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Nashville, Tennessee
JUNE 2019

FDA APPROVES parathyroid detection device

SENSORS COLLECT campus air quality, mobility data

AI TAKES ON looming RF spectrum crunch

THE DESIGN ISSUE

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Bruce and Bridgitt Evans Dean Philippe Fauchet celebrates Commencement 2019 with Founder's Medalist David Zhang (center) and Ian Faucher, the School of Engineering's banner bearer. Photo John Russell/Vanderbilt.

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JUNE 2019

Partnership puts eyes on campus mobility and air quality

The first few of what could be two dozen sensor arrays will begin collecting air quality and mobility data on the Vanderbilt campus before classes begin in August 2019.

The sensors, each equipped with a camera, are part of large-scale, $9 million project backed by federal, state and university funding. The arrays will measure levels of carbon monoxide, ozone, air particulates, weather conditions, noise levels and more, including three types of light produced by the sun. In concert with other Internet-linked devices, such as shared scooters and bicycles, automobile GPS systems and mobile phones, the system will capture mobility patterns in ways that anonymize the data and protect individual privacy.

Vanderbilt in late 2018 received a $4.5 million, three-year grant through the federal Congestion Mitigation and Air Quality Improvement program to encourage greater use of sustainable travel options among faculty, staff and students. With the university's $4.5 million match, the program will fund shuttle operations, shuttle shelters, bike share shelters and other efforts in addition to sensor rollout.

The ambitious project will make Vanderbilt "a preeminent university testbed for managing mobility and improving air quality," said Dan Work, associate professor of civil and environmental engineering.

Sensor nodes collect air quality and transportation data across the Vanderbilt campus. The arrays are about 18 inches tall, 14 inches deep and 9 inches wide.

> "The convergence of technology and transportation provides new opportunities to design transportation services that are smart, sustainable, resilient, and efficient."
>
> **Dan Work, associate professor of civil and environmental engineering**

Vanderbilt University and Vanderbilt University Medical Center's joint status as Middle Tennessee's largest employer presented a significant opportunity to expand the university's leadership role in addressing congestion and air quality, according to professors with the Vanderbilt Center for Transportation and Operational Resiliency. A VECTOR team led by Craig Philip, research professor of civil and environmental engineering and center director, and Mark Abkowitz, professor of civil and environmental engineering, led the effort that secured the federal funding.

Installing the sensors is just the first phase, with complex technological, financial, logistic and regulatory challenges.

The sensors leverage three technologies:

- **Array of Things**, which are customizable sensor nodes and, in this case, based on more than 100 used and tested in a similar Chicago project;
- **Multisensor cameras**, which collect video data to run computer vision techniques and determine traffic modes and trajectories; and
- **BlueTOAD**, a proprietary technology by TrafficCast, which uses Bluetooth signatures to identify and anonymously track passing vehicles to later reconstruct travel times and likely routes from specific data points.

Metro Nashville and the Tennessee Department of Transportation also have—or will have—BlueTOAD sensors and the partnership with Vanderbilt gives the project regional scope.

Several graduate and undergraduate students in Work's group are involved with the project, which also creates research opportunities with FutureVU and MoveVU, the university's planning and mobility efforts, respectively.

But collecting data is only the beginning. Researchers will process it with computer vision and machine learning algorithms to support development of tools to improve everything from traffic signal timing and congestion management to environmental protection and transit planning. Other targets for optimization include travel mode choice, routing, sidewalk usage and safety.

"The convergence of technology and transportation provides new opportunities to design transportation services that are smart, sustainable, resilient, and efficient," Work said.

EISENHOWER FELLOWSHIPS ATTEST TO TRANSPORTATION PROGRAM CLOUT

Four engineering Ph.D. students have received prestigious Dwight David Eisenhower Transportation Fellowships, highlighting Vanderbilt's strength in connected cities and transit research.

The awards are made by the U.S. Department of Transportation's Federal Highway Administration. The 2018-19 fellows are:

- **Will Barbour**, civil and environmental engineering, who also received Eisenhower fellowships in 2016 and 2017, focuses on artificial intelligence solutions for efficient and sustainable railroad operations. He also works on smart cities technology research, personal mobility and large-scale transportation data.
- **Charles Doktycz**, civil and environmental engineering, also an Eisenhower Fellow in 2017, uses loss and damage databases to determine vulnerable areas of a community in order to make climate adaptation decisions. His research involves the risk and resilience of infrastructure systems affected by severe weather.
- **Derek Gloudemans**, electrical engineering and computer science, whose research involves using machine learning methods for detection and classification of faulty components in electric motors.
- **Yanbing Wang**, civil and environmental engineering, whose research involves estimation for complex traffic flow that involves multiple mobility services, such as bikes, scooters and passenger cars.

"Our outstanding students are not just technically strong but they also are emerging leaders interested in improving our community through their research and service," said Dan Work, associate professor of civil and environmental engineering.

All four students are members of the Vanderbilt Center for Transportation and Operational Resiliency. Barbour, Gloudemans and Wang also are research assistants at the Vanderbilt Institute for Software Integrated Systems.

New home boosts VISE's profile and growth potential

It takes the dean of the School of Engineering a quick 75 seconds to walk to the office of the CEO of Vanderbilt University Medical Center, who also is dean of the School of Medicine. The new home of the Vanderbilt Institute for Surgery and Engineering is along the way.

Dr. Alexander Langerman, associate professor of otolaryngology in the School of Medicine, works with Emelina Vienneau (left) and Abbie Weeks, engineering graduates and VISE affiliates, in the new space.

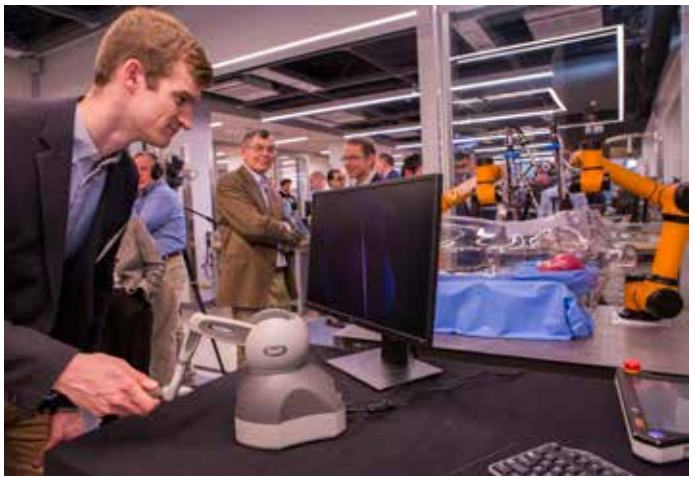
The 7,000-square-foot suite with a mock operating room and large work space in Medical Center North is expected to expand collaborations among engineering professors, physicians and students in engineering and medicine. VISE, which started as an initiative in 2010, had been a "virtual institute" with no physical home.

A packed open house in December 2018 included a technology showcase of more than two dozen cross-disciplinary collaborations advancing health care techniques from the lab to patients. VISE already has an impressive track record:

- At least 50 students have earned their doctorates since the program's start
- 69 current graduate students and more than 20 undergraduates are engaged in research
- 30 patents have come out of this collaborative work
- Vanderbilt has at least seven licensing arrangements to commercialize advancements
- VISE researchers have more than $30 million in active grants
- 11 core engineering faculty and more than 40 clinicians are affiliated with VISE

"VISE is the best example of transinstitutional collaboration on campus. We have an incredibly compact campus where engineering and medicine are adjacent to one another, and that's a great advantage that will never go away."

Philippe Fauchet, the Bruce and Bridgitt Evans Dean of Engineering



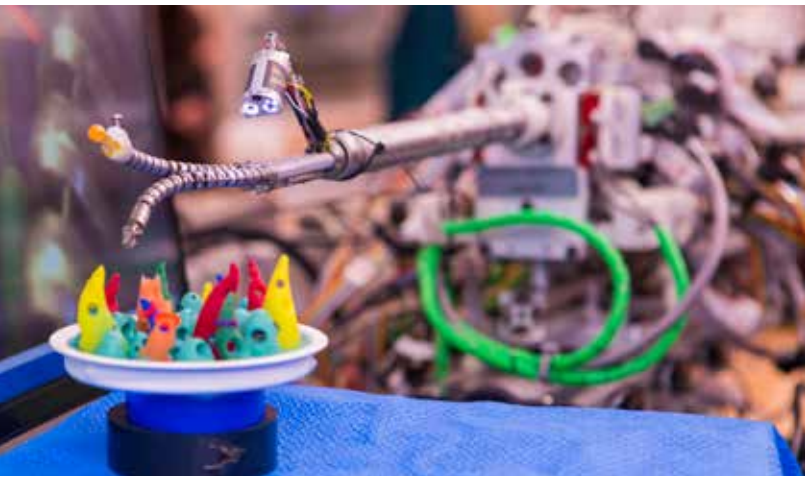
(Above) A mock operating room in the Vanderbilt Center for Surgery and Engineering draws crowds of campus dignitaries, professors, physicians and students during a grand opening celebration.

(Right) Patrick Anderson, a mechanical engineering doctoral candidate, adjusts arms for robotics-assisted surgery to access hard-to-reach lung nodes.

(Above) A surgeon demonstrates the "CleOpATra" surgical video system.

(Right) Graduate student Rashid Yasin works on a project for the Advanced Robotics and Mechanism Applications Lab.

(Below) Developed by Nabil Simaan, professor of mechanical engineering, snake-like surgical robots grasp and release small objects.



Partnership with Army targets innovation and

A new five-year agreement between Vanderbilt University and the Army Futures Command is a potential model for academic-military collaboration across the country, linking creative soldiers with engineering experts and technology.

The goals include accelerating deployment of new equipment for use in the field, providing enhanced leadership training for students and soldiers and promoting greater understanding among institutions.

Vanderbilt hosted leaders of Army Futures Command—including Command Sergeant Major Michael Crosby and Command Innovation Officer Jay Harrison—and representatives of the 3rd Brigade Combat Team, 101st Airborne Division from nearby Fort Campbell in April for a signing ceremony and a full day of interaction with Vanderbilt administrators, professors and students.

Crosby credited Colonel John Cogbill, the 3rd Brigade commander, with initiating the relationship between the Army and Vanderbilt after seeing the value of soldier-inspired innovation.

"Having feedback from soldiers who have been on the battlefield, understanding their complex experiences, and putting that together with researchers is going to be invaluable to address real-life challenges and to ensure American soldiers dominate any future conflict," Crosby said.

In the Army, it can take years to design, prototype and produce a device for a specific task. Pairing soldiers with scientists and engineers can shorten the process into weeks, or even days with 3D printers, laser cutters, injection molding machines and other gear.

Members of the Bravo Company 21st Engineer Battalion had a daylong lesson at the Wond'ry using that gear in August 2018, prototyping explosive ordinance housings. Field testing that followed at Fort Campbell was successful as well.

"The soldiers at Fort Campbell are really interested in innovation, and we have rapid fabrication tools to improve their sustainability and operational readiness," said Director of Making Kevin Galloway, a research assistant professor

of mechanical engineering and director of Design as an Immersive Vanderbilt Experience.

"We want to come up with solutions that soldiers can use in the field and make them more prepared for the scenarios that they encounter," Galloway said. "From an educational point of view, working with soldiers can empower students to take charge and explore ideas and feel confident to try different things."

Capt. Aimee J. Valles, the company's commander, said makerspace equipment not only allows soldiers to design their own solutions to tasks, but it also saves time and money. Soldiers can fabricate their own one-use parts they otherwise would have to order through the Army's supply chain.

"This absolutely revolutionizes the way we do things," she said. "Something like 3D printing or laser cutting is going to reduce that time and give us the ability to use parts or devices in our training or on the battlefield faster."

In April, Army personnel met with several researchers whose work could have immediate benefit for soldiers.

"I look at what Vanderbilt and the 101st are doing as a new business model that was being prototyped within the Army without any explicit direction or permission from highest levels of leadership," Harrison said. "Now, we at Army Futures Command want to formalize that relationship and make sure it has the resources to scale and grow beyond the opportunities it would have on its own."

Vice Provost for Research and Professor of Computer Science Padma Raghavan, who signed the agreement on behalf of the university, said she's delighted the Army appreciates Vanderbilt attributes that long have been recognized in the research community.

"Our research is very curiosity-driven," she said. "Either by design or by self-selection, it's in our DNA. We're always wondering what's at the fundamental core of whatever we're looking at, we're willing to test anything and we're not afraid to fail. Our labs are full of graduate and undergraduate students working night and day, on cross-disciplinary teams, solving problems at their core.

"It's the fact that so many of our researchers are multilingual—they can speak chemistry, mechanical engineering, management, psychology, all at the same time—that makes our cross-disciplinary teams unique."

The agreement is expected to increase learning for both soldier and civilian students in STEM (science, technology, engineering and math), management, entrepreneurship and design, plus grant the Department of Defense more laboratory space and expertise to address modern challenges.

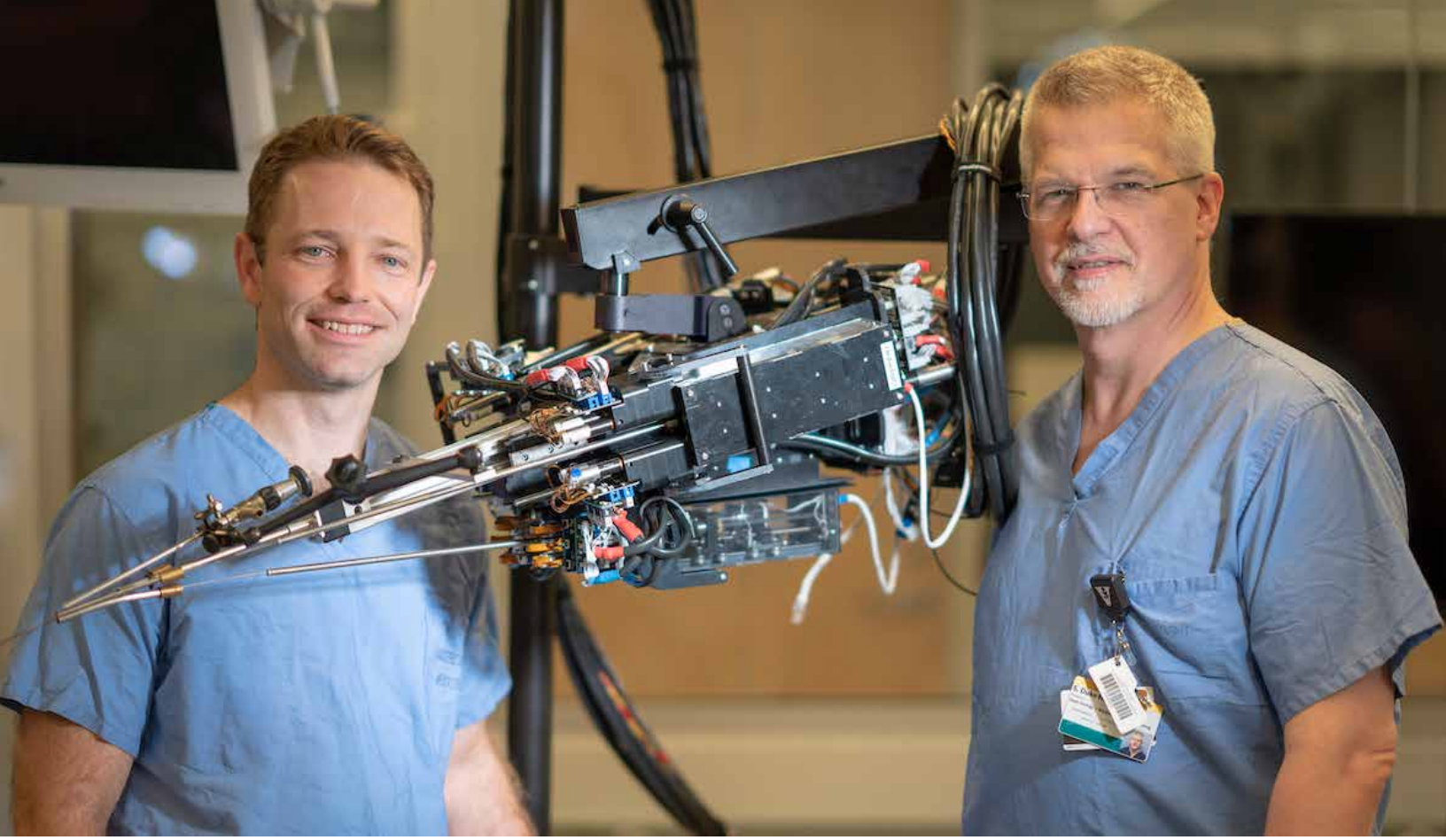
Headquartered in Austin, Texas, Army Futures Command went operational last year to more fully prepare Army leadership to understand future operational needs, predict and assess emerging threats and embrace state-of-the-art technology.

Futures Command leadership

(Previous page, top) Officials from the Army Futures Command and the 101st Airborne Division from Fort Campbell look over equipment prototyped in the Wond'ry during a day of events on campus.

(Bottom) Capt. Aimee J. Valles of 3rd Brigade Combat Team works with 3D-printed components during a training at the Wond'ry in August 2018.

(Above) Director of Making Kevin Galloway, research assistant professor of mechanical engineering, discusses Vanderbilt's rapid prototyping abilities.



Hand-held robot points to less invasive prostate surgery method

Robert Webster III, the Richard A. Schroeder Professor of Mechanical Engineering (left) and Dr. Duke Herrell, a urologic surgeon at VUMC, aim to make prostate surgery less invasive with an endoscopic robotic system. Photo courtesy of VUMC.

Vanderbilt collaborators focused on minimally invasive prostate surgery are developing an endoscopic robotic system with two-handed dexterity at a much smaller scale than existing options.

A key part of the design—telescoping, curved, concentric tubes—received U.S. patent protection in March 2019, the same month the principal investigators secured a $2.1 million R01 grant from the National Institutes of Health to advance the project. In January, Virtuoso Surgical, the team's Nashville-based company, was highlighted as a "startup to watch" by *MedTech Strategist*.

The goal of Robert Webster III, the Richard A. Schroeder Professor of Mechanical Engineering, and Dr. Duke Herrell, a urologic surgeon at Vanderbilt University Medical Center, is prostate removal through the urethra and support of delicate reconstructive suturing.

"The concentric tube idea lets us make our manipulators an order of magnitude smaller than the surgical robots doctors use today," Webster said. "This, along with accessing the prostate from a natural orifice will dramatically reduce surgical invasiveness, helping patients heal faster."

Both Webster and Herrell are core affiliates with the Vanderbilt Institute for Surgery and Engineering. Collaboration is central to the mission of VISE, where engineers, surgeons and other experts work side-by-side to develop next-generation instruments that require less tissue and organ disruption and improve surgical outcomes. Giving surgeons two-handed dexterity with small tentacle-like arms at the tip of the endoscope is a significant advancement.

"Making complex endoscopy easier is a game-changer for multiple surgical

and interventional specialties, and most importantly for patients," said Herrell, a professor of urologic surgery, biomedical and mechanical engineering, and director of Minimally Invasive Urologic Surgery and Robotics at VUMC.

In American men, prostate cancer is the second most common cancer behind skin cancer, and the second leading cause of cancer death, behind lung cancer. Up to 1 in 9 men will develop prostate cancer, and about 1 in 41 will die of it.

In the U.S. alone, more than 90,000 prostate surgeries are performed each year, many as open procedures with an incision 8 to 10 inches long made below the navel. In laparoscopic and robot-assisted laparoscopic prostatectomies, surgeons make several small incisions across the belly for insertion of surgical tools and a camera.

The Vanderbilt project would make the surgery much less invasive by introducing tiny surgical instruments through the natural opening provided by the urethra, a process called endoscopic transurethral prostatectomy. The approach would eliminate the need to dissect through healthy tissues from the abdomen into the pelvic area and cause less disruption to the the nerves that control continence and erectile function.

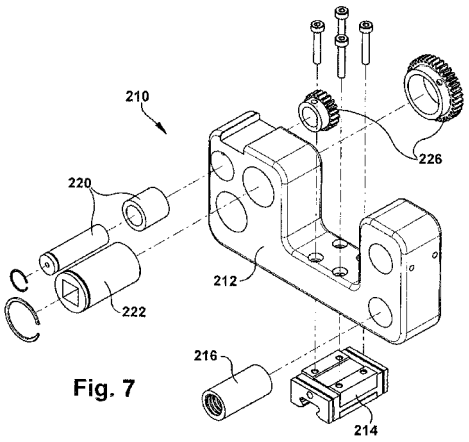


Fig. 7

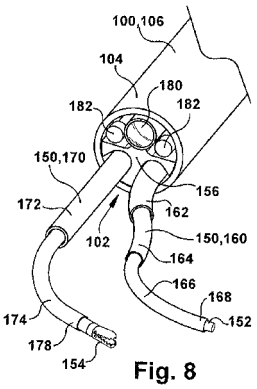


Fig. 8

The patented innovation includes telescoping, curved concentric tubes.

This is the first rigid endoscopic robotic system to provide two-handed dexterity at this size. Webster and Herrell jointly invented the concept to deliver needle-sized robotic arms through a standard endoscope.

The project, R01 EB026901, is funded by the National Institute of Biomedical Imaging and Bioengineering. The Vanderbilt Center for Technology Transfer and Commercialization worked with the team on the intellectual property process and the university received a patent for a "system and method for endoscopic deployment of robotic concentric tube manipulators" in March.

Prostate Cancer by the numbers (U.S. estimates for 2019)

66 average age at the time of diagnosis

1 MAN IN 9 will be diagnosed with prostate cancer in his lifetime

Prostate cancer is the second most common cancer in American men. Skin cancer is the most common.

174,650 new cases of prostate cancer

31,620 deaths from prostate cancer

Source: The American Cancer Society

FDA-approved device aids surgeons with real-time detection of parathyroid tissue

A Vanderbilt-developed device that enables surgeons to detect parathyroid tissue in real time has received FDA approval and is in use at U.S. hospitals, including Vanderbilt University Medical Center.

Parathyroid glands are difficult to locate and distinguish from other tissues during head and neck surgeries such as thyroidectomies and parathyroidectomies. A healthy parathyroid gland can be resected or damaged accidentally. Even worse, a surgeon can remove a lymph node or thyroid tissue assuming it is a diseased parathyroid gland. Damage to healthy parathyroid glands can lead to post-surgical hypocalcemia, while failure to remove a diseased parathyroid gland results in costly repeat surgeries and complications.

"Surgeons have relied mostly on their eye to find the parathyroid gland. Other available techniques like ultrasound or sestamibi scans tend to work only when the parathyroid is diseased," said Anita Mahadevan-Jansen, Orrin H. Ingram Professor of Biomedical Engineering and director of the Vanderbilt Biophotonics Center. "For identifying a normal parathyroid, there hasn't been an effective technique, except the surgeon's eye or biopsy."

The FDA in late 2018 cleared the PTeye System to aid surgeons in identifying healthy or diseased parathyroid tissue during head and neck surgeries. Mahadevan-Jansen and colleagues at Vanderbilt developed the system in collaboration with Ai Biomed Inc., a Santa Barbara-based medical device company.

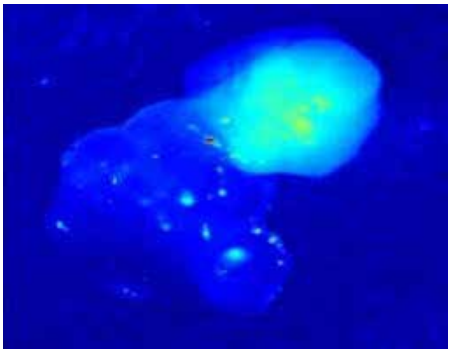
Mahadevan-Jansen made the scientific breakthrough underlying the technology 10 years ago—parathyroid tissues glow under near-infrared light.

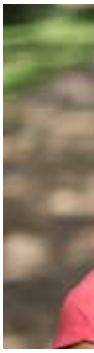
"When we discovered this strong autofluorescent signal in the parathyroid, we thought it was stray light," she said. "But the consistency of the signal proved that it was real."

"It had previously been assumed that there was no intrinsic biological fluorescence in soft tissues beyond about 650 nanometers," she said.

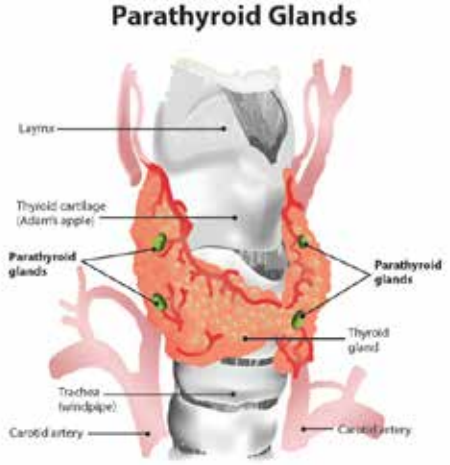
From submission to the FDA to approval took less than two years. In considering Ai Biomed's application, the agency reviewed the device under its *de novo* pathway, which applies to novel technology that poses low-to-moderate risk. The PTeye System is non-invasive and can function with ambient operating room lights, allowing easy integration into the existing surgical workflow.

"What we are essentially trying to do is offset costs for patients and save time for surgeons," said Giju Thomas, a postdoctoral fellow at the Biophotonics Center. "By using





Autofluorescence of the parathyroid tissue on the upper right is twice as strong as that of thyroid tissue, providing an immediate way to differentiate the two. (Photo/Mahadevan-Jansen Lab).



Orrin H. Ingram Professor of Biomedical Engineering Anita Mahadevan-Jansen also is director of the Vanderbilt Biophotonics Center. (PTeye/courtesy of Ai Biomed. Illustration/ Michael Smeltzer)

a device like PTeye, you can confirm the identity of suspect tissue almost immediately."

Unlike other systems, PTeye does not look for just diseased parathyroids. It provides anatomical guidance to support surgeons in identifying the parathyroid gland, whether it is diseased or not. When the probe touches a parathyroid gland, it beeps to warn surgeons to proceed with caution. The device also stands apart from others as there is no need for surgeons to administer dyes or contrast agents to visualize parathyroid tissue.

The parathyroid glands are vital structures that regulate blood calcium levels in the human body to support normal heart, nervous system, kidney and bone function. These four tiny glands are typically each about the size of a grain of rice, tucked within lobes of the larger thyroid gland.

Vanderbilt University Medical Center contributed to this story.

Celebrex use increases risk of valve calcification, big-data study finds

A big-data analysis of patient records at Vanderbilt University Medical Center has found a link specifically between Celebrex and heart valve calcification.

After correcting for other risk factors, the research team discovered that patients who had taken the popular arthritis drug had a 35 percent increased prevalence of valve disease.

The conclusion comes three years after a well-known, four-year study found Celebrex no more dangerous for the heart than older drugs in its same classification—commonly called NSAIDs.

W. David Merryman, professor of biomedical engineering, and Meghan Bowler, Ph.D.'18, started out by testing celecoxib, the active compound in Celebrex, on valve cells to see if it could double as an aortic stenosis therapy. It made the problem worse.

To confirm their theory about the link to increased calcification, Merryman, who is also a professor of pharmacology, medicine and pediatrics at Vanderbilt, recruited Michael Raddatz, a M.D./Ph.D. student, to analyze more than 8,600 relevant, anonymous patient records from Vanderbilt University Medical Center. Raddatz checked whether there was a link between Celebrex use and aortic valve disease and corrected for other risk factors to conclude patients who had taken Celebrex showed valve calcification at a rate 35 percent higher than cardiac patients who did not.

"If we extrapolate data from the cohort of patients we studied, in the 9 million Americans who are prescribed celecoxib every year, an additional 297,000 will develop aortic sclerosis than if they had been taking other NSAIDs," Merryman said.

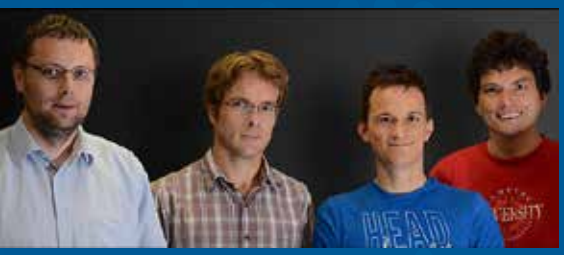
The 2016 *New England Journal of Medicine* study that found Celebrex no more damaging than naproxen and ibuprofen looked only at cardiovascular death and nonfatal heart attack or stroke, not valve disease, which affects more than a quarter of the U.S. population older than 65.

"In this study, we're adding a long-term perspective on celecoxib use," Bowler said. "Calcification in the aortic valve can take many years. So if you're at a higher risk for it, you might want to consider taking a different painkiller or rheumatoid arthritis treatment."

The team's results were published in the *Journal of the American College of Cardiology (JACC): Basic to Translational Science*. The work was funded by the following grants: NIH R35 (HL135790), NIH R01 (HL115103), NIH T32 (GM007347), NSF CAREER Award (1055384), and NSF Graduate Research Fellowship (2013170175).

As crunch looms, Vanderbilt team to compete in DARPA finals for RF allocation overhaul

Statistica estimates number of connected Internet of Things devices, including nearly 5 billion mobile phones in use now, will reach 30 billion by 2020 and pass 75 billion by 2025. That doesn't even include satellites and thousands of public and private entities whose transmissions drive our times.



Team MarmotE (L-R) Peter Horvath, Peter Volgyesi, Sandor Szilvasi and Miklos Maroti will compete in DARPA's Spectrum Collaboration Challenge grand prize round.

The radio frequency spectrum itself is fixed and the crunch is here. But how frequencies are allocated is overdue for a major upgrade, and a team of Vanderbilt computer scientists and research engineers has been working on the problem for five years. Team MarmotE will compete in the live, final round of the U.S. Defense Advanced Research Projects Agency's Spectrum Collaboration Challenge in October.

The goal is machine-learning algorithms to sort out frequency priorities based on urgency—emergency and critical safety scenarios in real time—and to cooperate rather than compete for bandwidth.

MarmotE was one of six teams awarded a $750,000 prize in 2018, coming in second in Phase II, after leading 10 teams in Phase I competition. The grand prize is $2 million.

Team members Peter Volgyesi, Miklos Maroti, Sandor Szilvasi and Peter Horvath are current or former researchers and Ph.D. students working at the Vanderbilt Institute for Software Integrated Systems.

"Our team has a strong background in low-power multi-hop wireless network communication and time synchronization. Our approach is: 'We question every assumption, have original ideas and can engineer a working and robust solution,'" said Volgyesi, a research scientist at the institute and a lecturer in the Department of Electrical Engineering and Computer Science.

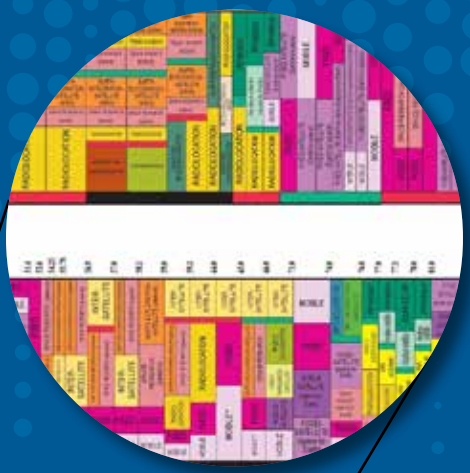
Maroti, a former EECS research associate professor, is now at the University of Szeged, Hungary. Szilvasi is a radio frequency and field-programmable gate array engineer in Atlanta. Horvath is at Budapest University of Technology.

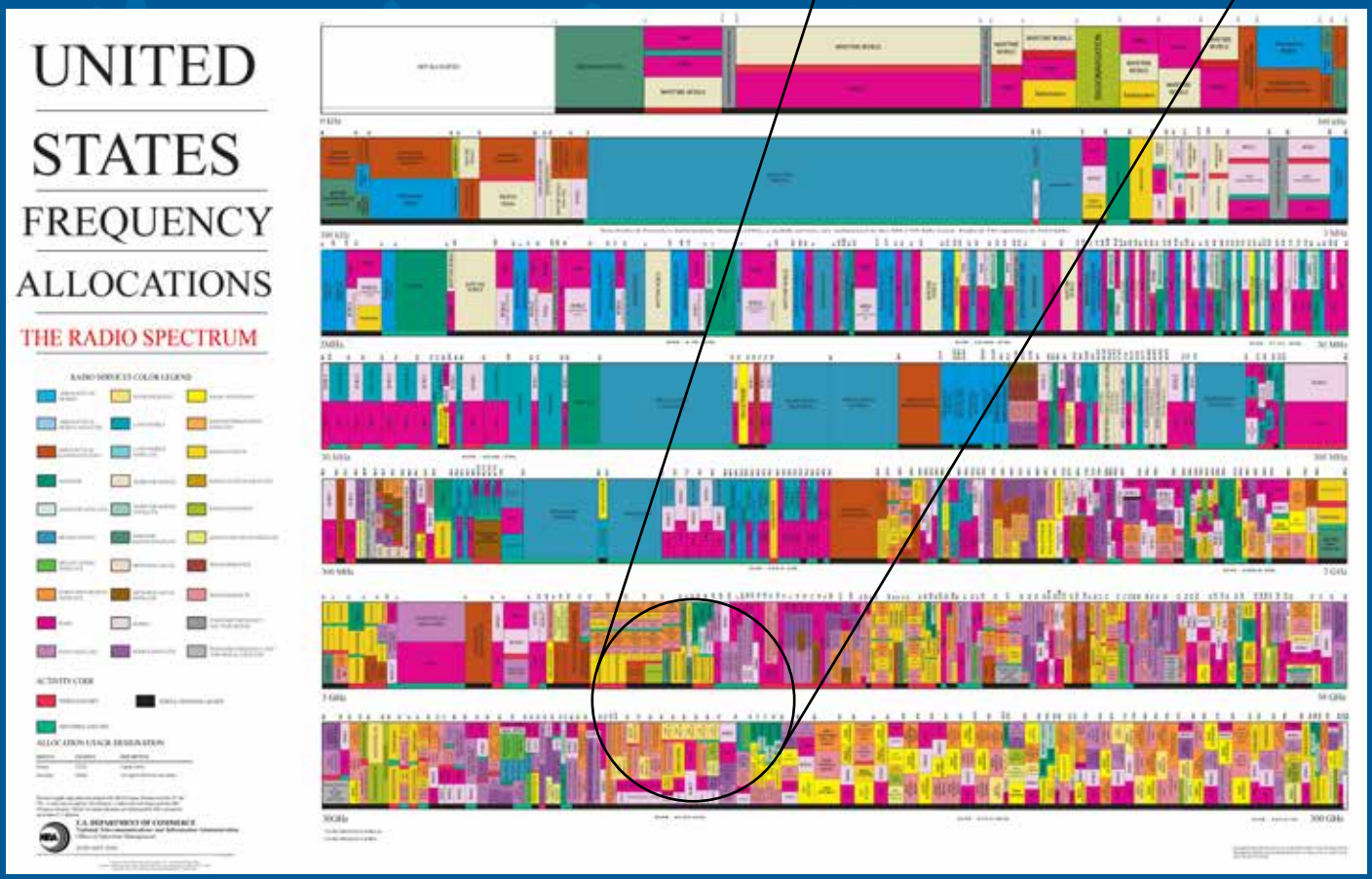
The teams had to show their AIs could not only collaborate to manage the spectrum but also do it more effectively than chopping spectrum into defined bands, the current practice. The hope is devices can manage their own spectrum use after training them to listen for gaps in transmissions, broadcast which frequencies they intend to use and even negotiate with nearby devices with needs of their own.

The radio frequency spectrum is fixed and running out of space—fast. DARPA hopes AI algorithms will better allocate precious bandwidth.

The challenge comprised a series of matches representing real world scenarios such as managing transmissions from deployed soldiers in an urban environment or from Wi-Fi routers attempting delivery despite a nearby radio jammer. Each AI scored points based on the number of connections delivered using the available spectrum—spectrum shared with two, three or four other AIs at a time.

The radio frequency portion of the electromagnetic spectrum in the U.S. is regulated by the Federal Communications Commission and the National Telecommunications and Information Administration.





Watson Room, robot workshops, qubit chat celebrate IBM support

Dozens of students built and programmed small robots that responded to their voice commands. IBM provided the kits as well as an internship for a mechanical engineering undergraduate who designed the curriculum and led the workshops.

Top IBM officials led seminars on blockchain technology, quantum computing and entrepreneurship. And the company established a Watson Room, a suite of IBM products and services located at and supported by the Wond'ry.

Events throughout the academic year celebrated IBM's longstanding support of engineering education at Vanderbilt. The IBM Graduate Fellows Program was established in 1981 as an endowed fund to support highly competitive graduate students in all engineering departments.

In September, Robert Sutor, vice president for IBM Q Strategy and Ecosystem at IBM Research, presented "Quantum Computing: Don't Count Your Qubits Before They're Hatched," part of the John R. and Donna S. Hall Engineering Lecture Series. A qubit is the fundamental unit of quantum information.

Mubarak Ganiyu, a rising junior, did not have to master qubits but he did conquer the TJBot platform during his internship, which also involved mastery of the resources IBM provides through its Academic Initiative. He created workshops to expose students to robotic engineering and encourage creativity and problem solving in building and coding their TJBots.

"This internship at the Wond'ry and with IBM not only gave me the opportunity to utilize my organizational skills to create workshops for the Vanderbilt community but, most importantly, it provided me with an immersive and experiential learning experience that I will cherish forever," he said.

(Top and right) VR/AR technology is among IBM services and support on campus. (Above) Mubarak Ganiyu, a rising junior, demonstrates his work with TJBot kits and workshop curriculum development at the university's annual Celebration of Learning.

Robot-guided video game targets isolation, movement and cognition

Every so often, a squat little robot off to the side would remind players of the object of the game: Get your avatar's books into the right bin and earn extra points by helping the other player.

The gamers were two residents of Elmcroft Senior Living who sat side-by-side facing a large screen, raising their hands in tandem as watch-style devices on their wrists controlled the avatars in front of them. This simple game has big goals – getting seniors in the early stages of dementia out of their rooms, moving their bodies and, most importantly, working together. Isolation is a contributor to dementia's progression and this robot-guided video game may be an effective, low-cost solution for caregivers.

Vanderbilt University's Nilanjan Sarkar, professor and chair of mechanical engineering, Linda Beuscher, an assistant professor in the School of Nursing, and their team tested the game in two nursing homes with a total of 15 older adults, both with and without cognitive impairments. Fourteen of them kept coming back to play the game, gradually increasing the amount of time they wanted to spend with it.

With those results, the team is seeking grant money for a larger, more extensive study that could open doors to human therapists being assisted by robot colleagues.

"There are not enough younger people to take care of our older generations, and that's why we're designing intelligent, social robots that can talk to them, keep them from becoming isolated, lead them in appropriate physical exercise and help them with memory and cognition," said Sarkar. "It's not the total solution, but it can go far in helping the world's elder generations."

A 2014 study showed nearly half of Americans age 65 or older require some sort of assistance from another person, typically an informal caregiver. The U.S. Census projects that population will double to 98.2 million by 2060.

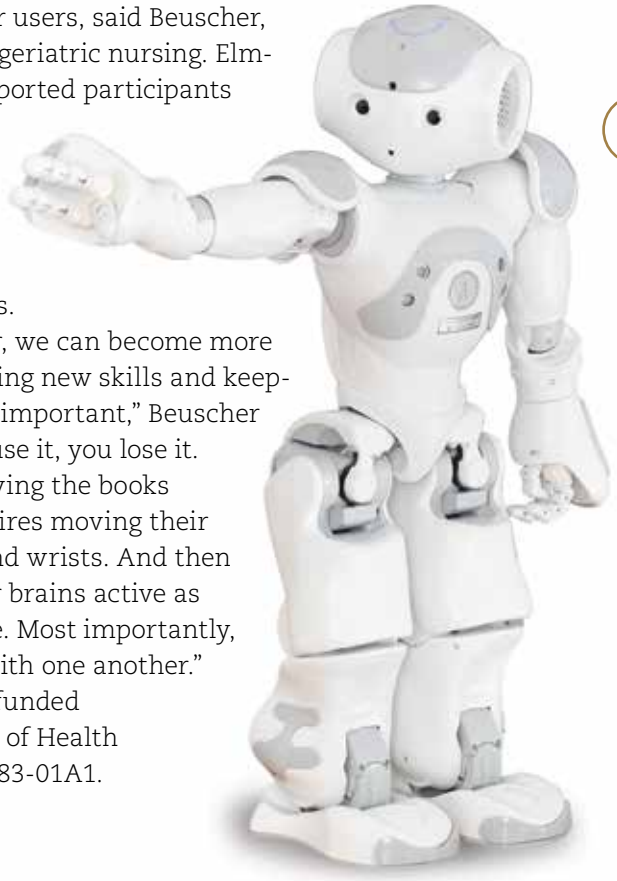
Jing Fan, a mechanical engineering graduate student, developed the video game and programmed the robot to say participants' names during instructions. Elmcroft resident Kathryn Brown, who joined the pilot study to learn more about the technology, said she got a kick out of hearing her name.

"It took some effort, but I don't think the game was too difficult," Brown said. "It made me think more and be careful about my arm movements. This might very well help other senior citizens."

Robot-led therapy has potential to attract and entertain older users, said Beuscher, whose specialty is geriatric nursing. Elmcroft employees reported participants in the pilot program were engaging with other residents a little more, even after a few sessions.

"As we get older, we can become more isolated, and learning new skills and keeping moving is very important," Beuscher said. "If you don't use it, you lose it. We know that. Moving the books on the screen requires moving their shoulders, arms and wrists. And then we're keeping their brains active as they play the game. Most importantly, they're engaging with one another."

This work was funded National Institutes of Health grant 1R21AG050483-01A1.



A robot programmed to address participants by name guides two players through a video game designed to combat social isolation and early dementia.

7 Questions with CJ Warner,
BE'80, CEO of Renewable Energy Group

Cynthia Julien "CJ" Warner left "big oil" for "big algae" in 2009 and in January 2019 became president and CEO of Renewable Energy Group, Inc., the largest North American producer of advanced biofuels. Over the past three decades, Warner has held executive leadership roles at global energy companies including Sapphire Energy, Andeavor, British Petroleum, UOP and Amoco. Earlier this year Warner, who earned a Vanderbilt bachelor's degree in chemical engineering and an MBA from Illinois Institute of Technology, was named to the school's Academy of Distinguished Alumni. We asked CJ about her career—and about lessons learned from a pre-dawn run punctuated by a rattlesnake bite on her first day at Sapphire.

1 **You've talked about switching directions/majors at Vanderbilt. What was it about Chemical Engineering that made such an impression?**

I found the teamwork and collaboration, which was highly encouraged in the ChemE department, to be fun, exciting and rewarding. There were so many instances where classmates could come together and make things work, or make sense of things, in a way we never would have been able to do on our own. We fostered relationships and respect for one another that has lasted a lifetime. At the time I just knew it was a work and learning style I preferred, but over my career I've come to realize that collaboration is the pathway to both superior results and true breakthroughs. And, just as it was in my Vandy days, it makes the journey so much more enjoyable and meaningful.

2 **Why and at what point did you decide to pursue a MBA and the leadership track?**

I had about five years of experience, mainly in refinery catalyst and process development, when I started doing more technical services work for the refineries. I could see the uncaptured value potential in making targeted improvement investments and became interested in more strongly linking the concepts of process technology, operational excellence and commercial/business development. These disciplines didn't always communicate as well as they could. I realized what I could learn through an MBA program would help me with the financial aspects as well as the leadership it would take to bring these disciplines together more powerfully to create new ideas. My first role after completing my MBA enabled me to start doing just that. I was responsible at a refinery for performance reporting and analysis. Through this role I was able to "translate" process variables and yields into financial results (for the accountants) and financial results back to process conditions (for the engineers). Bringing together disparate elements and finding ways to help people work together across boundaries have consistently been a pathway for success in my various roles.

Renewable Energy Group produces advanced biofuels for transportation and biodiesel for heat, power generation and other industrial purposes in addition to transportation. The company, which has biorefineries throughout the U.S. and Europe, sold about 650 million gallons of fuel in 2018. Photos courtesy of Renewable Energy Group.

3 **How would you, in general, compare company culture, decision-making processes, and chain-of-command structure at traditional oil/gas v. renewables-focused firms?**

In general, culture is much more leader-specific than industry-specific. I do think there has been a significant trend from strong command-and-control leadership styles prevalent in my early days of working to a more distributed, empowered and collaborative leadership style today. This applies to both industries and I'm gratified to see this trend continuing—the need for differentiated and breakthrough performance in both segments truly demands it. You can see that companies that adopt this more empowering culture tend to outcompete the others.

5 **What skills and training from your time at Vanderbilt contributed the most to your career development?**

1. How to learn—a lifelong skill that I must constantly draw upon.
2. Teamwork and collaboration, and how to appreciate what others bring to the table, and work together to get through tough times.
3. Material and energy balances! While basic, it is amazing how often business proposals ignore the basic laws of chemical engineering and thermodynamics.
4. Appreciation for the value of cross-disciplinary connections and the breakthroughs that can come from pairing unlikely thought partners.

4 **What makes REG your dream job?**

Granted that I'm only about five months into my CEO role at REG, but this truly feels like the culmination of all I've been learning and preparing for in my former experiences. The company culture and the people are terrific—dedicated, passionate, hardworking and focused on scaling up a much cleaner, very low carbon form of energy with the potential to compete economically and grow significantly. Making all of this happen draws on all of my past experiences in some way, shape or form and certainly motivates me every day!

What is the closest thing, metaphorically, to getting bit by a rattlesnake on your first day at Sapphire in the transition from traditional energy companies?

6

My biggest lesson from the real rattlesnake bite was to take time to absorb local knowledge before forging ahead too quickly (I should NOT have been running where I was running). The same thing is true when transitioning to a new area or field. There are a LOT of analogies to past experiences upon which I have been able to draw but, equally, there have been a lot of things I didn't fully appreciate immediately. Biology is a big example. So is farming. These two areas are essential elements of the biofuels field and having expert knowledge to lean upon is critical.

7

What would you tell your 21-year-old self that you wish you'd been told?

Don't let the judgment of others define you or diminish your self-confidence. Be clear and honest with yourself on what is important for you to be accomplishing, and assess yourself on that scale; ask for help if you feel you are falling short. Enjoy the adventure—you don't have to have it all figured out in the early days. Just follow your instincts, apply your energies to things that have meaning for you, and an amazing adventure will unfold.

Inclusion is the key to superior performance

You've talked about female classmates leaving the profession after getting "tired of competing and having to prove yourself for the 15-millionth time." Do you still feel you need to?

Thankfully, I haven't had that sense of needing to prove myself recently—there is definitely something truly energizing about immersing oneself in an environment where most everyone around you has a sense of meaningful purpose and works together to make that happen. In other words, competing together rather than against one another. I've been fortunate (and selective) in that my last few roles were with firms and teams that truly wanted to make a positive difference.

Having said that, I am keenly aware through my past experiences and my affiliation with other women in the field that—in general—company culture continues to foster an environment that makes it feel harder than it needs to be for women. And many very talented women realize somewhere along the line that it isn't worth all of the extra effort to fight through that when what they really want to do is apply their talents and work with others to contribute to a successful outcome. They choose to move on. When talented women (or talented people of any race or background) choose to "opt out," everybody loses something.

I don't think this is done purposefully but rather is an unconscious adherence to a culture that simply isn't as comfortable or energizing or nurturing of women or people who are different from the prevailing culture. Leaders who decide they are going to proactively address this DO make a big difference and attract and retain a diverse workforce, which ultimately results in superior performance. I'm convinced this is the right direction both because it's the right thing for people AND because it helps firms to create superior value.

Why is this an area I'm passionate about changing for the better? Because I don't want others to have to do what I and others have had to and fight through so much negative energy to get ahead; I want things to be better for my daughter; I want things to be better for our energy industry and other technically based industries so that we are all working together to make a positive difference, create value and develop a strong future.

And I'm convinced that inclusion—as simple as it might sound—is key to making all of those things happen.

Tyler Bernstein, left, and Jonathan Segal are two founders of Zeno Power Systems.

POWERING REMOTE SCHOOLS AND HOSPITALS FROM DECAY

Zeno Power Systems made a big pivot. The original idea behind the Vanderbilt student-led startup was to provide the aviation industry with a jet fuel alternative but the NSF's program for new entrepreneurs grounded their attention.

The company is now focused on developing a small clean energy system to serve schools and hospitals in remote locations.

Tyler Bernstein, a rising senior majoring in computer science, credited the Innovation Corps program, which provides grants and training, with saving the team untold time and money. In ICorps classes at The Wond'ry, Bernstein and other cofounders worked through the basic but oft-skipped step of establishing a product-market fit and realized their original plan missed the mark.

"We thought we were on a great track and it probably would have taken us a long time while we were on a path that failed," he said. "In the discovery interviews we found a stronger fit in solutions other than aerospace."

The team is ramping up, raising angel investment and securing several federal grants while building out its prototype.

"We're using radioisotopes—a resilient, clean energy source—in a device no larger than a tabletop that potentially could power even small villages that currently rely on diesel or coal," said Bernstein, the CEO. "Our device could fuel critical infrastructure for months or years with no maintenance."

In basic terms, the idea is to turn the heat from a decaying radioisotope into energy to create consistent power. The simple gets complex because the plan involves radioactivity and, with that, a regulatory maze.

That's where Steven Krahn, professor of the practice of nuclear environmental engineering and a noted expert in the field, plays a crucial role. As the idea developed, Krahn went from adviser to team member, making industry introductions and herding regulatory issues.

Jonathan Segal, BS'19, and Jake Matthews, MS'18 in mechanical engineering, round out the team.

Zeno Power was among 20 startups selected from a nationwide pool to take part in the University Innovation and Entrepreneurship Showcase in Washington, D.C., in April. The company also took part in Vanderbilt University Venture Group's Inaugural Pitch Night in June.

Bernstein and Segal, a human and organizational development major, said Vanderbilt supported their efforts by allowing their internship requirements to be fulfilled through working in their own company. Both are doing so now from Washington D.C.

"Not only have we received the education and skills we need to be successful, we've also received encouragement and support for entrepreneurship," Segal said. "That's critical to launching a company at the same time as completing a degree."

> The exoskeleton, 10 years in the making, weighs 26 pounds and has no bulky backpack-mounted components, exposed cables or upper-body attachment.

Exoskeleton wins R&D 100 award

With a lightweight modular design, Indego allows paraplegic users to transport and put on the device unassisted, enabling them to walk. The exoskeleton, 10 years in the making, weighs 26 pounds and has no bulky backpack-mounted components, exposed cables or upper-body attachment.

What the Vanderbilt-developed device does have is a prestigious R&D 100 Award, accepted jointly in late 2018 by co-inventors Michael Goldfarb, H. Fort Flowers Professor of Mechanical Engineering, and Ryan Farris, Ph.D.'12, engineering manager at Parker Hannifin Corporation. The R&D 100 Awards are considered among the most globally prestigious recognitions of invention and innovation.

Parker Hannifin purchased an exclusive license to market the design in 2012 and has worked closely with Goldfarb's research group to develop commercial and therapeutic versions of the technology. The U.S. Food and Drug Administration granted clearance to market and sell the powered lower-limb exoskeleton in 2016.

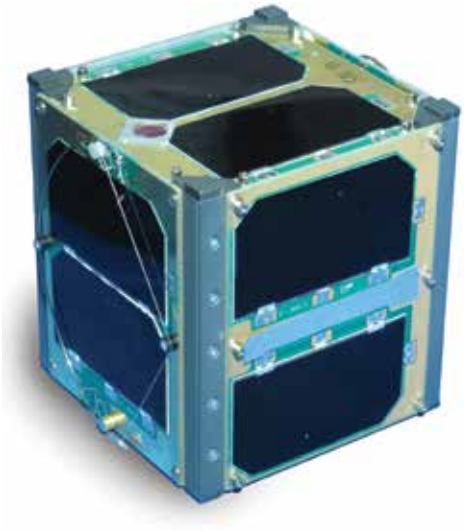
Running sensors flub the force

A segment of the multibillion-dollar wearables industry aims to save runners from potential stress fractures but the devices measure the wrong thing.

Sensors measuring only the impact of the foot hitting pavement—which most of them do—tell users little about the forces on bones that lead to stress fractures. Assistant Professor of Mechanical Engineering Karl Zelik and a doctoral student Emily Matijevich confirmed muscle contraction, not ground impact, accounts for the vast majority of force on the bone. "Measuring ground reaction force may be convenient, but it's the wrong signal," Zelik said.

In general, you cannot assume increases in ground reaction force indicate increases in bone stress, said, Matijevich, herself an avid runner. In several cases, lower ground reaction forces actually meant more stress on the tibia, a finding opposite of what most athletes believe and counter to how most existing wearables work.

The Vanderbilt engineering team worked with a local running club and an orthopedic specialist who advises the NFL Players Association.

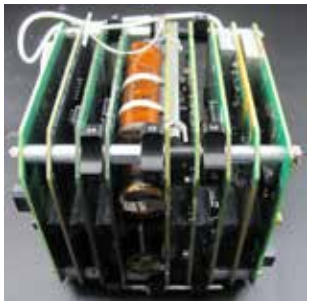


Vanderbilt's Institute for Space and Defense Electronics sends another CubeSat into orbit, this time aboard a SpaceX rocket.

EXPERIMENT HOPS ABOARD SPACEX

When the SpaceX's Falcon 9 rocket launched in December 2018 its payload included a Vanderbilt radiation experiment, a spare of one already in orbit and the third small satellite from Vanderbilt's Institute for Space and Defense Electronics.

Falcon 9 delivered 64 small satellites into sun-synchronous low-Earth orbit—setting a U.S. record for the largest single rideshare mission. The smallsats took off in a 20-foot-tall payload stack shielded by the rocket's fairing.



Vanderbilt's rig is a CubeSat, which is smaller than a MicroSat. Fox-1Cliff, the official designation, is a 4-inch cube weighing 2.2 pounds. Fox-1Cliff was among 15 MicroSats and 49 CubeSats from government and commercial entities including universities, startups, and even a middle school aboard Falcon 9.

ESB COLLECTS DESIGN AWARDS

Vanderbilt's Engineering and Science Building has been recognized for lab design and sustainability in separate, prestigious awards. The building won an international S-Lab award in April 2019 in the category of Engineering and Related Buildings for Wilson HGA, a national architecture firm specializing in science and technology facilities for higher education. S-Lab is a nonprofit initiative in the U.K. that works with universities, research institutes and laboratory sectors to support best practice in laboratory design, operation and management internationally.

In January 2019, the ESB was awarded gold LEED status by the U.S. Green Building Council. LEED, or Leadership in Energy and Environmental Design status, is the system used to rank buildings of all types as certified, silver, gold or platinum based on the building's environmental and cost-saving green features. The 230,000-square-foot, seven-story building, adjacent to the School of Engineering's Olin Hall, was completed in 2016.

VU adds coding camps, online degrees

Adults looking to advance their careers or switch fields to tap into Nashville's huge need for technology talent have new options to receive a top-notch Vanderbilt education.

The School of Engineering and digital education company 2U, Inc. have partnered to deliver a suite of two online graduate engineering degrees: a master of science in computer science and a master of engineering in engineering management.

Separately, Vanderbilt University Boot Camps, offered cooperatively by the engineering school, Owen Graduate School of Management and Trilogy, started in January 2019 with two sections of web development, twice what was expected at launch. Another cohort of coding starts in July 2019, as do separate boot camps in data analytics and cybersecurity. The face-to-face courses are taught in campus classrooms and the curriculum is approved by computer science faculty.

More information on the online engineering degrees is available at **https://engineeringonline.vanderbilt.edu/**. Boot Camp information is at **https://bootcamps.vanderbilt.edu/**.

Breck Jones, BS'81, fails at retirement but excels at pharma startup

After an unsuccessful two-week retirement at 40, P. Breckinridge Jones Sr. began a two-year quest that led to his seventh start up, US WorldMeds.

Today, US WorldMeds is 18 years old and marketing six pharmaceutical products in the United States, three of them also licensed abroad. The company has achieved FDA approval of three products in the past year and Breck Jones expects approval of three more products within the next 18 months.

Jones is the company's founder and CEO and a 1981 magna cum laude graduate in engineering science, economics and business administration. He credits his ability to navigate the path of US WorldMeds to that education.

"It's been incredibly challenging with unimaginable ups and downs, which is exactly what any Vanderbilt trained engineer would cherish tackling and effectively resolving," Jones said.

VANDERBILT UNIVERSITY SCHOOL OF ENGINEERING

Pharma portfolio

US WorldMeds, a Kentucky-based specialty pharmaceutical company, develops drugs through FDA approval and then commercializes them. The business is privately held and does not disclose financial results, though Jones said revenue has grown 135x over what it was in 2011.

The company's product line includes treatments for loss of movement control in patients with advanced Parkinson's disease, but it is Lucemyra, the first and only non-opioid to treat and relieve opioid withdrawal symptoms, that has attracted a good share of media attention.

The FDA announced in May 2018 that Lucemyra, a non-narcotic, was shown in clinical trials to reduce the severity of side effects in easing off drugs that doctors and scientists say prevent many from kicking their painkiller habit.

"Withdrawal pain and discomfort is the #1 reason an estimated 12 million dependents remain on opioids today," Jones said. "Lucemyra can get opioid addicts through withdrawal symptoms, which I'm so proud to say."

That said, health care payers, including major Medicare Part D players and pharmacy benefit managers, have been reluctant to cover Lucemyra, which is stunning considering the impact of the national opioid crisis, Jones said.

More than 130 people in the United States die each day after overdosing on opioids commonly used in prescription pain medications, according to a January report from the National Institute on Drug Abuse of the NIH. The CDC estimates the total U.S. economic burden of prescription opioid misuse alone is $78.5 billion a year, including the costs of health care, lost productivity, addiction treatment and criminal justice involvement.

Deep Vanderbilt and Nashville roots

Jones, who is a member of the Sloan family that owned and operated Cain-Sloan department stores for many decades in Nashville, said he's lost count but believes "at least 20 family members are now Vanderbilt alumni including my grandfather, my mother and my two oldest children."

Following his Vanderbilt graduation and with an MBA in 1983 from The Wharton School, Jones returned home to Louisville, Kentucky, to pursue his entrepreneurial dreams and spend time with his father who died from colon cancer 18 months later.

Over the next 15 years he founded or co-founded six companies—four successes and two failures—completed two leveraged buyouts and acquired 750,000 square feet of commercial properties. Connections made in the School of Engineering have been important to Jones, from solid career advice offered by a professor to lifelong friends.

"I'm very proud of my Vanderbilt engineering science degree—I call it my Arts and Science of Engineering degree," Jones said. "I regularly share that my engineering degree has been invaluable in terms of training me the right way to think, to process information, to tackle problems and to undertake challenges."


DESIGN
DAY VU

Greening a Nashville interstate corridor

A land bridge over a section Nashville's Interstate 65 corridor would create 14 acres of public green space, reconnect neighborhoods and put Music City on a leading trend in urban planning.

Three senior civil engineering students worked with the Nashville Civic Design Center on a feasibility study for such an undertaking and identified no "fatal flaw that should prevent further consideration of [a] cap project." The center sponsored the team's senior design project, which looked at engineering aspects, potential costs, utility conflicts and existing traffic patterns, pedestrian access and accidents.

The potential price tag is high—$234 million if started today. The students used data from similar projects in Dallas (completed), Atlanta, Ga. (unfunded, preliminary design) and, in Pennsylvania Pittsburgh (under construction) and Philadelphia (funded, in design) to arrive at the figure.

"We were surprised by how ideal the site was from a variety of perspectives, such as utilities, bike and pedestrian connectivity, etc.," said Ian Faucher, BE'19.

"The project definitely changed the way we think about urban spaces and interstates in particular. The vision that NCDC has defined for the interstate cap is so bold that it really stretched the boundaries of what we thought possible for the Nashville community," he said. "We're usually trained in engineering to think of projects discretely. This project was an opportunity to think about how engineering can reshape a large section of a city over multiple decades, which was really exciting."

As envisioned, the project would cap Interstate 40/65 between 12th Avenue on the south and Church Street on the north, creating a tunnel-like area 3,500 feet long and roughly 250 feet wide for the expressway.

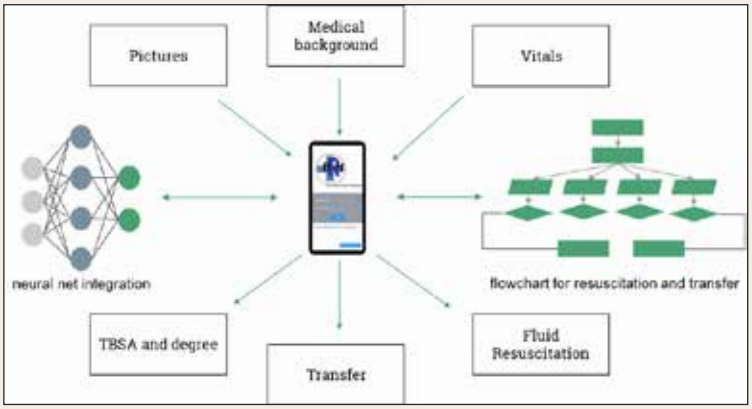
The three engineering students—Claire Chandler and Hunter Conti in addition to Faucher—all were campus planning interns, civil engineering majors and 2019 graduates. The team also won the department's award for Best Senior Design project.

Advisers included Gary Gaston and Eric Hoke from the design center, Charlie Smith and Mary Vavra from Barge Design Solutions, Michael Payne from S&ME and Peter Westerholm of the Greater Nashville Regional Council.

"We would be thrilled to see an interstate cap reconnect neighborhoods in an inclusive way, provide much needed green space, and make Nashville a more beautiful, more livable city," the team said in a statement.

Improving burn calculations and patient care

Evaluating the severity of a burn injury—and whether it requires transfer to a Burn ICU or not—has been more art than science. About 79 percent of Total Burn Surface Area calculations are incorrect, sending more patients than necessary to specialized facilities, straining resources and compromising resuscitation and patient care.



A senior engineering design team used artificial intelligence to improve the science. They wanted to develop more accurate and consistent estimates of patient burn injury severity and fluid resuscitation needs. The result is a prototype app with which a physician inputs patient vitals and history and takes photographs of the burned areas.

A neural network determines the burn surface area and degree from the photos, and the algorithm combines burn area information with the patient's vitals to get fluid volume needed for resuscitation. It also compares the patient data against the American Burn Association transfer criteria to determine if transfer to an upper level burn center is necessary.

Eric Yeats, a computer engineering major, joined biomedical engineering majors Jacob Ayers, Hannah Kang, Dominique Szymkiewicz, Nora Ward and Thomas Yates, all BE'19 graduates. Yeats designed the algorithm and trained the neural network with 275,000 images—small 50-by-50 pixel sections of 200 larger photos of burns of varied severity over varied body areas.

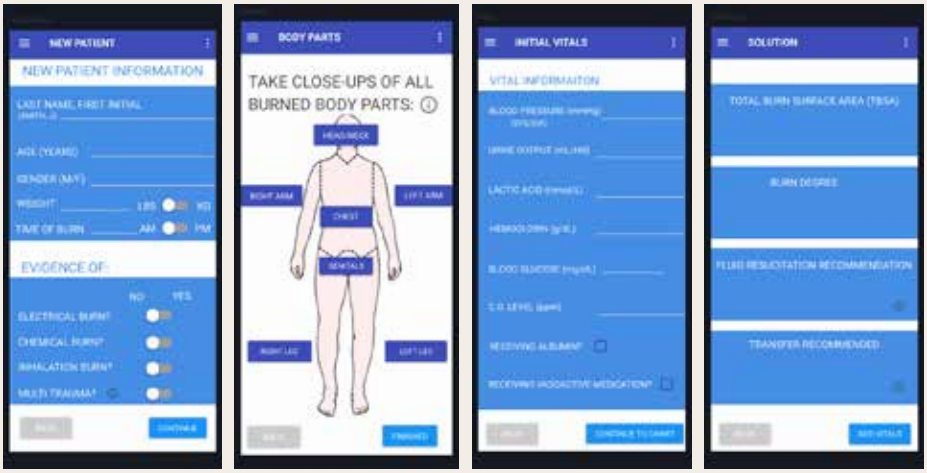
The app, which goes far beyond anything now available to clinicians, runs photo inputs through a convolutional neural network, where burned skin, healthy skin and background are differentiated. It works on all skin colors, ages and even accounts for tattoos.

The impressive effort won the BME design award, the Thomas G. Arnold Prize. The project, on which Dr. Avinash Kumar of VUMC's Division of Anesthesiology and Critical Care Medicine continues to be adviser, is seeking grants and Yates is working on the project over the summer.

Next steps, in consultation with VUMC Burn ICU staff members, involve testing for performance accuracy, both the neural network burn area calculation component and the overall application functionality.

Estimating Total Surface Burn Area now is subject to human error, subjectivity and different body types, and preliminary misdiagnosis has significant consequences. Over-resuscitation of a patient, including delivering too much fluid, can cause hypertension, kidney damage and other complications. Underestimating burn area can mean a burn patient does not receive enough fluid.

An estimated 40,000 people are hospitalized with burn trauma in U.S. hospitals each year, 30,000 of them at a dwindling number of specialized burn centers. The U.S. has roughly 123 burn ICUs, down from 180 in 1976, according to the American Burn Association.



The student team built a user-friendly interface for health care providers to input patient data, take photos, add patient vitals and receive preliminary burn area calculations and fluid recommendations.

2019 Senior Design Winners

THOMAS G. ARNOLD PRIZES

The Thomas G. Arnold Prizes for Biomedical Engineering Systems Design and Research is shared by **Ethan Thomas Jones**, Cookeville, Tennessee, (research), and for design (Burn Resuscitation and Management for Early Responders), **Jacob Thomas Ayers**, Saint Louis, Missouri; **Dominique Danielle Szymkiewicz**, Miami, Florida; **Hannah Eunhae Kang**, San Diego, California; **Nora P. Ward**, Frankfort, Illinois; **Thomas John Yates**, Cincinnati, Ohio; and **Eric Christopher Yeats**, Gainesville, Florida.

CIVIL ENGINEERING DESIGN AWARD

The Civil Engineering Design Award goes to **Claire Chandler**, Edwardsville, Illinois; **Hunter Conti**, New Providence, New Jersey; and **Ian Faucher**, Boise, Idaho; for their senior design project: Capping the Interstate.

MECHANICAL ENGINEERING DESIGN AWARD

The Mechanical Engineering Design Award is shared by two teams. The winners are the Surgical Video System Design Project and the Mechatronic Design of a Surgical Robot Project. The video system team members are **Robert Crawford** (ME), Mechanicsville, Virginia; **Danny Levy** (CompE), Lithonia, Georgia; **Gianna Riccardi** (ME), Eliot, Maine; **Izzat Rushaidhi** (ME), Masjid Tanah, Malaysia; **Minh Vu** (EE), Hanoi, Vietnam; and **Mohamad Ali Yazdani** (ME), Kota, Malaysia. The surgical robot team members are **Michael Beans**, Hollywood, Florida, **Alyson Chason**, Owings Mills, Maryland, **Siyuan Jiang**, Weifang, China, **Jacob Rogatinsky**, Hollywood, Florida; and **Keaton Scherpereel**, Flagstaff, Arizona.

WALTER C. CRILEY PRIZE

The Walter C. Criley Prize in electrical engineering is awarded to the VADL Payload Team: Collaborative UAV Search and Deploy Mission for Space Exploration: **Nick Belsten** (EE), Melbourne Beach, Florida; **Rachel Erbrick** (EE), College Park, Georgia; **Emily Herron** (CompE), Charlotte, North Carolina; and **Liam Kelly** (EE), Montclair, New Jersey.

KENNETH A. DEBELAK AWARD FOR EXCELLENCE IN DESIGN

Winners of the Kenneth A. Debelak Award for Excellence in Design in chemical and biomolecular engineering are *First place (tie)*: Design of a Continuous Chlor-Alkali Electrolysis Process and Lab Module, **Logan Guy**, San Antonio, Texas; **Zack Morrisey**, Glen Carbon, Illinois; **Isaac Richardson**, Columbus, Indiana; and **Jackson Stacy**, Pawleys Island, South Carolina; *and* Design of a 500 Ton Per Day Sulfuric Acid Plant, **Lindsay Eller**, Commack, New York; **Jade Gomez**, Vallejo, California; **Justin Lynch**, Trumbull, Connecticutt; and **Hailey Weller**, La Grange, Illinois. *Second place*: Design of an Environmentally-Friendly Acrylonitrile Production Facility, **Nikki Kragt**, La Vista, Nebraska; **Felix Tiet**, Pembroke Pines, Florida; **Masturina Sukri**, Kota Bharu, Malaysia; and **Samantha Kaczaral**, Woodstock, Georgia. *Third place*: Designing an Industrial Plant to Produce 50 Tons Per Year of Silane, **Nur Najihah Mohd Asri**, Tanah Merah, Malaysia; **Aqlil Izzatie Ismail**, Baling, Malaysia; **Mohd Syakir Mohd Nordin**, Pendang, Malaysia; and **Yun Sik Oh**, Seoul, Korea.

Preface

On behalf of the School of Engineering, welcome to Design Day 2019. This year you'll see more than 75 engineering and computer science capstone projects completed in partnership with sponsors including Nissan North America, FedEx, NASA Marshall Space Flight Center, Metova, International Bridges to Justice, Cumberland River Compact, Nashville Civic Design Center, Polymer & Chemical Technologies, LLC, and many more. We thank all of our project sponsors, advisors, and mentors for their support of our design teams and the whole program.

Senior design courses provide students with experience working on real-world projects that involve design constraints, budgets, reviews and deadlines. Students learn about professionalism, licensing, ethics, teamwork, entrepreneurship, intellectual property and all the key skills of their disciplines. As their projects take form, student teams interact with their industry and faculty advisers, hold meetings write formal documentation and present their work. By the end of the academic year, the teams produce prototypes, simulations, design processes, or virtual demonstrations. Design Day is the showcase for the lessons learned over four years of their engineering educations.

We recognize the value of senior projects mentored and supported by external advisors—industry representatives, entrepreneurs, non-profit mentors, as well as research and clinical faculty. This experience allows you to work with Vanderbilt engineering seniors and discover what makes our students stand out among other applicants when it comes to employment and postgraduate study. If you or your colleagues are interested in mentoring or sponsoring a project or to learn more, please contact me.

Sincerely,

Thomas Withrow
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Associate Professor of the Practice of Mechanical Engineering
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BIOMEDICAL ENGINEERING

TEAM

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Lucas Harward, ME
Andrew Haymaker, ME
Leela Hegde, ME
Luke Hogewood, BME
Ben Klapper, BME
Ben Litt, BME
Nick Sanchez, ME
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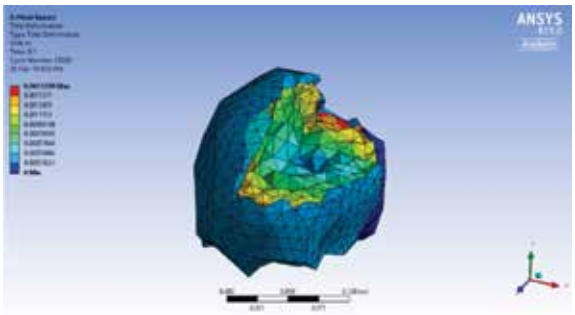
Finite Element Model of the Human Brain

The long-term effect of sports-related concussions has become a public health concern over the past decade as the media continues to spotlight the dangers Traumatic Brain Injury (TBI). Knowledge of the effects of concussions is limited by the lack of physical symptoms that present themselves when someone experiences a concussion. It is imperative to identify an alternate route to concussion diagnosis. Our design team created a Finite Element Analysis (FEA) model of the human skull and brain that can take a vector input representing an impact and translate the data into an output that describes how the impact affected the brain. The research market offers models that perform similar computations. However, our model is the only open-source model that maintains a high degree of analytical accuracy. It is the design team's goal that this model will put the power of concussion diagnosis at the fingertips of athletes and trainers everywhere, creating a safer competitive environment for all.



Mesh model of the human brain generated by first reading MRI/CT scans into 3D Slicer, an image analysis software. The model was segmented to acquire the geometry of the skull and brain. In Meshlab and Gmsh, the model was modified further to convert surface mesh into volumetric mesh. The entire model was imported into ANSYS to run impact simulations on the virtual model of the brain.

BIOMEDICAL ENGINEERING

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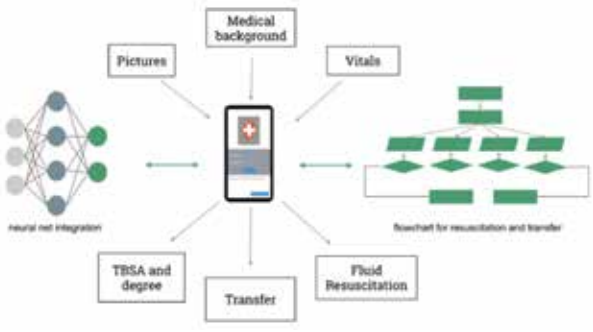
Burn Resuscitation and Management for Early Responders

There are 123 Burn Intensive Care Units in the United States. These are smaller than traditional ICUs and require longer stays. Currently, about 79 percent of total burn surface area (TBSA) calculations are incorrect because physicians estimate this value, which may cause unnecessary transfers to Burn ICUs that could limit bed space and lead to incorrect resuscitation and patient deaths.

The project objective is to improve burn treatment using technologies to accurately estimate burn surface area, prevent the overburdening of burn centers and improve the overall treatment of a patient. Our team created an Android application to enable a physician to input patient vitals, history, and take photographs of the burned areas. A neural network determines the burn surface area and degree from the photos. The application's algorithm combines TBSA with the patient's vitals to output necessary fluid volume for resuscitation. Additionally, this application compares the patient data against the American Burn Association's transfer criteria to determine if transfer to a burn center is necessary.



The application addresses issues associated with the overestimation of burn surface area by integrating the neural network analysis of patient photographs, vitals and medical history to more accurately and rapidly determine the resuscitation needs of a patient.

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BIOMEDICAL ENGINEERING

Multisensory Pre-alarm Device for Physicians

Intensive Care Units have an overwhelming number and range of alarms that can disturb both patients and physicians. Oversaturation of noise and visual stimulation leads to the low positive predictive value (≥23%) associated with ICU alarms and has caused patients to develop panic related psychological issues. This project aims to address the need of physicians to track patients' vital signs in a less intrusive manner before an alarm threshold is met.

The principal components of the system are a bone conduction headset, soundscapes, wearable haptic actuators and haptic signals. Each physiological parameter and direction (high/low) is associated with a sound, and haptics are incorporated to enhance the distinction between abnormal and concerning pre-alarm zones. The team conducted efficacy studies that trained and tested subjects on multisensory combinations. The results were analyzed to determine what composition resulted in the highest user accuracy, intuition and comfort. This design improves upon previous ones by comparing more multisensory combinations, by increasing precision and by incorporating more qualitative analysis. The study aims to find a combination of signals that will make a pre-alarm monitoring system intuitive and comfortable enough for use in an ICU setting.

This multisensory pre-alarm system will transmit auditory and haptic signals through a bone conduction headset and wearable subwoofers to allow physicians to monitor vital signs. Instrumental sounds will be associated with each physiological parameter and haptic signals will enhance discernibility between concerning and abnormal pre-alarm ranges.

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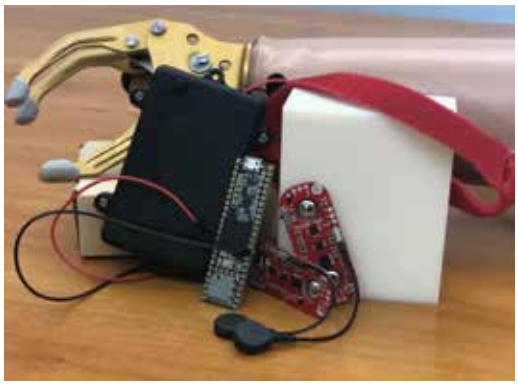
BIOMEDICAL ENGINEERING

Continuous Force-based Control System for a Myoelectric Hand Prosthesis

The Functional Neural Interface (FNI) Lab at Case Western Reserve University integrated tactile sensation into the prostheses of distal arm amputees using an implanted nerve electrode system. Because this current system relies on the linear feedback control of myoelectric prostheses rather than the continuous control seen during natural hand posture maintenance, this system has reached a barrier in acquiring quantitative data as they begin in-home trials. Our team developed a novel control system that interfaces with commercially available prostheses to integrate the natural, continuous feedback system present in intact musculature hand control. The system uses an embedded software controller that maps incoming electromyography signals from forearm muscles and leverages a feedback loop mechanism to replicate intact muscle control. Output pulse-width modulation signals will allow for prosthetic actuation and hand posture maintenance through continuous muscle activation. The system will be validated using a human subject and a servo motor that mimics prosthesis behavior. This device will be implemented into the FNI Lab project to improve the quantitative characterization of the effectiveness of their nerve electrode prosthetic system.



The prosthesis hardware additions include a battery pack, microcontroller and electromyography muscle sensors.

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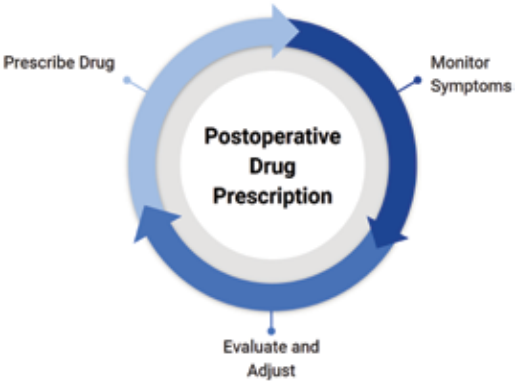
Pharmacogenetic Trial for the Prevention of Postoperative Effects of Cardiac Surgery

Open-heart surgery requires weeks of recovery. It is critical that physicians prescribe the correct doses of vital medication given after surgery to ensure patients are comfortable and safe as they recover. Typically, this is a guessing game since every patient is different and that may cause prolonged patient stays. By genetically testing patients before surgery, we can predict what doses they need in a tailored fashion, hopefully saving time and alleviating pain.

This genetic technology is already available. However, due to a lack of knowledge on how to interpret genetic test results, it is not readily used. We have designed a clinical decision support tool that automatically notifies providers about how to best use genetic test results for a vital medication when they choose to prescribe it. This integrated software tool is the basis for a clinical trial to confirm the effectiveness of a pharmacogenetic approach for a new drug, Metoprolol, which prevents atrial fibrillation.



With pharmacogenetics, we can determine correct drug doses to be administered to patients after open-heart surgery.

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34

Wireless Control of Oxygen Liter Flow Rate on In-home Oxygen Concentrators

Idiopathic Pulmonary Fibrosis (IPF) is an autoimmune disease that causes lung tissue to thicken and scar, thus decreasing the rate of lung-blood oxygen transfer. Individuals diagnosed with IPF require Long-Term Oxygen Therapy (LTOT) to improve their blood oxygen concentrations.

Often, patients on LTOT keep their oxygen concentrators set at a constant oxygen flow rate in one location. However, people require different oxygen concentrations for different activity levels. An IPF patient can suffer long-term side effects if oxygen flow rates are not adjusted to accommodate various activities. Our device attaches to in-home oxygen concentrators. A smartphone application allows adjustments to the oxygen liter flow rate. The application's algorithm adjusts flow rate based on a patient's blood oxygen saturation level. Together, the device and application will allow individuals on LTOT to receive an adequate amount of oxygen at various activity levels more conveniently.

We created a device that connects to an oxygen concentrator and wirelessly adjusts oxygen flow. A smartphone application allows a user or caretaker to control the oxygen when they are far from the concentrator.

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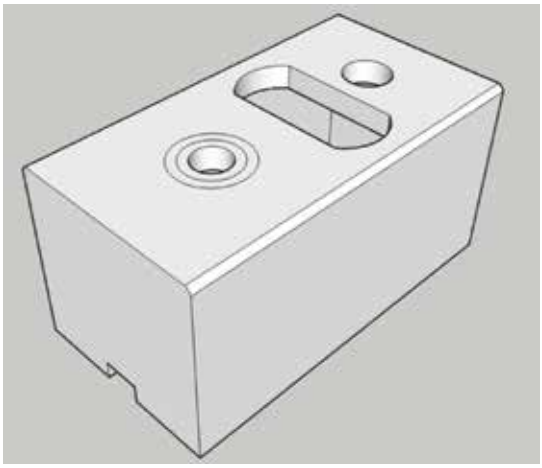
BIOMEDICAL ENGINEERING

X-ray Localization Device for Radiation Oncology Mouse Studies

Radiation therapy exposes patients to a controlled amount of radiation as a form of cancer treatment. It is a widely used and effective technique, used in 40 percent of all cases where patients are cured of cancer. This treatment method is studied and refined constantly.

In particular, mouse models have become an essential tool for radiation therapy research. In these studies, X-ray beams focus on certain areas of the mouse's body and the effects are analyzed. Excess exposure during radiation therapy can lead to radiation toxicity, which results in cellular degradation and damage to DNA. Current radiation shielding involves adjusting lead shields to create an aperture targeting the desired structure. This results in inaccuracy in beam placement and leakage to non-targeted areas of the mouse as the aperture cannot be adjusted easily.

Our team designed a device that localizes X-ray therapy to the brains, lungs and hips of multiple mice while protecting untreated areas. Our shielding design will provide the option of adjustable apertures for the desired tumor sites, and attenuates 90-95 percent of X-ray beams at non-target sites, allowing for accurate beam focusing and decreased toxicity.



X-ray shielding device prototype.

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BIOMEDICAL ENGINEERING

Co-culture Device to Study Minimal Microbiomes

A growing field of interest in microbial research is understanding the influence chemical signals have on microbiome dynamics. To study this, microbes can be kept physically separate while still allowing them to share culture media. Current co-culture devices accommodate two separated microbes, or a combination of microbes that are not physically isolated. There is not an option to culture more than two microbes in the same environment while preventing physical interactions.

Our team designed three connected custom-built glass flasks for microbe cultures that allow chemical signals and metabolites to share a common culture media while filters between the flasks prevent the microbes from passing. This allows researchers to identify the role chemical signaling plays in the overall dynamics of microbiomes. A co-culture device is not limited to microbial research; this device also can be implemented in any lab that seeks to observe the interactions of three separate cultures. The device successfully maintained separate cultures throughout incubation and allowed for passive diffusion of metabolites between compartments. Currently, the Townsend lab uses the device for research purposes.

A co-culture device composed of three custom 1 L Erlenmeyer flasks connected by clamps and gaskets. While sharing culture media, microbes are physically separated by 0.2 micron filter paper placed between connection points.

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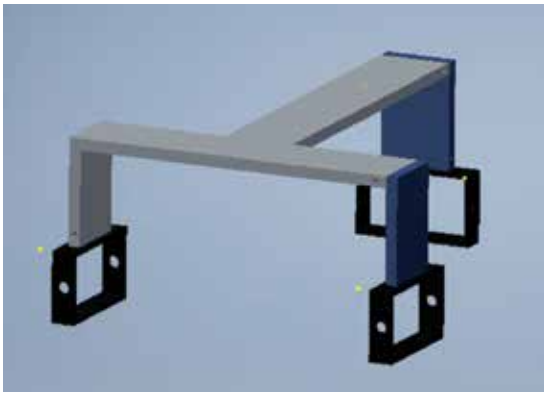
Ultrasound Brain Helmet

After paralysis, differently abled people lose the ability to manipulate their world. While previous studies show that real-time brain monitoring can translate thoughts into actions on a computer, these techniques are either too impractical to be a long-term solution or too invasive to be feasible. One method that shows promise for discovering brain signals is ultrasound (US). However, there are inconveniences for using US in this application. A probe must hold the same position at a point in the skull where a signal can be read. In addition, multiple US probes are needed for viable readings and, thus, signals must be aligned.

To address these issues, our design group is creating an Ultrasound Brain Helmet. This helmet will have the capability to hold three US probes at the three points in the skull where signals are obtained: the left temple, the right temple and the suboccipital triangle. The helmet is fully adjustable to fit each patient's head and customizable for the localization and fixed placement of US probes.



A CAD design of the ultrasound brain helmet. The black portions hold ultrasound probes and control the helmet's vertical adjustment. The blue portions control horizontal adjustment.

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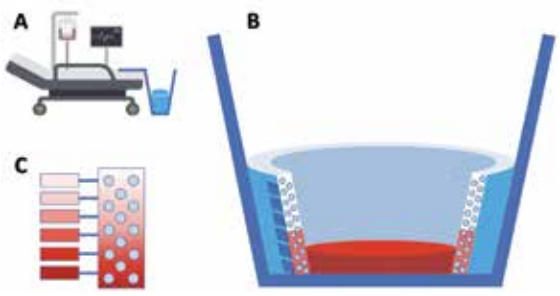
Quantifying Blood Loss in Vaginal Births to Reduce Maternal Morbidity and Mortality

Significant advances in obstetrics have improved outcomes for mothers giving birth. However, blood loss over 500 mL, termed postpartum hemorrhage (PPH), in the hours after a delivery still poses a significant threat to the mother. Due to its rapid onset and unpredictable nature, PPH is one of the leading causes of maternal mortality in the United States. The gold standard for clinical intervention typically involves visual estimation of the amount of blood lost, but this approach often leads to a gross underestimation. More robust techniques for quantification often disrupt workflow in the delivery room and can be costly. To more accurately detect PPH, the team designed a device to collect and differentially measure blood loss. The device contains a superabsorbent biomaterial that collects blood and other fluids, and utilizes a standardized chemical gradient to quantify a critical level of blood loss. The solution integrates well with current childbirth protocols and offers a cost-effective, timely and non-invasive approach for measuring maternal blood loss and alerting clinical care providers.



(A) Our system interfaces with the standard draping system of hospital birthing beds. (B) Interwoven with cellulose, our sodium polyacrylate-based biomaterial can easily absorb the amount of blood volume lost during postpartum hemorrhage. (C) The climbing blood absorption level is integrated with a standardized chemical gradient to signal when blood loss has reached a point of critical attention.

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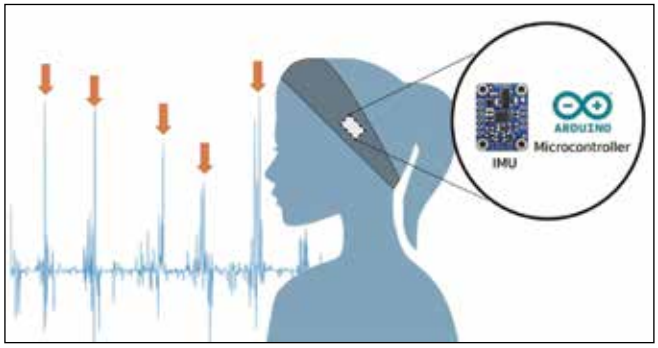
BIOMEDICAL ENGINEERING

Head Rotational Tremor Alert Device

An 11-year old patient experiences a complex motor stereotypy due to Rhombencephalosynapsis, a brain malformation. The condition causes a head and neck tremor that occurs periodically but can be controlled when her attention is focused. The team designed a wearable device that detects an oncoming head tremor and sends a discreet notification to the patient.

The wearable device is a fabric headband with a built-in inertial measurement unit (IMU) that characterizes the patient's head motion. Tremors are detected in real time by continuously comparing the patient's current head motion to the characteristics of a known tremor. When a tremor is detected, a signal is sent to a vibrating bracelet to alert the patient. The bracelet is programmed with a variety of vibration types to reduce the effects of habituation. The team also is including a counter to determine the number of times tremors occur daily. The patient is exploring pharmacotherapy as a treatment option and this device will allow her to quantify the effectiveness of a new medication.



A headband's pocket contains the electronics necessary to detect an oncoming tremor and alert the patient. An inertial measurement unit (IMU) characterizes the head motion. A microcontroller processes the signal, detects a specific tremor pattern and sends an alert to the patient.

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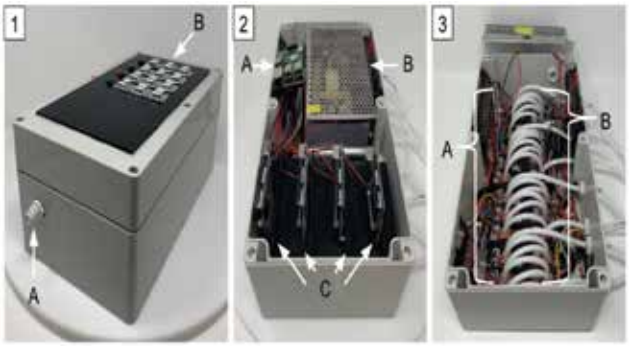
BIOMEDICAL ENGINEERING

Multichannel Peristaltic Pump System with Non-contact Inline Flow Sensors

Multichannel peristaltic perfusion pumps are used in bioreactors to recapitulate in-vivo nutrient delivery to cells. However, current pump systems are expensive and lack the capacity, scalability, real-time feedback and resolution necessary for accelerated biomedical experimentation.

Our team developed a cost-effective, 24-channel peristaltic perfusion pump system. The sealed system is housed within a bioreactor and incorporates non-contact inline flow sensors for real-time feedback and control. This system operates via a custom graphical user interface that communicates wirelessly with a Raspberry Pi, which then controls four Arduinos through a serial protocol. Each Arduino interfaces with six Easy Drivers and their corresponding stepper motors.

This system provides flow rates down to 1 microliter per minute in order to mimic physiological capillary action and support various cell types. The user can tune various parameters for each of the 24 pumps, including speed, media type and duration. A non-contact inline flow sensor verifies the speed at which the media is delivered to the cells through the pump system with high precision and accuracy. Our novel peristaltic pump system provides an inexpensive solution for improved capacity, resolution, reliability and usability.



1) Hermetically sealed container for the perfusion pump system with (A) a port for power connection and (B) 24 ports for motor connections. (2) Top level of the pump system consisting of the (A) Raspberry Pi, (B) the power source for all of our components, and (C) the four Arduino controllers. (3) Bottom level of the pump system with (A) all 24 Easy Drivers laid flat with the (B) water cooling tubing in place to take heat away from each driver.

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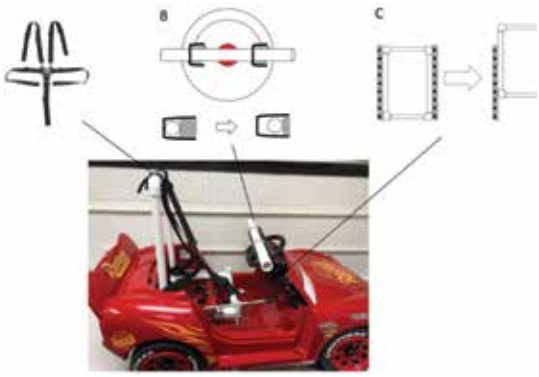
Optimization of Devices to Aid in Cognitive and Physical Development in Children with Mobility Restrictions

In early childhood, interaction with the environment is critical for normal cognitive development. However, children born with physical impairments that limit mobility experience decreased stimulation by their surroundings and later suffer developmental issues that otherwise may have been mitigated. Therefore, devices that increase mobility can facilitate environmental stimulation and aid in development. Currently, there are few inexpensive devices that are widely applicable to children.

Our design project uses contextualized adaptations of common materials and toy cars to create an affordable kit for at-home modification and creation of a mobility device. This device includes a novel steering system and an augmented mode of acceleration to account for low muscle tone in arms and legs. Additionally, a fully adjustable seat and harness provide moderate individual customization for a range of abilities and growth. The Susan Gray School at Vanderbilt and the Belmont School of Occupational Therapy are using the design to evaluate developmental benefits.



A toy car is modified to aid in early cognitive development of small children with physical and mobility limitations. This design depicts (A) a five-point harness, (B) a novel steering and acceleration mechanism and (C) a fully adjustable seat frame. All modifications not shown.

BELMONT UNIVERSITY

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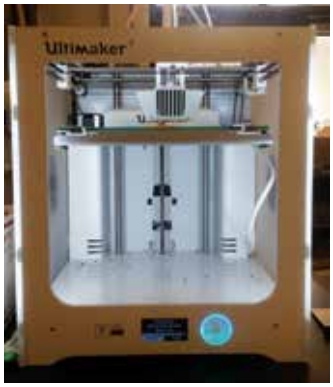
CHEMICAL AND BIOMOLECULAR ENGINEERING

3D Printing of Lab Scale Chemical Reactors and Peristaltic Pumps

Chemical companies are in constant need of innovation but the development of novel technologies can be expensive and time consuming. 3D printing is an efficient, affordable method for producing prototypes of new parts. Our team designed 3D printed devices for testing new machine parts for the Process Innovation Center, a laboratory space for chemical engineering undergraduates at Vanderbilt University. The team focused on improving two specific pieces of lab equipment: a peristaltic pump rotor and a plug flow reactor (PFR).

The team used Autodesk Fusion 360, a CAD program, to design parts that are then sent to an Ultimaker 3 3D printer and fabricated. We developed experiments that measure the efficacy of each printed part under different conditions. The team aims to determine how our newly designed components compare to existing laboratory equipment and, if applicable, make recommendations for new equipment for the Process Innovation Center.



Ultimaker 3D printer fabricating a rotor for a peristaltic pump.

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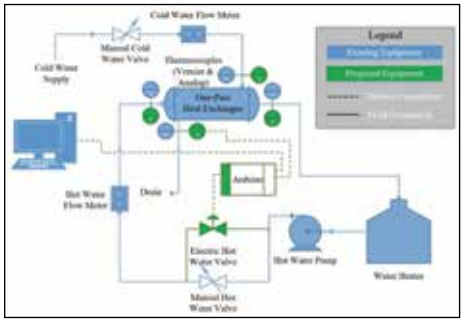
CHEMICAL AND BIOMOLECULAR ENGINEERING

Design and Analysis of a Process Control Laboratory Module

Regardless of industry, large-scale production facilities depend on the control of numerous process variables that determine the safety and efficiency of operation as well as the quality of the final product. Control systems monitor the states of key variables, identify deviations from expected or ideal behavior, and adjust related operations accordingly to restore or achieve the desired state.

Vanderbilt University's undergraduate chemical engineering students study process control only in a classroom setting. We designed a hands-on interactive laboratory experiment to incorporate into the undergraduate chemical engineering curriculum for students to gain tangible experience with process control. This experiment expands upon a previously existing module, which utilizes a single-pass heat exchanger to heat cold water. Our module assignment aims to have students manipulate this system using process control hardware and software in the Vanderbilt Process Innovation Center laboratory and apply their findings to a theoretical industry-scale problem.



The software designs an optimal network for maximum recycling of wastewater back into an industrial process.

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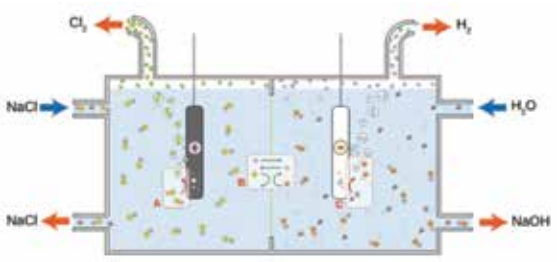
Design of a Continuous Chlor-alkali Electrolysis Process and Lab Module



Model of a continuous Chlor-Alkali generator.

Electrochemistry plays a vital role in a number of chemical production industries. The most essential electrochemical process is the chlor-alkali process, which converts NaCl (table salt), water and electricity into chlorine gas and sodium hydroxide. In turn, these products are indispensable raw materials for the chemical production industry. Additionally, the conversion of small-scale batch processes to continuous processes is an essential chemical engineering skill.

The Vanderbilt Chemical Engineering Department desired an undergraduate lab module that would emphasize both electrochemistry and reactor design. The team modified an existing lab scale chlor-alkali generator from a batch chemical reactor to continuous chemical reactor. This involved determining measurement techniques to quantify concentrations and power supply during the chlor-alkali reaction as well as physically adding pumps and control mechanisms to the reactor. The team also designed a lab experiment based around the new reactor. In addition, the team redesigned the reactor, adding pumps and additional measurement capabilities so this reactor can run in both batch and continuous mode, making it ideal for use in an undergraduate lab setting. Finally, the team included a safety and scale-up requirement in the lab write-up.

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3D-Printed Prosthetics for Canine with Below Knee Amputation

Prosthetics offer a second chance for canines with disabilities to live a normal life.

The Nashville Humane Association reports that more than 165,000 dogs and cats are diagnosed each year in the United States with limb deformities that require prosthetics. One prosthesis costs about $600 to $1,500, which can be quite expensive for pet owners. Without a prosthetic, a pet can develop acute spinal issues.

The team created a cheaper, convenient and comfortable alternative using 3D printing. We focused a type of limb deformity—below knee amputation—that can occur due to cancerous osteosarcoma, a birth defect or severe trauma. Using commercial computer-aided design software, the team created an elevated socket prosthesis design that has the same if not enhanced criteria as the conventional ones. Our team also used a FILABOT extruder to produce our own polymer that is lightweight, easy to clean and waterproof. Economic analysis for our 3D-printed prosthetics proves a significant cost reduction compared to the commercial prosthetics. A 3D manufacturing method offers a shorter process time, varying hind legs sizes and versatility.

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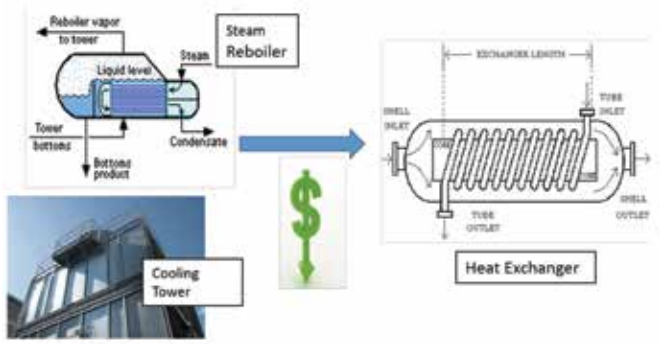
CHEMICAL AND BIOMOLECULAR ENGINEERING

Utility Optimization in a PVC Plant Through Heat Integration Design



Cost and energy minimization by replacing the steam reboiler and cooling water by utilizing heat exchanger integration system

Polyvinyl chloride (PVC), a strong yet flexible thermoplastic, remains ubiquitous in industries from construction piping to the medical industry. A typical PVC plant consists of smaller operations including chlor-alkali electrolysis to produce chlorine, which when combined with ethylene from oil synthesizes ethylene dichloride (EDC). Through thermal cracking of EDC, vinyl chloride monomer (VCM) is formed and subsequently polymerized to produce PVC. Manufacturing the third most widely used plastic in the world in this multi-step process utilizes over a billion BTU-per-hour in heat exchange efforts alone.

Our team sought integration opportunities to match hot and cold streams in order to reduce the amount of steam and cooling water required in each sub-plant, implementing previously designed Heat Exchange Network Optimization Software (HENOS). Safe cost-effective pressurization techniques allowed for further optimization of the heat exchange and water network design. The final design will reduce energy consumption by over 100 million BTU-per-hour and save millions of dollars per year in utility costs alone.

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Design of a Bioreactor for the Large-scale Proliferation of Induced Pluripotent Stem Cells (iPSCs) for the Production of Cultured Meat

Bovine iPSCs are proliferated in a large-scale bioreactor before being sent for further processing and formation into comestible ground beef.

The conventional meat industry that involves the rearing and slaughter of animals poses a serious threat to the environment, human health and animal welfare, especially as the global demand for meat continues to rise. The emerging cultured meat industry aims to mitigate this damage by offering a more ethical and sustainable source of meat—muscle cells grown in bioreactors. In order to succeed, the industry must develop low-cost (and likely serum-free) medium, create effective animal-derived cell lines, design large-scale cell proliferation processes, develop differentiation and separation techniques, and overcome a host of other biological and chemical engineering challenges. The team designed a bioreactor for the large-scale proliferation of induced pluripotent stem cells (iPSCs) for the production of cultured meat and performed a feasibility analysis on this process given current costs and technologies.

CHEMICAL AND BIOMOLECULAR ENGINEERING

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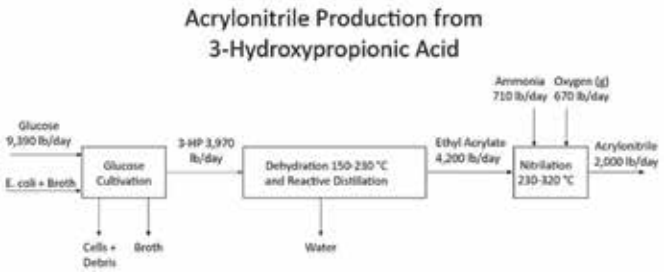
Design of an Environmentally Friendly Acrylonitrile Production Facility



Block flow diagram of acrylonitrile production using the 3-HP reaction pathway where nitrilation encompasses aminolysis and amide dehydration.

Acrylonitrile (ACN) is a commodity chemical with more than 14 billion pounds produced annually for the production of acrylic fibers, plastics, rubbers and resins. Currently, ACN is produced from petroleum in an energy intensive and hazardous process, so there exists a need for a more sustainable process. Our team researched a chemical process that produces ACN from biomass-derived sugars and designed a chemical plant to utilize this chemical process in a cost-effective manner. The chemical process begins with the glucose fermentation in metabolically engineered *Escherichia coli* to produce 3-hydroxypropionic acid (3-HP). Reactive distillation then converts 3-HP to ethyl acrylate. The ethyl acrylate undergoes aminolysis and amide dehydration to produce ACN. The plant design includes layout of appropriately sized unit operations, energy conservation plans, plant emissions plans and detailed safety analyses on select plant sections.

Polymer & Chemical Technologies, LLC

Chemical Engineering Design Advisory Board

CHEMICAL AND BIOMOLECULAR ENGINEERING

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Chemical Engineering Design Advisory Board

Designing an Industrial Plant to Produce 50 Tons Per Year of Silane

Silane is a vital compound used in the solar panel and semiconductor industries.

Today, the global silane market is increasing, estimated to reach more than $2 billion(US) in five years. Silane is a vital resource for many industries. The semiconductor and solar panel industries value silane because it can be converted into various higher order forms of polysilane that have different characteristics. The demand for higher order polysilane is projected to increase in the next ten years. Therefore, determining a profit-maximizing manufacturing process to produce semiconductor grade silane is of great interest.

Our team designed a silane production plant that produces 50 tons per year of semiconductor-grade silane. Large-scale processes are common in industry and have operating capacities between 20,000 and 30,000 metric tonnes per year. Designing a medium sized production plant that maximizes the purity and minimizes the cost and waste is essential to thrive in this niche market. Our team studied, modified and designed an optimum silane production process that produces 50 tons per year of silane.

Chemical Engineering Design Advisory Board

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SPONSOR

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CHEMICAL AND BIOMOLECULAR ENGINEERING

Design of a 500-ton-per-day Sulfuric Acid Plant

A rendition of a typical sulfuric acid plant.

Sulfuric acid is one of the most important commodity chemicals in the world. It is used in countless industries critical to everyday life, including fertilizer, paper, food and batteries. Our goal was to design a greenfield plant for the production of 500 tons per day of sulfuric acid that efficiently reached production and emissions goals.

Our team designed a double contact process for producing sulfuric acid that begins with burning elemental sulfur in dry air. Key targets for our plant design included the generation of 98.5% and 93.5% sulfuric acid products and an emissions limit of 2 pounds of SO2 per ton of acid produced. A byproduct from this process was 600 psig steam, which was exported to industrial neighbors in exchange for boiler feed water to reduce operational costs. We also investigated the most effective catalyst bed arrangement to reach our production specifications and determined that the overall conversion of sulfur to sulfuric acid was 99.85%. After performing material and energy balances, we were able to size equipment, determine capital costs and establish the plant layout. Our final design successfully portrays an efficient method for generating sulfuric acid while achieving all of our objectives.

CIVIL AND ENVIRONMENTAL ENGINEERING

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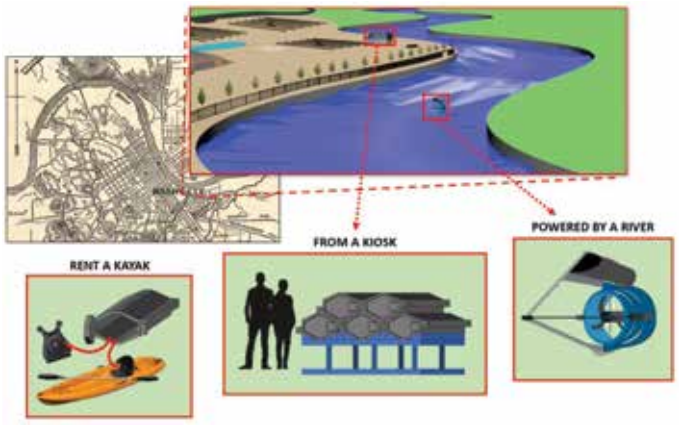
SPONSORS

Nashville Civic Design Center
Cumberland River Compact

Boat Kiosks with Power Generation

In order to promote recreational use of the Cumberland River, the Nashville Civic Design Center has proposed the concept of a blueway that would allow individuals to engage with the river in new ways. Increased recreational use of the Cumberland will promote a greater awareness of Nashville's relationship to local and regional waterways. The team has designed a paddle-craft kiosk system that stores kayak equipment for public rental.

The "smart" paddle-craft kiosk employs modular cells. This design follows sustainable manufacturing practices that minimize the number of molds. The team also identified a composite that has minimal environmental impact. The team used site and conceptual route analyses to identify accessible and recreationally utilizable locations for kayak deployment. Trends in shared mobility aided the development of an app that guides users through the payment and checkout process, communicates information and safety alerts, and unlocks the designated cell. Finally, the team tested and adapted a method of sustainable electrical generation using the flow of the Cumberland River and battery storage.



A subsurface micro-turbine in the Cumberland River will power the paddle-craft kiosk with a supply of 100% renewable energy. This supply powers the locking mechanism, lights and signal transmission abilities on each of the modular cells that form the kiosk.

CUMBERLAND RIVER COMPACT

NASHVILLE CIVIC DESIGN CENTER

CIVIL AND ENVIRONMENTAL ENGINEERING

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SPONSOR

Nashville Civic Design Center

Capping the Interstate

Interstate caps that cover below-grade portions of urban interstates with at-grade structural caps usually topped with public parks are growing increasingly popular across the United States. These caps create vibrant public spaces by connecting bisected communities, improving bicycle and pedestrian mobility, reducing noise pollution, and creating opportunities for development of neglected areas.

With the Nashville Civic Design Center as a partner, we designed a cap of I-65/I-40 west of downtown Nashville. The team produced an engineering feasibility study including preliminary construction cost estimates, a transportation design for the cap from Broadway to Demonbreun Street, and a structural design of the cap to augment the center's conceptual drawings of the park and provide a technical basis for the project as it is considered by local and state leaders. The team hopes its engineering support will bring this inspiring vision a step closer to reality.

A cap of I-65/I-40 near downtown Nashville would reconnect communities, improve bicycle and pedestrian mobility, and positively affect property values by creating roughly 14 acres of public green space.

NASHVILLE CIVIC DESIGN CENTER

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SPONSOR
Nashville Civic Design Center

CIVIL AND ENVIRONMENTAL ENGINEERING

Infill Housing Above the WeGo Central Station

A sketch of the multi-story affordable housing structure above the WeGo Central Station in downtown Nashville.

The Tennessean reports that Nashville will need 31,000 new affordable housing units by 2025, just one of many voices describing Nashville as a city on the precipice of a housing crisis. The WeGO infill housing project, initiated by the Nashville Civic Design Center, aims to meet the need for urban affordable housing.

The goal is to create an initial design of a structural plan for wood-frame construction of affordable housing above the WeGO bus terminal. Using a wood-framed structure allows the team to maximize the number of stories to create space for additional housing units. A baseline analysis of the existing loading capacity of the concrete bus terminal is complete. Next, the team will assess and design for the gravity and lateral systems for the wood structure. Following the design of the structural frame itself, the team will make recommendations for additional project details, such as cost estimates, financing plans and sustainability measures. In addition, other project deliverables will include detailed CAD floor plans and profile views, connection schematics for the controlling elements of the structure and a 3D model of the building.

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FutureVU

CIVIL AND ENVIRONMENTAL ENGINEERING

Living Building and Transportation Hub

The courtyard of the Vanderbilt University Club. The Living Building Challenge focuses not only on the infrastructure of the building but also the health and happiness of the occupants as well as the beauty of the surrounding area.

A Living Building meets all of its energy and water needs on site. It is regenerative in that it does not harm the environment around it, and it improves the quality of life for occupants. Even the "greenest" buildings typically consume a significant amount of water and energy and use harmful materials that negatively impact the surrounding environment. We designed a renovation of the University Club building on campus, focusing on four of the petals of the Living Building Challenge: place, water, energy and materials. We redesigned the existing site, adapted a modular water treatment system, utilized energy efficient design techniques and PV solar arrays to provide clean energy, and extensively researched manufacturers in order to recommend healthy materials with low embodied energy.

Our final product includes the design for an educational transportation hub that teaches the general public about the importance of sustainability, acts as a living classroom to expose students to innovative water treatment processes, and connects Vanderbilt's campus with Nashville's greater transportation system, all while simultaneously improving the air and water quality around it.

CIVIL AND ENVIRONMENTAL ENGINEERING

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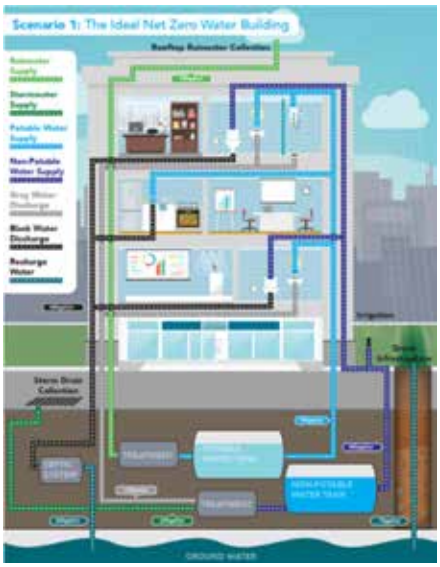
SPONSORS

Future VU, Vanderbilt University
Nashville Metro Water Services

Living Building Modular Water System

This project provides a framework for water acclamation and treatment and wastewater treatment and reintegration system of a Living Building located anywhere in the continental United States. A Living Building is a facility that generates more than it uses from its environment in terms of energy, water and quality of living space. Living Buildings will play an important role in sustainable development as world population grows and resources dwindle. The goal is to establish a methodology by which someone who wants to build a Living Building can easily select the best design elements for their water/wastewater system. The design team developed a program that recommends water treatment designs based on user inputs, and drew detailed schematics and built a physical prototype for one possible system. The program allow users to easily select the design of a treatment system so their facility can operate independent of a water or wastewater grid anywhere in the country. The design team will develop all the necessary elements for such a system in a part of the country with a moderate climate and the modifications that may be necessary to make the system work elsewhere.



Illustrative diagram of a Living Building harvesting water for reuse and recharging the natural hydrology of the land.

CIVIL AND ENVIRONMENTAL ENGINEERING

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Avery deGurion, Executive Director, Vanderbilt Center for Latin American Studies

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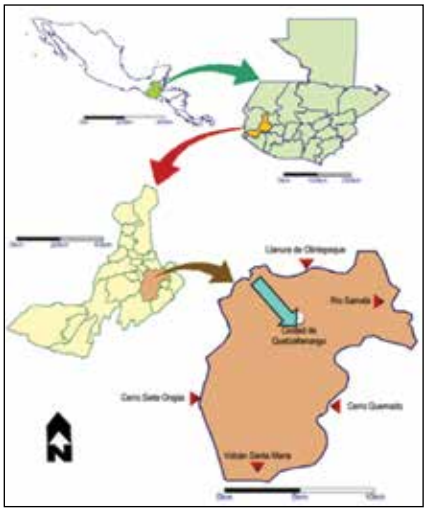
Primeros Pasos

Guatemala Water Treatment

Candelaria is a rural community of 500 people located just outside Quetzaltenango, Guatemala. Around the year 2000, the Municipality of Quetzaltenago constructed a water distribution system for Candelaria that provides tap water to most households in the community. Unfortunately, the water is extremely contaminated and not safe for drinking. Previous health studies have indicated that more than half of the village suffers from illness caused by bacterial parasites found in the local water supply.

The design team investigated the underlying causes of the community's poor water quality, exploring possible design solutions, selecting an effective and appropriate option, and developing the solution with respect to technical design, a sustainability plan, and an economic analysis. Rather than distributing point-of-use filters to every household, the team designed a central filtration system to be installed in the school at the community's center. The system takes in water from the current distribution network, filters it, disinfects it by UV light and chlorination, and stores it in 20-liter bottles. The bottles are distributed to every household and regularly replaced by a hired member of the community in exchange for a public service fee.



Location of the water treatment system in Guatemala.

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American Institute of Steel Construction

CIVIL AND ENVIRONMENTAL ENGINEERING

Steel Bridge Competition

The purpose of the Steel Bridge project is to design and build a steel bridge conforming to the 2019 AISC Student Steel Bridge Competition rules. The bridges must withstand loading up to 2500 pounds while being judged on categories such as stiffness, weight, construction time, aesthetics, and enter them into a weighted formula. In competition, all teams assemble their bridges.

Our team focused on minimizing overall bridge deflection. The theoretical deflection was found by inputting the initial bridge design into STAAD design software. The final bridge design includes a matching overhead Warren truss on either side of the bridge as well as some unique elements whose purpose is to resist deflection and twisting in the bridge. The bridge is fabricated in a civil engineering laboratory. Team members use machining tools such as a band saw, MIG welder, belt sander, drill presses, plus other miscellaneous steel fabrication tools. The goal of the Steel Bridge team is to place within the top four at the 2019 Southeast Regional Competition in order to qualify for, and compete at, national finals in May.

Steel Bridge team members cut, welded and/or drilled each individual part and piece of the steel bridge.

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Craig E. Philip, Research Professor of Civil and Environmental Engineering, VECTOR Director

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CIVIL AND ENVIRONMENTAL ENGINEERING

Adaptation of the Built Environment to Emerging Shared Mobility Systems

Our objective is to ensure a successful integration of electric scooters on Vanderbilt's campus. The focus of our project includes three areas: ridership analysis, safety and charging. Using ridership analysis, we will identify primary scooter paths and submit recommendations for ideal designated paths. We will identify safety hazards on campus, provide solutions and promote safe ridership. We will identify preferred locations for charging stations and create a charging station design. The charging station design is intended to incentivize students to register as "chargers" for Bird and Lime in order to keep scooters out of dorms and provide easy-to-use locations to charge scooters overnight.

Bird scooters ready for pickup after a morning of charging.

FUTUREVU

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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UCOR
Vanderbilt School of Engineering

East Tennessee Technology Park History Center Electric Vehicle Charging Station

The planned K-25 History Center parking lot will provide EV charging capabilities for two vehicles, rendered on this site elevation from UCOR.

The K-25 Gaseous Diffusion Plant at the Oak Ridge National Laboratory is undergoing a transition from part of the military-industrial complex to a commercial business space under a new title of East Tennessee Technology Park. Planning for the ETTP began as the K-25 facility ceased uranium enrichment processes in 1987. As part of clean up, renovation and repurposing, a K-25 history center will be dedicated to the contributions made to American security at this location. To serve visitors to this landmark of scientific progress, our group designed plans for the installation of an electric vehicle charger at the history center. Elements of the project include modifying existing plans to accommodate the charger and creating new drawings that follow government regulations and processes so the client, the Department of Energy through engineering contractor UCOR, can seamlessly integrate created documentation into their system.

UCOR

VANDERBILT
School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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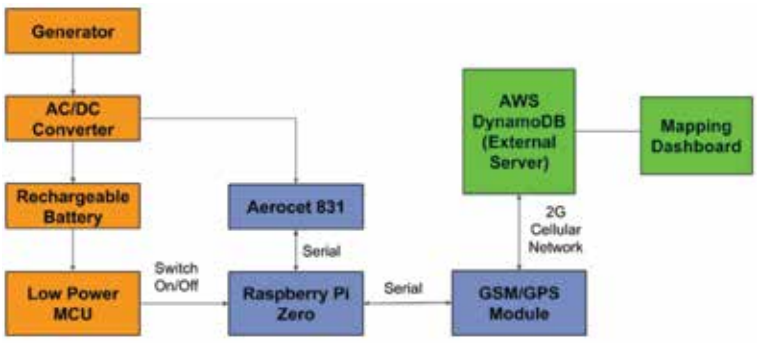
Air Quality Evaluation and Data Collection with Nashville's B-Cycles



A block diagram of the sensor system. 1. A power management subsystem converts pedaling to DC power, switches on/off the Raspberry Pi. 2. Embedded sensor components read air quality/ geospacial data, communicating with a remote server using a 2G GSM network. 3. Data visualization and analysis components, hosted through Amazon Web Services, pull and format data into visual elements like maps and tables, and monitor the two other components.

The Metro Nashville Health Department contacted Vanderbilt University to help with a Smart City Challenge/Green Initiative. Our project goal is to record both public-use bicycle data and mobile air quality data. This information will not only help the city plan future bicycle infrastructure projects but also help with current infrastructure issues (i.e. adjusting hybrid buses to use only electric power in neighborhoods with poor air quality). The main function of the design is that it is completely autonomous. A device powered by a generator on a bicycle wheel will send data to a website. The data collection design involves a single-board computer sending commands to an air quality sensor and receiving the data. From there, it sends the data through a 2G network to a website where it is added to a database and visualized. The system is powered by a battery to allow continuous data collection and the whole design is enclosed in an existing basket.

VANDERBILT
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Vanderbilt Motorsports

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Electrical System Design for Formula SAE Electric Vehicle

The Formula Electric team is a subdivision of the Vanderbilt Motorsports team. This year, the team began building its first electric powered vehicle for the Formula SAE competition series. Our goal is to design, build, test and provide a functional electrical system for the Motorsports vehicle. The primary focus of our task is two-fold: design a functional low-voltage system to power, monitor and analyze the performance of the vehicle, and design an efficient, reliable and robust high-voltage system to propel the car. State-of-the-art lithium ion (Li-ion) batteries power the vehicle. While we expect great performance from our first electric car, we also expect this car to serve as a foundation for improvements for future Motorsports teams.

Formula electric vehicle with battery boxes in side pods.

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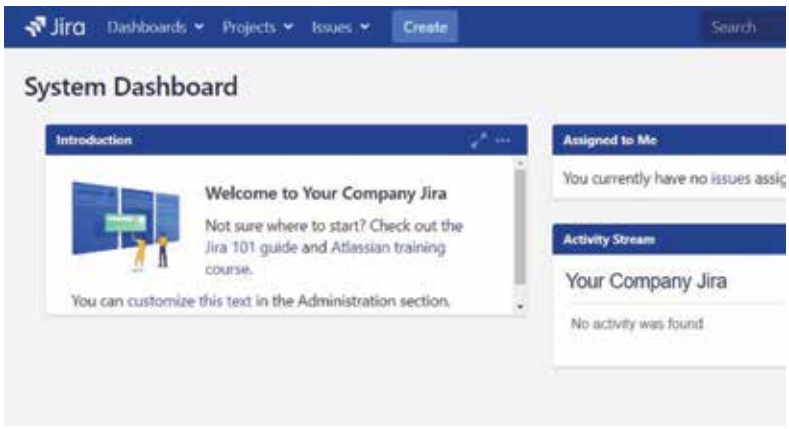
SPONSOR
Inventiv Tools

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Critic Plugin for JIRA

Our team aims to integrate the functionality of our sponsor's bug-tracking software, Critic, with a project management service called JIRA by Atlassian. Many Critic users select JIRA as their preferred project management service. These services have no existing interactivity. To create JIRA Issues for Critic bug reports, one must manually input the bug report data into a new Issue. We are using the Atlassian Software Development Kit to create a plugin that improves ease of access for clients who use both Critic and JIRA by automatically creating new Issues in JIRA for newly created Critic bug reports. Using our plugin, JIRA users can sign into their Critic account within their JIRA portal and specify certain attributes for newly created Issues, such as Issue Type and Priority. Our plugin will be made available free on the Atlassian Marketplace.



Atlassian JIRA interface.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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SPONSOR
Metova

LoRa Locate

Internet of Things devices often run with low power consumption. However, this makes them unable to use traditional GPS modules, making geolocation challenging. Using LoRa, a growing technology to wirelessly power local positioning system, gateways will multilaterate LoRa transceivers in a technique similar to GPS, and send the data into a web-based application that displays transceiver positions on a map. With this system, IoT applications that rely on batteries lasting months or years will be able to take advantage of local location services. Existing solutions drain batteries faster than LoRa. However, our solution increases the battery life of devices requiring geolocation. The team anticipates good precision and power use with possible optimizations in the future.

METOVA

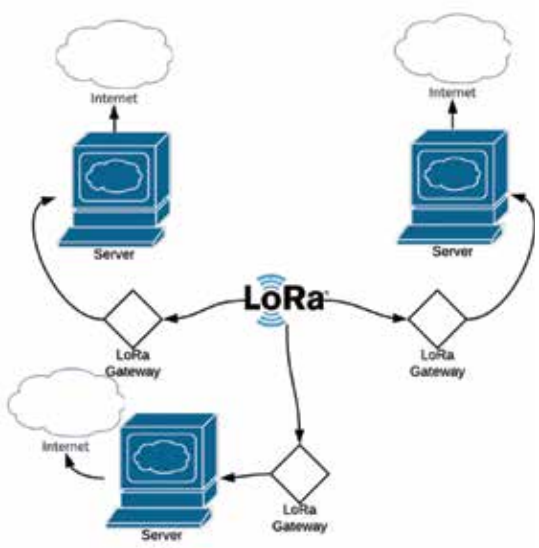

Illustration of how LoRa transceivers will communicate with LoRa gateways to determine location.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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SFEG

50

IoT Integration for Excel Dryer

SFEG wants to improve the design and user experience of their Excel hand dryer by adding IoT functionality. The team's design includes adding a Wi-Fi hub to the dryer's microcontroller to read and transmit sensor data, and modifying the microcontroller source code provided by SFEG to enable data transfer between the hub and sensors. A mobile application will provide a user interface that allows sensor data to be analyzed, and allows a user to send commands to the microcontroller, such as changing the heat temperature and motor speed. The project includes low-level microcontroller programming, transmission of data over Wi-Fi, user interface and application design, software and hardware testing. The result is a hand dryer with functions that can be easily modified remotely using an intuitive user interface on a mobile app.

SFEG's Excel Dryer-Xlerator.

SFEG
a Scott Fetzer company

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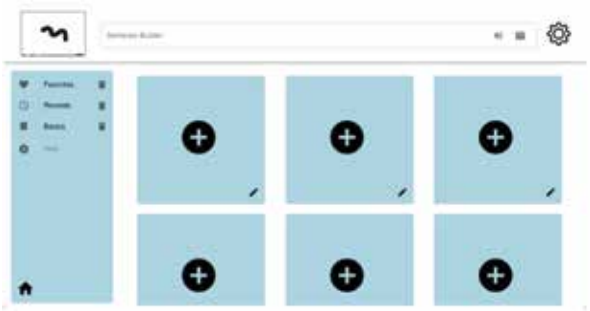
Vanderbilt Bill Wilkerson Center, Vanderbilt University Medical Center

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Assistive Technology App for Aphasia Remediation

Aphasia is a language disorder that affects a person's ability to understand or express speech. Many speech-language pathologists use assistive technology as a remediation tool to improve their patients' ability to communicate. There are several decent applications currently available for Android and iOS platforms, but they are expensive and not user-friendly. Desired features for an improved app include a dynamic grid display, text-to-speech capabilities, easy and intuitive navigation, and ability to record voice and video. Our goal is to create a low-cost application that incorporates these desired features. We designed a progressive web app that will be available across platforms, easy to maintain and affordable. The design incorporates the best features of similar apps and improves the user experience by integrating many customizable settings for the appearance and function of the display.



The main user interface of the app includes the dynamic grid display of icons, the categories bar and the sentence builder.

VANDERBILT UNIVERSITY MEDICAL CENTER

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Aphasia Remediation App

Aphasia is a condition of speech pathology in which patients have difficulty communicating language but are able to formulate concepts. Our app offers several features not found in existing apps. It is intuitive and customizable as well as less expensive than existing apps. It features a categorical breakdown of words and concepts with a visual navigation that allows users to form illustrative sentences one word/image at a time that can be read aloud. It provides image search and integration to email messages as well as several tools for customization, including voice options, sizing and layout options, and tile editing.

Word and concept categories with visual navigation.

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Peabody College, Vanderbilt University

Ultra Low-cost Eye Tracking System for Educational Research

Our project is to design a low-cost yet robust eye tracking system with matching software for research purposes. The goal is to deploy these devices in middle school classrooms to collect data on student interaction with instructional videos and learning programs. Current systems and associated software are functional but expensive. Our design aims to lower hardware costs by using Google AIY Vision kits as well as eliminating software costs to the researchers. To replace existing technology successfully, the ability to track gaze must be fully functional. The product must be portable from class to class, durable for use with children and ideally be able to track multiple students performing the same task. Software should be customizable for various research purposes including test duration and data output. The program should be entertaining to maintain the attention of young users and come with a precise calibration method. Maintaining data collection while a subject is moving is a common problem with younger children. A solution is to use a two-camera system with a larger field of view camera that relays the position of the head and a second moving camera to zoom in on a child's eyes.

Eye-tracking prototype.

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VADL Payload Team: Collaborative UAV Search and Deploy Mission for Space Exploration

A VADL payload team will collaborate with the VADL rocket team to compete in NASA's 2019 Student Launch competition. They have selected one of two payload options offered to college teams: a deployable unmanned aerial vehicle that flies to a designated target after the rocket completes its flight. Following rocket landing, two autonomous UAVs will deploy from the rocket payload bay and complete a collaborative search-and-deploy mission through a self-contained navigation system.

Our team has designed the UAVs using carbon fiber quadcopter frames with navigation systems and electric motors for propulsion. A flight controller running the Arducopter library handles stabilization, radio control and motor output. A dedicated high-power processor handles image processing and higher-level navigation and guidance. After the rocket lands, the UAVs deploy from the payload bay and begin a search for the visual signature of the NASA-specified Future Excursion Area (FEA). Upon identification of the FEA, one UAV will land, deploy its navigational beacon and communicate the target's location to its sibling UAV, which will also complete the mission. Positioning and orientation is determined using a vision-based localization algorithm, GPS and compass to allow for direct performance evaluation.

Pictured above is one of two autonomous UAVs that will deploy from a rocket payload bay and complete a collaborative search-and-deploy mission through a self-contained navigation system.

NASA

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Change++

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Nashville Affordable Living Application

The cost of housing in Nashville is rising dramatically. Change++ is approaching the challenge of finding affordable housing by creating a website that provides a map of housing by income level as well as integrating lifestyle information such as grocery stores, restaurants, public transportation, concerts and more that correspond to an indicated level of affordability. Our team implemented login and registration functionalities, designed a page to provide budget and spending recommendations based on a user's income, and is working to consolidate other information that would be useful to current and potential Nashville residents.

The app's map feature allows users to see the average price of each highlighted neighborhood.

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Toward Patient-centered Stewardship of Research Data and Research Participant Recruitment with Blockchain Technology

Significant effort is required to recruit and validate patients for research studies. Researchers are typically limited to subjects with whom they have a physical touchpoint—for example, patients at medical centers they see or learn about. This physical access limitation reduces the research attention received by patients with rare diseases with limited geographic concentration and poorer patients in rural areas. This project aims to use blockchain technology to recruit patients for validated research studies. Sophisticated dependency graph theory is used to facilitate a confidential yet streamlined process for narrowing a patient's list of potential study matches. The problem is approached from standpoints of UX, scalability and security, and will showcase a potential solution using technologies such as Android, Flask and Solidity/Ethereum.

Research study preview screen.

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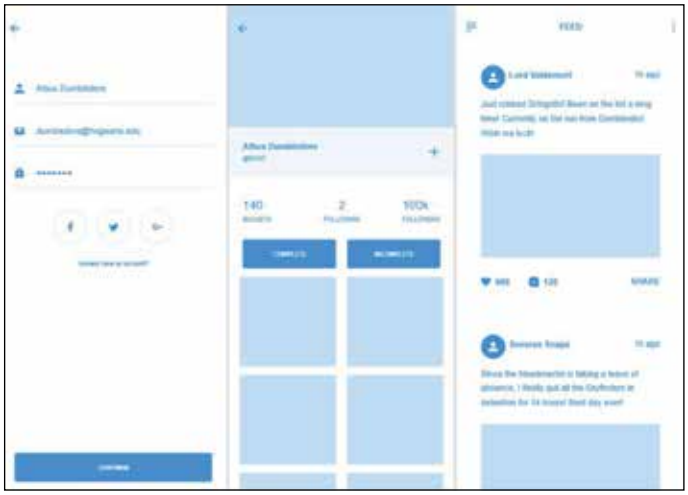
BucketList

To avoid missing cool local activities either solo or with friends, we developed a multiplatform app that can help users knock items off their bucket lists in a more social manner. The app shares a unified backend via Google Firebase and it provides both a mobile and desktop user experience through its Android, iOS and Web platforms. Core features include personal bucket list tracking, bucket list activities (add/complete items) of people users follow, and join in or emulate others users' fun plans. The app is designed to encourage users to accomplish goals, both serious and just for fun, and encourage others to accomplish their goals with them by leveraging social media in a positive way.



Core features of the platform include existing internet accounts integration, profile page with personal bucket list, and activity feed of friends' bucket list activities.

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Vanderbilt Wond'ry, Innovation Garage

Classroom Quality Real-time, Empirically Based Feedback (CQ-REF)

There is no method for pre-K coaches evaluating teachers to produce and share results of their evaluations in real time. The Innovation Garage is working with the Peabody Research Office (PRO) to create CQ-REF, a progressive web application for pre-K coaches that allows them to evaluate teaching techniques in real time. The evaluation is based on PRO's Magic 8, eight teaching principles proven to increase student test scores. The key actions of CQ-REF are observation of a teacher based on one of the Magic 8 principles and viewing the results of these observations. Throughout the year, our team at the Innovation Garage has held weekly meetings with the PRO team to design and refine the application using Agile methodologies. The application will provide coaches with effective feedback they can use in coaching sessions with teachers in order to improve upon important areas in preschool education.

Magic 8 allows users to select one of eight teaching principles to evaluate. After selecting one, the user goes to a page to record parameters surrounding the chosen principle.

theWONDRY

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

SideScroller

Our team is building a side scroller game using Unity, which gives programmers various tools and services such as graphics rendering and engine performance. In this side scroller game, a main character completes different levels by defeating enemies. A player will use classic keyboard controls to maneuver the character as well as a mouse to shoot the enemies. As the user completes a level, the next level will increase in difficulty. Each level varies in difficulty based on the complexity of platforming, type and number of enemies and their health and attack capacities. Our overall goal for the project is to give a player a challenging yet enjoyable experience by creating a variety of levels with different themes. Although the game may not be graphically intensive, our intention is that the game showcases core elements of classic side scroller games.

A snapshot from a level in the game displaying shooting and health mechanics along with platforming and sample enemies.

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Vanderbilt-Ingram Cancer Center

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Cancer Genetic Counseling

When cancer patients start the process of genetic testing, they are required to receive a brief education on the subject in order to give informed consent. A shortage of genetic counselors related to the number of patients is an issue. The education each patient receives needs to be identical. Our team addressed the problem by helping Vanderbilt-Ingram Cancer Center automate the education process, allowing counselors to serve more patients. The team created a web application to inform a patient about hereditary cancer and genetics, and administer a required evaluation to assess their understanding of the topics. This solution uses ReactJS, BlueprintJS, Firebase and REDCap. Eventually, we hope this web application will be used in clinics across the country.

Opening page of web application.

VANDERBILT-INGRAM CANCER CENTER

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International Bridges to Justice
Change++

Change++: Connecting Lawyers and Clients in Syria

International Bridges to Justice (IBJ) is an organization dedicated to protecting the basic legal rights of individuals in developing nations. These rights include the right to legal representation, the right to protection from cruel and unusual punishment and the right to a fair trial. IBJ accomplishes this goal by coordinating a global network of lawyers passionate about pro-bono cases.

Change++, an organization dedicated to building applications for nonprofits, worked with IBJ to build JusticeHub, an app to automate IBJ services and to connect lawyers with clients in developing nations. The initial version of JusticeHub will deploy in Syria and includes an interface for clients to submit cases, a search feature for lawyers to browse cases and to connect with clients, and a messaging service for lawyers and clients to communicate important case details. The app was built for iOS and Android devices using React Native, an open-source programming framework. Future iterations will involve e-learning features for lawyers, the facilitation of a community of lawyers on the app, and the ability for family members of incarcerated individuals to connect with lawyers.

A design layout of the JusticeHub application to connect lawyers and clients and used to translate English text to Arabic for use in Syria.

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Stevenson Tour Guide

The Stevenson Center is a cluster of seven buildings connected by a series of hallways, tunnels and elevators. Classrooms and laboratories are scattered throughout the buildings and undergraduate students often experience difficulty navigating the complex. Our team is designing an Android mobile application and a web application to provide users with detailed directions and path images of the shortest route between any two locations in Stevenson. The team continues to update a model of Stevenson Center that represents all rooms and connections between buildings. The model resides on a server powered by Amazon Web Services. Finally, a "tour guide" mode is being developed to lead a user through the major parts of all seven buildings to better acquaint them with the complex.

The splash screen for the Stevenson Center Tour Guide app.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

JACKAL: College Rental Marketplace

College students participate in a number of activities such as camping, intramural sports and a wide range of themed social events. Even some day-to-day activities require equipment and other miscellaneous goods that students may not own. Jackal provides students a simple and accessible platform to rent from other students and to lease their own items. Students can access Jackal's rental marketplace online by registering with their Vanderbilt email. They can post requests for items and describe a specific need, such as how long an item is needed and how much they are willing to pay for it. Students can fulfill a request by chatting with the requester and negotiate a final price and location for the transaction. PayPal is used for transactions.

Jackal's marketplace design (above) allows users to browse and search for items to rent from a fellow student rather than make a more costly and permanent purchase.

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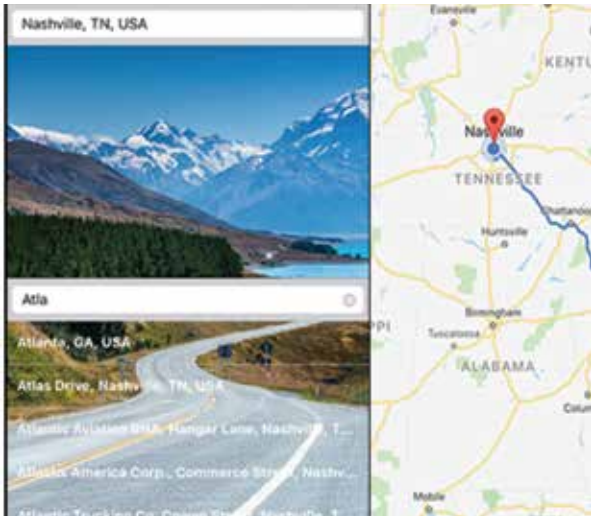
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Trippy: The Comprehensive Road Trip Planner

Trippy is a mobile application for iOS and Android devices that provides a comprehensive road trip experience. Trippy allows users to plan an optimized route by setting specific criteria such as points of interest, lodging for multi-day travel, and lunch and bathroom breaks. Trippy calculates the route by collecting information about driver(s) such as how long per day they are comfortable driving on a trip-by-trip basis. The app's flow begins with a login/signup screen. A user has the option to view the routes of previous trips or to create a new trip. Next, a user enters start and end locations—based on Google's Places API—and completes a short survey. Then, a map shows the created route. From this point, a user can be deep-rooted to Google Maps to receive turn-by-turn directions.



Creating a road trip route from Nashville to Atlanta.

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School of Engineering

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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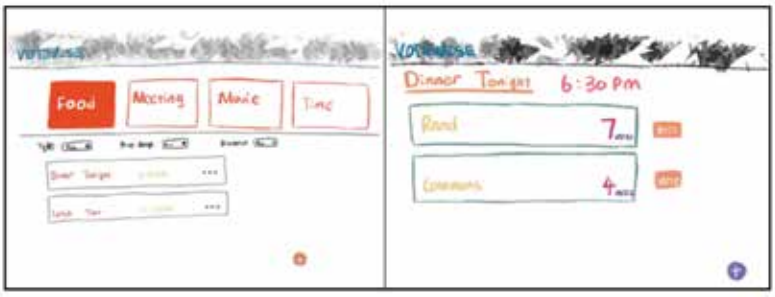
VoteWise

VoteWise is a responsive web application that allow users to poll their preferences for group activities.

Among other things, users can create polls for what to eat, when to leave and where to meet up for activities. Unlike other applications with polls as a side feature, VoteWise serves as a central location for managing all group decisions with easy to track results. Creating polls with VoteWise potentially will reduce time wasted when using group chats for decision making.



Left, Main page user interface concept. Right, Event page drawing.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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Using Machine Learning Models to Study Financial Market Movement

We are using machine-learning models to determine how well we can predict financial market movement. Focusing on cryptocurrency markets, we are investigating how well different models and algorithms perform in the context of long-term decision making using a moderate amount of past data provided to the models. Our approach aims to optimize decisions to conform to common goals, typically maximizing profit or minimizing loss, and use machine learning to train a model that makes decisions that support the long-term goal. Developing automated trading tools for crytocurrency markets is speculated to provide a stabilizing effect on cryptocurrency prices.

A glimpse into the financial market.

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Vanderbilt University Medical Center, Department of Biomedical Informatics

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Use of Machine Learning and Deep Learning Models with Longitudinal EHR to Better Predict 10-year Stroke Risk

Our team is using machine-learning techniques to develop a predictive model for an individual's 10-year stroke risk based on longitudinal electronic health records. Although several studies, such as the Framingham Stroke Risk Profile, have focused on predicting stroke risk, they did so only through the examination of conventional stroke risk factors (i.e. smoking, age, diabetes). Increased attention to stroke prevention behaviors have decreased the prevalence and impact of many conventional risk factors. However, stroke remains a major cause of death worldwide, second only to heart disease, which demonstrates a clear need for new systems to predict risk. Our team is using decision trees along with other models to predict the risk of stroke in patients and comparing the performance of such techniques with the Framingham Stroke Risk Profile.

```
def id3(data, list_of_features):
    global counter
    if data.empty:
        return None
    potential_classifier = check_if_classifiers_all_same(data)
    if potential_classifier != False or len(list_of_features) == 0:
        return  Decision_Node(get_majority_classifier(data), data)
    max_info_gain = 0
    best_feature = 0
    best_feat_num = 0
    feat_num = 0
    for feat in list_of_features:
        info_gain_of_set = infoGain(data, feat, feat_num)
        if info_gain_of_set > max_info_gain:
            max_info_gain = info_gain_of_set
            best_feature = feat
            best_feat_num = feat_num
        feat_num = feat_num + 1
    if best_feature == 0:
        return None
```

A snapshot of the ID3 algorithm used to determine the best feature in decision trees.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Hot or Not: Using Machine Learning to Classify Success of Boy Bands

Boy bands like *One Direction, Five Seconds of Summer* and the *Jonas Brothers* dominate popular music. This is not new. Boy bands have played a significant role in pop culture for the last 70 years, but what makes certain bands achieve huge and lasting success while others struggle to reach relevancy? We are using machine-learning techniques to explore the relationship between certain features of boy bands, such as brand sponsorship and demographics, and their success. We aim to create a classifier to predict the success of emerging boy bands and determine which features are the best predictors of success. We are investigating ways to use this fun and accessible topic as a way to demonstrate how machine learning works.

Boy bands, past and present.

VANDERBILT Blair School of Music

VANDERBILT School of Engineering

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Flight Delay Predictor

Our team is building a flight delay prediction app using Python. The application uses flight information such as date, weather predictions, starting point and destination to predict if a flight will be delayed or not. The application uses various supervised learning algorithms from machine learning to make a prediction. We also are creating a web-based user interface to interact with the application. Our overall project goal is to give a user the opportunity to check the probability of delays before booking flights. This predictive capability would be useful to travelers and to airlines.

The struggle with flight delays is real.

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

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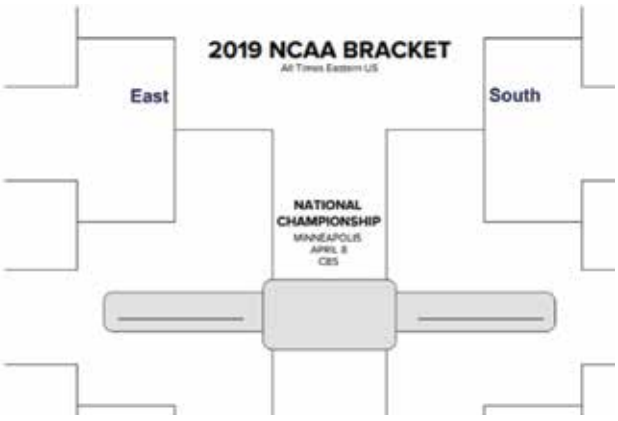
60

Predicting March Madness Using Machine Learning

Our team is developing a machine-learning model to predict NCAA men's basketball games. Using averaged team stats for both teams going into a game, the model will predict a score and winner. We are training the model on conference games from all Division 1 teams over the past 10 years. We will evaluate our model on NCAA and conference tournaments and to a subset of regular season games. We are experimenting with a variety of machine learning techniques including decision trees, neural networks, Bayes classifiers and nearest-neighbor models. Although predicting a 68-team tournament is a challenge, we will study how well our models work and why on individual games as well as on full tournament prediction.



NCAA Men's Basketball Tournament bracket before the model makes its predictions.

VANDERBILT
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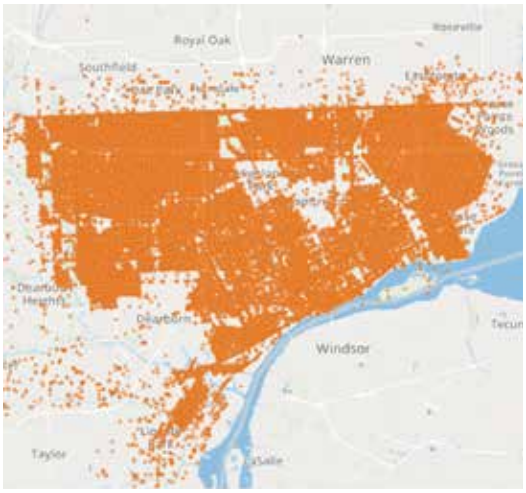
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Exploring Police Response Times in Big Cities through Machine Learning

Data from 911 calls and the subsequent responses by emergency services are an example of "big data" analyzed for insights using new technology-based approaches. Analyses of urban area data could yield important findings for emergency service agencies to refine and improve their services. Our team is using supervised machine learning techniques to explore police response times in Detroit. Using public datasets on 911 calls and corresponding response times from the Detroit Police Department to build our models, we are investigating if response times can be predicted from other known features of the incident such as time of day, location (including demographic information of the area), kind of incident, proximity to a police station, and more. We also are examining the extent to which our results are generalizable to other large cities in the United States.



A map of police calls for service in the City of Detroit from Sept. 20, 2016 to March 19, 2019. Each orange dot represents a response to either a 911 call or an officer-initiated call. Source: Detroit Police Department

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ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

Supervised Learning Algorithms for March Madness Bracket Predictions

We are developing a variety of algorithmic classifiers using popular machine learning techniques such as decision trees, neural networks, K-Nearest Neighbors and Naive Bayes classification to explore which approach is best suited to the task of bracket prediction. For such predictions, an agent picks a probable winner for a match-up between two teams using a variety of historical data such each team's current season statistics (seed, win/loss percentage, shooting accuracy, conference, past tournament matches, etc.). The agent will try to learn the potentially complex relationships among these statistics to predict the outcome of the match. A successful classifier presents both financial and academic value by possibly revealing non-intuitive relationships and reinforcing or disrupting traditional thought, or revealing which traditional beliefs are the most impactful for accurate decisions.

NCAA MARCH MADNESS

NCAA March Madness, Division I Men's Basketball Tournament.

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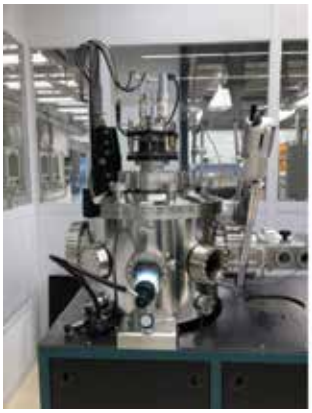
Prevention of Building-Related Bird Strikes

Bird strikes against buildings are among the leading cause of North American bird deaths—more than one billion bird casualties annually. The current green building initiative exacerbates this underreported problem because low-emissivity windows used in efficient building designs feature high-gloss finishes. Birds perceive the high-gloss reflections as a continuation of their natural surroundings. Due to birds' inability to distinguish between reflections and open areas, they collide with the panes at high speeds, with little chance of survival. Since birds are able to see ultraviolet light, the team created a UV light-reflecting nanoscale coating for window glass. The nanoscale coating does not affect visible light transmission and is minimally detectable from building exteriors, making it feasible for widespread use. The glass coating was fabricated at the Vanderbilt Institute of Nanoscale Science and Engineering. The team used a design of experiments (DOE) method and qualitative and quantitative UV photo analysis to test the reflectivity of multiple materials.



Left, A thin film deposition system that coated the prototypes. Right, A prototype glass sample coated with a triple bi-layer of aluminum oxide with titanium dioxide.

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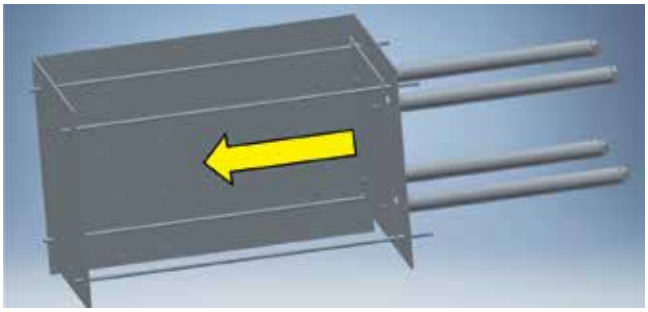
Nissan North America

Cardboard Conveyance Project by Nissan North America

More than 12 million pounds of cardboard are transported annually throughout Nissan's Smyrna, Tennessee, plant, the largest automotive manufacturing plant in North America. Nissan currently outsources its cardboard transportation to a third party logistics company that completes approximately 550 trips per day, manually driving open cardboard boxes from partially filled collection bins throughout the plant to a central compactor room. Nissan advisers asked our team for a solution to improve the efficiency of cardboard conveyance.

The design constraints included limited floor space, limited use of human capital in the design, a continuously changing plant layout and a two-year payback period. The design team built a box compactor prototype that uses four pneumatic cylinders to push a steel plate across the volume of container to crush the cardboard contents. The current design allows for elimination of a floor footprint and is more cost effective than industrial compactors/balers. The compactor's volume reduction directly correlates to fewer number of trips required and, thus, a reduction in expenses.



The cardboard compression system has four pneumatic cylinders with 2-inch diameters to push a steel plate across a container to compact cardboard boxes.

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MECHANICAL ENGINEERING

Surgical Video System Design Project

Alexander Langerman, M.D., wears the surgical camera system during a procedure

High-quality video is critical for surgeons to review procedures, enable immersive educational experiences, provide clarity in malpractice cases, and formulate normative surgical practices. Traditional camera systems are mounted to overhead booms and the bodies and movements of the surgical staff obstruct video streams frequently. Our team designed, built and tested a wearable camera system for the purpose of capturing unobstructed, high-quality video of open-case surgeries.

The design features a chest-mounted system with a camera extending over the top of the surgeon's gown and aimed at the surgical field. Computing systems and controls are located on the device, and a waist-mounted battery provides electrical power. Using its own video stream, the fully enclosed camera programmatically acquires and physically tracks the open surgical field during a procedure to ensure an uninterrupted view. Real-time video may be streamed to OR screens to provide the entire surgical team with the surgeon's perspective and saved for documentation and review.

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Design and Construction of a Martian Habitat

Our team designed a habitat capable of sustaining five astronauts on Mars for 500 days. Inspired by artist and engineer Chuck Hoberman, three collapsible domes connect by telescoping hallways, which can be manufactured using existing technologies. The habitat will fit inside a standard payload fairing. We focused on compressibility requirements, interior layouts, structural design, materials and manufacturing processes suitable for planetary construction based on NASA-3001 technical standards that include protection from lethal surface conditions, cargo specifications and human needs. Our project provides a novel entry into habitat design by emphasizing modularity, comfort, efficiency and safety.

The habitat's three domed structures connect by hallways. The larger dome (24m diameter) is the three-tiered living area containing a communal space, exercise area, kitchen, bedrooms, bathrooms and a controls area. The two small domes are a two-tiered medical facility and a research lab (9.4m and 9.6m diameters, respectively).

MECHANICAL ENGINEERING

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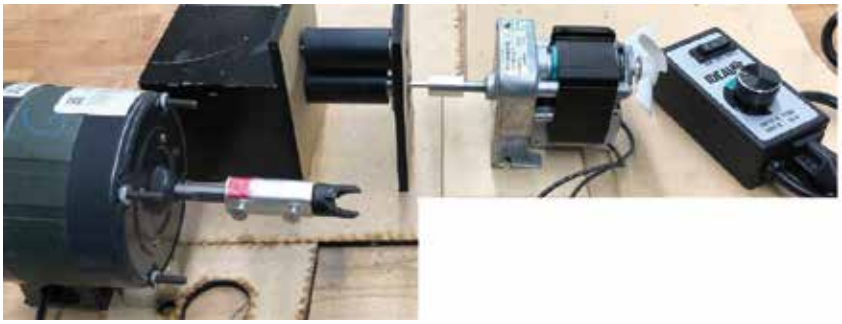
Polymer Pelletizing Project

Halmos Technologies is working to infuse gold nanoparticles into polylactic acid (PLA), a thermoplastic polymer used in 3D printing. This doping process is seamless; however, they face a challenge when cutting the infused PLA into small useable pellets. We designed and built a desktop-sized polymer-pelletization system capable of producing plastic pellets for filament extrusion or for direct use in fabrication. The pelletizer cuts unusable 3D printing filament into variable-sized pellets using a motor-driven cutter fed by rollers operating at adjustable rates. Adjustable motor speeds enable various pellet sizes. Acrylic shielding allows observation of the process, provides pellet containment and enhances safety.



A general layout for the pelletizer-filament feeds in from the top of the image, then goes through the pair of rollers into the cutter. There will be a feeder block at the entrance to the rollers and the unit will be encased with acrylic to enhance the usability and safety of the system.

HALMOS

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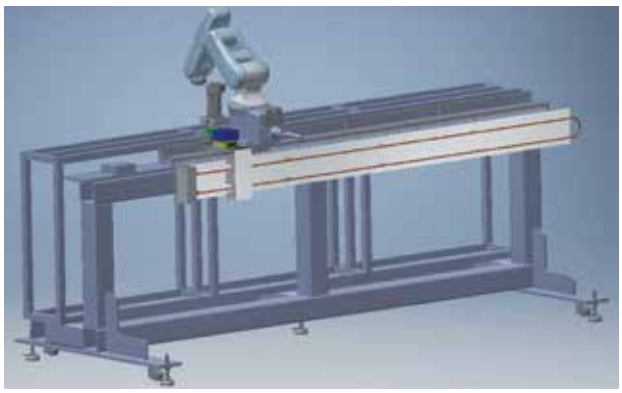
DENSO 400W Wireless Power Transfer System Development

DENSO Manufacturing seeks to accelerate their electronics production processes through further automation. They plan to mobilize existing six-axis robotic arms to perform operations at multiple locations in their workspace. DENSO's clean room calls for contactless power transmission to support robotic arms and carriages. To accomplish this, we designed a new wireless power transfer method. A receiver slides along a transmission line without making contact with the wire. A system of rectifiers, inverters and filters allow the high-frequency power required for efficient inductive power transfer and provides a stable DC output from the receiver. Designed to maximize efficiency, the receiver and the full system can be integrated easily into existing rack-and-pinion track used in the facility.



The powered line transmission system mounts to a workstation to allow unbroken power transfer to the carriage as it moves between assembly nodes.

DENSO

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MECHANICAL ENGINEERING

Development of the Next-generation Courier Station

Model of laser-diode projector system in FedEx station environment.

Our team examined a FedEx Express sorting process to propose a cost effective technology/system design to improve the efficiency of the local package sort. The local sorting process is the only point in the FedEx system where a package's barcode information is read and reapplied simultaneously to the package as a label. Our goal is to eliminate expensive handheld equipment and labels by automating this part of the process. We examined hands-free scanning and communication of information to couriers about packages designated for their delivery routes. We investigated the potential application of several technologies, including machine vision, inkjet printing, flexible labeling, laser-diode projection, and LED and LCD displays. Our testing and analysis of these solutions will allow FedEx to reallocate human capital to other time sensitive areas of the sort, improve cost savings by eliminating handheld equipment and labels, minimize the number of initially unsorted packages, and help couriers identify their packages and load their vans faster.

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MECHANICAL ENGINEERING

Nissan Information Display Project

Left, Prototype on a sample kit cart running its path in the factory. Right, Brushes and contacts meet to transfer power and data to update the e-paper display.

Nissan North America's Smyrna plant uses kit carts to transport car parts to the appropriate assembly line. Automated guided vehicles (AGV's) pull the carts along set floor paths. Currently, a sheet of paper taped to each cart contains vital information such as body and sequence numbers that distinguish each cart from the others. Nissan wants to automate this method of displaying information on kit carts. We have designed a low power, durable and flexible system comprised of Arduinos and a brush/contact system to meet the design requirements. An Arduino is placed at each programming point in the factory. When the copper brushes on the carts reach designated programming points, power and data are transferred through copper contacts. This connection powers up the 4.3-inch e-paper screen secured to the cart and displays the appropriate body and sequence number before heading to the production line and repeating the process.

MECHANICAL ENGINEERING

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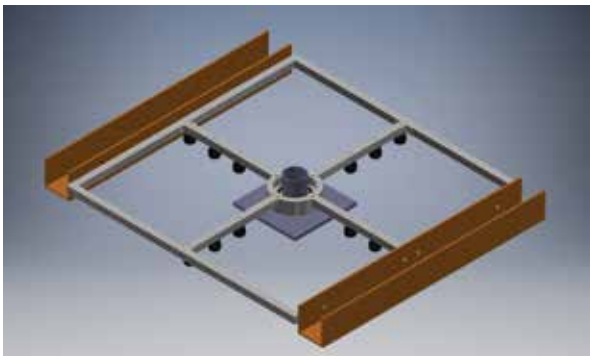
Manufacturing Kit Cart Project

Manufacturing kit carts transport predetermined items for specific vehicle models to assembly lines at the Nissan plant, which has limited space where kit carts are loaded. Carts travel one side of an aisle of components; they must make a 180-degree turn to travel down the other side to receive the remainder of car parts. The carts travel via a track in the floor. They must be released from the track at the end of an aisle for operators to rotate them for the other side.

We designed a manually-operated turntable at the end of the kitting area that allows an operator to control the cart while rotating it to secure it on the adjacent track. The system is designed to move the cart off and on tracks easily and faster with less effort by the operator. The result is a functional product with simple components that can withstand a cycle per minute (nearing almost 500,000 per year) over the lifespan of the system.



Model of the open air rotational guidance system for kit carts.

NISSAN

MECHANICAL ENGINEERING

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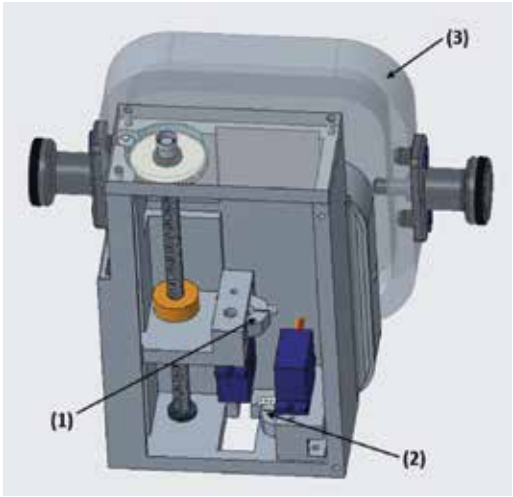
66

Mechatronic Design of a Surgical Robot

One in 16 people in the United States are diagnosed with lung cancer. However, only about 30% of patients are candidates for surgery because certain comorbidities can make an invasive procedure too risky. The Vanderbilt MEDLab has created CRISP, a continuous, reconfigurable, incisionless, surgical, parallel robot. This robot inserts into a patient's open cavities two flexible needlescopic nitinol tubes, which a surgeon can then control remotely. Our team designed the robot's end effector, which features a dynamic gripper attached to a lead screw that drives the nitinol into a patient's body. Once the dynamic gripper reaches the bottom of the lead screw, a stationary gripper clasps the nitinol in place so the dynamic gripper can return to the top in order to move the tube further. This design allows for an accurate continuous drive that can withstand the forces needed throughout the surgical procedure.



The closed dynamic gripper (1) pulls down a nitinol tube/needle while the open stationary gripper (2) remains at the bottom. When Gripper 1 reaches the bottom of a lead screw, Gripper 2 clamps shut and Gripper 1 opens to reset at the top. The quick attach mechanism (3) enables users to attach and detach the system from robotic arm with ease.

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MECHANICAL ENGINEERING

Permobil: Accessibility Robotic Arm

Many wheelchair users have difficulty with simple daily tasks like picking up an object from the floor. Medical robotic arms, such as the JACO by Kinova, offer solutions but they are expensive with limited mobility and effectiveness. We designed a mobile platform for a robotic arm that is capable of driving on a surface. The setup functions wirelessly. Its control hub, a Raspberry Pi, is mounted to the wheelchair and has several input ports, giving users the ability to control the setup with a device of their preference. Designed with modularity and user experience, the primary goal was software architecture that can correctly map several types of input devices to a corresponding output device.

The device attached to the arm of a wheelchair allows a user to wirelessly control a robot arm and its mobile base with a 3D mouse.

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MECHANICAL ENGINEERING

Wrist-actuated Partial Prosthetic Hand for a 9-year-old Boy

Born with a right hand with only a thumb and little finger, Gage, 9, dreams of grasping toys, bike handles and utensils with his right hand. A budding engineer, Gage has brainstormed and prototyped his own prosthesis designs using household materials. A commercial prosthesis is too costly to scale up with Gage's growth. Our team introduced additive manufacturing as both an iterative design tool and an economic manufacturing method. We designed his new prosthetic hand to be lightweight, durable, compatible with his anatomy, ergonomic and aesthetic. Passively actuated by his wrist, our design minimizes parts and maintenance without sacrificing performance or comfort.

Gage wears the first prosthetic prototype. The hand is designed, built and tested to be a custom wrist-actuated prosthetic for a very active youngster.

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Physiological Monitoring Sensor Suite for Divers

Diving to depths of up to 300 feet, naval divers are very susceptible to diving-related illnesses such as nitrogen narcosis, decompression sickness and oxygen toxicity. Our team created a suite of sensors in a waterproof pressurized housing for real time physiological monitoring. The sensors provide information about heat flux, ambient water temperature, body temperature and heart rate. Data are outputted from a Teensy microcontroller and graphical information is displayed in real time. A low-profile vest's adjustable straps hold the sensors securely to the body. A small waterproof pressurized box houses the electronics, attaches easily to a diver and reduces the risk of wire entanglement. This technique proved successful during underwater testing at a simulated 45-foot depth.

A test subject wears a complete sensor suite under a low-profile vest and holds the waterproof electronics housing.

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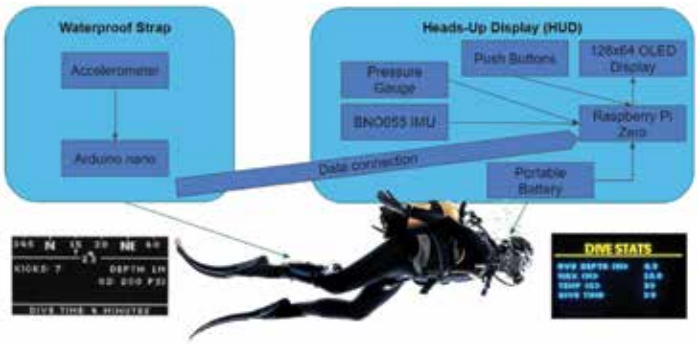
Special Forces Diver Information Display

Special Forces divers operate in environments that require constant monitoring of several instruments, often in murky waters. Our project had two objectives, 1) automate methods divers use to track parameters such as their direction, depth and number of kicks to estimate distance travelled, and 2) consolidate information–compass heading, depth, temperature, number of kicks, and dive time–into a heads-up-display that is readable in low-light settings. The team programmed and tested components that measure diver metrics, most notably a kick-counting algorithm because a current method of manually counting kicks is tiresome and unreliable. We automated the kick-counting process using accelerometer readings analyzed via a finite state machine with dynamic thresholding. We then integrated components into a single interconnected system, which displays the critical information by projecting an OLED screen onto a transparent reflective film located a few inches from a diver's face. To assist divers, we also implemented features such as a safety stop warning and a post-dive statistics report.



The chart shows the locations of the electronic components used to measure compass heading, depth and number of kicks as well as the flow of information between them.

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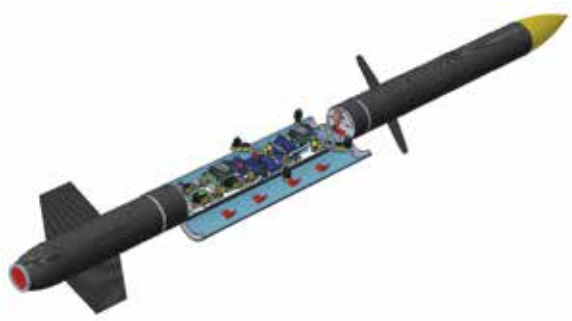
MECHANICAL ENGINEERING

Spacecraft for Delivering Deployable UAV Payload

The Vanderbilt Aerospace Design Lab has designed, built and tested a rocket to deliver and deploy an unmanned aerial vehicle payload. The rocket meets a number of NASA requirements necessary to compete in the agency's 2019 Student Launch Competition in Huntsville, Alabama. The rocket reaches apogee at 4,500 feet, deploys a UAV payload that executes its own target-searching mission, and returns to Earth in reusable condition. Our team developed and tested some novel subsystems such as the bay door design and an Autonomous Reorientation System (ARS). Spring-loaded legs in the Leg Deployment System (LDS) allow the payload section to land using four level supports. The rocket consistently deploys its two UAVs in a known orientation. The designs have been validated through extensive ground-based testing and multiple test launches.



CAD illustration of VADL rocket in open payload bay configuration for UAV deployment.

Design and project faculty

We take great pride in recognizing these faculty members who are the core of our design program. Their outstanding contributions and excellence as instructors, advisers and mentors in our senior design and project courses have led to the work exhibited at Design Day 2019 and have transformed our Class of 2019 into young professionals.

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