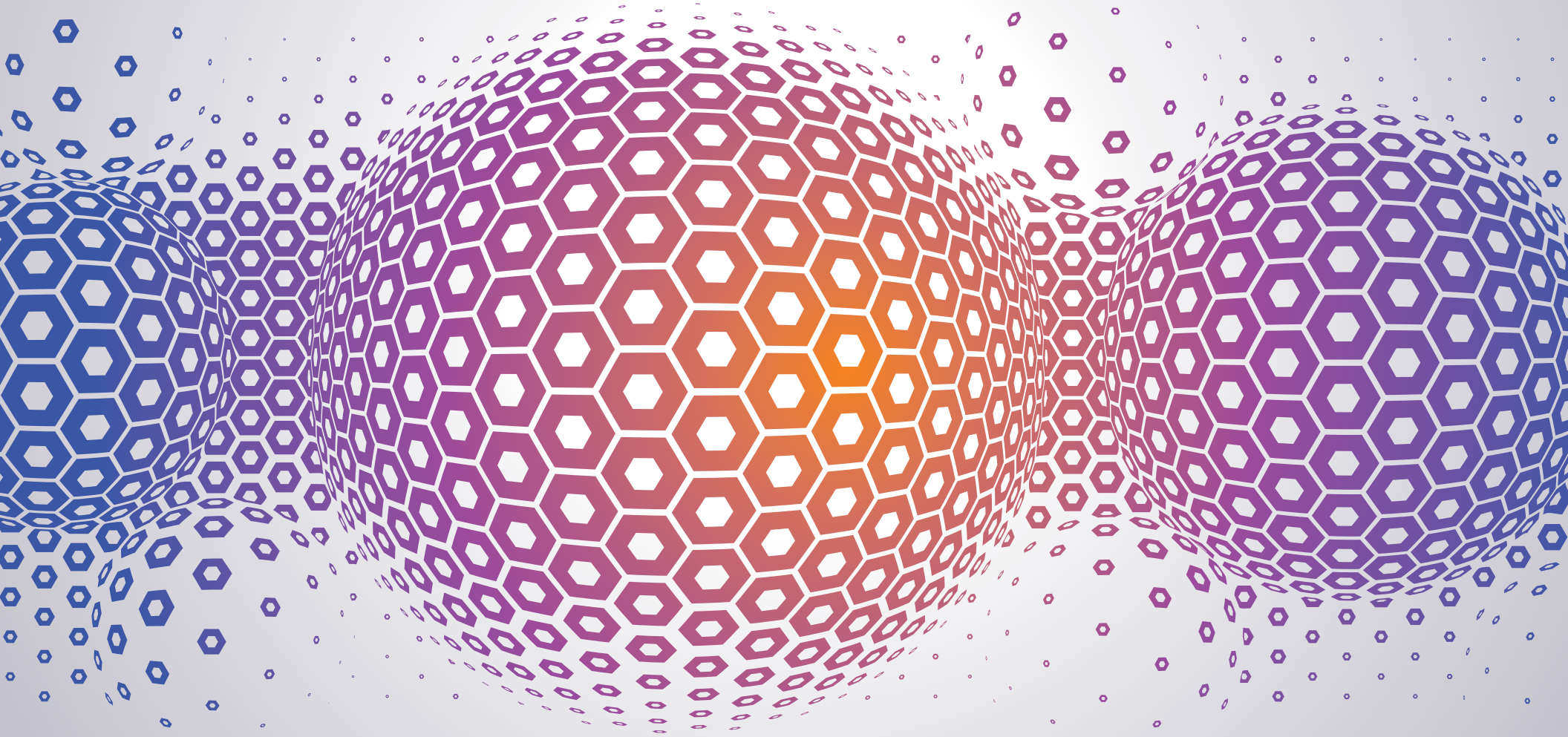
SOLUTIONS

2016-2017

Vanderbilt University School of Engineering



INSIGHT ◦ INNOVATION ◦ IMPACT®

WELCOME

Using nanotechnology to create cars that emit water vapor instead of exhaust.

Retraining the body's immune system to kill neuroblastoma tumors from the inside out.

Helping communities determine whether their infrastructure can withstand climate change disasters.

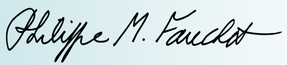
In this year's *Solutions*, you will read about the remarkable work going on within our intellectual neighborhoods—a rethinking of how to classify our research enterprise in a way that maximizes our impact and emphasizes our interdisciplinary strengths. We unveiled the new concept last year and take pride in its success, shown by the diversity of ideas being recognized and rewarded. This strategy is guiding every aspect of our growth from the pursuit of major research programs to valuable partnerships with corporations and foundations.

We're thrilled at the attention being received by the Wond'ry at the Innovation Pavilion, our newly opened innovation center adjacent to the cutting-edge Engineering and Science Building, on schedule for a phased opening through early 2017. The Wond'ry is the most compelling evidence of a movement gaining even stronger momentum here at Vanderbilt: a determination to nurture the culture of design and making among students, faculty, and residents of Nashville and beyond. I invite all to join our extensive network of mentors and makers. Using state-of-the-art equipment, expert guidance, and a web of campus and local makerspaces, you may launch the world's next game-changing company or simply expand your personal spirit of invention. Just go to **vu.edu/wondry** to explore the site and join the mailing list.

The Engineering and Science Building will be home to our regenerative medicine and rehabilitation engineering laboratories, student classrooms, and collaboration centers, plus perhaps the most exciting feature—a commercial-grade clean room to support our growing nanoscale engineering and science research.

Thank you for joining us on this journey through the pages of *Solutions*. Far from simply being the name of this publication, it's what we're striving to find every day at Vanderbilt University, and we're making the investments to prove it.

Best Regards,



Dean, School of Engineering
Dean's Chair in Engineering
Professor of Electrical Engineering

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Dean Philippe Fauchet, who holds the Dean's Chair in Engineering, greets undergraduate students in the just-opened Engineering and Science Building on the first day of classes.

The Wond'ry humming with cross-campus courses and projects

Vanderbilt's much-anticipated innovation center, the Wond'ry at the Innovation Pavilion, designed to be the hub of innovation and entrepreneurship on campus, opened at the start of the fall semester. The center, which furthers Vanderbilt's signature culture of cross-campus collaboration, is already buzzing with student and faculty projects.

"Students from all across campus are tremendously interested in using the center for innovation and entrepreneurship," said Robert Grajewski, the center's Evans Family Executive Director. "Our calendar is already booking up with makerspace workshops, symposia and collaborations."

The Wond'ry at the Innovation Pavilion, which is adjacent to the new Engineering and Science Building, will play a central role in Immersion Vanderbilt, the university initiative for all undergraduates to engage, question and forge change through a mentored multiyear, immersive experience.

A prime example is the first course to be held in the center—New Product Design and Development, a collaborative project between the School of Engineering and the Owen Graduate School of Management. "The course isn't new, but this is the first time it is being taught in an environment that is the focus of the course itself," said David Owens, P.E., professor of the practice in both management and innovation at Owen and engineering management in the School of Engineering. He also holds an appointment in the School of Medicine.

In the course, teams of engineering undergraduates and MBA students work side by side to solve real-world problems presented by Vanderbilt University Medical Center, the Monroe Carell Jr. Children's Hospital at Vanderbilt and other companies. The teams develop and prototype solutions and then deliver them at a product fair at the semester's end.

"Being located between the engineering school and the Medical Center allows us to literally move from discussing ideas in the classroom to making observations on site. Then we can head back to the Wond'ry's shop to do prototypes," Owens said. "This kind of hands-on learning, testing and synthesis is key to teaching a topic that, despite being an engineering science, still has so much art to it."

In November, the student organization VandyHacks will host its third, and largest-yet, annual hackathon in the center. The hackathon will bring together hundreds of students from universities across the country to build apps and design software and hardware while building relationships with their peers and being mentored by tech industry leaders.

Also planned for the center are entrepreneurship breakfasts and roundtables, startup accelerators and training programs for undergraduates and graduate students on using the makerspace.

"With our three key programs now in their launch phase—innovation garage, entrepreneur pre-flight, and social ventures—there is a tremendous amount of buzz and energy around the Wond'ry," Grajewski said. "It's an exhilarating time."

The School of Engineering invites alumni, industry leaders, entrepreneurs, faculty, staff and other mentors to be a part of the Wond'ry's network. Go to vu.edu/wondry to explore the site and join the mailing list.

Engineering student's design immersion proposal chosen for Vanderbilt's QEP

An exciting maker-style immersion experience will be open to all Vanderbilt students in fall 2017 thanks to a successful proposal co-authored by mechanical engineering sophomore Will Berger. Lori Troxel, associate professor of the practice of civil and environmental engineering and the proposal team chair, has been named the initiative's director.

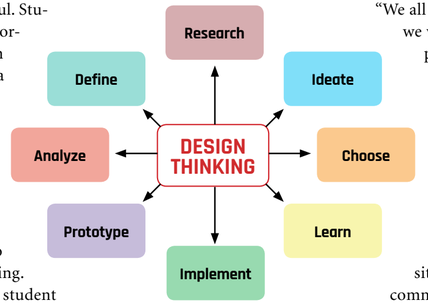
Troxel

Berger

Design as an Immersive Vanderbilt Experience (DIVE) is part of Immersion Vanderbilt, a centerpiece of the university's Academic Strategic Plan. Provost and Vice Chancellor for Academic Affairs Susan R. Wente recently announced the selection of DIVE as Vanderbilt's Quality Enhancement Plan.

DIVE was selected after a yearlong campus-wide consultative process and topped 44 proposals from students, faculty and staff for new immersion programs.

"DIVE offers students the chance to build confidence in their creative abilities," said Berger. "Some students don't necessarily see themselves as creative types, and DIVE aspires to change that. We want to combine a 'no-wrong-answers' attitude with an environment where students can become truly playful. Students will have the opportunity to collaborate on projects that can leave a lasting legacy for both Vanderbilt and the greater community."



Students who participate in DIVE will utilize human-centered design methodology to facilitate problem solving. Small interdisciplinary student teams will research, brainstorm and design tangible solutions to problems facing the Nashville community and the Vanderbilt campus. DIVE projects will engage students in collaborative work, creative thinking, community issues and immersive problem solving. Each team will be guided by a faculty member trained in human-centered design. Campus constituents are creating a comprehensive implementation plan now for DIVE.

"Working on (the DIVE) proposal team was one of the most rewarding and enjoyable experiences I have had at Vanderbilt," said Troxel. "We all agreed early on that we wanted to create a program that would help the entire campus—students, faculty and staff—gain creative confidence to solve problems in both the Nashville and Vanderbilt communities. Valuing diversity and caring for the community are two needs that we believe will be met through working on diverse interdisciplinary teams."

DIVE will be assessed for five years as a component of Vanderbilt's reaffirmation of accreditation by the Southern Association of Colleges and Schools Commission on Colleges.

Members of Vanderbilt's Aerospace Club make field adjustments to their rocket, Trustworthy, at NASA's annual student launch competition in April. Taking first place for the fourth year in a row makes them the most successful team in Vanderbilt history.

Rocket club scores a four-peat in NASA challenge

Vanderbilt student rocketeers scored an unprecedented four-peat in May when they took home the top prize in NASA's Orbital-ATK University Student Launch competition for the fourth year in a row, beating out 40 other university teams in the yearlong national competition.

This year's challenge from NASA was to design rockets that can fly up to an altitude of 5,280 feet and carry a scientific payload that supports the development of the Space Launch System, the most powerful rocket NASA has ever built. According to Amrutur Anilkumar, director of the Vanderbilt Aerospace Design Laboratory, the secret to the Vanderbilt team's success is two-fold: the quality and enthusiasm of the students involved and the multidisciplinary structure of the program, which attracts a dedicated group of graduate students who mentor the stream of undergraduates who participate. Career placement could also be a factor—out of 60 program alumni, 35 have gone on to aerospace engineering positions, including eight at SpaceX.

Centers and institutes involved in the rocket program include the Institute for Software Integrated Systems, a national leader in cyber-physical systems that combines computers with sensors and mechanical systems; the Center for Intelligent Mechatronics, where the latest technology is used to develop the next generation of prosthetic devices; the Laboratory for Systems Integrity and Reliability, where nondestructive test procedures to evaluate complex materials and structures are being developed; and Peabody College's Center for Science Outreach, which specializes in STEM outreach to Middle Tennessee K-12 schools.

Vanderbilt testing cyber-physical systems in next-generation planned community

Sterling Ranch is rising from the prairie grasses south of Denver, Colorado, providing a unique opportunity for Vanderbilt engineers to test technology involving cyber-physical systems and the environment.

Thanks to this partnership between Vanderbilt and the next-generation planned community, teams of professors, Ph.D. students and undergraduates from across the engineering disciplines travel to Sterling Ranch for research projects. Homes, public spaces and water systems all provide test beds. Adjacent to Colorado's Front Range and two state parks, the 5-square-mile, $4.3 billion development will be a model of sustainability and futuristic living.

Fulfilling the promise of a university Trans-Institutional Program award that helps fund the partnership, a smaller team from Peabody College of education and human development is designing next-gen school buildings and curricula for Sterling Ranch, which expects to have 31,000 residents at its completion in 20 years. Students and a professor from the College of Arts and Science are studying water quality and the intersection of sustainable design and human behavior.

Sterling Ranch is the creation of Colorado entrepreneurs Harold and Diane Smethills and their son, Brock, a Vanderbilt engineering alumnus and the project's COO. Brock Smethills (BE'13) envisioned the partnership and began working on it with School of Engineering leaders two years ago.

Construction is underway for the 1.5-million-gallon water tank that will supply about 12,000 homes at Sterling Ranch, the next-generation planned community near Denver in which Vanderbilt is a partner.

Alex DeWind/Colorado Community Media

Goldfarb's exoskeleton gains FDA approval for market

The U.S. Food and Drug Administration has given clearance to market and sell the powered lower-limb exoskeleton created by a team of Vanderbilt engineers and commercialized by the Parker Hannifin Corporation for both clinical and personal use in the United States.

H. Fort Flowers Professor of Mechanical Engineering Michael Goldfarb developed the exoskeleton with a team of engineers and students in his Center for Intelligent Mechatronics.

A patient practices climbing stairs with the Indego.

"It is particularly gratifying because it is the first thing that has come out of my lab that has become a product that people can purchase, which hopefully will make a significant improvement in their quality of life," Goldfarb said.

The Indego exoskeleton, which allows people paralyzed below the waist to stand up and walk, is the result of an intensive, 10-year effort. The initial development was funded by a grant from the National Institute of Child Health and Human Development. In 2012, Parker Hannifin, a global leader in motion and control technologies, purchased an exclusive license to market the design and has worked closely with Goldfarb's group to develop a commercial version of the medical device.

The device acts like an external skeleton. It straps tightly around the torso. Rigid supports are strapped to the legs and extend from the hip to the knee and from the knee to the foot. The hip and knee joints are driven by computer-controlled electric motors powered by advanced batteries. Patients use the powered apparatus with walkers or forearm crutches to maintain their balance.

"The intent of everything we work on is to improve the quality of life," Goldfarb said. "It's much harder to improve the quality of life if your work only ends up on the pages of a journal."

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Assistant Professor of Mechanical Engineering Karl Zelik and Michael Goldfarb, the H. Fort Flowers Professor of Mechanical Engineering, pose with the Indego exoskeleton in the lab.

ENGINEERING NEIGHBORHOODS

IN A GLOBAL WORLD where Skyping with a colleague half a world away or reviewing medical test data via email from remote areas of Africa is commonplace, what is meant by "neighborhood" is being redefined and revitalized. At Vanderbilt University School of Engineering, neighborhood is how we describe our distinctive culture of trans-institutionality, collaboration and cross-pollination both within and beyond the traditional walls of departments, schools, institutions and disciplines.

Vanderbilt Engineering has a long and successful tradition of collaboration with colleagues at other universities and at Vanderbilt University Medical Center, the College of Arts and Science and the other colleges and schools that make up one of the nation's top research universities.

In developing its own bottom-up strategic plan, the School of Engineering has identified nine major areas of emphasis—nine neighborhoods drawing faculty, staff, students and outside researchers together in the search for solutions. These neighborhoods are not closed nor exclusive: It's actually common for a Vanderbilt engineer's research to be part of more than one neighborhood.

Regenerative Medicine works to replace, engineer and heal damaged tissues and organs. Biomedical, chemical and biomolecular engineering research may involve tissue engineering, drug delivery, drug efficacy and molecular biology.

Cyber-physical System technology seeks to develop processes, protocols, networking and technology needed for the seamless integration of cyber (software) and physical (hardware, networks and users) systems. It impacts almost every facet of modern life.

Nanoscience and Nanotechnology concerns the discovery and application of how materials and processes behave on the nanoscale in diverse areas of engineering, science and health care.

Biomedical Imaging and Biophotonics uses physical phenomena such as magnetic fields, radiation and light to aid diagnoses and treatments of disease and dysfunction.

Risk, Reliability and Resilience focuses on improving risk assessment and predictability, as well as increasing reliability of systems, infrastructure and materials. It includes the creation of technology with increased resilience.

Rehabilitation Engineering involves developing mechanics and robotics to help restore lost physical and cognitive functions.

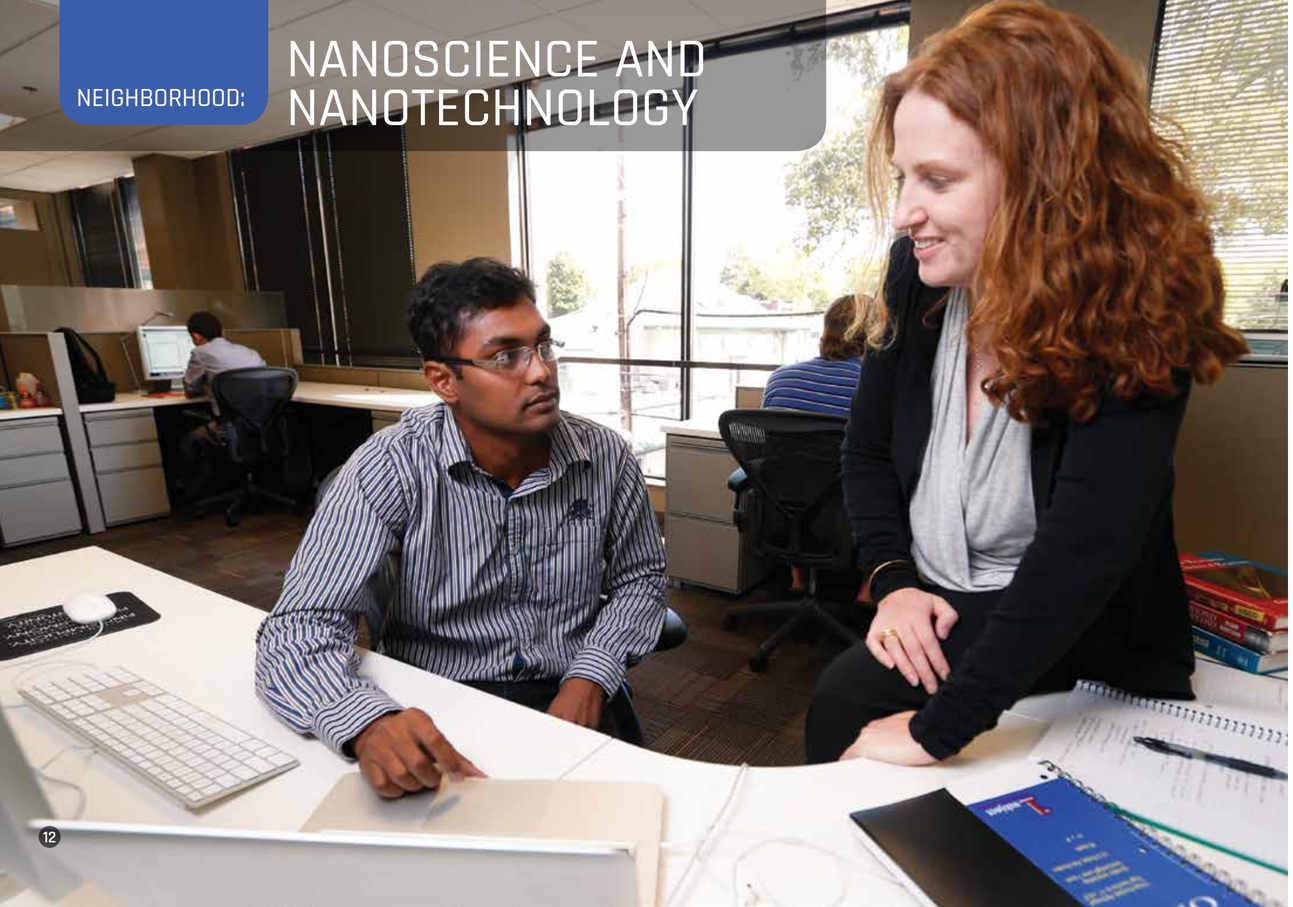
Surgery and Engineering concentrates on the collaborative efforts of engineers and surgical experts to create, develop, implement and evaluate technology, methods and tools that improve patients' outcomes and experiences.

Energy and Natural Resources targets transformative research that will enable sustainable resource and energy conservation, production and recovery.

Big Data Science and Engineering aims to develop tools and processes to harvest and use knowledge from collections of large data sets. The goal is to accelerate progress in health care, science and engineering research and innovation.

NEIGHBORHOOD:

NANOSCIENCE AND NANOTECHNOLOGY



Predicting the true behavior of molecules through nanotechnology

Professor Clare McCabe's research focus brings the virtual world of molecular modeling into the nanoworld of real-life molecules, where neither classical theory nor quantum mechanics are enough to predict the true behavior of molecules.

She is particularly interested in depicting the behavior of organic molecules and, in the process, is coming up with new mathematical theories for engineers and chemists to use in designing chemical processes. Physics can tell us what a handful of atoms might do together, McCabe said, but when you throw in the hundreds of molecules interacting at the nanoscale, quantum mechanics becomes difficult to do.

Clare McCabe's research using nanoscale modeling and simulation to predict how molecules will behave picks up where quantum mechanics and classic theory leave off. Above, McCabe (right) works with students.

"Experimental measurements can be very costly and time-consuming," said McCabe, professor of chemical and biomolecular engineering. "Computer modeling and simulation are an attractive and valuable means with which to fill in the gaps in experimental literature and obtain important information."

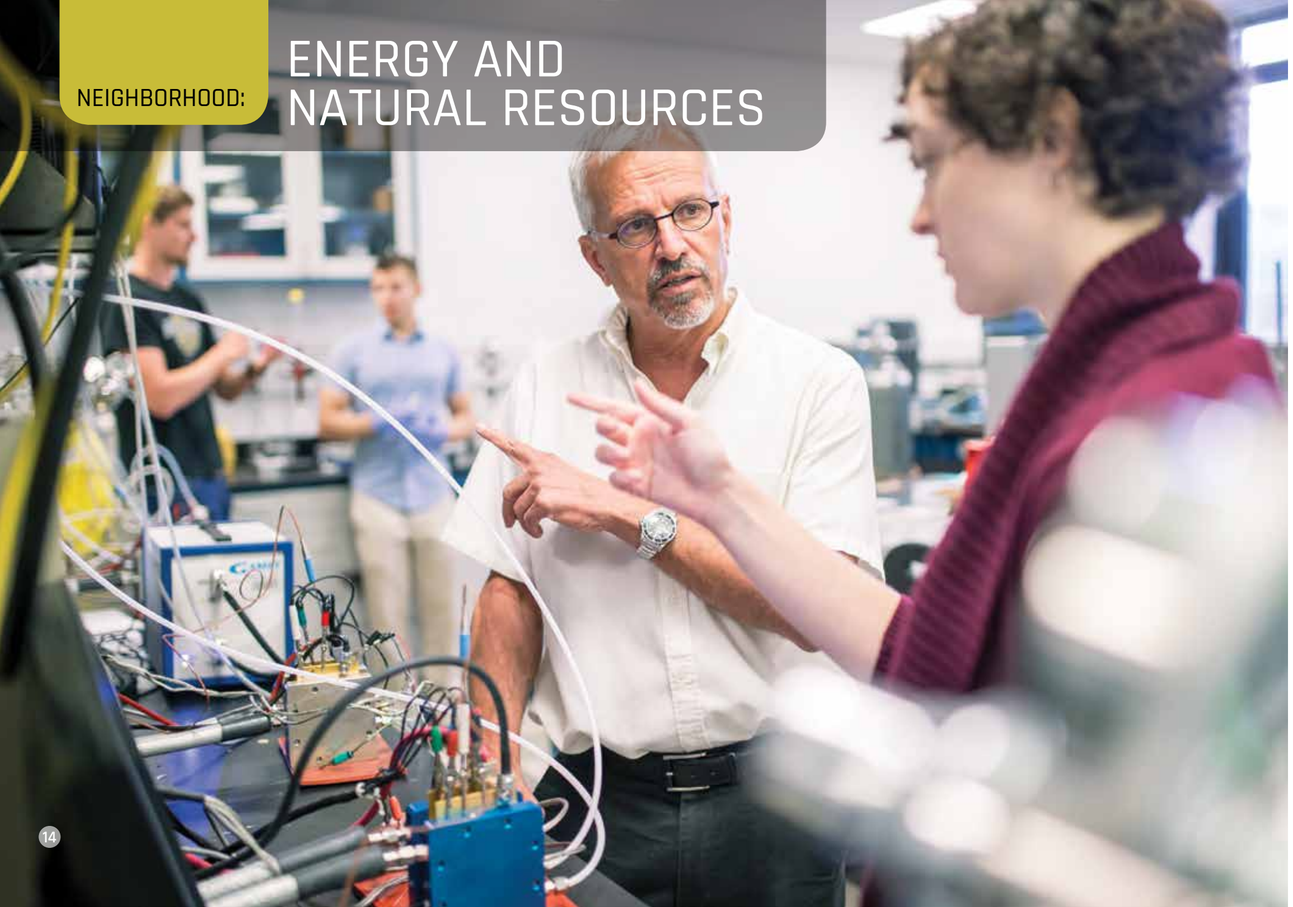
Computer modeling and simulation are particularly useful in determining how materials will behave at extreme conditions, such as very high pressures and temperatures—common in applications as practical as automobile engines.

McCabe's recent work focuses on understanding the self-assembly behavior of skin lipids. Skin's outermost layer is composed of ceramides, cholesterol and free fatty acids. Phospholipids, the major components of most biological membranes, are completely absent. This unique composition enables the lipids of the outer layer of skin to form highly organized membranes, which are believed to control the barrier function of the skin.

While much is known about the nature of skin lipids from extensive experimental studies, a clear understanding of how and why these molecules assemble into the structures observed through microscopy and biophysical measurements does not yet exist. McCabe is using molecular simulations to probe the behavior of skin lipids as they self-assemble, providing insight into their organization that can't be provided by experiments.

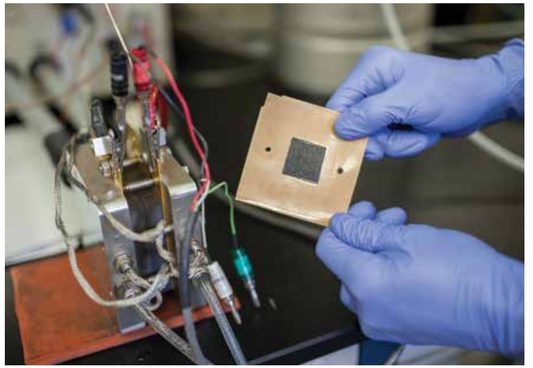
In addition, McCabe's National Science Foundation-funded research promises to make important contributions to understanding friction and wear at the nanoscale. In collaboration with researchers in the School of Engineering's Department of Chemical and Biomolecular Engineering and the Institute for Software Integrated Systems, she is developing tools that will enable other researchers to easily perform state-of-the-art molecular simulations of very complex lubrication systems.

The research is partially supported by National Science Foundation grant OCI-1047828 and National Institutes of Health grant R01AR057886.



New fuel cells use nanotechnology to boost power, cut costs and increase durability

At the same time Honda and Toyota are introducing fuel cell cars to the U.S. market, a team of researchers from Vanderbilt University, Nissan North America and Georgia Institute of Technology have teamed up to create a new technology designed to give fuel cells more oomph.



Left: Peter Pintauro, the H. Eugene McBrayer Professor of Chemical Engineering, talks with a student in the fuel cell lab. **Above:** New nanotech fiber technology developed by Pintauro helps make fuel cells cheaper, more durable and more powerful.

The project is part of a $13 million Department of Energy program recently announced to advance fuel cell performance and durability and hydrogen storage technologies. Fuel cells in vehicles create electricity to power an electric motor.

The collaboration is based on a new nanofiber mat technology developed by Peter Pintauro, the H. Eugene McBrayer Professor of Chemical Engineering, that replaces the conventional electrodes used in fuel cells. The nanofiber electrodes boost the power output of fuel cells by 30 percent while being less expensive and more durable than conventional catalyst layers. The technology has been patented by Vanderbilt and licensed to Merck KGaA in Germany, which is working with major auto manufacturers in applying it to the next generation of automotive fuel cells.

Like a gasoline engine, fuel cells need fuel and air to run. But like a battery, they produce electricity. Fuel cells convert fuel to electricity with efficiencies ranging from 40 percent to 60 percent. There's no moving parts, so they are quiet. The only waste product is water, so they are environmentally friendly.

Conventional fuel cells use thin sheets of catalyst particles mixed with a polymer binder for the electrodes—typically platinum on carbon powder. The Vanderbilt approach replaces these solid sheets with mats made from a tangle of polymer fibers that are each a fraction of the thickness of a human hair, providing a larger surface area of catalyst and higher fuel cell power while using less platinum—a costly material.

"Right now, much of the research work on fuel cell electrodes is very Edisonian," said Pintauro. "It is mainly trial-and-error experiments. We don't know what will happen when we change the composition or structure of the electrodes in hydrogen/air fuel cells. With a better understanding of the interdependence of composition and nanostructure for fiber electrodes, we could accelerate the pace of our research, which would help us to achieve the cost and performance targets needed for automotive fuel cell commercialization."

This work is supported by Department of Energy grant DE-EE0007653.

BIOMEDICAL IMAGING AND BIOPHOTONICS

DIY guide could bring big breakthroughs in focused ultrasound therapy

Focused ultrasound is an emerging, minimally invasive therapy approved to treat bone metastases, uterine fibroids and prostate tumors, with research showing promise in treating dozens of other conditions.

But the prohibitive cost of dedicated focused ultrasound machines has been a barrier to further research.

Enter William Grissom, assistant professor of biomedical engineering. Working with Charles Caskey, assistant professor of radiology, he is throwing open the doors of access by producing a do-it-yourself guide using open-source software so researchers can convert imaging machines into focused ultrasound machines and find their own applications.

"The lack of well-described, accessible, preclinical focused ultrasound systems (FUS) limits progress and decreases repeatability of new developments," Grissom told the Focused Ultrasound Foundation. "Our open-source system can deliver repeatable, precise and quantifiable thermal- and mechanical-focused ultrasound over an extended period in small animals."

The instructions for hardware and the needed software are downloadable for free on the Vanderbilt University Institute for Imaging Science website. The hardware costs about $10,000, mostly for the MR-compatible transducer and amplifier and the function generator, Grissom said, and making the information widely available will be a boon to research.

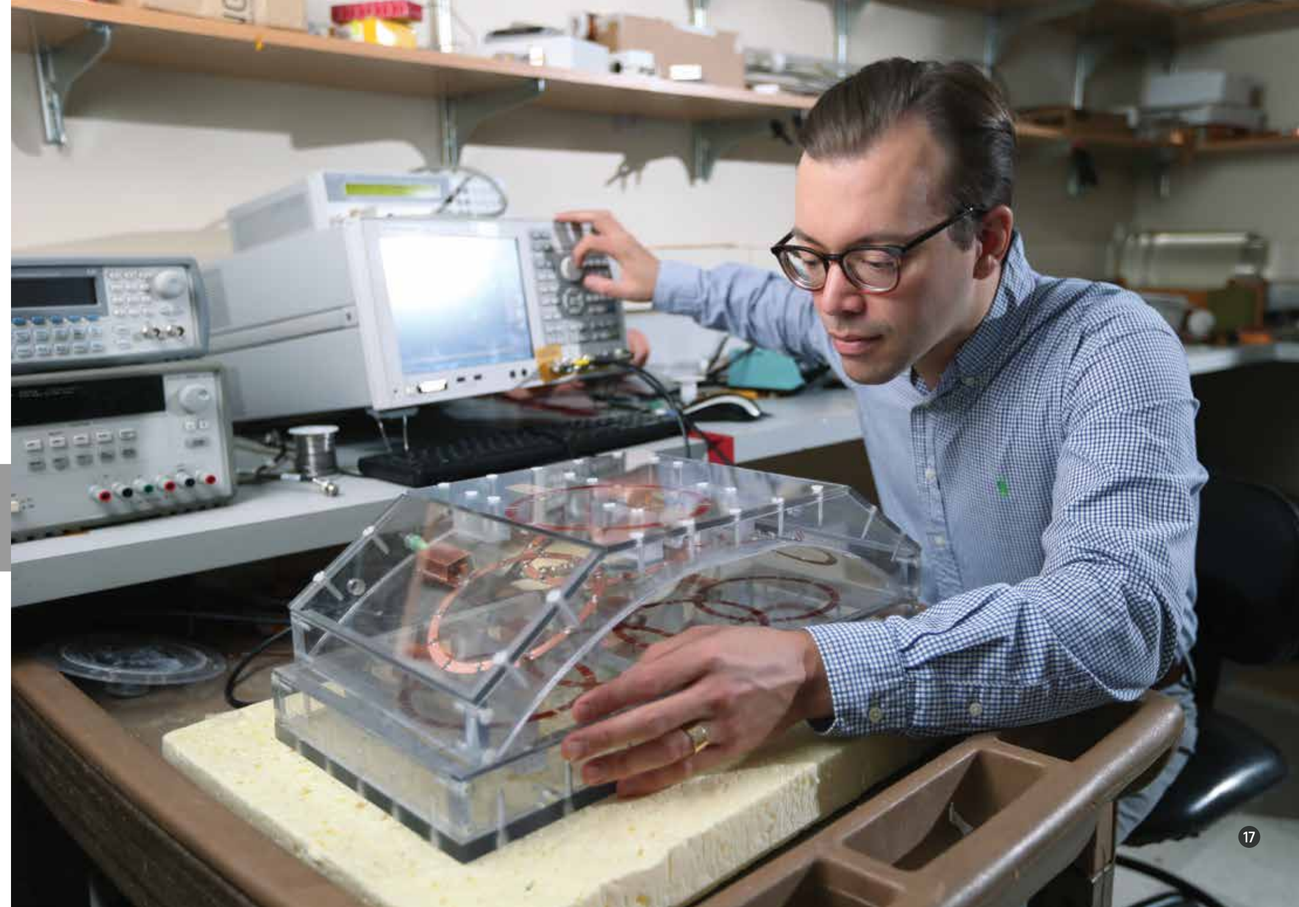
The underlying principle of focused ultrasound is similar to the experiment in any beginning science book—use a magnifying glass to focus the sun's rays, and you can generate enough heat to burn a leaf. Focused ultrasound uses an acoustic lens to concentrate the ultrasound beams on a precise spot in the body, leaving the surrounding tissue unharmed.

"It's just cranking the power way up on a regular ultrasound system and using a lower frequency than with imaging ultrasound," Grissom said. "You can put a lot of focused energy into one place, and the mechanical acoustic energy is converted into heat. The heat is what ends up killing the targeted tissue, with no damage to the intervening tissue."

In addition to not harming surrounding tissue, focused ultrasound requires no incisions and, unlike metal devices that must be inserted into the body, is usable with magnetic resonance guidance so surgeons can see what they're targeting.

The project was funded through a Department of Defense grant to investigate whether FUS could be used to train the immune system to kill the body's cancers, leveraging the abscopal effect, where localized treatment of tumors also shrinks tumors outside that zone.

The research is partially supported by Department of Defense grant W81XWH-12-BCRP-IDEA.



In addition to focused ultrasound, Assistant Professor of Biomedical Engineering William Grissom works on a radio frequency coil array for imaging the prostate using ultra-high-field MRI.

Predicting cooperation: One good deed often leads to another

Two Vanderbilt engineers have built a computational model of human behavior based on game theory and techniques from machine learning that reliably predicts a player's most likely behavior in game after game in a setting where there is a significant tension between cooperative and selfish behavior.

"In essence, we can use our approach to identify a combination of factors that makes selfless behavior—cooperation—significantly more frequent," said Assistant Professor of Computer Science and Computer Engineering Yevgeniy Vorobeychik.

Vorobeychik and graduate student John Nay, MS'13, studied the Prisoner's Dilemma, a game widely used to understand the tension between social and individual interests. Game theory is a branch of applied mathematics primarily used to model how people behave in strategic situations.

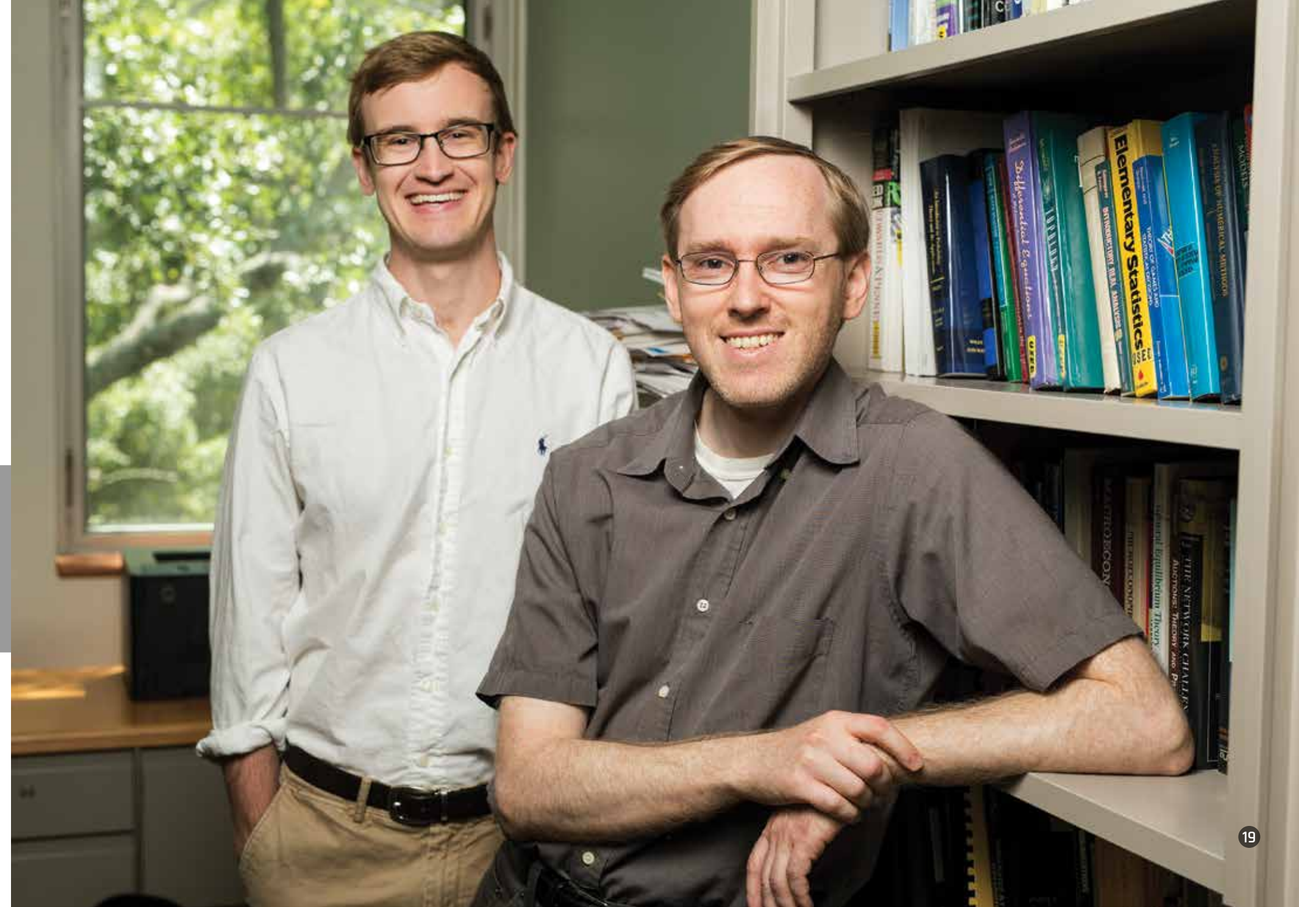
In the Prisoner's Dilemma, players must decide whether to cheat or cooperate with a partner. In a single round of the Prisoner's Dilemma, the best strategy is to cheat—squeal on your partner and you'll get less jail time. But if the game repeats over and over, cooperation becomes achievable. The model created by Nay and Vorobeychik relies on data they integrated from thousands of experimental observations: 168,386 real decisions in 30 different game scenarios. That's a big difference from similar studies that use only a few scenarios, according to the researchers.

"An important number to remember here is 86 percent. Our relatively simple model predicts the next action a player will take at the individual level with 86 percent accuracy. This is a remarkably good prediction," said Nay, an interdisciplinary doctoral candidate in the School of Engineering and a research fellow in Vanderbilt Law School's Program on Law and Innovation.

From experiments in published papers and publicly available data sets that used real people and real financial incentives, the pair built a comprehensive collection of game structures and individual decisions—what Nay, the first author, calls a "meta study." Their work was published in May by PLOS One, *Predicting Human Cooperation*.

"Our model is successful, not merely at fitting the data, but in predicting behavior at multiple scales," Nay said. "For example, in one of the game designs, the model predicted the initial (high) level of cooperation almost exactly and then perfectly matched the observed cooperation level throughout the next seven periods of play. If we can build models that accurately predict human behavior, then we can run simulation experiments to find institutional and policy designs that increase cooperation and other desirable social outcomes, and our work is a step in that exciting direction."

The research is partially supported by U.S. National Science Foundation grants EAR-1416964 and EAR-1204685; the U.S. Department of Energy Solar Energy Evolution and Diffusion Studies Grant, Office of Naval Research (N00014-15-1-2621), and U.S. National Science Foundation (IIS-1526860).



Graduate student John Nay and Assistant Professor of Computer Science and Computer Engineering Yevgeniy Vorobeychik used more than 168,000 real-life decisions made in 30 game scenarios to develop a highly reliable model for predicting how well people will cooperate with each other.

Using virtual reality to help teenagers with autism learn how to drive

Astronauts and pilots use them. So do truck drivers and Formula One race car drivers. Now teenagers with autism spectrum disorder, or ASD, have a virtual reality simulator as well, this one specifically designed to help them learn to drive.

None of the off-the-shelf driving simulators available has the capabilities built into the Vanderbilt VR Adaptive Driving Intervention Architecture, or VADIA. While it teaches adolescents with ASD the basic rules of the road, VADIA also gathers information about the unique ways they react to driving situations, allowing the system to alter the difficulty of driving scenarios so users stay engaged and get the training they need.

"A number of high-functioning individuals with ASD do drive," said Nilanjan Sarkar, professor of mechanical engineering and director of the Robotics and Autonomous Systems Lab. "Studies have shown that when they are learning, they tend to make certain kinds of mistakes more often than other beginning drivers. So how you train them is very important." He describes the project in detail in an article published in *Transactions on Interactive Intelligent Systems*.

Nilanjan Sarkar, professor of mechanical engineering, watches Brandon Roberson, a teen with Asperger's syndrome, learn the rules of the road with the virtual reality driving simulator.

To use the simulator, participants don a headset that reads their brain's electrical activity and hook up to an array of physiological sensors to record the electrical activity of the driver's muscles and heart, galvanic skin response, blood pressure, skin temperature and respiration. The elaborate monitoring allows the researchers to determine if the driver is engaged or bored by the simulation.

The simulator portrays a city with four different districts—downtown, residential, industrial and arboreal—ringed by a freeway, and the software can vary the degree of difficulty, including speed, aggressiveness of drivers and weather conditions.

"One of our preliminary results is that the teenagers really like it," Sarkar said.

"This would definitely be a good teaching aid for driving, without a doubt," confirmed Brandon Roberson, 16-year-old with Asperger's syndrome who has been participating in the studies. He has his learner's permit and would like to drive by himself. "Going out and doing what I want to do is something I have never been able to do because I have not been able to drive."

A preliminary study with 20 adolescents diagnosed with ASD have confirmed Roberson's assessment. Half of the teenagers were tested in the performance mode, and half were tested in the gaze contingency mode. After six 45-minute sessions, both groups showed improvements in performance. By the end of the test, they were completing driving trials faster with fewer errors.

"Of course, we will have to show that these improvements will carry over into real life, but we have good reasons to think it will," Sarkar said.

The research was supported in part by National Science Foundation grant 967170 and National Institutes of Health grant R01MH091102-01A1.

REGENERATIVE MEDICINE

Beating the enemy at its own game

John T. Wilson is working to beat a common childhood cancer, neuroblastoma, on its own turf by finding new ways for the body's immune system to identify and extinguish tumors.

This promising research in the nascent field of immunoengineering by the assistant professor of chemical and biomolecular engineering garnered two key awards in 2016: a five-year, $500,000 National Science Foundation Faculty Early Career Development award and a three-year, $450,000 A Award from the Alex's Lemonade Stand Foundation. Wilson's Laboratory for Immunomodulatory Biomaterials focuses on the trans-institutional intersection of engineering and immunology to improve human health.

About half of children with neuroblastoma have an aggressive, high-risk form of the disease, Wilson said, which is resistant to treatment in part because these tumors can suppress the immune system's defenses. Survival rate for these patients is less than 40 percent.

The NSF grant—Engineering Polymeric Nanomaterials for Programming Innate Immunity—will allow Wilson to develop synthetic materials to "encode" immunological messages, tightly regulating their delivery to the organs, cells and pathways of the immune system.

"This research will address a fundamental need for new tools to control, understand and harness the immune system, which has significant ramifications in vaccine development, cancer immunotherapy, and treatment of autoimmune disorders," Wilson said.

Wilson's goal for the Alex's Lemonade Stand grant is to develop an implantable "immunotherapy bomb" that will retrain the patient's immune response to sneak past a neuroblastoma tumor's line of defense and trigger an immune response from the inside out to kill tumors. The immune cells will be triggered to remember this response in case future tumors develop.

"This support will jump-start our work in developing new therapeutics and drug delivery strategies," Wilson said. "I am also excited about the interdisciplinary collaborations and relationships that this award will help foster, which I think will inspire creative new ideas that get us closer to finding cures for childhood cancers."

The research is partially supported by Alex's Lemonade Stand and National Science Foundation Career Award No. 1554623.

Assistant Professor of Chemical and Biomolecular Engineering John T. Wilson is on the hunt for ways to teach a cancer patient's immune system to kill a particularly deadly kind of tumor from the inside out.

NEIGHBORHOOD:

CYBER-PHYSICAL SYSTEMS

Smart City research aims to make lives safer, more efficient

He started with a real-time bus application aimed at making that mode of travel so easy and rewarding, Nashvillians could hardly resist it. Now Abhishek Dubey, assistant professor of computer science and computer engineering, and his team are expanding into apps for a host of other uses that create Smart Cities, aimed at making our lives safer and more efficient.

"Smart systems are those that improve and evolve as more and more data comes in," Dubey said. "These systems aren't just deployed; they have to interact with humans. They are right in front of us, not running on a single computer but distributed on our smartphones, the traffic lights, in parking garages. There are millions and millions of processes and sensors.

"My vision is to create an ecosystem where you don't have to manage them, because they are managing themselves."

The Vanderbilt Initiative for Smart-City Operations Research (VISOR) is a recently funded Vanderbilt Trans-Institutional Program that provides an umbrella for a number of Smart City projects. Those include Dubey's collaboration with Gautam Biswas, professor of computer science, computer engineering and engineering management, and Yevgeniy Vorobeychik, assistant professor of computer science and computer engineering, on a safety analytics project with the Metro Nashville Fire Department.

The team is using fire department data on motor vehicle accidents and other emergency incidents to study various clustering algorithms. They want to create a model that predicts the likelihood of an incident in a certain neighborhood and, after identifying hot spots, creates a dispatch algorithm that ensures resources are in the right places.

Dubey also is leading a team building a next-generation, self-managing computation platform called CHARIOT for Smart Cities. It enables designers to build modular and adaptive applications that allow apps to plug in another component automatically if the first component fails.

For instance, if a parking app is supposed to tell drivers how many spots are left in a lot, but the monitoring camera fails because of rain, the app will automatically search for a different mechanism and switch to it for the information.

Finally, the busy researcher is on a team headed by Gabor Karsai, associate director of Vanderbilt's Institute for Software Integrated Systems, that earned a $3.5 million award from the Department of Energy's Advanced Research Projects Agency–Energy. They're creating software to control the Smart Grid—a power system that is more efficient, sustainable and reliable than America's current electrical power delivery.

Assistant Professor of Computer Science and Computer Engineering Abhishek Dubey and his team are developing more apps like their Music City Transit Tracker to create Smart Cities that make lives safer and more efficient.

The research is partially supported by a Vanderbilt University Trans-Institutional Program award, National Science Foundation grant 1528799, Department of Energy's Advanced Research Projects Agency–Energy grant DE-AR0000666 and Siemens grant F-310-02-11.

NEIGHBORHOOD:

RISK, RELIABILITY AND RESILIENCE

Building a better formula to predict climate change impact

Researchers know climate change means extremes in temperature, rainfall and catastrophic storms. The mystery lies in just how devastating these conditions may be and how, particularly, they may affect the infrastructure we rely upon.

Assistant Professor of Civil and Environmental Engineering Hiba Baroud's research lies in Bayesian statistics, where she can integrate multiple sources of information—including historical data and expert knowledge—to improve prediction accuracy. For example, in predicting the impacts of a flood on inland waterways and creating a recovery strategy, Baroud uses historical data such as weather, previous disruptions and the condition of the infrastructure. But she also uses information gathered from decision-makers and rescue workers who have managed recovery efforts for decades.

With the Trans-Institutional Program award her team earned this year from the university, Baroud will use those statistical methods to build a foundation of knowledge that researchers can use to predict the risks around climate change and assess the resilience of utilities, roads and other systems. The consequences of inaction can be as severe as those seen in New York and New Jersey during Hurricane Sandy in 2012, when the superstorm washed out roads, flooded subway tunnels and knocked out the power grid.

Baroud also is looking at the nexus of water and energy and how climate change will affect that.

"We're trying to find ways to produce energy from renewable sources, but in the upcoming years when we have less water, it will be more challenging to use it for that," she said. "Also, with higher temperatures, we may be taking more showers or watering our lawns more often, increasing the demand as the supply decreases."

With a better idea of what's coming, government and private sector decision-makers can design infrastructure systems that protect against the elements without overbuilding or overinvesting.

Part of the challenge, Baroud said, is the fact that climatologists' roughly 20 models for temperature and rainfall, which provide forecasts through 2065, are widely disparate. The potential effects on both human behavior and on infrastructure add another layer of complexity, which is why Baroud's grant team includes a Vanderbilt climatologist and psychologist in addition to three other engineering professors.

"The key is having all of these groups talk to each other and building from there," Baroud said. "Then engineers can find solutions to these shortfalls."

The research is partially supported by a Vanderbilt University Trans-Institutional Program award.

Assistant Professor of Civil and Environmental Engineering Hiba Baroud pulls together a varied set of data and history with Bayesian statistics to better predict the devastation of floods and other severe events on infrastructure.

NEIGHBORHOOD:

SURGERY AND ENGINEERING

Tiny mechanical wrist opens big horizons in needlescopic surgery

A tiny mechanical wrist developed by a team of engineers and doctors at Vanderbilt University was named as one of six new medical technologies to watch by the *Wall Street Journal* this summer.

A research team headed by Associate Professor of Mechanical Engineering Robert Webster in his Medical Engineering and Discovery Laboratory has developed a surgical robot with steerable needles equipped with wrists less than 1/16th of an inch (2 mm) thick. With the innovative wrist, the inventors hope to give needlescopic surgery a whole new degree of dexterity.

Needlescopic surgery, which uses instruments the diameter of sewing needles, is the ultimate form of minimally invasive surgery. The incisions required can be sealed with surgical tape and usually don't leave a scar. However, the difficult technique is used by only a handful of surgeons around the world.

Webster's new device is designed to provide needlescopic tools with a previously unknown degree of dexterity. Surgeon-operators will be able to perform procedures that haven't been possible before, and the new system will reduce invasiveness through use of needle-sized instruments in areas such as the nose, throat, ears and brain.

Associate Professor of Mechanical Engineering Robert Webster puts his latest invention—a needlescopic surgical robot with tiny wrists—through its paces. The invention will allow surgeons to perform procedures that hadn't been possible.

"We knew this was a game-changer," Webster said. "The wrist lets the surgeon turn a corner with the end of the tool. It can work in a lot of different surgeries. We're looking at transnasal brain surgery—going through the nose up into the brain. This mechanical wrist lets us think outside the normal ways of doing these things."

Webster's needles can operate in areas of the body that neither manual endoscopic instruments nor Intuitive Surgical's da Vinci robotic system can reach.

"The smaller you can make surgical instruments the better … as long as you can maintain an adequate degree of dexterity," said Professor of Urologic Surgery S. Duke Herrell, who is collaborating on the project. "In my experience, the smaller the instruments, the less postoperative pain patients experience and the faster they recover."

Webster also holds associate professor appointments in electrical engineering, otolaryngology, neurological surgery and urologic surgery. He was named a Chancellor's Faculty Fellow earlier this year.

The achievement is described in a paper titled "A Wrist for Needle-Sized Surgical Robots" presented in May at the International Conference on Robotics and Automation in Seattle. Vanderbilt University has applied for a patent on the design.

The research is partially supported by NIH grant R01 EB017467.

Numbers of Note

Faculty Honors

82

Faculty named fellows

Jobs

81% of graduates in 2016 had job offers before Commencement (U.S. citizens and permanent residents)

Engineering Students

30.1% women

18.9% international students

15.2% minority students

Faculty:Student Ratios

16:1
undergraduate students to faculty member

5:1
graduate students to faculty member

Institutes, Centers and Groups

12

Graduate Honors

11 engineering students awarded 2016 graduate research fellowships

Externally Funded Research Expenditures

$69.3 million (in FY15)

Student Global Experiences*

26 percent of the Class of 2016 studied or interned abroad for at least a month. (Countries and number of students below)

Europe (continental): 49
U.K. and Ireland: 8
South and Central America: 16
Australia and New Zealand: 20
China: 9
Africa: 2
Singapore: 5
Israel: 2
Russia: 1
Other: 2
(e.g., Semester at Sea)

*includes study abroad, exchange and overseas service learning programs

Student Life

23 student engineering organizations

53% of undergrads participate in research projects outside the classroom

Selected Honors and Leadership

Unless otherwise noted, the following lists organizations to which Vanderbilt School of Engineering faculty have been elected to as fellows (as of Sept. 1, 2016).

American Academy of Forensic Sciences
American Association for the Advancement of Science (AAAS)
American Geophysical Union
American Heart Association
American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
American Institute for Medical and Biological Engineering
American Physical Society
American Society of Civil Engineers (ASCE)
American Society for Engineering Education
American Society for Laser Medicine and Surgery
American Society of Mechanical Engineers
American Vacuum Society
American Welding Society
Association of Women in Science
Biomedical Engineering Society
Council on Basic Cardiovascular Sciences of the American Heart Association
Electrochemical Society
Engineering Mechanics Institute
Heart Rhythm Society
Geological Society of America
Institute of Electrical and Electronics Engineers (IEEE)
Institute of Physics (U.K.)
Institute of Transportation Engineers
International Society for Magnetic Resonance in Medicine
International Society for Optical Engineering (SPIE)
Materials Research Society
Microscopy Society of America
National Academy of Engineering, Members
National Academy of Sciences, Advisory Committees Member
National Academy of Sciences, National Associate
Optical Society of America
Royal Danish Academy of Sciences and Letters
Royal Society of Chemistry (U.K.)
Royal Swedish Academy of Engineering Sciences
U.S. Air Force Scientific Advisory Board, Member
U.S. Nuclear Waste Technical Review Board, Presidential Appointee

Innovation to Commercialization

Rebekah H. Griesenauer, a Ph.D. candidate in biomedical engineering, center, worked with MBA and law students to adapt her lab-based tumor imaging research to a clinical setting.

$1,437,369 Revenue for VUSE technologies

93 U.S. patent applications filed

54 New invention disclosures received

15 License agreements executed

15 U.S. patents issued

11 Startups with a connection to the School of Engineering

These figures were provided by Vanderbilt's Center for Technology Transfer and Commercialization for the most recent fiscal year (July 1, 2015, through June 30, 2016).

RESEARCH GROUPS

As the engineering arm of an internationally recognized research university, Vanderbilt University School of Engineering fosters strong partnerships inside the university and with its research peers. The combination of innovative research, commitment to education and collaboration with a distinguished medical center creates an invigorating atmosphere where students tailor their education to meet their goals and researchers join to solve complex questions affecting our health, culture and society. Vanderbilt is ranked 20th in federal research and development funding obligations among U.S. colleges and universities.

Biophotonics Center at Vanderbilt
Anita Mahadevan-Jansen
Orrin H. Ingram Professor of Biomedical Engineering
vanderbilt.edu/vbc

Center for Intelligent Mechatronics
Michael Goldfarb
H. Fort Flowers Professor of Mechanical Engineering
research.vuse.vanderbilt.edu/cim

Consortium for Risk Evaluation with Stakeholder Participation
David Kosson
Cornelius Vanderbilt Professor of Engineering
Charles Powers, Co-PI
Professor of Environmental Engineering
cresp.org

Institute for Software Integrated Systems
Janos Sztipanovits
E. Bronson Ingram Professor of Engineering
isis.vanderbilt.edu

Institute for Space and Defense Electronics
Ron Schrimpf
Orrin H. Ingram Professor of Engineering
isde.vanderbilt.edu

Laboratory for Systems Integrity and Reliability
Douglas Adams
Daniel F. Flowers Professor
Distinguished Professor of Civil and Environmental Engineering
vu.edu/lasir

Multiscale Modeling and Simulation Group
Peter Cummings
John R. Hall Professor of Chemical Engineering
my.vanderbilt.edu/mums

Vanderbilt Institute for Energy and Environment
George M. Hornberger
Craig E. Philip Professor of Engineering
University Distinguished Professor of Civil and Environmental Engineering and Earth and Environmental Science
vanderbilt.edu/viee

Vanderbilt Institute for Integrative Biosystems Research and Education
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vanderbilt.edu/viibre

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Professor of Chemical and Biomolecular Engineering
Sharon Weiss, Deputy Director
Professor of Electrical Engineering
vanderbilt.edu/vinse

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Cornelius Vanderbilt Professor of Engineering
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