VANDERBILT
School *of* Engineering

Solutions

FALL 2022

Engineering the Future of Medicine

From bio-manufacturing to micro-robotics, technology is revolutionizing advancements in health care

INSIDE: INNOVATIVE CANCER VACCINE | EXOSUIT HELPS SOLDIERS | DATA MINING THE BRAIN

50.1%

of first-year engineering undergraduates for fall 2022 are women.

The School of Engineering had a record-high enrollment of undergraduates and graduates for fall 2022. There were 1,437 undergraduates, including **a majority of first-year females** and a growing number of first-year underrepresented minorities. As for graduates and professionals, there were **830 seeking advancement**. Of that number, **652 were in on-campus programs** with **530 students enrolled in eight Ph.D. programs**, the largest number ever, and **122 enrolled in master's programs**. Another **178 students were enrolled in online master's programs**.

"Just looking at the School of Engineering's federal research expenditures from the most recent fiscal year, a full 30 percent came from the National Institutes of Health."

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Is there an engineer in the house?

Medical and health research increasingly relies on the contributions of engineering.

Those of you familiar with Vanderbilt's campus know it's a unique academic and research oasis nestled within a thriving commercial district near downtown Nashville. The School of Engineering itself resides at the very center, brushing up against the labs and research space of the world-renowned Vanderbilt University Medical Center.

For much of the university's history, this proximity of Vanderbilt Engineering to biomedical researchers and physicians has largely been a matter of circumstance—the natural formation of a kind of scientific neighborhood. In recent years, however, there's been an intentional shift to foster and cultivate these important ties.

Vanderbilt has established numerous centers focused on areas like surgical innovation, imaging technology, biomanufacturing and biophotonics. These places have become busy hubs of disciplinary crosscurrents, where engineers and physicians run ideas past each other, ask incisive questions about new fields and—most importantly—think together about the "what if..." possibilities that fuel new advances.

Just looking at the School of Engineering's federal research expenditures from the most recent fiscal year, a full 30 percent came from the National Institutes of Health. Dig deeper, and it turns out that even much of the funding from agencies like the National Science Foundation and the Department of Defense are for grants dealing with a range of health and medical-related research.

You'll see examples of this throughout this issue of *Solutions*, from the development of a lightweight exoskeleton for the U.S. Army that can help prevent muscular injuries and assist soldiers in the field lifting 100 lbs. or more (see page 20), to the work being done by biomedical engineers to expand a promising area of research into cancer vaccines (see page 16). And across multiple fields within healthcare and beyond, we've seen how artificial intelligence, machine learning and computational analysis are offering revolutionary insights (see page 26).

As I prepare to step away from my role as dean after more than a decade (see story on page 6), I'm personally heartened to see the progress we have made in the School of Engineering and as a university overall. Our faculty, students and staff are thriving in unimaginable ways. Not only have our ranks grown more diverse across a number of important measures, but we have also strengthened our presence in key research areas—from energy and infrastructure to biomanufacturing and computer science.

Our remarkable progress would not have been possible without the support of all of you. For that, I will be forever grateful. And I look forward to the exciting new chapter ahead for Vanderbilt's School of Engineering.

Sincerely,

Philippe Fauchet

Philippe Fauchet
Bruce and Bridgitt Evans Dean of Engineering

Featuring

Back cover photo by Larry McCormack/Vanderbilt

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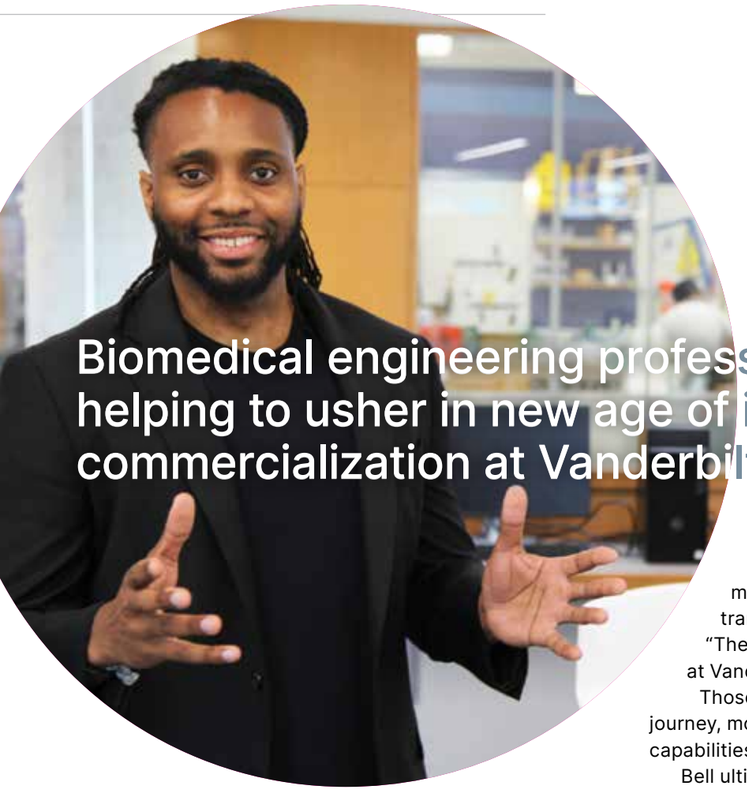
Departments



Biomedical engineering professor, entrepreneur helping to usher in new age of innovation and commercialization at Vanderbilt

Ten years ago, when he was still a Vanderbilt graduate student in biomedical engineering, **Charleson Bell** received the call most budding entrepreneurs hope to get one day: A venture capital firm was impressed with the innovations he'd pitched them, and they wanted to invest.

All he needed to do was form a corporation and acquire the intellectual property, the VCs told him. They would take care of informing the university.

It was all happening for Bell, who would join a medical device accelerator program in Memphis, where he would launch business operations, establish the corporate lab, and enjoy connections to additional funding and industry contacts.

Then as quickly as things began, Bell—who is now research assistant professor of biomedical engineering, Hub director of the Mid-South Innovation Corps (I-Corps) Hub, and director of entrepreneurship and biomedical innovation at the Wond'ry, Vanderbilt's Innovation Center—seemed to hit a roadblock.

"My faculty preceptor, Todd Giorgio, and I met with members of Vanderbilt's technology transfer office," he recalls of the 2012 encounter. "They told us that nothing like this had happened at Vanderbilt before."

Those words would end up shaping Bell's Vanderbilt journey, motivating him to help grow the university's capabilities around innovation and entrepreneurship.

Bell ultimately did launch his company, BioNanovations Corporation, relocating to the San Francisco Bay area in an effort to raise enough capital to propel his product through FDA regulatory approval. While he didn't quite reach his fundraising goal, the experience prompted him to return to Vanderbilt to finish his Ph.D. and explore ways to ensure that future Vanderbilt innovators received more support for their ventures.

He quickly began working with David Owens, the Evans Family Executive Director of the Wond'ry, and Deanna Meador, the Wond'ry's deputy director.

"Together, we sought to make it so that no Vanderbilt-affiliated stakeholder would struggle to learn commercialization processes to translate their innovations into impactful solutions," Bell says. "In 2022, under the guidance of Vanderbilt's leadership, innovation is becoming a crucial aspect of our culture."

In his current role as director of entrepreneurship and biomedical innovation at the Wond'ry, Bell is constantly looking for opportunities and programmatic solutions for enabling biomedical innovation at Vanderbilt and in Nashville.

"The development of an end-to-end continuum that merges human-centered, customer-focused, evidence-based commercialization processes with biomedical research is the key to cultivating a pipeline of Vanderbilt-affiliated startups," says Bell, who was recently selected by Global Action Platform for the Young American Leaders Program at Harvard Business School.

"The vision is to enable a diverse group of innovators to seed the region, become prominent, and create a unique, influential startup culture," he says, adding that it's important to build an innovation pipeline that addresses needs across geographic, demographic and socioeconomic lines.

The Biomedical Innovation Continuum builds on the Wond'ry's entrepreneurship courses by connecting them to innovation specialties—like basic sciences research or biomedical engineering—across schools and departments on campus, Bell says. For example, someone who is developing a unique computational tool or a novel cancer-targeting molecule can access Wond'ry programming, while working simultaneously with Vanderbilt's Center for Technology Transfer and Commercialization. This continuum of campus resources, Bell says, can then support a robust pathway to creating a profitable product or partnering with industry to do so.

"This continuum-based ecosystem will instill Vanderbilt-affiliated innovators with the capability to contribute their transformational visions to humanity," Bell says. "Nashville—which is in the midst of explosive growth—is primed to launch a sustainable, inclusive innovation ecosystem of firms based on deep, cutting-edge technology."

"The vision is to enable a diverse group of innovators to seed the region, become prominent, and create a unique, influential startup culture."

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The number of U.S. patent applications Vanderbilt University filed in fiscal year 2022. In the same period, Vanderbilt researchers received **18 patents**. Within the School of Engineering, there were **62 invention disclosures** made to the university, representing **contributions from 114 researchers**.

Source: Vanderbilt Center for Technology Transfer & Commercialization

Philippe Fauchet to conclude deanship in 2023

National search for next dean underway

Philippe Fauchet, who has led the School of Engineering through a decade of significant and strategic growth in research collaborations, academic programs, endowed chairs, faculty and student recruitment and more, will step down as dean effective June 30, 2023.

Fauchet, the Bruce and Bridgitt Evans Dean of Engineering and professor of electrical engineering, will return to the faculty in 2024 after a sabbatical.

"We are grateful for Philippe Fauchet's leadership, especially his commitment to building and strengthening technology and innovation partnerships across our campus and region during a pivotal time for both," Chancellor Daniel Diermeier said.

Search Committee Named

Provost and Vice Chancellor for Academic Affairs C. Cybele Raver has appointed a committee to conduct a national search for the next dean of the School of Engineering, chaired by Larry Marnett, dean of the School of Medicine Basic Sciences.

The members of the search committee are:

- **Camilla Benbow**, Patricia and Rodes Hart Dean of Peabody College of education and human development
- **Gautam Biswas**, Cornelius Vanderbilt Professor of Computer Science and computer engineering and engineering management
- **Joshua Caldwell**, Flowers Family Faculty Fellow in Engineering and professor of mechanical engineering
- **Maria Lopez Cavastany**, biomedical engineering Ph.D. student
- **Duke Herrell**, professor of urology and professor of biomedical and mechanical engineering
- **Bennett Landman**, professor and chair of electrical and computer engineering
- **Matthew Lang**, professor of chemical and biomolecular engineering
- **Sankaran Mahadevan**, John R. Murray Sr. Professor of Engineering
- **David Owens**, Evans Family Executive Director of the Wond'ry
- **Cynthia Reinhart-King**, University Distinguished Professor of Biomedical Engineering
- **Corey Thomas**, BE'98, CEO and chairman of the board of Rapid7, member of the Vanderbilt University Board of Trust
- **Tracey George**, vice provost for faculty affairs, ex officio

George has met with the School of Engineering staff advisory council to gain insight for the search process. The committee will work with Issacson, Miller, an executive search firm with extensive experience across higher education, nonprofits and foundations.

Cynthia Reinhart-King takes part in national summit on biomanufacturing

Cynthia Reinhart-King, Cornelius Vanderbilt Professor of Engineering and University Distinguished Professor, was among a handful of national experts invited to participate in the White House Summit on Biotechnology and Biomanufacturing on Sept. 14 in Washington, D.C.

The event, co-led by the National Economic Council, marked the launch of an initiative to develop bio-based solutions to global challenges ranging from food security and climate change to health security and supply chain disruptions.

Heads of U.S. government agencies and members of Congress, as well as leaders from industry, academic institutions and nongovernmental organizations—representing a range of bio sectors and regions—attended the summit. The panel comes on the heels of two major federal initiatives: the signing of the CHIPS and Science Act of 2022, which provides billions of dollars in new funding to boost domestic research and manufacturing of semiconductors in the U.S.; and the creation of Advanced Research Projects Agency for Health at the National Institutes of Health, which will fund high-risk, high-reward, use-inspired biomedical and biotechnology research.

"The significant investment this administration is making in biotechnology and the bioeconomy is a landmark and will ensure that the U.S. continues to lead in technological and manufacturing innovation," said Reinhart-King, who is also senior associate dean for research at the School of Engineering.

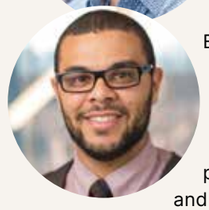
No. 1

Vanderbilt named No. 1 in Fortune's 2022 Best Online Master's in Computer Science Programs

The online master's program in the School of Engineering's Department of Computer Science ranked No. 1 in *Fortune* magazine's inaugural survey of online CS graduate programs, according to the 2022 list that was released in July. *Fortune* ranked 13 online CS master's across the U.S. based on three components: selectivity (50%); successful completion (30%); and demand (20%). Vanderbilt's 30 credit-hour program had one of the highest average undergraduate GPAs and among the most students enrolled of any schools in the ranking.

Two engineering faculty members named 2022 Chancellor Faculty Fellows

Engineering professors John T. Wilson and Karl Zelik are among 11 outstanding faculty members from across the university who have been designated 2022 Chancellor Faculty Fellows. The cohort comprises highly accomplished, recently tenured faculty.



John T. Wilson, associate professor of chemical and biomolecular engineering, works at the interface of molecular engineering and immunology to innovate technologies to improve human health. His multidisciplinary research program is supported by productive and synergistic collaborations with oncologists, cancer biologists, immunologists, chemists, and other engineers.

Karl Zelik, associate professor of mechanical engineering, co-directs the Center for Rehabilitation Engineering and Assistive Technology (CREATE) and directs the Biomechanics and Assistive Technology laboratory. An accomplished scientist in the fields of engineering and biomechanics, Zelik pioneers research, development, and technology that augments human performance and health. He is the chief science officer and co-founder of HeroWear.

These faculty members hold the title of Chancellor Faculty Fellow and are supported by an unrestricted allocation of $40,000 a year for two fiscal years that began July 1, 2022. The funds can be used to support innovative research, scholarship and creative expression that will further propel their careers.

Paul Laibinis is chair of the Department of Chemical and Biomolecular Engineering

Paul E. Laibinis has been named chair of the Department of Chemical and Biomolecular Engineering Department. He succeeds Professor Kane Jennings, who served as department chair for nine years.

Laibinis, professor of chemical and biomolecular engineering, has served as associate chair and director of undergraduate studies in the department. He is a faculty member in the Vanderbilt Institute of Nanoscale Science and Engineering.

Laibinis is the recipient of an Office of Naval Research Young Investigator Award, a Presidential Early Career Award for Scientists and Engineers (PECASE), a Vanderbilt University Ellen Gregg Ingalls Award for Excellence in Classroom Teaching, and the School of Engineering's Edward J. White Engineering Faculty Award for Excellence in Service.

Prior to joining the Vanderbilt engineering faculty as a full professor in 2005, Laibinis held academic posts at the California Institute of Technology, MIT, and Rice University. He received a Ph.D. in chemistry at Harvard University.

Laibinis' new position was effective July 1, 2022.

Sanjiv Gokhale named Engineering Endowed Director of Construction Management

Sanjiv Gokhale, professor of the practice of civil engineering and longtime director of the Construction Management graduate program, has been named the Engineering Endowed Director of Construction Management.

Gokhale joined the Vanderbilt civil engineering faculty as a visiting associate professor in 2001. In 2003, he was appointed associate professor of the practice and the construction management program was established, with the first cohort in 2004. A structural engineer by education and training, Gokhale has been involved in the design, construction, and program management of a variety of institutional, commercial, and recreational facilities.

"Over the past 18 years we have successfully matriculated more than 160 students who are serving the engineering and construction industries from health care to multi-family. In addition to building hospitals and offices and residential towers, our students have been instrumental in building the nation's infrastructure from airports to water and waste water-treatment facilities," Gokhale said.

Graduates of the Construction Management program are highly sought after and find a wide range of employment opportunities in design, consulting, and construction in both the private and public sectors. The program currently boasts 100% internships and professional placement, Gokhale said.

Janey Camp to lead center focused on transportation research

Janey Camp has been named the director of the Vanderbilt Engineering Center for Transportation and Operational Resiliency (VECTOR) where interdisciplinary groups work on a variety of transportation and infrastructure resilience projects using groundbreaking applications and risk management practices.

"It is an absolute honor to move into this leadership role for VECTOR at such an exciting time for transportation and resilience research," said Camp, research professor of civil and environmental engineering. "A few key objectives I want to focus on include continued growth in our research portfolio, increasing visibility and recognition of our faculty and graduate students, and further developing mutually beneficial partnerships with diverse agencies and organizations at all levels."

VECTOR research projects emphasize the integration of transportation engineering, planning and management. Current projects are focused on smart cities, safety, security and risk management, climate change, transportation system management, policy and operations, intermodal freight and advanced information systems.

Caldwell, Landman win Chancellor's Award for Research

Engineering professors **Joshua Caldwell** and **Bennett Landman** won a Chancellor's Award for Research at the 2022 Fall Faculty Assembly. Vanderbilt faculty marking 25 years of service to the university also were recognized, including five engineering professors.

Chancellor Daniel Diermeier, Provost and Vice Chancellor for Academic Affairs C. Cybele Raver and the Faculty Senate celebrated faculty achievements and provided key university updates at an on-campus event held Sept. 1.

Caldwell is a Flowers Family Chancellor's Faculty Fellow and professor of mechanical engineering. Landman is professor and chair of electrical and computer engineering. The Chancellor's Award for Research recognizes excellence in works published or presented in the last three calendar years. Honorees receive $2,000 and an engraved julep cup.

Caldwell and Landman share the award for their co-authored piece "Deterministic inverse design of Tamm plasmon thermal emitters with multi-resonant control," which was published in the journal Nature Materials in 2021. They were nominated for the award by Nilanjan Sarkar, David K. Wilson Professor of Engineering and chair of the Department of Mechanical Engineering.

In the News

Washington Post: "Move over, Iron Man: The Army has a new suit to solve soldier back pain." **Karl Zelik**, associate professor of mechanical engineering, is quoted.

Newsweek: "How U.S. space ambitions compare to China, Russia as Artemis launch delayed." **Amrutur Anilkumar**, professor of the practice of mechanical engineering, is quoted.

Wall Street Journal: "Flash floods: What to know and how to stay safe." **Janey Camp**, research professor of civil and environmental engineering, is quoted.

Fortune: "Meet the new robots helping to solve the depression and loneliness epidemic in aging adults." **Nilanjan Sarkar**, professor of mechanical engineering, is quoted.

Computer scientist seeks to make existing car systems smarter as part of $6 million NSF grant

Computer science professor **Jonathan Sprinkle** is among seven principal investigators using a $6 million grant from the National Science Foundation to explore a new way to engineer cyber-physical systems (CPS).

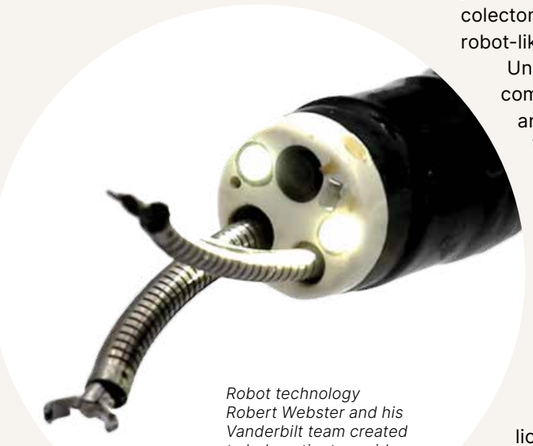
Examples of CPSs—which involve algorithms, networks and physical components—include smart power grids, implantable medical devices and transportation technology such as self-driving cars, which are the focus of the five-year, multi-institutional project.

Sprinkle's role will be to find ways to enhance the capabilities of existing sensors and on-board computers currently installed in many vehicles.

"Technology in systems such as cars is accelerating, with more and more driver assistance features each year, but it is not easy to upgrade these features unless they are redesigned," said Sprinkle, whose research interests and experience are in model-based approaches to cyber-physical systems. "I'm pleased to be part of this cutting-edge research, and I look forward to collaborating with the various partners to help transcend the computational challenges of traditional methods."

Vanderbilt professor to use portion of $2.3 million grant on robot technology to help patients avoid invasive colectomies

Robert J. Webster III, Richard A. Schroeder Professor of Mechanical Engineering and associate professor of medicine and urology at Vanderbilt University, is part of a collaborative team that has received a more than $2.3 million grant to further develop technology that seeks to prevent patients from having invasive colectomies by using steerable robot-like instruments.



Robot technology Robert Webster and his Vanderbilt team created to help patients avoid invasive colectomies.

Under his second startup company, EndoTheia, Webster and members of his team at Vanderbilt have developed sheaths about the size of a needle that can bend and extend like tiny octopus tentacles. They help surgeons perform precise surgical procedures deep inside the human body without making any incisions in the skin.

There are about 6.3 million colonoscopies a year, with roughly 50% finding lesions, according to Webster. He says the difficulty of removing a subset of these – those with challenging sizes, shapes, or locations – is due to the limited dexterity of conventional endoscopes.

He said the grant will also create four jobs for doctoral students at Vanderbilt as well as the University of Tennessee and the University of North Carolina at Chapel Hill, which are sharing the grant.

Other Vanderbilt collaborators on the grant are **Keith Obstein**, professor of medicine; **S. Duke Herrell**, professor of urology; **Nicholas Kavoussi**, assistant professor of urology; **Naren Nimmagadda**, instructor, Department of Urology; **Scott Webster**, adjunct assistant professor of mechanical engineering; **Joshua Gafford**, adjunct assistant professor of mechanical engineering; **Patrick Anderson**, adjunct assistant professor of mechanical engineering; and **Peter Connor**, graduate student, mechanical engineering.

Vanderbilt research on nuclear safety offers new pathways for clean energy, leads to industry awards

Two leading energy companies that used a Vanderbilt-pioneered process to develop safer nuclear reactors received a prestigious technology award from the Electric Power Research Institute (EPRI) in June 2022.

A team led by **Steve Krahn**, professor of the practice of nuclear environmental engineering, worked in collaboration with EPRI to develop a "safety-in-design" methodology that was adopted by Southern Company and TerraPower. The companies received the EPRI's Technology Transfer Awards for using the technology.

Andrew Sowder, EPRI senior technical director in advanced nuclear technology, described the Technology Transfer Award as the "Oscar" of the industry's R&D community, adding that he appreciated Krahn and his team's work in the field.

Krahn said the collaboration with EPRI has involved nearly 10 years of developing, refining and implementing methods to enhance the environmental, health and safety performance of nuclear facilities.

Simaan tapped as co-editor of IEEE special issue on surgical robots

Mechanical Engineering Professor **Nabil Simaan** was named a co-editor of a special issue on surgical robotics for *Proceedings of the IEEE*. The July 2022 special issue, "Surgical Robotics and Computer-Integrated Interventional Medicine," provides a research overview of the major applications and enabling technologies in the growing field of surgical robotics. The issue contains an overview of emerging clinical applications and consideration of topics such as safety, sterility, and operating room compatibility. It also lays out a roadmap of trends in technology and control paradigms for these systems.

Simaan's research interests include medical robotics, kinematics, robot modeling and control, and human-robot interaction. He is a faculty member in the Vanderbilt Institute of Surgery and Engineering and director of the Advanced Robotics and Mechanism Applications Laboratory at Vanderbilt. Simaan is a fellow of IEEE and the American Society of Mechanical Engineers.

Vanderbilt Engineering professor, student receive prestigious Fulbright awards to study abroad

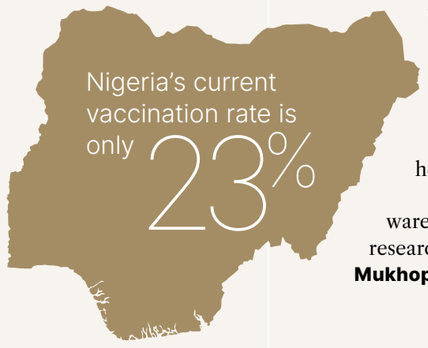
A professor and an undergraduate student in Vanderbilt University's School of Engineering are both recipients of esteemed 2022-2023 Fulbright awards that allow scholars to teach and conduct research abroad. **Ravindra Duddu** is an associate professor of civil and environmental engineering and **Kristi Maisha** is a civil engineering major.

Duddu will use his Fulbright-Kalam Climate Fellowship to travel to the Indian Institute of Technology Madras in Chennai, Tamil Nadu, India. He will spend five months teaching and conducting research on how ice-rock avalanches are triggered and identify the vulnerabilities of Himalayan glaciers, of which the second largest in the world is in India. Duddu's project is titled MIRACLES (Modeling Ice-Rock Avalanches using Computationally Efficient Schemes).

Maisha, who received her Fulbright under the student category, will work at the National University of Singapore where over 10 months she will continue research she has been doing at the National Renewable Energy Laboratory on sustainable building technology and implementation.

Fulbright is the world's largest and most diverse international educational exchange program.

Artificial intelligence researchers win international "social good" award for tool designed to optimize childhood vaccinations in Nigeria



A team of Vanderbilt computer scientists, working in collaboration with Google and a global aid organization, HelpMum, received top honors in the "social good" category for a paper describing a new tool designed to optimize childhood health and wellness in Nigeria at the 2022 International Joint Conferences on Artificial Intelligence (IJCAI) held in Vienna in July.

Institute for Software Integrated Systems research scientist, **Ayan Mukhopadhyay**, PhD'19, worked with **Abhishek Dubey**, associate professor of computer science and computer engineering, and Ph.D. student **Michael Wilbur** on the project along with collaborators from Google Research.

Each day, Nigeria loses as many as 2,300 children under the age of 5, due to poor health conditions and a vaccination rate of only 23%. The project, "ADVISER: AI Driven Vaccination Intervention Optimizer," draws on various data to optimize health interventions amid uncertainty. The system is designed to increase vaccine uptake and will be used by seven local governments in the Nigerian city of Ibadan.

Vanderbilt adds computer science, clean energy expertise

The Vanderbilt University School of Engineering has appointed nine new faculty members for the 2022-2023 academic year, with research and teaching activities ranging from artificial intelligence and cyber security to medical devices and clean energy.

Thomas Beckers

Beckers is postdoctoral researcher in the Department of Electrical and Systems Engineering at the University of Pennsylvania. He will join the faculty as an assistant professor of computer science Jan. 1, 2023. His research interests include physics-enhanced learning, nonparametric models, and safe learning-based control. Beckers works to bridge the gap between machine learning and control theory to develop new algorithms toward safe, robust, and intelligent control of physical systems. For this work, he focuses on Bayesian model as a learning method. He earned a Ph.D. in electrical engineering in 2020 from the Technical University of Munich. He received B.Sc. and M.Sc. degrees in electrical engineering in 2010 and 2013, respectively, from the Technical University of Braunschweig, Germany. In 2018, he was a visiting researcher at the University of California, Berkeley.

Mona Ebrish

Mona Ebrish will join the Vanderbilt engineering faculty Jan. 1, 2023, as an assistant professor of electrical and computer engineering. She is a postdoctoral fellow at the U.S. Naval Research Lab in Washington, D.C., investigating wide-bandgap semiconductors for high-voltage applications. Her research has resulted in more than a dozen patents and over 30 papers and abstracts in major journals and conferences. Ebrish is a Fulbright Scholar who received a B.S. degree in electrical engineering from the University of Tripoli, Libya, and a M.S. and Ph.D. in electrical engineering from the University of Minnesota, in 2011, 2015 respectively. She joined IBM as an Advisory Research Scientist where she spent four years working on CMOS technologies and non-volatile memory.

De-en Jiang

Professor of Chemical and Biomolecular Engineering De-en Jiang joins the faculty from the University of California, Riverside, where he was a professor of chemistry. Jiang's research focuses on applying state-of-the-art computational methods to important chemical systems and energy-relevant problems. He has authored and co-authored more than 270 peer-reviewed publications in such journals as *Science, Nature Materials, Nature Communications, Journal of the American Chemical Society, Nano Letters, ACS Nano, Accounts of Chemical Research*, and *Angewandte Chemie*, a journal of the German Chemical Society, that together have been cited more than 15,000 times. In 2009, he won the U.S. Department of Energy Early Career Award; in 2010, he won the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honor bestowed by the United States government on outstanding scientists and engineers in the early stages of their independent research careers. In 2012, he was named a Kavli Fellow by the National Academy of Sciences. Jiang received his B.S. and M.S. degrees from Peking University and his Ph.D. degree from UCLA, all in chemistry.

Dan Lin

Professor of Computer Science Dan Lin joins the school from the University of Missouri where she was the Robert H. Buescher Faculty Fellow and associate professor with appointments in the Department of Electrical Engineering and Computer Science and the Department of Management. Lin's research interests include data analysis and privacy protection in different domains such as cloud computing, mobile applications, social media platforms, and Internet of vehicles. Her research has been supported by the National Science Foundation, National Security Agency, and the Department of Energy. She currently serves as an associate editor for two top security journals: *IEEE Transactions on Dependable and Secure Computing* and *Association for Computing Machinery's Transactions on Privacy and Security*. Lin received a Ph.D. from the National University of Singapore, and she was a post-doctoral scholar at Purdue University.

Andrea Locke

Andrea Locke, assistant professor of biomedical engineering and chemistry, focuses on developing novel optical biosensing platforms to address current clinical diagnostic challenges at the point of care. Locke's joint appointment in chemistry and biomedical engineering allows her to merge bioassay design and optical engineering to design novel devices in this area. One of Locke's projects is developing an at-home monitoring tool for early detection bacterial infection. Locke earned a B.S. in 2010 and a Ph.D. in 2016 in biomedical engineering at Texas A&M. She was a postdoctoral researcher in the Center for Remote Health Technologies and Systems at Texas A&M, 2016-2018, and an Academic Pathways Postdoctoral Fellow at Vanderbilt, 2018-2021.

Daniel Moyer

Assistant Professor Daniel Moyer's research focuses on machine learning applied to medical imaging. He currently works on tracking and reconstruction projects in fetal MRI, multi-site problems or 'harmonizaton' in medical image analysis, and segmentation problems in intra-vascular ultrasound. Moyer has published work on neuroimaging and diffusion weighted MRI models, for which he received the Medical Image Computing and Computer Assisted Interventions Society's Young Scientist Award in 2016. Moyer joins the School of Engineering from the Computer Science & Artificial Intelligence Laboratory at MIT where he was a postdoctoral scholar. Moyer has a bachelor's degree in mathematics of computation and a minor in statistics from UCLA where he also earned Latin Honors. He received his Ph.D. in computer science from the University of Southern California in 2019.

Bryan Ward

Assistant Professor Bryan Ward joins the engineering faculty from the Lincoln Laboratory at MIT where he was a technical staff member in the Secure Resilient Systems and Technology Group. His research focuses on the security and resilience of real-time and embedded systems in application areas critical to national security, such as industrial control systems and space systems. Ward is the first-prize winner of the 2020 AFCEA Cyber Edge Writing Challenge for his article coauthored with Ryan Burrow titled "Control Systems Need Software Security Too," which appeared in *Signal Magazine*. Prior to joining the Lincoln Laboratory in 2016, Ward earned both M.S. and Ph.D. degrees in the Department of Computer Science at the University of North Carolina at Chapel Hill. Ward holds a B.S. in computer science and engineering and a B.A. in mathematics from Bucknell University.

James Weimer

Assistant Professor James Weimer develops foundations and tools for safety and predictable performance of learning-enabled cyber-physical systems, primarily targeting the internet-of-medical-things (IoMT). Weimer addresses real-world medical problems with an interest in technology transfer and commercialization. He is a co-founder of wearable technology companies Neuralert Technologies and Vasowatch. Weimer is the author of several journal articles and conference papers, and he has won three best paper awards. He joins the school from the University of Pennsylvania where he was a research assistant professor in the Department of Engineering and Applied Sciences. Weimer earned a bachelor's degree in electrical engineering from Purdue University and master's and Ph.D. degrees in electrical and computer engineering from Carnegie Mellon University.

Pamela Wisniewski

Associate Professor Pamela Wisniewski is an expert in the interplay between social media, privacy, and online safety for adolescents. She was an associate professor of computer science and director of the Sociotechnical Interaction Research (STIR) Laboratory at the University of Central Florida. Wisniewski has authored more than 100 peer-reviewed publications and won multiple best papers awards. She is an ACM Senior Member and the first and only computer scientist to be selected as a William T. Grant Scholar for her work on reducing digital inequality of underprivileged youth. Her research has been featured by popular news media outlets, including ABC News, NPR, *Psychology Today*, and *U.S. News and World Report*. She earned a Ph.D. in computing and information systems from the University of North Carolina at Charlotte and bachelor and master's degrees in decision and information sciences from the University of Florida.

7 Questions with Philippe Fauchet

Philippe Fauchet, the Bruce and Bridgitt Evans Dean of Engineering and professor of electrical engineering, will step down as dean, effective June 30, 2023, and will rejoin the school's faculty in 2024 after a sabbatical. Under his leadership, the School of Engineering has grown in a number of areas, including the size of its faculty, research collaborations, academic programs, endowed chairs, faculty and student recruitment, the diversity of its undergraduate students, and the spaces on campus where innovative problem-solving can take place.

(Left to Right) Dean Philippe Fauchet greets students at the Ed and Sue Clark Grand Stair, a striking spiral staircase that circles through four levels of Vanderbilt University's Engineering and Science Building

Dean Fauchet attends a reception for Carmichael Towers implosion with his son, Nicholas (far left); Bruce Evans, BE'81, chairman of the Board of Trust; Vice Dean of Engineering Doug Adams; and Vice Provost for Research Padma Raghavan.

Dean Fauchet speaks at the Dec. 12, 2018, opening of dedicated space in Medical Center North for the Vanderbilt Institute for Surgery and Engineering.

VISE grand opening event.

Dean Fauchet attends a dinner to honor the initial Clark Scholars cohort from 2017.

Dean Fauchet with Lori Troxel, director of undergraduate studies in civil engineering and recipient of the 2020 Chancellor's Cup.

1 What would you say is your greatest accomplishment as Dean?

Well, it is tough to pick only one, so I will give you three. First, would be growing the size of the faculty in such a way that we can compete nationally and globally in specific research areas. We have hired the very best talent in selected areas so that we have the critical mass necessary for us to compete on that scale. Next, I would say we have made great strides in the diversity of our undergraduates and faculty—gender, race, and background. I am proud of that. Finally, and this is an important one, our faculty, from the newest hires to those who have been here for decades, are highly motivated to work on important problems where practical applications and progress are possible. They are interested in problem-focused research and partnerships to solve societal problems that affect millions of people worldwide.

2 What do you feel is still left to do?

I would say strengthening the focus on providing the best experiential education for our undergraduate students. What are the curriculum needs for tomorrow's students? It may require bold changes, not tweaks. I think we are at an inflection point in engineering education. For example, all students—not just engineering students—should learn the lingua franca of data.

3 What did you enjoy most about being Dean?

Meeting and engaging with so many interesting alumni who love the School of Engineering! I enjoy strategic planning. And it has been personally satisfying to help students, faculty and staff members realize their dreams and aspirations.

4 Was there a challenge as Dean you had not expected?

The school is an enterprise of over 2,500 people. The challenge of an enterprise that size is what I would call bridging the gap. That is the gap between the budget and what it takes to reach and meet the aspirations of the faculty and staff. Also, to be honest, I would have to say the amount of paperwork!

5 What are your plans for your sabbatical year?

I've been very busy making sure the school is in the best shape possible so that my successor will be able to focus on the next steps for the school. So, I've not thought that much about it and certainly don't have any concrete plans yet. I like to travel, so reconnecting with old scientific friends and making new connections, in the U.S. and abroad, seems appealing.

6 How has your tenure as Dean shaped your focus as you return to the faculty?

Frankly, research is a game best played by younger people. But I feel strategic planning and leadership is a game played well by more experienced (and yes, older!) faculty members. I am interested in what kind of strategic role I can play at Vanderbilt that would be useful to the university and perhaps beyond—on a national level. Also, after a decade as dean, I am interested in bringing what I've learned into the classroom.

7 Do you have any advice for the next Dean?

Be bold. Listen first, then develop bold plans together with the faculty and administration. Develop 'mega' support initiatives that will lead to achieving even greater long-term and far-reaching goals. Put people—students, faculty, and staff—first. And also, enjoy Nashville—it's a fantastic city and region.

Vanderbilt researchers provide hope with innovative breast cancer vaccine

By Lucas Johnson

AS A CHILD, **JENNA DOMBROSKI** WAS AT HER GRANDFATHER'S BEDSIDE WHEN CANCER TOOK HIS LIFE. A SCIENTIST, HE WAS HER INSPIRATION. YEARS LATER, THE VANDERBILT UNIVERSITY PH.D. STUDENT AND NATIONAL SCIENCE FOUNDATION GRADUATE RESEARCH FELLOW IS HONORING HIM BY LEADING THE DEVELOPMENT OF WHAT APPEARS TO BE A PROMISING TREATMENT FOR BREAST CANCER METASTASIS, AND POTENTIALLY OTHER TYPES OF CANCER.

"He encouraged us to pursue exciting and interesting careers, and I always liked science and engineering," says Dombroski, whose field of study is biomedical engineering. "His death to cancer had a lasting impact, and I'm grateful for the opportunity to combine science and engineering in research to fight the disease, and hopefully save lives."

The research led by Dombroski in the lab of Michael King, J. Lawrence Wilson Professor of Engineering and chair of the biomedical engineering department, has found that vaccinations of tumor nano-lysate (TNL) – cancer cells broken up into thousands of nanoparticles – delay primary tumor growth and metastasis after being challenged with a tumor cell implantation.

The study builds on years of King's research on circulating tumor cells (CTC) – how cancer cells travel throughout the body in the bloodstream – and the initiation of apoptosis by the protein TNF-related apoptosis-inducing ligand (TRAIL). TRAIL, combined with fluid flow, acts as an explosive, rupturing individual cancer cells into thousands of nanoparticles.

In the lab, Dombroski and King recreated the apoptosis effect without using TRAIL at all. Instead, the duo found the precise conditions required of ultrasound forces to recreate how the protein breaks apart the cancer cells into TNL. Working in the Vanderbilt Institute of Nanoscale Science and Engineering Analytical laboratory, Dombroski and King mimicked the effect down to the exact size, shape, protein composition, and electrostatic charge. The TNL was then injected into mice, and much like any other vaccine that trains the immune system to recognize and attack foreign viruses or bacteria, the native white blood cells not only responded to the TNL but learned to smash the CTC responsible for metastasis.

Dombroski says it is exciting to see the intersection of science and engineering in the TNL research.

"The engineering behind our project is that we're modifying cancer cells by disrupting the cell membrane via applied ultrasonic waves," she says.

Cancer vaccine research is a rich and active field, and international research teams are working on a number of complicated processing techniques. A widely used approach consists of removing white blood cells to treat them outside the body and then reinserting them to see how they respond to cancer cells. The King Lab has made some exciting strides in this field through their novel research into activating T cells by exposing them to fluid flow as an improved way to train them to attack cancer cells once they are reintroduced to the body.

Dombroski says their research is also somewhat unique in that "there is really little characterization of these cancer cell lysates."

"Our lab uniquely coined these as tumor nano-lysates for our vaccine, and we're able to do that because they're nanometer sized," she says.

Their new technique gives the King lab the ability to optimize the vaccine by adding other chemicals to improve the efficacy of cancer immunotherapy and increase the trial size, which could lead to breakthroughs in addressing other types of cancer.

"What we want to do next is figure out why this approach works so well," says King. "The why is important because it allows us to take a step back as engineers and see what we can do to make it better, to expand it. Right now, it's just for triple-negative breast cancer, but it's something that we can potentially extend to other cancers."

According to the Centers for Disease Control and Prevention, in 2019, the most recent incidence data, 1.7 million new cases of cancer were reported in the United

Professor Michael King and Jenna Dombroski set up to do more experiments.

"The engineering behind our project is that we're modifying cancer cells by disrupting the cell membrane via applied ultrasonic waves."

-Jenna Dombroski

States, and nearly 600,000 people died of cancer. In the case of breast cancer, specifically, each year in the U.S. about 264,000 cases are diagnosed in women and about 2,400 in men. Roughly 42,000 women and 500 men in the U.S. die each year from breast cancer.

Survival rates for the localized disease are 99% but fall to 27% in the latest, metastatic stage. This is caused when a cancer cell from a static tumor leaches into the bloodstream as a CTC. While most CTC die, some are able to survive in the bloodstream long enough to land in a different part of the body and grow into a new tumor in a different organ.

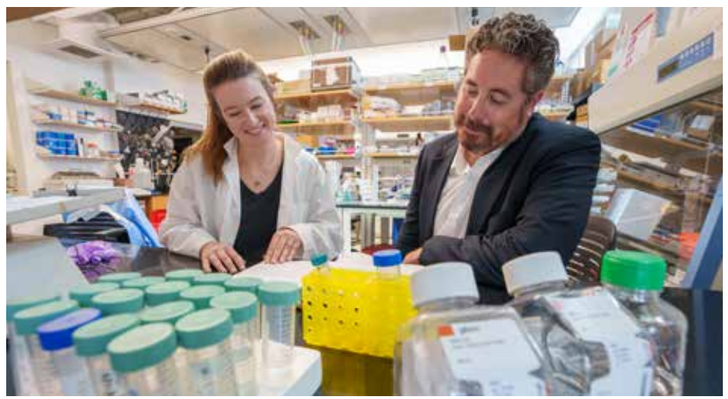
"Breast cancer can be caught very early with just a regular checkup, but unfortunately the stats are still high," says Dombroski. "However, the innovative research that we're working on here at Vanderbilt offers hope, and reassurance."

William Gradishar is director of the Maggie Daley Center for Women's Cancer Care in Chicago, Illinois, and chair of the National Comprehensive Cancer Network (NCCN) guidelines panel for breast cancer. He says efforts to develop vaccines for breast cancer have been underway for decades with various platforms, and that the research at Vanderbilt is indeed promising.

"The research from Vanderbilt is encouraging based on laboratory models of a new technique (nanotechnology) to deliver a vaccine," says Gradishar. "Only clinical trials in patients will determine if this strategy fulfills its promise."

Unlike chemotherapy, which acts directly on cancerous tumors, immunotherapy treats patients by acting on their immune system. In order to destroy cancerous tumors, chemotherapy is intended to attack rapidly dividing cells within the body, which may include both cancerous and non-cancerous cells, such as hair follicles and the lining of the gut. These attacks on healthy cells may cause some of chemotherapy's more well-known side effects, such as hair loss, nausea, and darkening of pigmentation.

Professor Michael King and Jenna Dombroski go over notes to plan next steps for TNL studies.



John Wilson is associate professor of chemical and biomolecular engineering at Vanderbilt and an expert on cancer immunotherapy and the use of cancer vaccines. He

was recently awarded grants to develop technology that seeks to boost a person's immune system to better fight cancer.

Wilson says there is still much to learn about how mechanical forces influence the fate and function of immune cells, and how that knowledge can be leveraged to develop safer and more effective immunotherapies for cancer, but that Vanderbilt is poised and equipped to make breakthroughs.

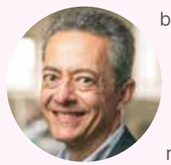
"Vanderbilt has a super strong mechanobiology community that is ideally positioned to tackle these challenges and lead in this exciting new area of cancer research," he says.

Nanoparticles boost anti-cancer immunity

The growth of epithelial ovarian cancer, one of the most lethal malignancies, is associated with the presence of tumor-associated macrophages (TAMs), white blood cells that can block the anti-cancer activity of the immune system and immunotherapy.

Fortunately, TAMs can be "repolarized," converted from immunosuppressive tumor-promoters to inflammatory tumor-fighters. Now, Associate Professor of Pharmacology Fiona Yull, Professor of Biomedical Engineering **Todd Giorgio**, and colleagues have demonstrated an ingenious targeted approach to TAM repolarization using nanoparticles in a mouse model of ovarian cancer.

Given that TAMs overexpress a receptor for the sugar mannose, the researchers developed a "mannose-decorated" nanoparticle bearing a cargo of small, interfering RNA. TAMs preferentially bind to the nanoparticle and take in the siRNA, which then activates a signaling pathway that enhances the expression of proinflammatory genes.

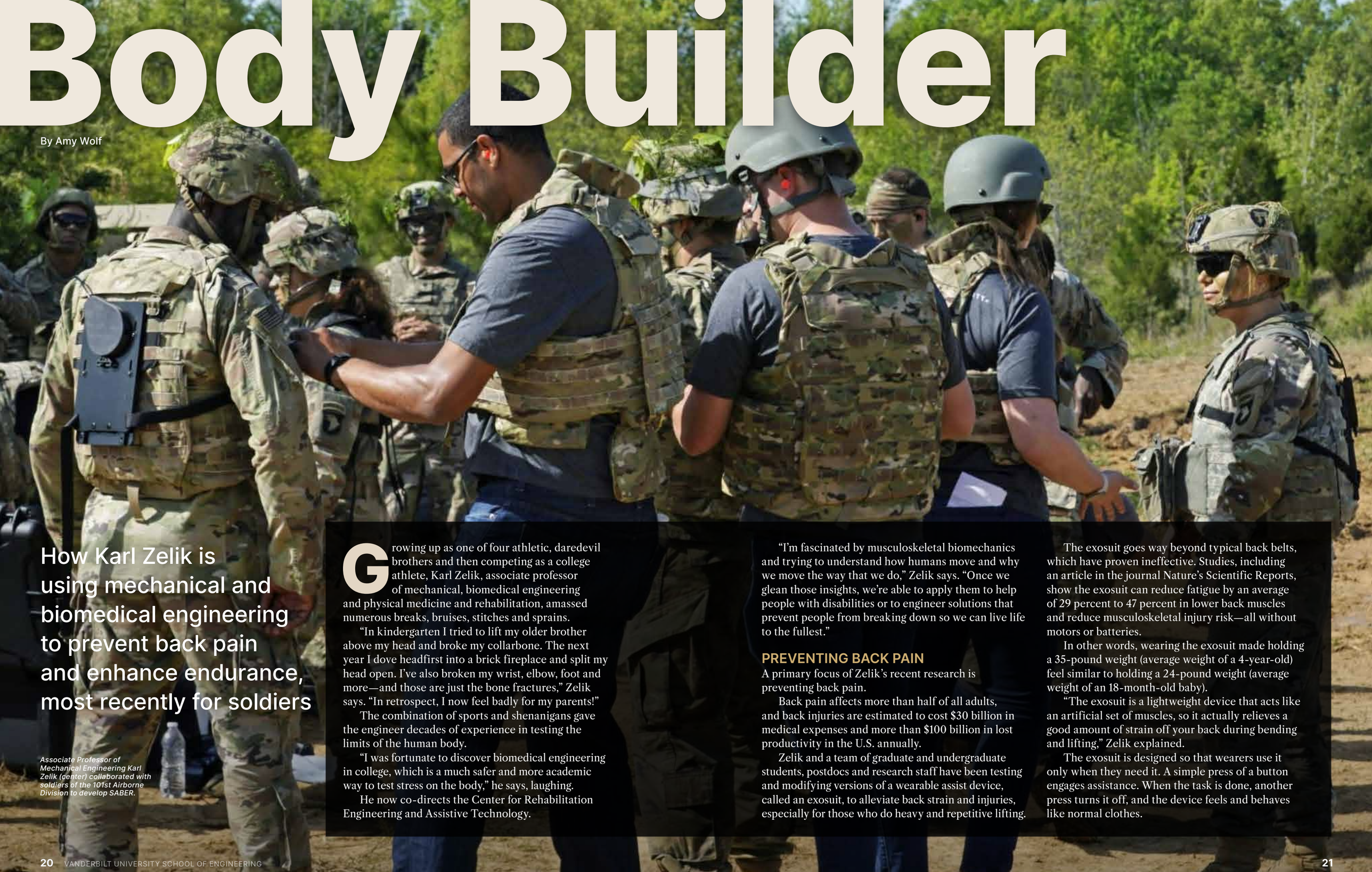


Reporting in the journal BMC Cancer, the researchers show that intraperitoneal injection of the nanoparticles significantly reduced the tumor burden in the mice. These findings suggest a way forward to increase anti-tumor immunity in patients with this deadly form of cancer.

The research was supported by the National Institutes of Health (grants CA214043, CA239367, CA247202, CA217987), a 2018 Burroughs Wellcome Fund Physician-Scientist Institutional Award to Vanderbilt University, and a generous gift from Chris Hill through Anglo-American Charity Ltd. – Bill Snyder

Body Builder

By Amy Wolf



How Karl Zelik is using mechanical and biomedical engineering to prevent back pain and enhance endurance, most recently for soldiers

Associate Professor of Mechanical Engineering Karl Zelik (center) collaborated with soldiers of the 101st Airborne Division to develop SABER.

Growing up as one of four athletic, daredevil brothers and then competing as a college athlete, Karl Zelik, associate professor of mechanical, biomedical engineering and physical medicine and rehabilitation, amassed numerous breaks, bruises, stitches and sprains.

"In kindergarten I tried to lift my older brother above my head and broke my collarbone. The next year I dove headfirst into a brick fireplace and split my head open. I've also broken my wrist, elbow, foot and more—and those are just the bone fractures," Zelik says. "In retrospect, I now feel badly for my parents!"

The combination of sports and shenanigans gave the engineer decades of experience in testing the limits of the human body.

"I was fortunate to discover biomedical engineering in college, which is a much safer and more academic way to test stress on the body," he says, laughing.

He now co-directs the Center for Rehabilitation Engineering and Assistive Technology.

"I'm fascinated by musculoskeletal biomechanics and trying to understand how humans move and why we move the way that we do," Zelik says. "Once we glean those insights, we're able to apply them to help people with disabilities or to engineer solutions that prevent people from breaking down so we can live life to the fullest."

PREVENTING BACK PAIN

A primary focus of Zelik's recent research is preventing back pain.

Back pain affects more than half of all adults, and back injuries are estimated to cost $30 billion in medical expenses and more than $100 billion in lost productivity in the U.S. annually.

Zelik and a team of graduate and undergraduate students, postdocs and research staff have been testing and modifying versions of a wearable assist device, called an exosuit, to alleviate back strain and injuries, especially for those who do heavy and repetitive lifting.

The exosuit goes way beyond typical back belts, which have proven ineffective. Studies, including an article in the journal Nature's Scientific Reports, show the exosuit can reduce fatigue by an average of 29 percent to 47 percent in lower back muscles and reduce musculoskeletal injury risk—all without motors or batteries.

In other words, wearing the exosuit made holding a 35-pound weight (average weight of a 4-year-old) feel similar to holding a 24-pound weight (average weight of an 18-month-old baby).

"The exosuit is a lightweight device that acts like an artificial set of muscles, so it actually relieves a good amount of strain off your back during bending and lifting," Zelik explained.

The exosuit is designed so that wearers use it only when they need it. A simple press of a button engages assistance. When the task is done, another press turns it off, and the device feels and behaves like normal clothes.

> We are working together to make meaningful impacts on the world by reducing disabilities, preventing injuries and improving well-being.
> – Karl Zelik

HEROWEAR

A version of the back-assist exosuit is out of the lab and being manufactured by HeroWear, a Nashville-based company launched by Vanderbilt alumni and researchers. It's being used by workers in more than 15 countries around the world.

Fatherhood and lots of lifting and playing with two small children inspired Zelik to focus his research on back pain and support issues.

"I wear exosuits all the time. I even have a picture of me wearing a prototype while having a tea party with my 4-year-old daughter," Zelik says. "People assume the hard part of designing exosuits is getting them to assist. The hard part is designing a wearable device that is comfortable and doesn't interfere with all the other things a person does on a daily basis."

This is the reason the team gravitated to soft exosuits rather than traditional rigid exoskeletons.

"Wearing prototypes regularly in my own life, even while playing with my kids, helps me empathize with end users, experience how the device functions for a wide variety of activities and create better wearable solutions," Zelik says.

MILITARY PARTNERSHIP

The latest evolution of the exosuit is the result of a special partnership between Vanderbilt University and the U.S. Army through the Pathfinder Program, which supports the innovation of soldier-inspired, research-based technologies.

In 2021, Zelik received a $1.2 million investment from the U.S. Army Combat Capabilities Development Command Army Research Laboratory and the Civil-Military Innovation Institute Inc. to adapt the exosuit for military use.

This summer, a team of Vanderbilt engineers completed the first phase of a collaborative project with soldiers of the 101st Airborne Division at Fort Campbell to design and test an exosuit that supports U.S. Army soldiers participating in field artillery operations and other sustainment and logistics jobs. The suit is called Soldier Assistive Bionic Exosuit for Resupply, or SABER.

"I was surprised to learn that there are over 460 back overuse injuries in the Army every single day," Zelik said. "These musculoskeletal injuries are from repetitive wear and tear due to the physical demands that these soldiers are under."

IMMERSIVE TESTING

The Vanderbilt team worked closely with the soldiers through a series of iterative design cycles and field tests. They ended up creating a back assist exosuit weighing less than three pounds that integrates with soldier's gear and takes more than 100 pounds of strain off the soldiers' backs each time they lift.

On the final day of field testing, most soldiers had not slept in 24 hours and were more than halfway through an extended live-fire mission.

"This was not a laboratory study," Zelik says. "We put exosuits on field artillery soldiers during a full-speed, combat-realistic, live-fire operation."

The soldier feedback was overwhelmingly positive. The exosuit helped them feel like they had more energy and endurance.

"Over the course of the day, lifting 60-pound rounds, you get worn out, especially after hours. It takes a toll on your body. Wearing the suit really helped a lot, especially with getting the rounds out of the back of the truck. It felt like it gave me an extra boost," says Pfc. Dale Paulson, a cannoneer in the 101st Airborne Division.

"I'm 23, and I already have back pain. Having this would be a good improvement for us. I was able to move freely, and it didn't get in the way of anything at all. I definitely would wear it," says Cpl. Badolo Yirliam, a utilities equipment repairer in the 101st Airborne Division.

For Zelik and his team, this project was about more than the exosuit.

"It was really humbling and inspiring to work with these soldiers because they're so committed to the work they do," Zelik says. "We're thankful that the science and technology we've been developing at Vanderbilt could help provide some much-needed relief to these soldiers. It's been a privilege."

The SABER project has transitioned from the Vanderbilt-led research and development phase to the HeroWear-led manufacturing and commercialization phase, with support from the U.S. Army.

Zelik, who also is chief scientist at HeroWear, continues to work on exosuit technology to see how it can be adapted to support other military and civilian workers. At Vanderbilt, his team is also exploring new applications of wearable technology to support clinical, sport and military users, including ways to offload and relieve strain from the soldiers' heavy body armor.

COLLABORATION AND HUMAN-CENTERED DESIGN

Zelik credits much of his success to Vanderbilt's culture of transdisciplinary collaboration and an active focus on solving real-world challenges through human-centered design.

"I'm blown away by the inspiring biomedical innovation and collaboration happening with partnerships between science and engineering researchers at the university and medical experts across the street at Vanderbilt University Medical Center," he says.

These collaborations within Vanderbilt and with outside groups like the U.S. Army are helping Zelik fulfill his lifelong dreams.

"We are working together to make meaningful impacts on the world by reducing disabilities, preventing injuries and improving well-being," he says.

(Far left) Karl Zelik explaining (and wearing) his exosuit at the Wond'ry.

(Near left) Karl Zelik wears his exosuit prototype while gardening with his children. (submitted)

(Above left) Vanderbilt SABER testing May 10, 2022, in Ft Knox, TN

(Above right) Zelik Family, (Top L-R) Daniel, Karl, Jonpaul, Samuel (Bottom L-R) Regina, Howard

U.S. Sen. Marsha Blackburn receives briefing on Pathfinder program during Vanderbilt visit

During a visit to Vanderbilt University, U.S. Sen. Marsha Blackburn was briefed about the Pathfinder program, which is a collaboration between teams of researchers from Vanderbilt and the Fort Campbell Army installation to develop soldier-inspired innovations.

Blackburn was among several Vanderbilt officials, including Chancellor Daniel Diermeier and Provost and Vice Chancellor for Academic Affairs C. Cybele Raver, who attended the briefing led by Doug Adams, vice dean of engineering and director of the Soldier-Inspired Innovation Incubator.

In 2021, Army Futures Command awarded Vanderbilt its inaugural Pathfinder Project, a one-year, $1.2 million investment from the Army Research Laboratory and the Civil-Military Innovation Institute Inc. to support collaborations between researchers and creative soldiers to rapidly innovate high-impact, research-based technologies with a path to commercialization and prompt acquisition of products by the Army.

Pathfinder supports the work of Associate Professor of Mechanical Engineering Karl Zelik and soldiers of the 101st Airborne Division of Fort Campbell to develop an exosuit (soft exoskeleton) for soldiers that will augment lifting capabilities and reduce back strain. The design concept expands on more than two years of informal design sprints, interviews and field exercises between Zelik's team and soldiers of the 101st Airborne Division to understand soldiers' needs and support their field artillery missions.

Vanderbilt is the first university to have signed an Educational Partnership Agreement with the Army Futures Command, which paved the way for the first Pathfinder Project award.

Top left: Doug Adams, vice dean of engineering and director of the Soldier-Inspired Innovation Incubator, gives a briefing on the Pathfinder program. Seated at the table are (l-r) Vanderbilt Provost and Vice Chancellor for Academic Affairs C. Cybele Raver; Chancellor Daniel Diermeier; and U.S. Sen. Marsha Blackburn.

MIddle left: Attendees hear from Brigadier General John Lubas, Deputy Commander for Operations, 101st Airborne Division, Fort Campbell, as Vice Provost for Research and Innovation Padma Raghavan looks on.

Bottom left: Dr. Tonia Rex, associate vice chair for Translational Research and Marlene and Spencer Hays director in Translational Vision Research, VUMC.

Top right photo: The Pathfinder program supports the work of Associate Professor of Mechanical Engineering Karl Zelik, who is wearing a prototype of his exosuit.

Bottom right photo: Seated (l-r) are Nathan Green, vice chancellor for government and community relations at Vanderbilt; C. Cybele Raver, provost and vice chancellor for academic affairs; Chancellor Daniel Diermeier; and U.S. Sen. Marsha Blackburn.

Making (Brain) Waves

Engineering researcher **Catie Chang** harnesses the power of computational analysis to gain new insights into how the brain works

By Ryan Underwood

Advances in neuroimaging over the past 25 years have ushered in nothing short of a revolution in technology for understanding the human brain. These new technologies have opened broad vistas for scientists, from being able to pinpoint regions of the brain responsible for various functions and behaviors to targeting new treatments for illnesses ranging from depression to Parkinson's disease.

At a deeper level, however, scientists lack a full picture of the fundamental network structures and mechanisms that govern not just our brains, but their interactions with many of the processes that take place throughout our bodies.

Writing in a Harvard Health blog post, Dr. Robert H. Shmerling underscores how difficult it is to discern the mechanics underlying certain traits and inclinations: "If you performed a CT scan, MRI scan, or even an autopsy on the brain of a mathematician and compared it to the brain of an artist, it's unlikely you'd find much difference. And if you did the same for 1,000 mathematicians and artists, it's unlikely that any clear pattern of difference in brain structure would emerge."

Catie Chang, a multidisciplinary Vanderbilt scientist who holds faculty appointments in electrical and computer engineering, computer science and biomedical engineering, is part of a growing field of scientists who suspect there are deeper patterns in the brain to be discovered.

To find them, however, will require new methods of computational analysis and machine learning.

Like others using powerful computers to reveal hidden patterns in complex data like weather systems, financial markets or human vital signs, Chang is captivated by what the typically discarded "noise" in fMRI datasets may be able to tell us about the brain.

Functional MRI (fMRI) technology has been used primarily to shed light on how the brain responds to particular stimuli, whether subjects are being asked to solve a math problem or being shown images designed to provoke an emotional response. Similarly, EEG technology measures electrical activity in the brain, whether it's while we're sleeping or engaged in some cognitively demanding activity.

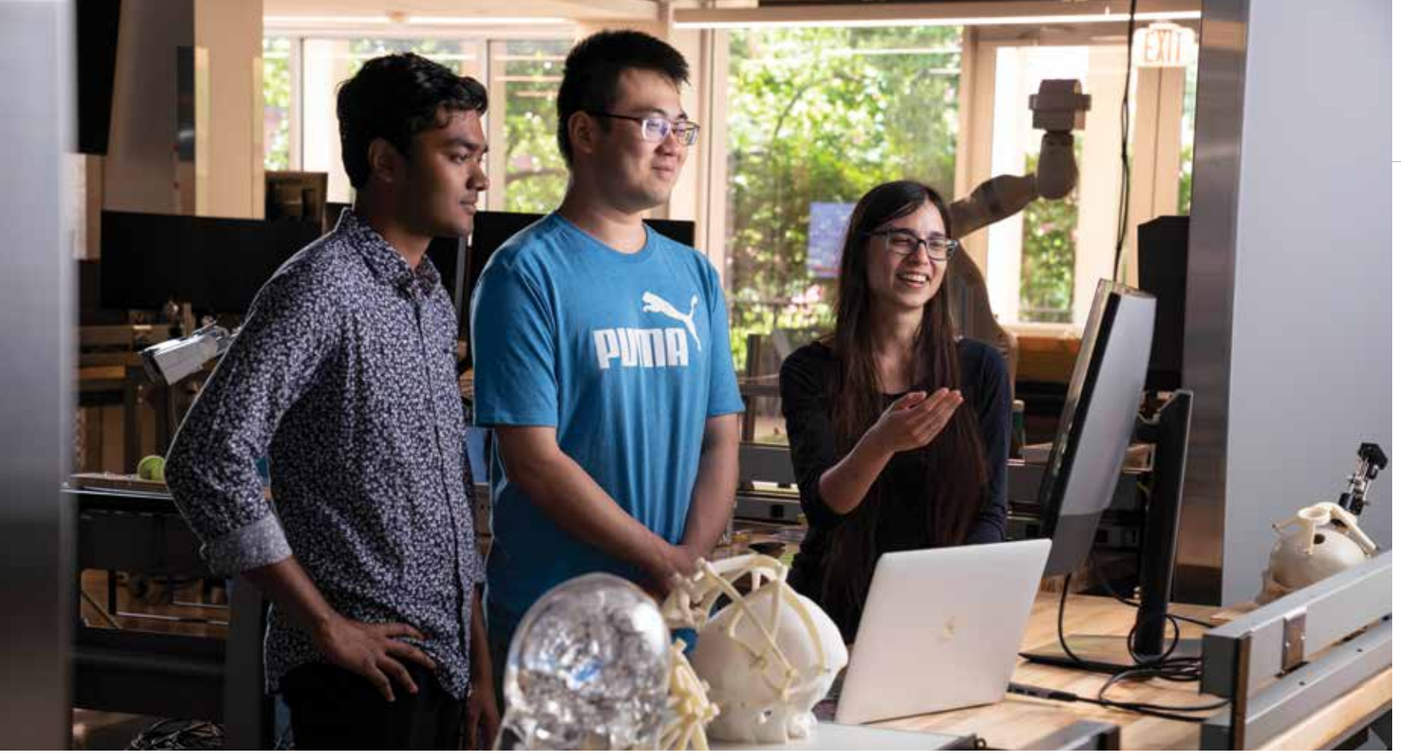
Both technologies capture vast amounts of background data that tends to be disregarded in many research studies. But to Chang and others, this information may contain tantalizing clues that could revolutionize our understanding of the brain.

"Neuroimaging technology has come very far," Chang says. "But we're still left with a ton of data that holds much untapped potential."

For Chang, the possibilities are enticing. She says one avenue for the field is to use data-driven approaches to make new discoveries. Another is to employ machine learning to uncover biomarkers that could be used to make more accurate health predictions.

In addition to searching for direct clinical outcomes, she says, these new advances in computational analysis will ultimately give scientists a deeper, more precise understanding of how the brain works.

"The field has been asking questions like, how does the ongoing, background activity of the brain reflect and shape how people perceive things, or how people remember things," Chang explains. "As the field advances, there's more and more that we're finding in all of this data."



Catie Chang discusses findings from functional neuroimaging experiments with Ph.D. student Shengchao Zhang and undergraduate student Nafis Ahmed, at the Vanderbilt Institute for Surgery and Engineering.

DUAL INTERESTS LEAD TO SINGULAR FOCUS

Chang's own path to this intersection of computation and neuroscience began with an early fascination of biology. Growing up, she hadn't been exposed to computer programming or engineering, but then as an undergraduate at MIT, she became captivated by her computer science classes and ended up majoring in the subject. Yet she never let go of her affinity for the biological sciences and was particularly interested in the brain.

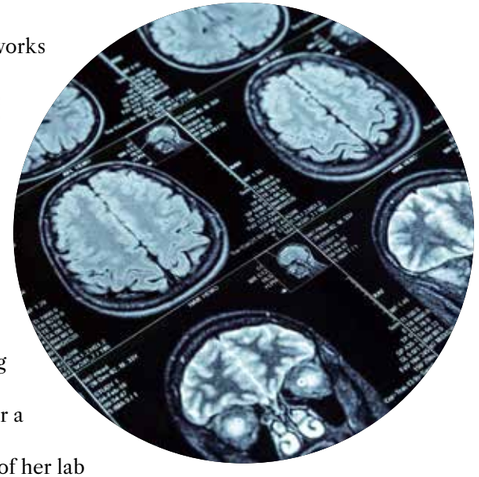
As a student, she worked in what was then MIT's standalone Artificial Intelligence Lab (it has since been absorbed into a wider lab, CSAIL) on an area known as biologically inspired computing. "It was trying to take biological principles and figure out how they can improve computing," Chang says. "For instance, we looked at things like how cells—which are these distributed agents with no central command—grow in the body, and then explored how to replicate that in computers."

By the time she began graduate school at Stanford, Chang once again found herself drawn to neuroscience, but always with a computational element involved. She performed research in a lab that was using computational methods to understand data from noninvasive neuroimaging technologies like fMRI and EEG. "That's the research area in which I ended up continuing my Ph.D."

Following graduate school, Chang worked as a postdoctoral and research fellow at the National Institutes of Health before joining Vanderbilt's faculty in 2018. Today, Chang's Neuroimaging and Brain Dynamics (NEURDY) Lab is an active member of the Vanderbilt Institute for Surgery and Engineering (VISE).

And in 2019, Chang and Dr. Dario Englot, Vanderbilt University Medical Center surgical director of epilepsy and associate professor of neurological surgery, electrical engineering, radiology and radiological sciences and biomedical engineering, received a $3 million NIH grant to study disturbances in brain networks in patients with epilepsy. That work continues today, as the team uses a combination of EEG and fMRI data to explore whether network disturbances caused by epilepsy contribute to cognitive deficits.

"This work points to a common set of patterns that seem to account for a lot of the observed dynamics in the brain."



Although much work in the field seeks to quantify specific brain networks and explain how they operate, more recent efforts have sought to extend that understanding by looking at how these networks fluctuate over time or in different states of consciousness. This concept forms a key piece of the team's work on epilepsy, and Chang is expanding this work to other neuroscience and clinical research areas as well.

"In this work, we can often take inspiration from spatiotemporal data and models from other fields and build upon these approaches to search for new insights in brain activity datasets," Chang says. She mentions a recent collaboration with researchers at UCLA and Emory University that found a series of patterns in brain study data that are thought to constitute a set of building blocks that may link together what other researchers are observing in their studies—toward a kind of unifying model for the fundamental activity patterns in our brain.

"This work points to a common set of patterns that seem to account for a lot of the observed dynamics in the brain," Chang says.

By its nature, Chang's work is inherently multidisciplinary. Members of her lab come from areas ranging from biomedical and electrical engineering to physics and computer science. Similarly, research collaborators from across Vanderbilt include researchers from Peabody College, psychology, the Institute for Imaging Science and biostatistics.

"The work that Catie's lab is doing—not just at VUMC, but across the field—could help revolutionize our collective understanding of how the brain works in an interconnected way with many different systems throughout the body," says Bennett Landman, chair of the Department of Electrical and Computer Engineering, whose own expertise focuses on using computer-based statistical analysis to improve medical imaging technology. "Her work is also emblematic of the kind of robust, interdisciplinary research collaboration that Vanderbilt fosters. It's this kind of environment where true innovation can thrive."

1956

George Harsh Jr., BE, of Huntsville, Ala., retired from NASA's Marshall Space Flight Center in Huntsville 22 years ago. He worked mostly in the Test Laboratory supporting the Apollo moon landing and the space shuttle. He writes, "My 'claim to fame' is that I launched a 10,000 lb. thrust solid rocket motor from the Test Area—and we don't launch anything intentionally!"

1980

Sterling Alex Hollis Jr., BE, of Carlisle, Pa., recently accepted the role of head of the Advanced Analytics Section for risk management company DNV's hydraulic modeling and simulation software: Synergi Gas, Synergi Water and the Synergi Pipeline Simulator. These products are used by natural gas operating companies worldwide. The Advanced Analytics Section creates and maintains the computational engines for these modeling tools as well as researches innovation for new simulation techniques and numeric approaches. He joined DNV, then known as Stoner Associates, in 1987.

1984

Adrian C. Lock, BS, is leading veterinary health company Zomedica's sales organization, including Zomedica field sales personnel, sales management and professional service veterinarians, as well as existing PulseVet sales personnel. He is vice president and general manager of Ann Arbor-based Zomedica and was the founding CEO of PulseVet.

1989

Emile Zaki Chammas, BE, was promoted to senior vice president and chief operating officer at Sealed Air Corp. (SEE). He joined SEE in 2010 and most recently served as senior vice president, chief transformation and manufacturing/supply chain officer.

1993

Sharlene Newman, BE, of Tuscaloosa, Ala., was elected in January to the newest class of the American Association for the Advancement of Science fellows. Newman, executive director of the Alabama Life Research Institute at the University of Alabama, was selected for her pioneering work in developing new neuroimaging techniques and their use to study language processing in the human brain, executive function, mathematical and spatial processing, substance addiction and psychopathology.

1994

Gary Butler, MS, is chairman and CEO of Camgian, an award-winning technology company developing artificial intelligence and machine learning technologies. The company recently was given the 2022 R. Clay Simmons Exemplary Enterprise of the Year award by the Greater Starkville (Miss.) Development Partnership.

Mark Lepofsky, PhD, recently was appointed CEO of FACTOR Inc., where he previously served as chief organizational officer. FACTOR solves complex problems related to risk management through consulting and custom application development for industry and government clients. Mark will soon celebrate his 32nd anniversary with his wife, Tricia, and lives in Arlington, Va.

1995

M. Kristi Henzel, BE, of Cleveland Heights, Ohio, was promoted to associate professor of physical medicine and rehabilitation at the Case Western Reserve University School of Medicine in July 2021. She is assistant chief of the spinal cord injuries and disorders service at the VA Northeast Ohio Healthcare System, and, in August 2021 along with her engineering team, she was issued a U.S. patent on a smart position sensor for power wheelchair footplates for the prevention of lower limb injuries during wheelchair mobility. She serves on the board of directors for the American Paraplegia Society and was elected vice-president/president-elect in September 2021.

2003

Ash Jayagopal, BE, MS'05, PhD'08, recently was named chief scientific officer of Opus Genetics, a gene therapy company headquartered in Raleigh, N.C., developing treatments for orphan inherited retinal diseases. Jayagopal, a biomedical engineer, has more than 13 years of experience in drug development, drug delivery platforms and biomarker development for retinal diseases.

2004

David Garcia, BS, of Middletown, Conn., executive director of analytics and optimization at Foxwoods Resort Casino, was named to the Emerging Leaders of Gaming "40 Under 40" list compiled by research and advisory firm The Innovation Group.

2005

Dan George, BS, MBA'14, founder and CEO of Piper Key, has received the 2020 Nashville Emerging Leader Award in the human resources category. George is a Vanderbilt engineering science graduate with more than 15 years of experience in strategic workforce planning and people analytics, guiding Fortune 100 businesses and startups to better manage their workforces. He also is chair of the Nashville Technology Council's Analytics Summit.

Robert J. Matz, BE, is vice president of academic administration, dean of the faculty and professor of theology and preaching at Hannibal LaGrange University in Hannibal, Mo., a position he began in July 2021.

2008

David Sharvin, BE, and **Jamie Goldstein**, BA'10, were married in Park City, Utah, surrounded by family and many Vandy alums. Their first child, Maxwell, was born in May.

2010

Samuel Bearden, BE, and **Laura Quast, BA'15**, of Indianapolis were married Jan. 31.

2012

Weller Emmons, BE, is on the leadership team of a Nashville-based startup called Mployer Advisor, which recently received a second round of funding from local venture capitalist Martin Ventures.

2015

Clint Caudle, BS, and Hannah Nolte, BA, MSN'17, of Huntsville, Ala., were married Sept. 4, 2021. Hannah is a doctoral candidate in nursing at Vanderbilt.

2016

Parker Klein, BS, writes that he recently left Google to work on his tech startup, Twos (www.StopForgettingThings.com), to help people stop forgetting things. He is currently working in Tampa, Fla., and is looking for users, mentors, advisers and investors.

2020

MacInnis Andrew "Mac" Kraus, BS, of Johnson City, Tenn., from May to November of 2021, thru-hiked the entire Appalachian Trail from Georgia to Maine.

In Memoriam

Frank L. Parker was a global pioneer in nuclear waste remediation, environmental sustainability

International nuclear waste management pioneer and member of the U.S. National Academy of Engineering, **Frank L. Parker**, 96, died August 10, 2022, in Nashville, Tennessee. He was named Distinguished Professor of Environmental and Water Resources Engineering, Emeritus, and Professor of Civil and Environmental Engineering, Emeritus, in 2011 after a 43-year career at Vanderbilt University.

Parker generated seminal works in what are now seven distinct disciplines, ranging from hydraulics to law to the scientific foundations of the environmental sustainability movement.

At Vanderbilt, he initially concentrated on thermal pollution and water resources problems, but in later years he focused on radioactive and hazardous chemical waste problems, particularly in the former Soviet Union. He visited Moscow 30 times, beginning in 1964 at the height of the Cold War, a period of geopolitical tension between the United States and the Soviet Union and their allies.

"Frank Parker was a visionary leader in nuclear waste management whose expertise and kindness was appreciated and admired by his students and colleagues throughout the world," said David Kosson, Gass Family Professor of Energy and the Environment.

In Memoriam

Vanderbilt engineering professor killed in West Virginia helicopter crash

Kevin Warren, research associate professor of electrical engineering, died June 22, 2022 in a helicopter crash in the West Virginia mountains.

Warren, 51, was one of six passengers on a tour aboard a Vietnam era Bell UH-1B Huey chopper during its last planned flight at an annual reunion for helicopter enthusiasts where he served as a volunteer. The vintage chopper crashed just miles northeast of the Logan, West Virginia airport. All six people aboard were killed.

Warren was actively involved in general aviation and held commercial pilot certificates for single/multiengine aircraft and helicopters. He also was a certified flight instructor at Wingman Flight Academy in Dickson, Tennessee and a member of the Lebanon Flying Club.

At Vanderbilt, Warren earned master's degrees in chemistry, '97, and electrical engineering, '99, and a Ph.D., '10, in electrical engineering. He joined the Institute for Space and Defense Electronics as a senior research engineer in 2003 and assumed his faculty role in 2020.

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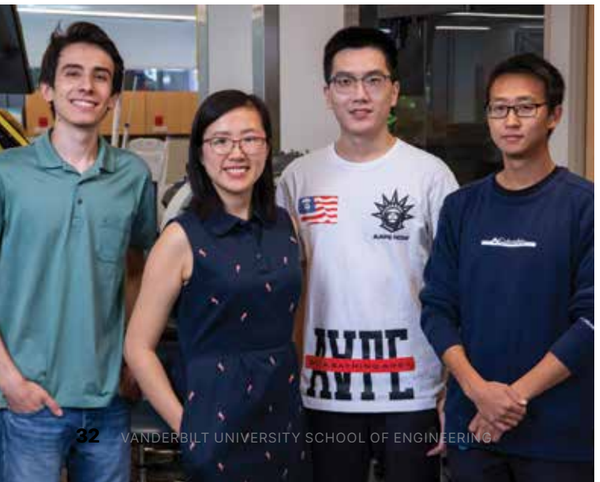
Surgical theater

As part of her Machine Automation, Perception and Learning (MAPLE) Lab, researcher Jie Ying Wu uses computer algorithms to enhance surgical robots—and the simulations doctors use to train on them.

We want to understand the different parts of surgeries, such as how patient anatomy changes throughout an operation and how surgeons develop skills. Our location in the Vanderbilt Institute for Surgery and Engineering (VISE) allows us to closely collaborate with surgeons and work with them from the start to design technologies to improve patient care. One project we are working on currently is to overlay information from CT and MRI scans onto the patient's anatomy during an operation. This could improve the success rate of kidney stone removals or help surgeons avoid cutting through arteries during liver surgery and causing excessive bleeding.

Another project focuses on understanding the mental effort surgeons experience during training. We aim to develop metrics for mental load by measuring surgeons' eye movements with a camera. This mental load metric can then be used to customize the training program for each surgeon and help them acquire skills more efficiently. Instead of requiring every surgeon to practice suturing a fixed number of times, we can use mental load metrics to monitor their progress and detect when they have mastered suturing.

—**Jie Ying Wu**, *assistant professor of computer science*



About the space

VISE's headquarters are hosted in 7000 sq. ft. of newly renovated space in the Vanderbilt University Medical Center. The space includes a 550-square-foot mock operating room, 14 graduate student stations, three development laboratories, one wet laboratory, a machine shop and one secured server room. The open development area is reconfigurable with wheel-mounted work benches. Power and network connections are ceiling-mounted and the space is lined with ceiling-mounted struts designed to support the weight of industrial robots used in the development of robot-assisted intervention procedures. The shared space accommodates interdisciplinary teams working on active projects aligned with VISE's core mission.

(Opposite page left) MAPLE lab group shot, left to right: Ayberk Acar, Jie Ying Wu, Yizhou Li, and Hongyi Yang

(Opposite page right) Yizhou shows the augmented reality scene he plans to deploy on the Microsoft Hololens to aid surgeons in the operating room.

(Top right) Ayberk sits at the Surgeon's Console of the da Vinci Surgical System as the rest of the lab discusses approaches to eye tracking on the surgeon's console..

(Above) Yizhou shows Hongyi how the patient-side robot manipulators move and how to attach a surgical instrument to it.

School *of* Engineering

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Douglas Chope, BS'86, MBA'88, a member of the School of Engineering Board of Visitors, and Teresa, BA'87, (at right of check) were among those who presented a reunion fundraising check to Chancellor Daniel Diermeier (in black cap) at the Vanderbilt football game against Ole Miss on October 8.