SOLUTIONS

Vanderbilt University School of Engineering

INSIGHT INNOVATION IMPACT®

2015

MARS IN THEIR SIGHTS

For the third year in a row, it was Vanderbilt at the top. In April, a black and gold Mini V rocket blasted into flight, reaching an altitude just short of 3,000 feet before popping its parachute and safely landing its payload. Defending national champion Vanderbilt Aerospace Club beat out 30 other university and college teams to win NASA's annual rocketry competition, the Student Launch Challenge. The team focused on developing solutions to problems that would be encountered on Mars. Vanderbilt's Mini-Mars Ascent Vehicle entry successfully included building a ground support robot that autonomously placed a simulated Mars soil sample in the rocket before liftoff.

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WELCOME

In addition to showcasing our groundbreaking research, this edition of *Solutions* presents a new way of looking at the Vanderbilt University School of Engineering.

This fall, we unveil the concept of intellectual neighborhoods, which focus on core competencies that we currently have established or are building upon. Intellectual neighborhoods cross disciplines and schools at Vanderbilt and even overlap each other in some of their research activity. They can be added to and phased out as the research funding landscape fluctuates and can easily adapt to trends in societal needs.

After going through this strategic exercise over the past year, I wasn't surprised that our existing research centers and institutes closely align with these neighborhoods. And in fact, the university just recognized one of our neighborhoods—the former Vanderbilt Initiative in Surgery and Engineering—as a full-fledged institute, bookending the three-year effort of a loose group of researchers to organically create a highly productive research organization.

The neighborhood concept also seeks to include those faculty who do not align with a current center or institute. Neighborhoods are described broadly enough to involve all our tenure/tenure-track faculty, nearly all research faculty, and some teaching faculty. Most important, the neighborhoods guide our allocation of resources such as space, equipment, staff, and new programs, as well as new faculty hires.

Traditional departments continue to exist, but as we all know, department-centric research and other activity is obsolete in both small and large programs. This model will increase the already strong collaborative nature of the School of Engineering by adding to the nimbleness of how we respond to external pressures and influences.

I invite you to read more about our nine intellectual neighborhoods. In the following pages, we highlight our outstanding faculty and their recent accomplishments and the research capabilities of the neighborhoods. I welcome feedback from you on this unique way of looking at a research-intensive engineering school.

Best regards,

Philippe Fauchet

RISING FAST

In just under a year, Vanderbilt's new Engineering and Science Building will be complete and in use. The 230,000-square-foot building will increase research and trans-institutional opportunities for students, faculty and staff.

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 re-vitalized. At the 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 the Vanderbilt University Medical Center, the College of Arts and Science and all 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.

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.

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

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

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

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

Big Data Science and Engineering aim 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.

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.

Surgery and Engineering concentrate 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 target transformative research that will enable sustainable resource and energy conservation, production and recovery.

NEIGHBORHOOD

CYBER-PHYSICAL SYSTEMS

Engineering for a Revolution

Americans have become well-accustomed to the sight of Fitbit-adorned wrists, their wearers marching in place so that their smartphones can reward them with a celebratory message about hitting a step goal. That's one small example of the Internet of Things.

And we're starting to hear about intersections where the traffic light changes to accommodate an approaching ambulance. We have smart clothes dryers that turn on when electricity is inexpensive. That's part of the Industrial Internet.

Both of these are precursors of the next technology revolution that Vanderbilt University's

Institute for Software Integrated Systems is helping launch. The intent is to extend the use and frontier of the Internet to create a deeply connected world where humans, their machines and the physical environment interact seamlessly, continuously and without mistakes and breakdowns that could lead to safety issues, security breaches, environmental harm, or other unintended consequences.

Imagine a convoy of six trucks communicating with each other to move safely as traffic lights accommodate their progress. Picture a smart home that locks itself up, but senses that there's still a person inside and opens doors if a smoke alarm goes off.

That technology is called cyber-physical systems, and it has been institute director Janos Sztipanovits' passion for a long time.

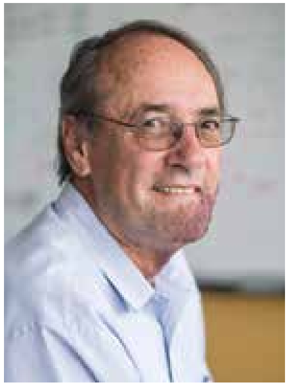
Cyber-physical systems technology focuses on designing systems so that people are living in a richly instrumented environment where virtually everything is connected to computers through networking—enabling a lot of automation, says Sztipanovits. The E. Bronson Ingram Professor of Engineering says the result is that many things will start interacting with each other that never interacted before. How can you keep track of all these interactions so you don't damage the safety of your home?

"The world is getting more connected. We need to understand what are the new engineering principles where you can create safety, security and stability," he says.

Through his participation, Vanderbilt was the first academic institution to join the pioneering Industrial Internet Consortium after it was announced in 2014. Technology giants AT&T, Cisco, GE, IBM and Intel founded the group, which now has more than 200 members supporting adoption of the Industrial Internet, integrating physical machinery with networked sensors and software.

Sztipanovits and Vanderbilt's Institute for Software Integrated Systems also manage the Cyber-physical Systems Virtual Organization for the National Science Foundation. They're charged with linking together all the organizations working on the topic, archiving and disseminating documents produced by research, and offering collaboration platforms for thousands of CPS researchers.

To show how much interest there is in CPS research and the foundational technology beneath it, Sztipanovits notes that in 2014, top information technology research company Gartner published a report outlining a long list of technologies belonging to the Internet of Things, the Industrial Internet and cyber-physical systems. The research group's general expectation is that technologies such as smart robots and autonomous vehicles, big data, mobile health monitoring and cloud computing will make a huge impact in the next 5 to 10 years.



Rethinking engineering for a new era comes with its challenges, Sztipanovits points out. The sheer number of platforms that must be addressed to make this level of interaction possible is daunting, not to mention the large numbers of engineers contributing pieces to a vast system.

The Internet of Things, the Industrial Internet and cyber-physical systems are all different components in a major, ongoing technology shift.

Perhaps the best comparison, he says, is the old tale of the blind men describing an elephant—the legs, trunk and tusks. All are important, but in the end, the goal is seeing the entire beast. What an amazing elephant it will be.

Some of the institute's cyber-physical systems research is supported by NSF award 0931632.

Opposite: Peter Volgyesi works on a sensor testbed as part of a trans-institutional NSF project led by a College of Arts and Science professor, Akram Aldroubi. **Right:** Janos Sztipanovits directs the Institute for Software Integrated Systems, which has been charged by the NSF with linking together all organizations working on cyber-physical systems for the agency.

NEIGHBORHOOD

BIOMEDICAL IMAGING AND BIOPHOTONICS

Through a New Window

The discovery of X-ray more than 100 years ago revolutionized medical care by opening a window into the human body. Now biophotonics promises us a new window for medical breakthroughs.

Researchers are using beams of light to stimulate and control bundles of nerve cells that may allow amputees to control and feel the movement of prosthetic limbs. Laser techniques are used in breast cancer and brain tumor detection and surgery. And biophotonics is playing a key role in the federal government's BRAIN Initiative and the National Institutes of Health's Precision Medicine Initiative, demonstrating support for interdisciplinary research and information sharing.

The new Biophotonics Center at Vanderbilt provides a home for the university researchers dedicated to translational research of such photonic technologies for biomedical research and clinical use. It brings together faculty members

who focus on the science and applications of light and light-based technologies to solve problems in medicine and biology.

It's more than that: Simply put, the research center—led by Anita Mahadevan-Jansen—opens a new window into the human body. The center's mission encompasses three main areas: cancer photonics, neurophotonics and multiscale photonics.

Although the center is new, many of the building blocks were already in place. Mahadevan-Jansen, the Orrin H. Ingram Professor of Biomedical Engineering and professor of neurological surgery, says they're poised to be a world-class program that can span from the laboratory bench to bedside and from academic environment to the marketplace.

Left: Surgeon Carmen Solorzano uses a near-infrared fluorescence system developed by Anita Mahadevan-Jansen (right) and Ph.D. student Melanie McWade to avoid the inadvertent removal of parathyroid glands during endocrine surgery. Patients have fewer post-surgery complications when the parathyroids are not affected.

Set up as core labs, and in part, as thematic research labs, the center's facility includes laboratories for clinical spectroscopy/diagnostics, Raman spectroscopy, optical imaging, optical coherence tomography, neurophotonics, high-power lasers and core support facilities. Those include bioluminescence imaging, spectrophotometry, image analysis and processing, microscopy, small animal surgery and fully equipped labs for cell and tissue culture as well as histology. It also includes a state-of-the-art optics teaching lab to provide undergraduate and graduate students with hands-on training in biomedical photonics.

Several of these labs have pioneered enhancements in optical imaging and applications for optical diagnosis and treatment of breast, cervical, thyroid, liver and skin cancers. They've also had success in using infrared light as an alternative to electrodes in peripheral nerve stimulation as a way of exciting and inhibiting nerves.

Forty faculty members from 25 academic departments across the university and clinical departments of Vanderbilt University Medical Center are affiliated with the research center. It interfaces with existing centers and institutes such as the Vanderbilt Ingram Cancer Center, Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University Institute of Imaging Science, the Brain Institute and Vanderbilt Institute for Integrative Biosystems Research and Education.

Mahadevan-Jansen says that that level of cross-campus collaboration demonstrates commitment to establish a leading center aimed at fundamental discovery and research, while at the same time pursuing optical technologies aimed at improving patient care.

The Biophotonics Center is headquartered in a recently renovated 5,000-square-foot research space within the W.M. Keck Free Electron Laser building. Current funding in biophotonics research at Vanderbilt totals nearly $25 million.

Research mentioned is supported in part by the Department of Defense Breast Cancer Research Program and National Institutes of Health.

NEIGHBORHOOD

REHABILITATION ENGINEERING

Uncovering Walking's Secrets

Karl Zelik was drawn to the topic of human locomotion by growing up in a family of four athletic boys. He was a perennial medal winner on the track and field team at Washington University, where he earned his bachelor's and master's degrees in biomedical engineering.

At Vanderbilt, he applies both his experience and education to helping people who lose limbs regain mobility.

In his effort to develop better prosthetic limbs, Zelik, an assistant professor of mechanical engineering, had to start with deciphering more

clearly how muscles function in walking. His path not only led to a better way of quantifying human locomotion, but also to the discovery that muscles around the hip and in the foot are more important to walking than previously thought.

Left: Professor Karl Zelik discovered that traditional methods of measuring the muscle power needed for walking were incomplete. When he used markers to record volunteers' locomotion (above), he was able to account for all the power—and determined that hip and foot muscles play a bigger role in walking than previously known.

The traditional way to estimate muscle power during walking and running is with three-degree-of-freedom (3DOF) inverse dynamics, a mathematical calculation of how muscles and tendons generate forces to rotate the body's limbs.

But when Zelik applied those calculations to previously collected data, he realized there was a large discrepancy. Based on 3DOF estimates, total muscle power generated by the body was 25 percent too low, meaning these estimates could not explain the kinetic and potential energy changes of the body over a stride cycle. Basically, 25 percent of walking movement could not be explained biomechanically.

To understand why, Zelik and his team recruited 10 healthy subjects, placed markers at 30 points on their bodies, and then had them walk at various speeds. They used a motion-capturing system to record leg movement and an instrumented treadmill to record the forces the walkers' feet exerted on the ground.

This work was supported in part by the Whitaker International Program.

They then developed a new way to combine the motion and force data, using a six-degree-of-freedom analysis of the hip, knee, ankle and foot. Using this method, calculations of the power generated by muscles and other biological tissues added up to account for 100 percent of the body's energy changes.

Zelik says that when he initially found the power gap, he was frustrated that so much science was built on measurements that didn't add up properly. It was teaming with other researchers and combining data that led him to the answer. He worked with Kota Z. Takahashi, a postdoctoral researcher who specializes in foot biomechanics, and Gregory S. Sawicki, a professor who specializes in muscle biomechanics, both of North Carolina State University. The team's results were published in *The Journal of Experimental Biology* in March 2015.

Their work also revealed that propulsive power generated by the hip is 50 percent greater than previously measured by conventional means. "Many prostheses and exoskeletons have focused on assisting the ankle," Zelik says. "The research suggests there may be ways to improve mobility by providing more assistance at the hip as well."

NEIGHBORHOOD

NANOSCIENCE AND NANOTECHNOLOGY

Improving Coronary Bypass Success

Since his postdoctoral fellow days, Craig Duvall has been looking for a way to improve intracellular peptide delivery to treat diseases such as cancer.

It wasn't until he was a newly minted assistant professor of biomedical engineering at Vanderbilt University that Duvall seriously considered a different use for his work. He happened to catch a presentation by Colleen Brophy, M.D., professor of surgery, about the intracellular-acting peptides she was researching to improve success rates in vascular transplants for patients suffering from heart disease.

They combined forces, and five years later, they celebrated a major breakthrough announced in a paper in the journal *Science Translational Medicine* and have a number of promising developments on the horizon. The breakthrough?

The trans-institutional team's nanoparticle delivery system may significantly improve the success rate of coronary artery bypass grafts.

They have licensed their delivery technology to Moerae Matrix Inc., and one of Duvall's former graduate students—Brian Evans, PhD'15, who served as lead author on the well-received journal article—is working with the company to seek Small Business Technology Transfer Research grants to fund further research and possible human trials.

"We really held onto this work for a long time instead of trickling out a number of incremental papers on it," Duvall says. "That paper is especially strong and is getting a lot of attention because it is highly interdisciplinary and covers a lot of ground, spanning new nanoparticle technology development through preclinical testing in human tissues and advanced in vivo models."

Nearly half of all saphenous vein grafts (a superficial leg vein used to bypass blocked coronary arteries) fail within 18 months because of inflammation and intimal hyperplasia—inward growth of cells in the vessel's inner lining that can block blood flow to the heart.

That process is driven by a signaling pathway involving the protein MK2. While a highly specific, cell-penetrating peptide-based MK2 inhibitor is in clinical trials in Europe, its effectiveness is limited because it gets trapped in the cell, where it is degraded.

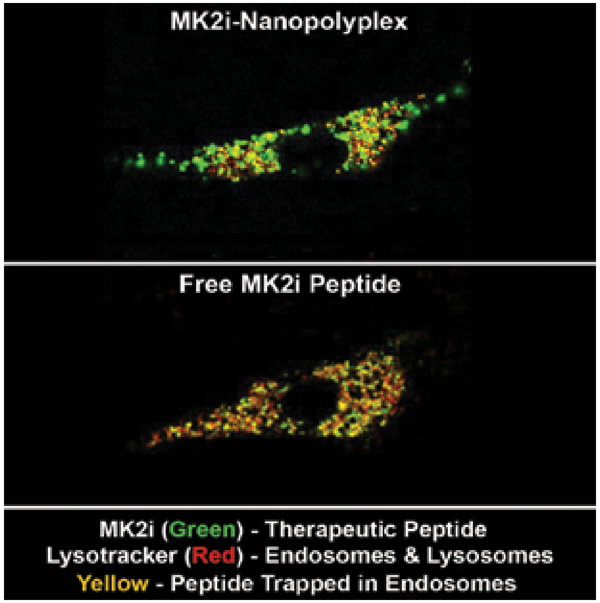
Brophy, Duvall and Evans developed nano-particles that can deliver the peptide inhibitor to vascular cells while avoiding degradation. In animal models, it was effective at treating the problem with virtually no side effects.

The peptide is a very promising drug, Brophy says. They're attempting to make it better by increasing its potency and durability in action so that the graft is protected while it recovers from the transplant procedure.

Further testing is necessary before human trials, but the approach may be useful for treating a wide range of disorders, including pathological vasoconstriction.

Recently, in the American Chemical Society journal *ACS Nano*, Brophy, Duvall and their colleagues reported that nanoparticle delivery of vasoactive peptides to isolated human vascular tissue prevented vasospasm, which can limit blood flow to the heart following coronary artery bypass. Vasospasm can also occur in the brain following a bleeding stroke. It causes nearly half of all stroke-related deaths.

Evans and Kyle Hocking, PhD'15, who earned their doctorates in biomedical engineering at Vanderbilt this year, led both studies. Their different skill sets helped the researchers cover a lot of ground, Duvall says. Those skills allowed the team to do basic nanoscience and technology development toward a real clinical problem with no current solution.



Left: A breakthrough in nanoparticle delivery made by a team that included former graduate student Brian Evans, PhD'15, and Professor Craig Duvall has been licensed and is undergoing further research. **Above:** Microscopy images show the peptide MK2i formulated in nanoparticles (MK2i-NPs) .

The work was supported by American Heart Association grant 11SDG4890030, a National Science Foundation Graduate Research fellowship to Evans, and a four-year exploratory/developmental research grant (R21 HL110056) to Duvall from the NIH.

NEIGHBORHOOD

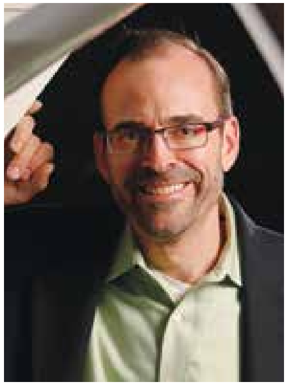
RISK AND RELIABILITY

Game-changing Materials

Two words: Advanced composites.

Advanced composite materials have broad possibilities in American manufacturing because of their elastic properties and ability to be very stiff while also remaining lightweight. They often outperform metals in terms of weight and strength. The high cost of these materials, however, currently limits their use to specialized, low-volume applications, such as aircraft parts.

A cutting-edge Vanderbilt engineering lab that studies how materials, structures and machines operate under real-world conditions is playing



a key part in the $259 million Institute for Advanced Composites Manufacturing Innovation, made up of a 122-member consortium of partner states, universities, national laboratories and industry leaders.

IACMI is the newest federally funded hub for manufacturing innovation. Announced by President Barack Obama in January 2015, its focus is on accelerating the prototyping and scale-up of carbon fiber composites used in clean energy manufacturing of automobiles, wind turbines and compressed gas storage tanks. One of the key objectives of the plan is supporting American manufacturing and raising the profile of industries in the U.S. as production processes change.

Much of Vanderbilt's work will take place at the Laboratory for Systems Integrity and Reliability as faculty, undergraduates and graduate students conduct research for IACMI's Composite Materials and Process Technology focus area. Doug Adams, Daniel F. Flowers Professor and chair of the Department of Civil and Environmental Engineering, leads Vanderbilt's efforts.

Advanced composite materials must be high quality when they are made and then maintain their performance as they are used. In addition to being very expensive, current advanced composites must undergo years of testing, making them inaccessible to high-production industries.

Left: Wind turbine blades made with lighter weight materials will translate into more electricity production and lower costs of renewable energy. Doug Adams (above) seeks to develop technologies that sense flaws in composite materials used for the blades and in vehicles. **Right:** This electrohydraulic vehicle simulator testbed puts the durability of lightweight composites to the test.

The IACMI is supported by the U.S. Department of Energy and comprises a consortium of over 120 companies, nonprofits, and universities.

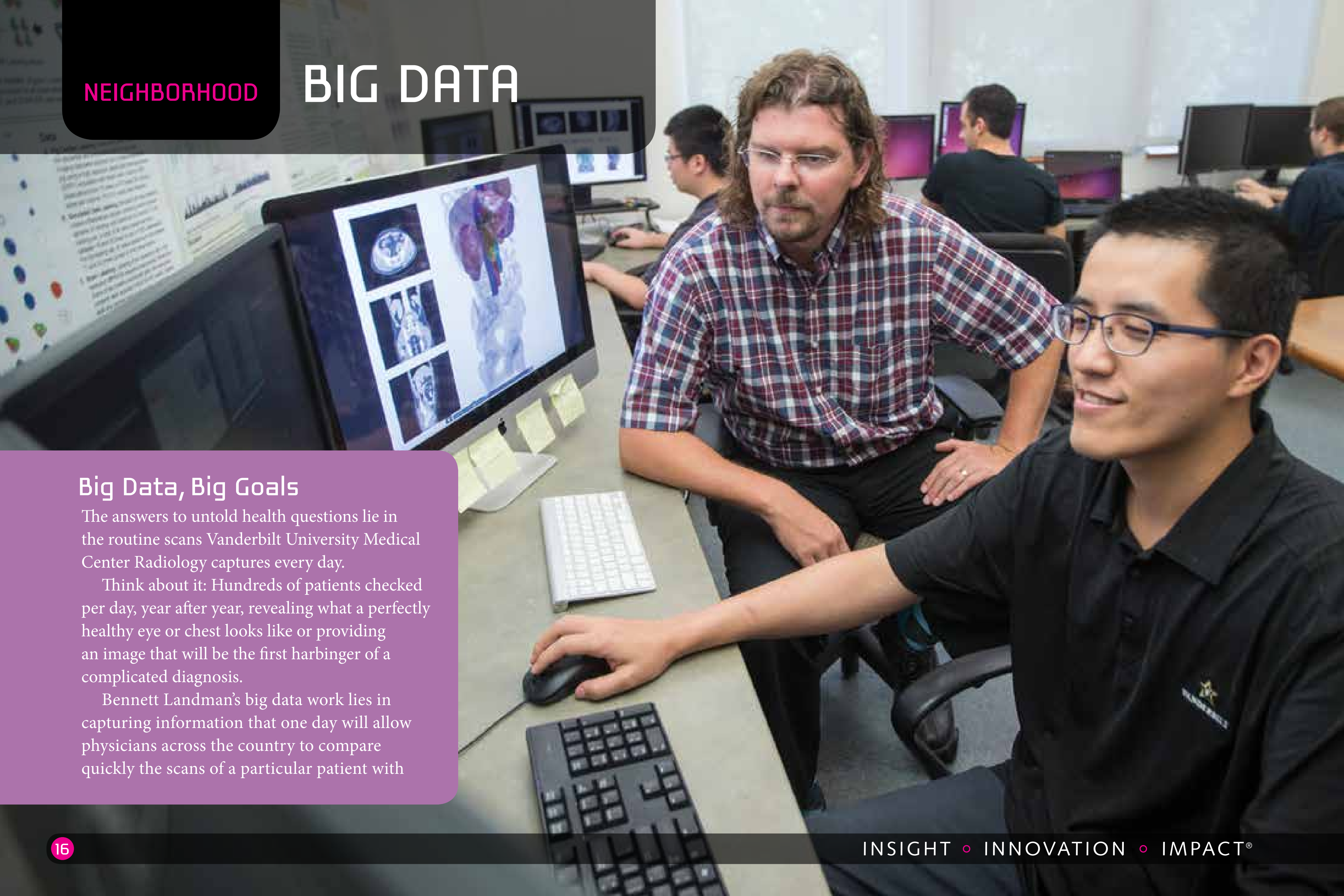
LASIR founder and co-director Adams says Vanderbilt is developing the measurement tools that will give intelligence to the machines that make these materials. That will enable workers to quickly diagnose and correct material quality on the fly. The rapid evaluation and correction will help bring the cost of high-performance composite materials within reach of a much wider range of industries.

In terms of economic impact, IACMI's analysis shows that the market for composite materials will nearly double globally by 2020. Making sure that workers, employers and suppliers in the U.S. are able to stay ahead of the curve on the process is seen as crucial by industrial, academic and political leaders across the spectrum.

Adams says it's exciting that Vanderbilt is a partner in the game-changing initiative to realize the Department of Energy's vision for advanced composites technology and a highly trained and skilled workforce. "Vanderbilt research will help shape the future of American manufacturing," he says.

NEIGHBORHOOD

BIG DATA



Big Data, Big Goals

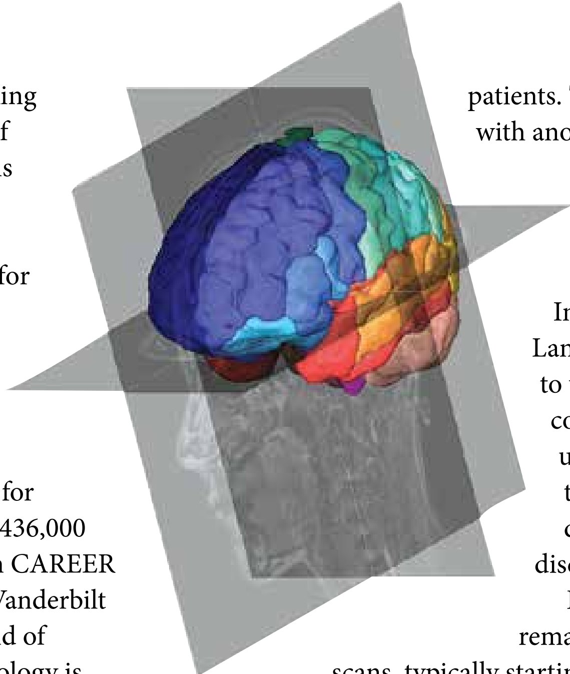
The answers to untold health questions lie in the routine scans Vanderbilt University Medical Center Radiology captures every day.

Think about it: Hundreds of patients checked per day, year after year, revealing what a perfectly healthy eye or chest looks like or providing an image that will be the first harbinger of a complicated diagnosis.

Bennett Landman's big data work lies in capturing information that one day will allow physicians across the country to compare quickly the scans of a particular patient with scans of other patients, looking for similarities. With a list of close matches, the physicians could see the diagnosis and treatment results for others and learn what might work for their patient.

Landman, assistant professor of electrical engineering and computer science, has been laying the groundwork for this research—funded by a $436,000 National Science Foundation CAREER Award—since his arrival at Vanderbilt in 2010. He says that this kind of revolutionary medical technology is only possible because he can leverage the unique trans-institutional capabilities of Vanderbilt's BioVU Program, Department of Biomedical Informatics, Advanced Computing Center for Research and Education, Center for Computational Imaging and Vanderbilt University Institute of Imaging Science.

First, identifiers had to be stripped from thousands of radiological images of Vanderbilt patients. Those were replaced with anonymous avatars bearing information about health history, but no personally identifiable information.



Left and this page: Bennett Landman and graduate student Yuankai Huo work on a big data project that involves constructing processes that allow for the analysis and comparison of pediatric brain scans.

In the next and current step, Landman and his team need to write reliable, open-source computer code that can be used by researchers across the globe and won't break down when faced with minor discrepancies from scan to scan.

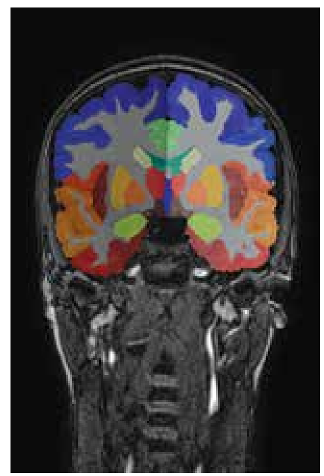
But a major hurdle remains: The sheer size of the scans, typically starting at 10 megabytes apiece. Vanderbilt collects countless terabytes of data per year in the course of regular health care.

Landman says that determining how to organize that information in a useful way is key. He has paired with the Medical Center's Department of Radiology and the Department of Biomedical Informatics to construct systems that allow retrieval of that data.

With his latest grant, he'll start by focusing on the Medical Center's littlest patients with some of the toughest diseases by enabling the analysis of tens of thousands of brain images from children and teenagers.

Analyzing brain scans of children is complicated. Because children change so rapidly and grow on such different timelines, it's tougher to determine what's abnormal and for doctors to find those abnormalities.

"Can we get all of those data in a space and examine what the different trajectories look like?" Landman asks. The new project will create the image processes that allow those computations to happen. To do that, his team will tap into a combination of the cloud computing structure Hadoop and a picture-archiving and communication system.



"We're going to construct low-cost technologies that allow us to perform those types of queries," he says. "We can't just buy a machine big enough to store all that data on a research budget."

This work is supported by NSF CAREER Award 1452485.

REGENERATIVE MEDICINE

Fatty Liver Disease on Notice

Some people may be overweight their whole lives and never suffer from nonalcoholic fatty liver disease's most deadly effects—diabetes, cirrhosis, liver cancer and organ failure.

But up to a quarter of Americans do suffer from that underlying condition, mostly due to poor diet and exercise habits. And sometimes the condition develops with no risk factors present at all.

Jamey Young, associate professor of chemical and biomolecular engineering, wants to learn more about what causes the difference. Since he began his research at MIT 10 years ago, he's discovered two very personal reasons to keep going: his father and brother.

When each had his gall bladder removed, liver biopsies done at the time showed they had fatty liver disease. Young says there's no FDA-approved treatment for the disease. The best current treatment is to lose weight and exercise more, the same as for other metabolic diseases.

If Young's research in the School of Engineering can decipher metabolic differences in the livers of those who develop fatty liver disease and those who don't, the answer could lead to more effective treatment—or even blocking the disease from its start.

People who are obese or diabetic carry high levels of fat in their blood, and the body deposits it in the liver. Metabolic differences determine whether that unhealthy situation leads to severe complications or not, Young says. Elevated liver enzymes in the blood are an early indicator of fatty liver disease, called steatohepatitis in its advanced stages.

Young's team is trying to inhibit the production of damaging free radicals in the liver to stop the progression of fatty liver disease. That involves using medication commonly prescribed to treat a different disorder plus vitamins.

He's working with School of Medicine and Medical Center colleagues David Wasserman, the Annie Mary Lyle Professor of Medicine and director of Vanderbilt's Mouse Metabolic Phenotyping Center, and Masakazu Shiota, associate professor of molecular physiology and biophysics.

Previous work developing methods of measuring metabolic rates in mice led to Young's hypothesis for his newest research: Mitochondrial metabolism is overactivated by the presence of fat in the liver, and that leads to the production of free radicals and compounds that damage the liver.

The research is being funded with a $1.7 million, 5-year grant (R01 DK106348) from the NIH.

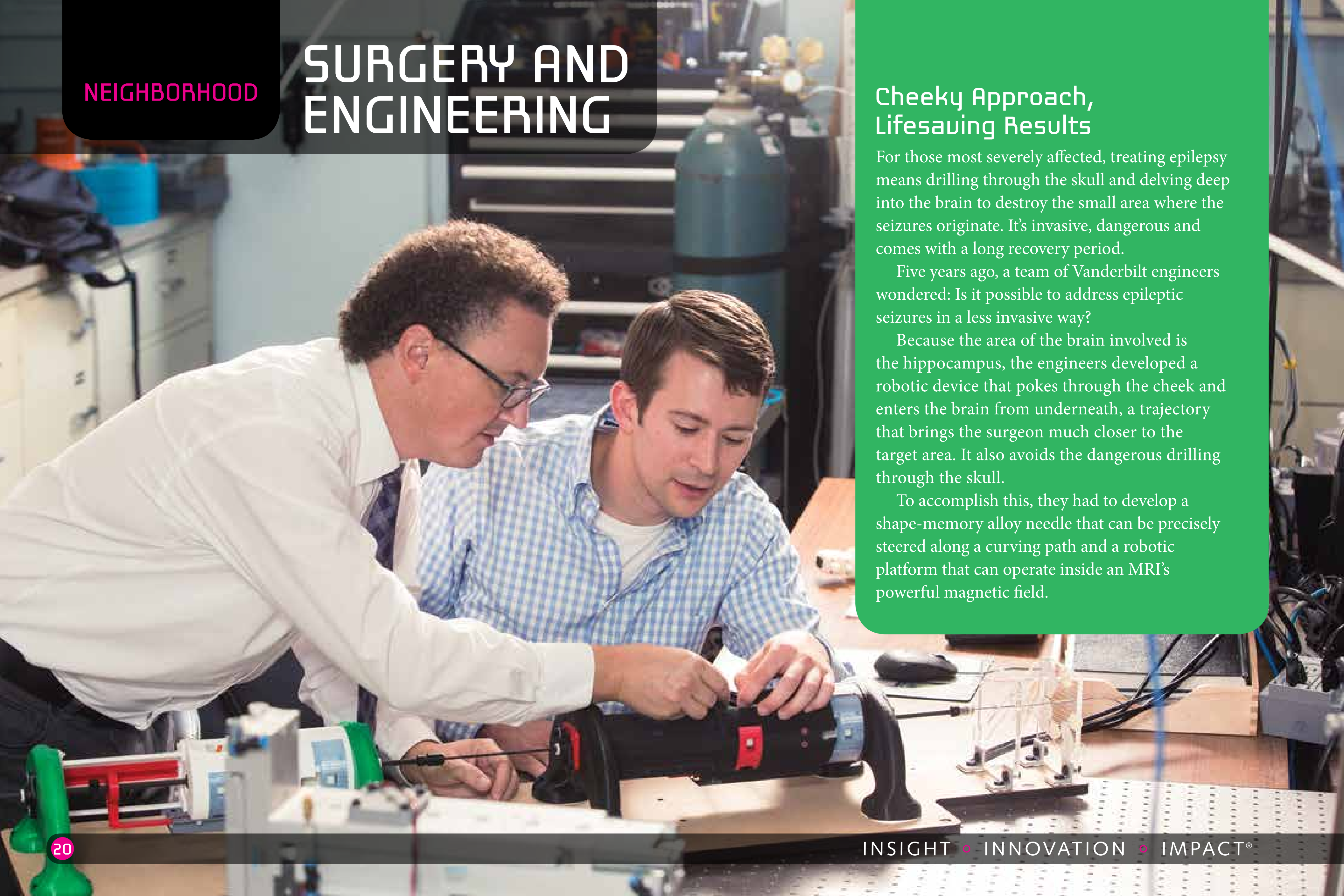
In May, they published a paper on the new measurement methodology in the *American Journal of Physiology–Endocrinology and Metabolism*. Young's new project studying metabolic differences that lead to fatty liver disease represents the first major research that will use the new methodology.

Young says he doesn't think he could do this research anywhere else in the world. He credits the culture at Vanderbilt for being able to obtain NIH funding and to tap into trans-institutional collaboration from the Medical Center.

Left: Professor Jamey Young and researcher Clint Hasenour, PhD'14, work on methods to inhibit the production of damaging free radicals in the liver. The goal is to stop the progression of fatty liver disease. **Above:** Graduate assistant Adeola Adebiyi, MS'15, in the Young lab.

NEIGHBORHOOD

SURGERY AND ENGINEERING



Cheeky Approach, Lifesaving Results

For those most severely affected, treating epilepsy means drilling through the skull and delving deep into the brain to destroy the small area where the seizures originate. It's invasive, dangerous and comes with a long recovery period.

Five years ago, a team of Vanderbilt engineers wondered: Is it possible to address epileptic seizures in a less invasive way?

Because the area of the brain involved is the hippocampus, the engineers developed a robotic device that pokes through the cheek and enters the brain from underneath, a trajectory that brings the surgeon much closer to the target area. It also avoids the dangerous drilling through the skull.

To accomplish this, they had to develop a shape-memory alloy needle that can be precisely steered along a curving path and a robotic platform that can operate inside an MRI's powerful magnetic field.

Left and right: Professor Eric Barth and Ph.D. student David Comber use nickel-titanium steerable needles and pneumatics in their search for a minimally invasive surgical method to treat epilepsy.

The business end of the device is a 1.14 mm nickel-titanium needle that is compatible with MRIs and that operates like a mechanical pencil with straight and curved concentric tubes that allow the tip to follow a curved path into the brain. Using compressed air, a robotic platform steers and advances the needle segments a millimeter at a time.

According to David Comber, the graduate student in mechanical engineering who did much of the design work, they have measured the accuracy of the system in the lab and found that it is better than 1.18 mm, which is considered sufficient for such an operation. In addition, because the needle is inserted in tiny steps, the surgeon can track its position by taking successive MRI scans.

Associate Professors of Mechanical Engineering Eric Barth and Robert Webster headed the project. Barth says the next stage in the surgical robot's development is testing it with cadavers. He estimates it could be in operating rooms within the next decade.

To come up with the design, the team began with capabilities that they already had.

Barth had done a lot of work in his career on the control of pneumatic systems. He knew they had the ability to have a robot in the MRI scanner. He and the team wondered what they could do that would have the highest impact.

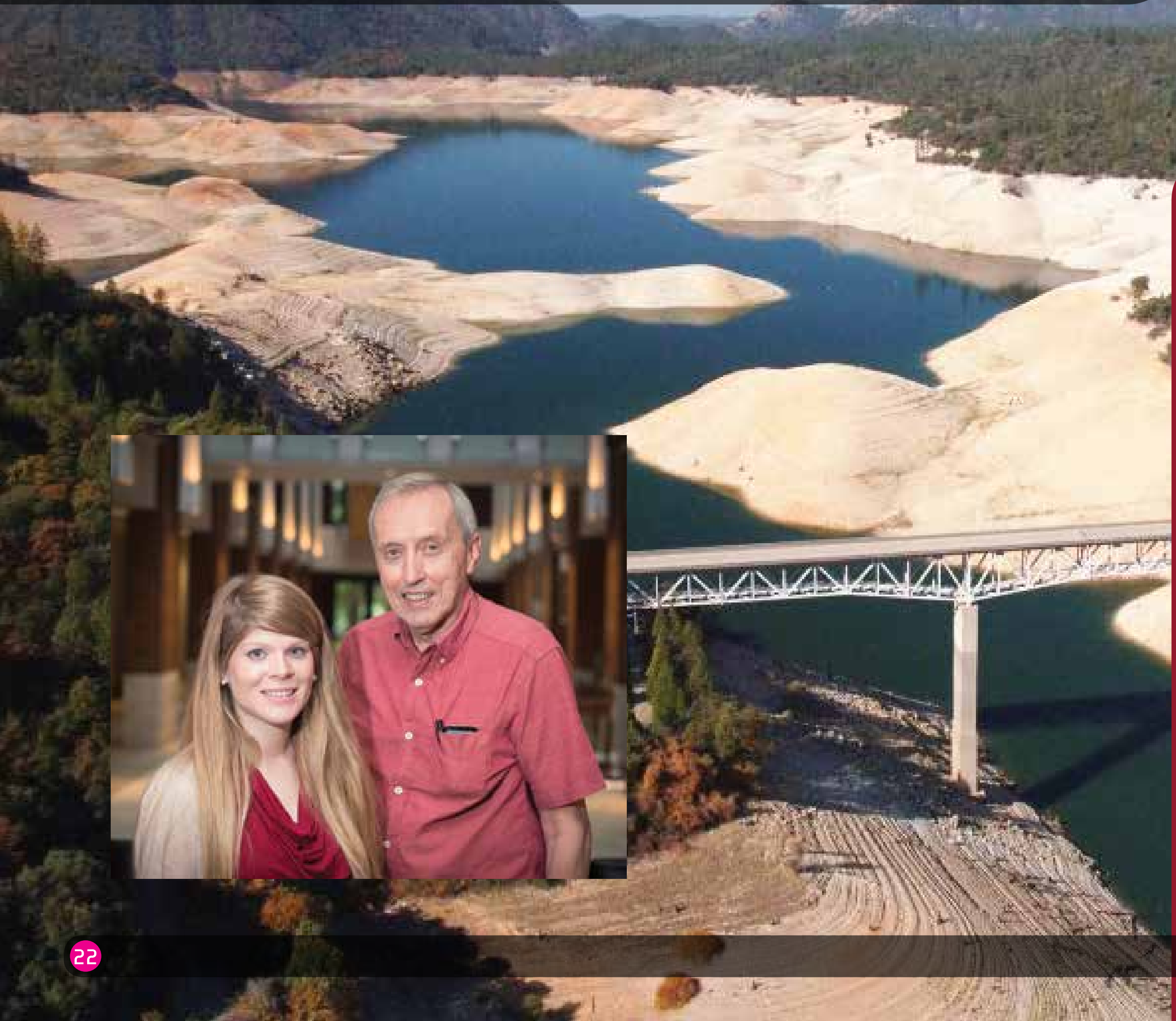
At the same time, Webster had developed a system of steerable surgical needles. He recalls talking in the hallway with Barth one day and determining that Barth's expertise in pneumatics could be combined with Webster's steerable needles.

The project is funded through the Center for Compact and Efficient Fluid Power, an NSF engineering research center for which Barth is a deputy director. The research is supported by NSF grant 0540834, sub award through the University of Minnesota T5306692601. The team recently won an NIH R21 grant and received past funding from Martin Ventures.

In discussions with Medical Center colleague Joseph Neimat, M.D., associate professor of neurological surgery, they identified epilepsy surgery as an ideal, high-impact application. Currently, neuroscientists use a through-the-cheek approach to implant electrodes in the brain to track brain activity and identify the location where the epileptic fits originate. But the straight needles they use can't reach the source region, so they must drill through the skull and insert the needle used to destroy the faulty neurons through the top of the head.

Comber and Barth shadowed Neimat through brain surgeries to understand how their device would work in practice. Neimat says having a system with a curved needle and unlimited access would make surgeries minimally invasive. The impact would be dramatic: They would perform life-changing surgery with nothing more than a needle stick to the cheek.

ENERGY AND NATURAL RESOURCES



New Tool to Fight Drought

A series of photographs illustrating the damage wrought by California's drought went viral this year, the link soaring from inbox to inbox.

Water trickling over Folsom Dam rather than gushing. Lake Oroville reduced to an anemic pond. Most of the state dried to a dusty brown rather than a lush green, as viewed from a satellite.

It's a crisis by any measure, but Vanderbilt University's environmental engineers created a new tool for managing it and other droughts worldwide. The Vanderbilt Institute for Energy and Environment team of graduate student Leslie Lyons Duncan, former graduate students Debra Perrone and John H. Jacobi, and VIEE director George Hornberger have written a new, more specific drought-measuring formula that could impact emergency planning, federal relief payouts and drought mitigation efforts.

The National Oceanic and Atmospheric Administration catalogs climate data in the historic Palmer Drought Severity Index but only at the relatively large climate division scale—meaning, for example, that Memphis, Tennessee, is in the same division as Cleveland, Ohio, even though their weather can vary significantly.

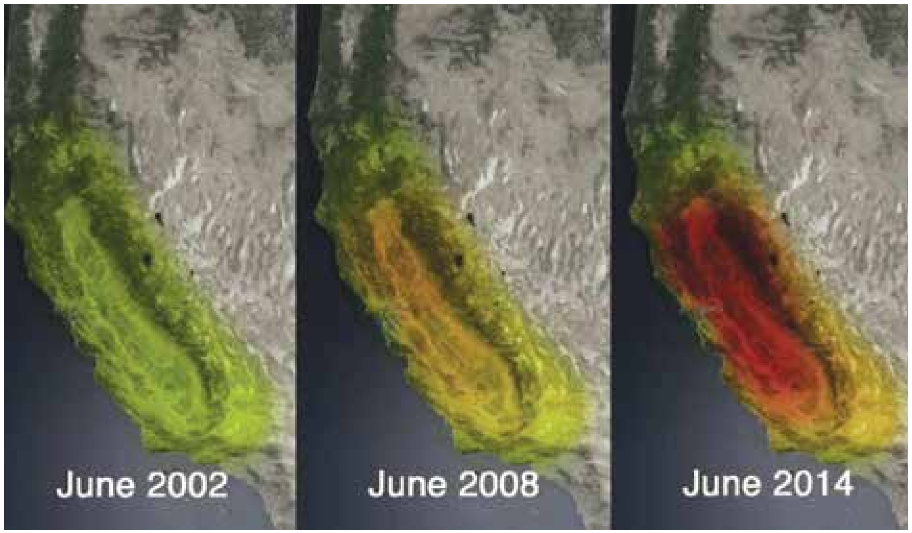
Duncan frequently used the Palmer drought indices while studying 1,200 years of Pacific Northwest drought patterns and their correspondence with solar cycles. The indices measure drought based on precipitation, temperature and the water-holding capacity of soil.

Duncan and her colleagues wondered if there was a smaller area at which it was possible to pick up more of the variation. Duncan says that they were concerned about working with too small an area because that would produce too much differentiation for decision-makers. After some analysis, the VIEE team chose to use half a degree latitude by half a degree longitude, or about 875 square miles.

The researchers created an interface where users can plug in the data that the Palmer indices use and calculate their own readings specific to a much smaller area. That means at the city and county level rather than regional.

And what did they find? The picture of drought can look very different when you're not looking at a huge section of the state at once.

Decision-makers can use the tool the Vanderbilt team created to calculate their own drought indices using local water, temperature and soil. The team located such data for smaller areas nationwide.



Left: This California Department of Water Resources photo of the Oroville Dam reservoir near Sacramento shows the impact of drought on the region. Graduate student Leslie Duncan, opposite with Ph.D. adviser George Hornberger, developed a new drought-measuring formula. **Above:** California water storage changes as seen from space.

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When they applied their calculations to the Pacific Northwest, for example, they found, in most cases, significant differences between the monthly climate division value for drought and their own value.

The same calculations can be used in the university's work with drought-stricken farmers in Sri Lanka, says Hornberger, who holds the Craig E. Philip Chair in Engineering and is the University Distinguished Professor of Civil and Environmental Engineering and Earth and Environmental Science.

He says that this could be an important tool. Government planning officials can use it to order water restrictions for certain areas based on specific conditions indicated by the Palmer index and then follow up using the tool to check week after week.

Duncan will receive her Ph.D. later this year. Perrone, MS'10, PhD'14, is a postdoctoral fellow at Stanford, and Jacobi, BE'09, MS'12, PhD'14, is a risk analyst with Aon Benfield.

Vanderbilt TIPs

Vanderbilt University launched a $50 million Trans-Institutional Programs initiative in November 2014 to provide support for cross-disciplinary research and collaboration—a core pillar of the university's new Academic Strategic Plan. TIPs create new and valuable knowledge by interweaving relevant perspectives, theories, methods and information from two or more disciplines. Seventeen cross-disciplinary projects involving 153 faculty from all 10 Vanderbilt colleges and schools were chosen for the initial set of awards. Of those 17, School of Engineering faculty are key to 10—more than half of all projects selected. We congratulate those selected and look forward to new discovery.

Graduate students Matthew Yandell (left) and Eric Honer explore different aspects of human locomotion under the direction of Assistant Professor Karl Zelik.

	Blair School of Music	College of Arts and Science	Jean and Alexander Heard Library System	Peabody College of education and human develpoment	School of Engineering	Law School	School of Medicine	School of Engineering Leads
Advanced Neuroimaging at Vanderbilt		■			■		■	Adam Anderson, John Gore, William Grissom
The Laboratories for Innovation in Global Health Technologies		■			■		■	Rick Haselton, Cynthia Paschal
NetsBlox: Digital Learning Technology for Computer Science Education		■		■	■			Akos Ledeczi
The Science of Music Research: Creating a Program for Music, Mind and Society	■	■		■	■		■	Philippe Fauchet
Sterling Ranch–Sustainability and Education Research Center		■		■	■			David Kosson, Ralph Bruce, Sanjiv Gokhale, Gabor Karsai, Xenofon Koutsoukos, Eugene LeBoeuf, Shihong Lin, Cynthia Paschal, Lori Troxel
A Trans-Institutional Big Data Architecture at Vanderbilt		■	■	■	■		■	Aniruddha Gokhale, Bennett Landman, Clare McCabe, Robert Weller
Vanderbilt Center for Molecular Probes		■			■		■	Leon Bellan
The Vanderbilt Pre^3 Initiative (Preventing Adverse Pregnancy Outcomes and Prematurity)				■	■		■	Frederick Haselton
VISE—Bringing Engineers and Surgeons Together					■		■	Benoit Dawant, Robert Galloway, Michael Miga, Robert Webster
Wisdom Working Group		■		■	■	■	■	Doug Fisher

Numbers of Note

Faculty Honors

79
named fellows

Faculty

14:1
undergraduate students to faculty member

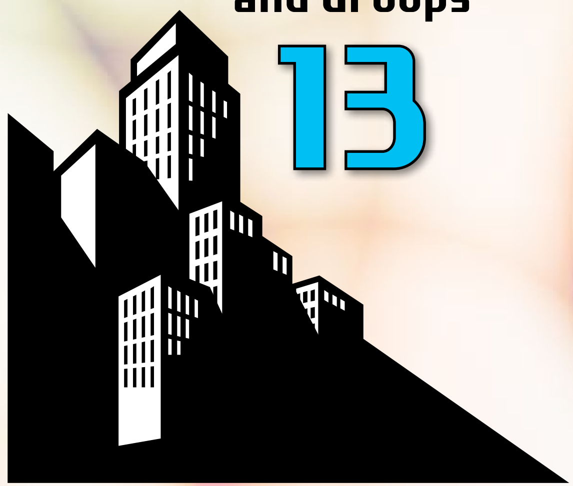
5:1
graduate students to faculty member

*Of those eligible to work in the U.S. who were seeking employment

Jobs

80%
2014 graduates* had job offers before Commencement

Institutes, Centers and Groups



13

Engineering Students

32% women

17.4% international students

22.5% minority students

Graduate Honors

12 current engineering graduate students awarded 2015 NSF graduate research fellowships

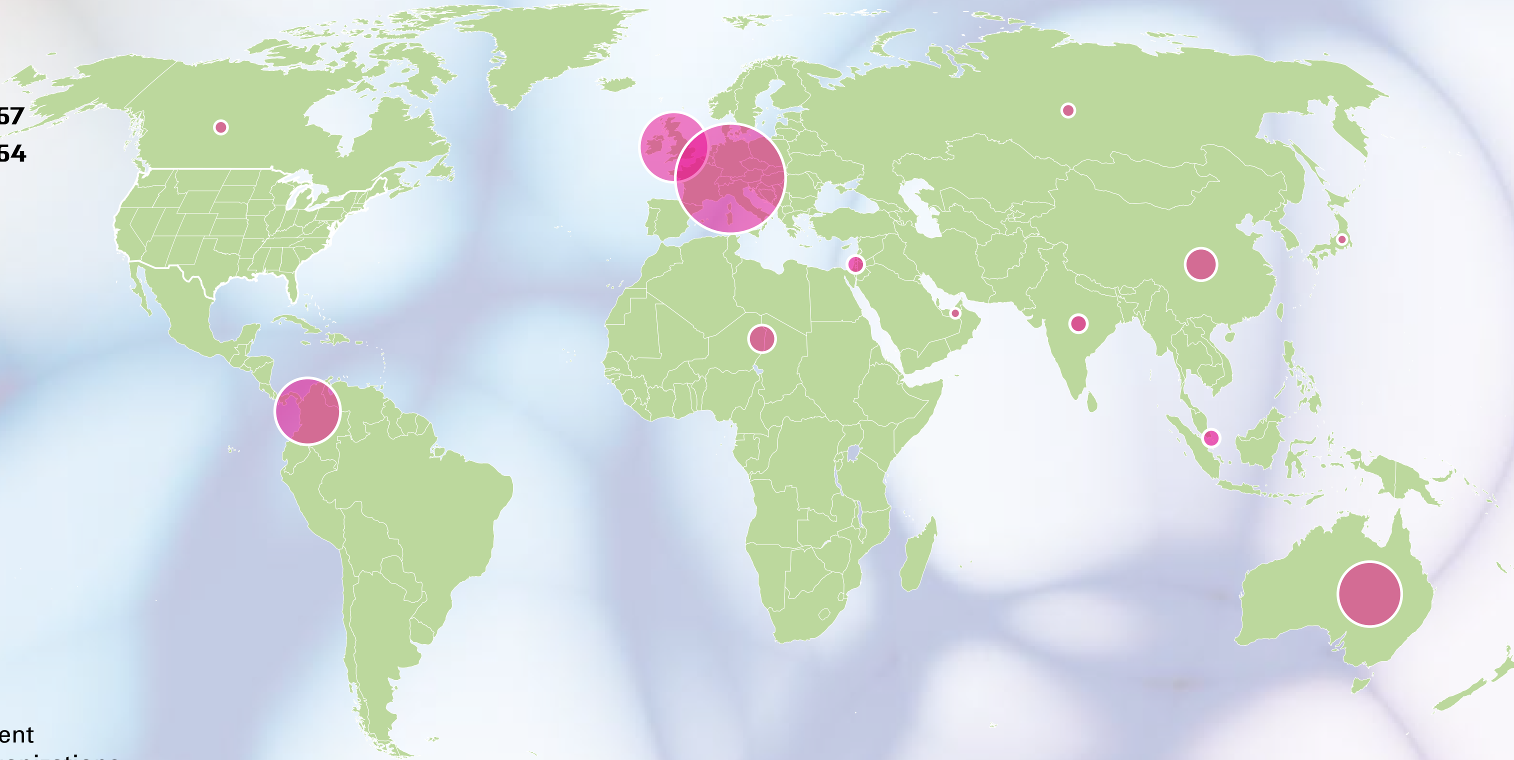
Externally Funded Research Expenditures

$74.4 million FY 2014

a 3.4% increase

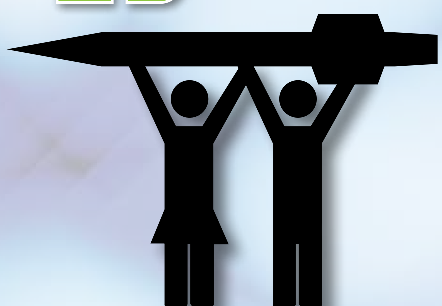
Student Global Experiences*, 2010-2015

Europe (continental): **189**
UK and Ireland: **72**
South and Central America: **67**
Australia and New Zealand: **64**
China: **27**
Africa: **16**
Singapore: **5**
India: **5**
Israel: **5**
Canada: **2**
Russia: **2**
Japan: **1**
UAE: **1**



Student Life

23 number of student engineering organizations



Undergraduate Research

53%

of all undergraduates participate in research projects outside the classroom

*includes study abroad, exchange and overseas service learning programs

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, 2015).

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 (UK)
Institute of Transportation Engineers
International Society for Magnetic Resonance in Medicine
International Society for Optical Engineering (SPIE)
Materials Research Society
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 (UK)
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

$1,238,710 Revenue for VUSE technologies

74 U.S. patent applications filed

58 New invention disclosures received

20 License agreements executed

15 U.S. patents issued (more pending)

7 Startups with a connection to the School of Engineering

These figures were provided by Vanderbilt's Center for Technology Transfer and Commercialization for the fiscal year July 1, 2014, to June 30, 2015.

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, the Orrin H. Ingram Professor of Biomedical Engineering
research.vuse.vanderbilt.edu/bmeoptics/index.htm

Center for Intelligent Mechatronics (CIM)

Michael Goldfarb, the H. Fort Flowers Professor of Mechanical Engineering
research.vuse.vanderbilt.edu/cim

Consortium for Risk Evaluation with Stakeholder Participation (CRESP)

David Kosson, the Cornelius Vanderbilt Professor of Engineering
Co-PI **Charles Powers,** Professor of Environmental Engineering
cresp.org

Institute for Software Integrated Systems (ISIS)

Janos Sztipanovits, E. Bronson Ingram Professor of Engineering
isis.vanderbilt.edu

Institute for Space and Defense Electronics (ISDE)

Ron Schrimpf, the Orrin H. Ingram Professor of Engineering
isde.vanderbilt.edu

Laboratory for Systems Integrity and Reliability (LASIR)

Douglas Adams, the Daniel F. Flowers Professor and Distinguished Professor of Civil and Environmental Engineering
vu.edu/lasir

Multiscale Modeling and Simulation Group (MuMS)

Peter Cummings, the John R. Hall Professor of Chemical Engineering
my.vanderbilt.edu/mums

Vanderbilt Institute for Digital Learning (VIDL)

John M. Sloop, Associate Provost for Digital Learning
vu.edu/digitallearning

Vanderbilt Institute for Energy and Environment (VIEE)

George M. Hornberger, the Craig E. Philip Professor of Engineering and Distinguished University Professor of Civil and Environmental Engineering and Earth and Environmental Science
vanderbilt.edu/viee

Vanderbilt Institute for Integrative Biosystems Research and Education (VIIBRE)

John Wikswo, the Gordon A. Cain University Professor and Professor of Biomedical Engineering
Deputy Director **Franz Baudenbacher,** Associate Professor of Biomedical Engineering
vanderbilt.edu/viibre

Vanderbilt Institute of Nanoscale Science and Engineering (VINSE)

Sandra Rosenthal, the Jack and Pamela Egan Professor of Chemistry and Professor of Chemical and Biomolecular Engineering
Deputy Director **Sharon Weiss,** Associate Professor of Electrical Engineering
vanderbilt.edu/vinse

Vanderbilt Institute in Surgery and Engineering (VISE)

Benoit Dawant, the Cornelius Vanderbilt Professor of Engineering
vanderbilt.edu/vise

Vanderbilt University Institute of Imaging Science (VUIIS)

John Gore, the Hertha Ramsey Cress Professor of Medicine, University Professor of Radiology and Radiological Sciences, and Professor of Biomedical Engineering
vuiis.vanderbilt.edu

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